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Monitoring post mining forest dynamics of the tropical thorn forest in Asola Bhatti Wildlife Sanctuary, India using multi-temporal satellite data

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Abstract

Recent advances in remote sensing technology and methodologies and in the integration of analytical results and evaluation schemes in a long-term monitoring protocol have created new and exciting opportunities for applying remote sensing data to meet monitoring needs. Asola-Bhatti Wildlife Sanctuary (ABWLS), encompassing about 32.71 km^2 area, represents a typical tropical thorn forest ecosystem of low hills layered with quartzite and has undergone drastic transformations due to massive open cast mining of feldspar and for red sand stone. Regeneration of secondary forests has occurred in mining pits that have been quarried. In the present study the rate of land use land cover change was determined for the period of two decades 1992-2013, which was divided into three sub-periods with a subsequent gap of 7 years and the land use land cover changes of these three sub-periods were compared. Land use land cover trajectory analysis showed the rate of change of LULC during the last two decades (1992-1999, 1999-2006, 2006-2013), which provided useful information of forest regeneration in a mining affected area. The study proved that the technique of GIS and remote sensing can provide land cover information and landscape characterization statistics for assessing habitat diversity and land cover change in a disturbance-dominated post-mining landscape.

Keywords: Land Use Land Use Cover, Asola-Bhatti, RS/ GIS, Change Detection

INTRODUCTION

India recognized the enormous importance of the forest resources and land use, land-use change, and forestry (LULUCF) activities in contributing towards GHG emissions [1]. Remote sensing and Geographical Information System techniques are becoming increasingly important to assess the change in forest ecosystems to prioritise the efforts of conservation [2-6]. Studying changes in land-use pattern using remotely sensed data is based on the comparison of time-sequential data. Detection and characterization of change in key resource attributes allows resource managers to monitor landscape dynamics over large areas, including those areas where access is difficult or hazardous and facilitates extrapolation of expensive ground measurements or strategic deployment of more expensive resources for monitoring or management [7-10]. In addition, long-term change detection results can provide insight into the stressors and drivers of change, potentially allowing for management strategies targeted towards cause, rather than simply the symptoms of the cause [11]. The goal of change detection is to discern those areas on digital images that depict change features of interest (e.g., forest clearing or land-covert land-use change) between two or more image dates [12]. At present regional economic development is in direct conflict with the protection of the natural environment. Such a conflict has caused the destruction to the forest resources and fragmentation of the forest landscape accompanied by forest degradation, even seriously in most part of the India [13]. Monitoring of change (deforestation or reforestation) is frequently perceived as one of the most important contributions of remote sensing technology to the study of global ecological and environmental change. However, studies on change detection in relation to impact of mining in forests of Delhi region are scanty. It is essential to study the land use land cover (LULC) dynamics and assess the future persistence of the forest ecosystems. It becomes a fundamental tool in assessing the environmental consequences of human activity and assessing conservation policies.

STUDY AREA

Asola-Bhatti Wildlife Sanctuary (ABWLS), a protected area located in the south-eastern part of the southern Delhi ridge, India; lies between latitude 28°24´00´´ to 28°30´00´´N and longitude 77°12´00´´ to 77°17´00´E (Fig 1) covering an area of about 32.71 km^2 and the entire sanctuary bio-geographically represents one of the oldest mountain system in India. Out of 542 Wildlife sanctuaries in India, the ABWLS is the only area, which represents north-eastern flat-topped hill form of country's oldest hill ranges- the Aravalli-a highly eroded remnant of Precambrian uplift. Bhatti area of the sanctuary has undergone massive open cast mining of feldspar (for preparation of high grade pottery) and subsequently for red sand stone or morrum (building material). Mining was stopped and Asola Wildlife Sanctuary (4707 acres) was carved in 1986 under section 18 of Wildlife (Protection) Act 1972 from the community-land of three villages namely Asola, Shurpur and Maidangarhi. Subsequently in 1991 another notification was issued to declare Bhatti (2167 acres) as a part of Wildlife Sanctuary. Therefore, the administration undertook extensive seeding and planting of the area with several tree species, of which *Prosopis juliflora* and *Acacia* sps. have been successful. The site is heterogeneous with intermixing of hard stable rocks and red sand mounds prone to erosion. This landscape has undergone drastic transformations due to mining, replacement of natural forest with commercial plantations of exotic species and urbanization. As a result, natural habitats have fragmented and degraded causing local extinction of several species. The climate of ABWLS is typically continental which is characterized by cold winter months and hot, dry summer months. Cool, oceanic air penetrates the area only during the monsoon months i.e., July to September). The annual precipitation is about 711 mm falling majorly during the monsoon months (July – September).

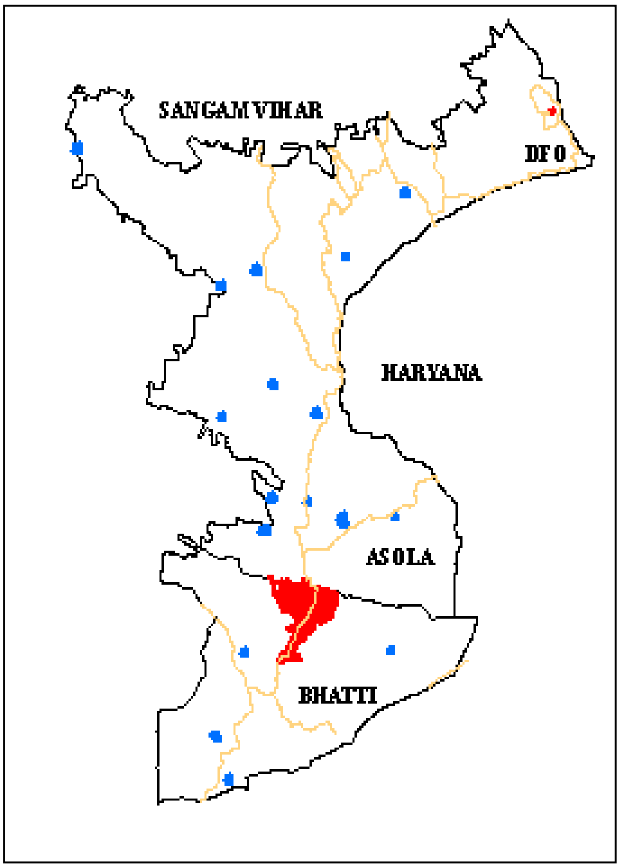


Fig 1: Location Map of Asola-Bhatti Wildlife Sanctuary (ABWLS)

MATERIAL & METHODS

Landsat remote sensing data was used as the primary data source for derivation of generalized land-cover information. Landsat satellites provide multispectral data from the early 1970s to the present. Given that the purpose of this study was to provide a general landscape characterization and change analysis instead of detailed vegetation and resource mapping, the spatial resolution of Landsat data was appropriate. Landsat data that represented the best match in time frame and, if possible, were close to the anniversary of image acquisition was searched in order to reduce seasonal effects. Four scenes of Landsat images, 1992 (TM data), 1999 and 2006 (ETM+ data) and 2013(OLI data) were acquired and processed (Fig 2).

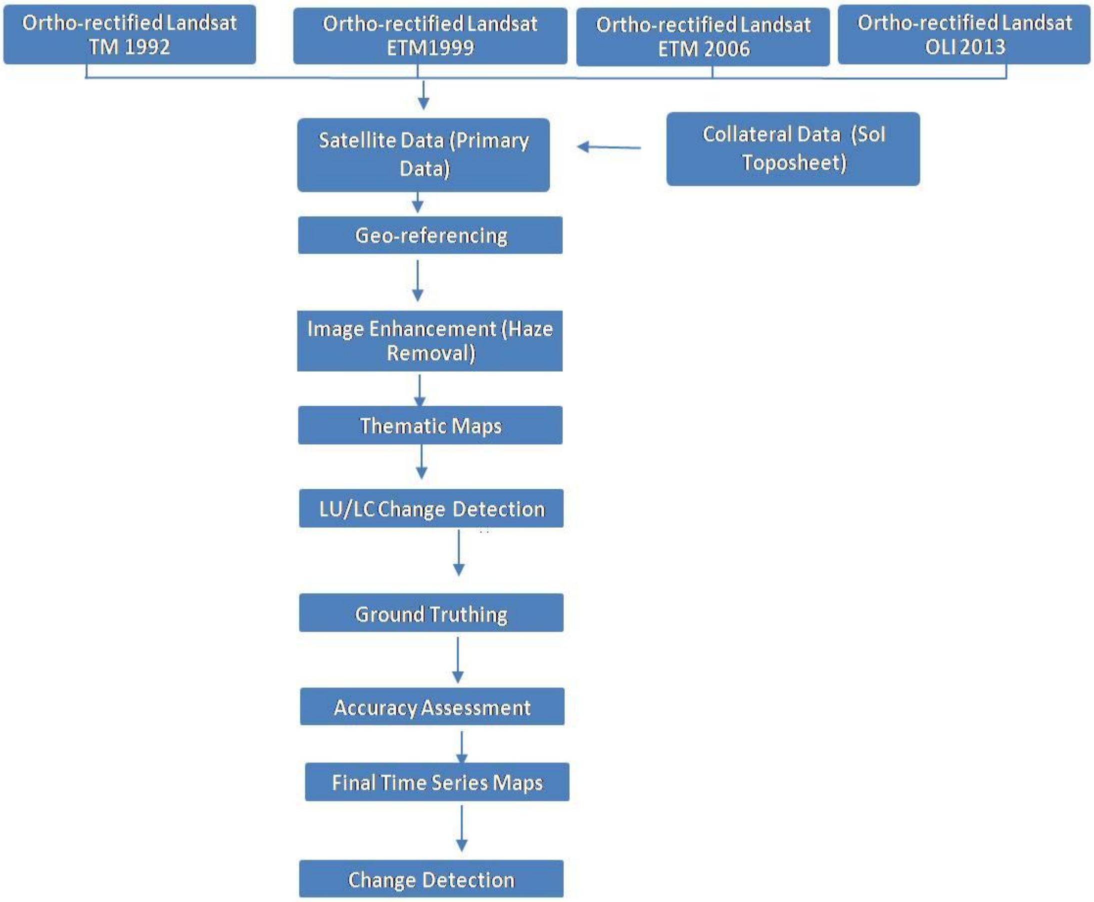


Fig 2: Flow chart of methodology for land use land cover classification of ABWLS

All images were projected into Universal Transverse Mercator (UTM) map coordinates and, when necessary, conducted geometric rectification with ortho-rectified Landsat TM, ETM+ and OLI images as the base.

Collateral Data Collection

Topographic maps of scale 1:50000 of the study area were procured from Survey of India. These maps were digitized by table digitization and were used to extract only the area of interest (AOI) from whole map.

Table 1: Hardware and software used for determining the land use land cover change in ABWLS

S.No.	Type	Particulars	Utility
1.	Hardware	P4 with Intel core two duo processor	Data storage and processing
2.	Hardware	GARMIN eTrex Venture HC Global Positioning System (GPS)	To complement the results of classification
3.	Software	*ERDAS Imagine 9.1*	Image processing and data analysis. Development of land use /land cover classes and subsequently for the change detection analysis of the study area.
4.	Software	*Arc GIS 9.3*	Map composition, spatial analysis and data base creation, display and processing of the data.
6.	Software	Microsoft Word 2007	Documentation
7.	Software	Microsoft Excel 2007	Field data analysis

This map was also used as ground truthing information in classifying the satellite image during supervised classification. Varieties of software were employed in the present study following the different requirements of the work (Table1).

Geo-referencing

Geo-referencing of Survey of India toposheet no 53 H/3/NE was done to extract the boundaries of the study area. After undergoing registration process, image to image registration of Landsat TM, ETM+ and OLI was carried out to make the image unified to a same coordinate system UTM/43N/WGS84 datum.

Image Enhancement (Haze Removal)

Image enhancement was used to increase the detail of the image by assigning the image maximum and minimum brightness values to maximum and minimum display values and it was done on pixel values and this made visual interpretation easier by increasing the visual discrimination between features in a scene and assists the human analyst: False colour composite (FCC), spatial re-sampling, etc.

Land Use/ Land Cover Change Detection

Satellite data of four years were mosaiced and the area of interest (AOI) was delineated. Visual interpretation of satellite imagery and reconnaissance survey of the area was carried out for obtaining patterns of vegetation and other land cover features during June 2012 to June 2014.

Image Classification (Maximum Likelihood Method)

Supervised classification was performed to classify the image into different land use changes as supervised classification has high accuracy to that of unsupervised classification since, the user can train the classes according to wish. The base map and further four mentioned year's maps for change detection were hence prepared by supervised classification. Data of the different land use land cover classes obtained from the field study (GPS location) were used as training sample for supervised classification. The maximum likelihood classifier (MLC) which is a widely used classification algorithm was used for the classification. Land cover was classified into the following seven classes (Table 2).

Table 2: Image interpretation key for different forest and land cover mapping

S.No.	Class	Tone, Texture and Pattern
1.	Barren land	White, Rocky or sandy areas with sparse vegetation or no vegetation. Barren land devoid of natural vegetation with heavily eroded top soil.
2.	Settlements	Cyan, Regularised
3.	Rock outcrops	Cyan, Rough
4.	Forests	Dark red to reddish green ; rough texture, but in dry season the areas take up greenish shade with no evidence of foliage
5.	Forests plantation	Reddish white
6.	Scrub	Whitish green; Mottled. Scattered stunted vegetation with exposed ground surface
7.	Water body	Greenish blue; Checkered pattern, smooth texture

This classification was used to prepare Land Use Land Cover map of ABWLS. Training data collected from field study was used for the classification of 2013 (OLI) satellite image whereas for the classification of 1992 (TM), 1999 (ETM) and 2006 (ETM) image, digital topographic map was used. All satellite imageries were rectified with the help of Survey of India topographical map (of 1:50,000 scale) and a common coordinate system was used for the study sites. These datasets were analyzed using Erdas Imagine 9.1 (ERDAS Inc., Atlanta, GA, USA) and ArcGIS 9.3 (ESRI, Redlands, CA, USA) was used to analyze landscape metrics.

The satellite imageries were classified and different land use and land cover categories were delineated on the basis of tone, texture, color etc. Based on the reconnaissance survey of the ground details and signatures, an interpretation key was developed to enable information extraction from the image. The classified maps of four time periods were produced. Independently classified images were then compared with each other to determine the changes of land use land cover types. The field observations provided essential independent reference data for identifying LULC types within the images as well as for accuracy assessment.

Ground Truthing

The ground reference points were measured during the field visit to the study areas in the period from October 2012 to February 2014. They were selected based on pre-classified maps for the imagery. The coordinates for each reference point were recorded using hand-held GARMIN eTrex Venture HC Global Positioning System (GPS). Information on land use and cover was recorded too.

Land Use/Land Cover Maps

To determine the rate of land use land cover change, the period of two decades 1992-2013 was divided into three sub-periods with a subsequent gap of 7 years and the land use land cover changes of these three sub-periods were compared. The first sub-period was from 1992-1999 the second sub-period was from 1999-2006 and the third period from 2006-2013. The comparative analysis in land use and land cover change focused on the three sub-periods. The spatial distribution of the average (annual) rate of land use land cover change between two periods was computed by the formula:

$$\Delta = \left[\frac{(A_1 - A_2)}{A_1} * 100\right] / (T_1 - T_2)$$

Where:

Δ : Average annual rate of change (%)

A_1 : Amount of land cover land use type in time 1 (T_1)

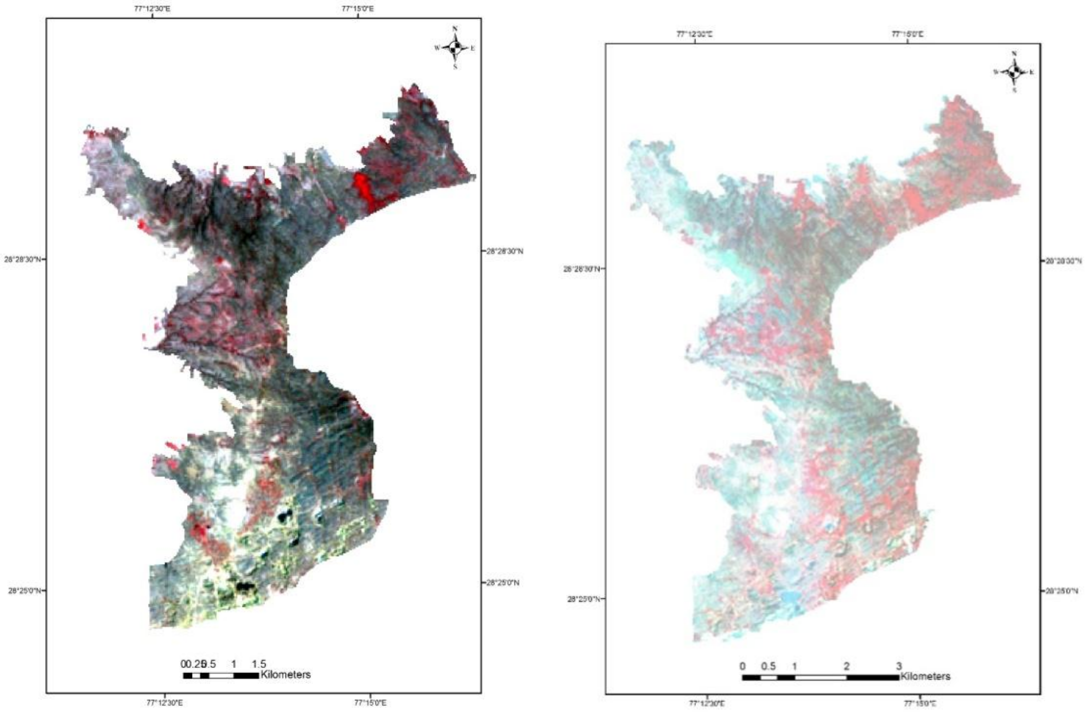
A_2 : Amount of land cover land use type in time 2 (T_2)

Change Detection

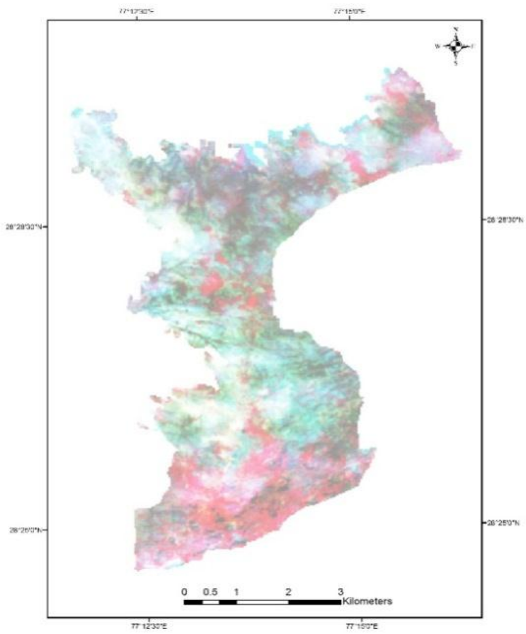
Post-classification comparison (change detection) of the imagery was applied to determine the changes in land use and land cover that had occurred in the study areas A and B and demonstrating the net degradation taken place over time. All the imageries were classified independently. Post-classification is most common approach used for monitoring land use land cover change since it provides more useful information on initial and final land covers types in a complete matrix of change direction. In the change detection application, the magnitude, rate and nature of the land use land cover change and conversion and change map were derived as well.

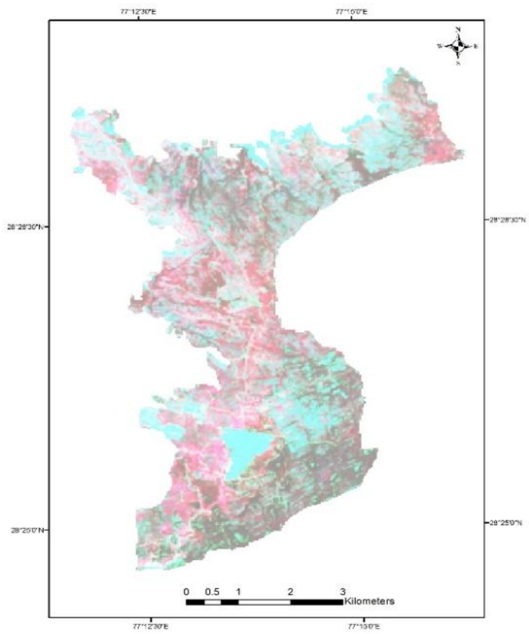
RESULTS

False color composite (FCC) images were produced using several band combinations (Fig 3). FCC of satellite imageries of study area for four years gave an overall impression of the distribution of different land cover patterns. Different land uses were represented by different tones. Infrared reflectance from the vegetation was seen as hues of red tones and texture; similarly, water body appeared blue in FCC, whereas, cyan color depicted the barren soil or settlement depending upon the texture and depth of color. False color composite (FCC) images were produced for the sanctuary with special emphasis on mining pits using several band combinations in order to depict the regeneration status there over (Fig 3).



(a) 1992 **(b) 1999**



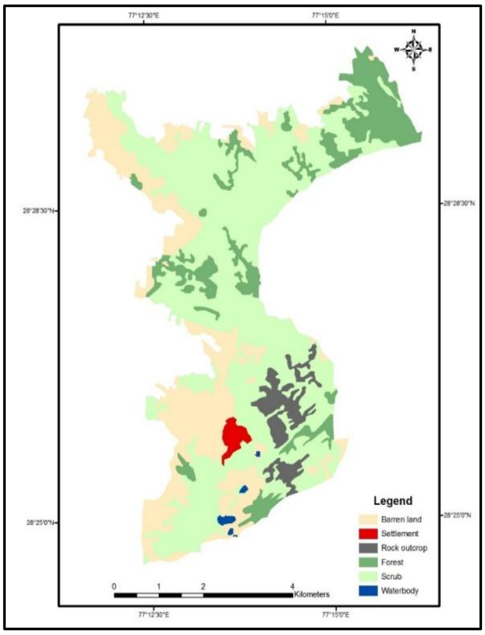


(c) 2006 **(d) 2013**

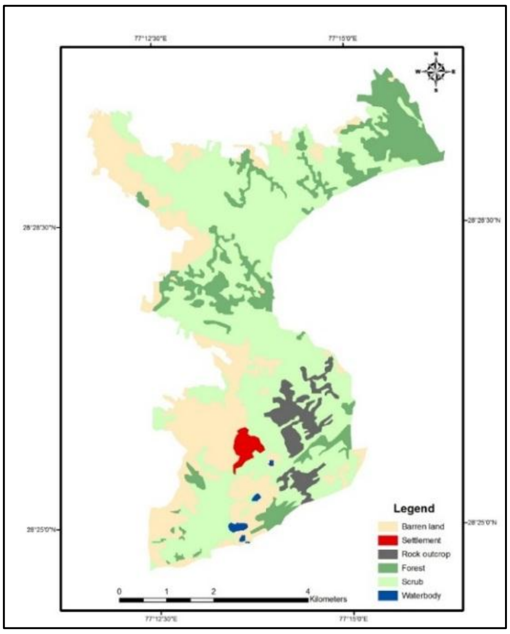
Fig 3: False Color Composites (FCC) images of ABWLS (a) Landsat TM 1992 (b) Landsat ETM+ 1999 (c) Landsat ETM+ 2006 and (d) Landsat 8 OLI 2013

Land Use Land Cover Classification

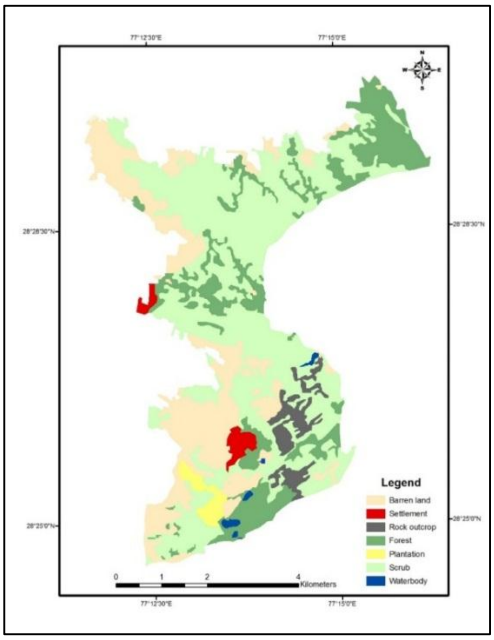
Assessment of land use and land cover was carried out. On-screen visual interpretation of the study area revealed the existence of various land cover classes. Vegetation and land use map prepared using on-screen visual interpretation facilitated stratification of different vegetation/land use classes with high accuracy. Supervised classification using the maximum likelihood algorithm in ERDAS Imagine 9.1 was used to generate seven main land use land cover classes for all images: (1) Forest (2) Scrub (3) Plantation (4) Barren Land (5) Water Body (6) Rock Outcrops (7) Settlements. These land use land cover classes were derived from images 1992, 1999, 2006 and 2013 for the study area. Fig 4(a) shows the land use land cover map of the ABWLS area for year 1992. In the year 1992, scrub and barren land accounted 54.42% and 25.74% respectively, of the total ABWLS's area (Table 3). During this time forests covered only 14.31% of the area and non-forest (including settlements, rocky outcrops, water bodies) area was nearly 5.5%. As the active plantation by the Department of Forests, The Government of NCT of Delhi was not started in this period hence the no plantation was recorded in 1992 image. Fig 4(b) shows the land use land cover map of the ABWLS area for year 1999. The Scrub, rocky outcrops and barren land registered a consistent decline from 1992 onwards and contributed 52.02%, 4.28% and 24.15% respectively (Table 3). By 1999, the area under forest increased to 18.28% (5.98 ha) of total sanctuary area. During this period as well the Forest Department of NCT of Delhi has not started the active plantation programmes resulting into zero recordance of plantations.



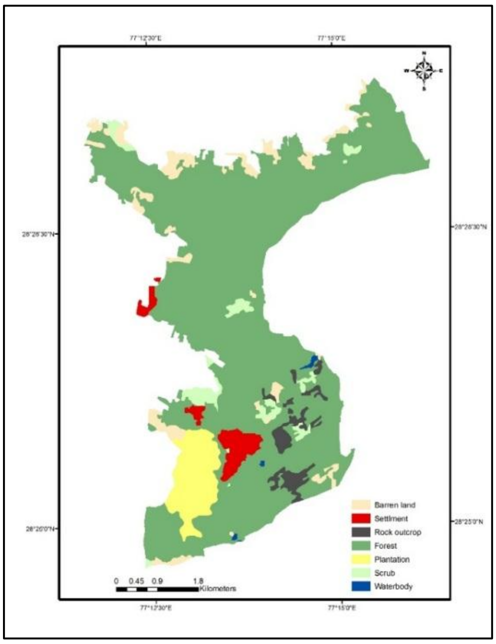
(a) 1992



(b) 1999



(c) 2006



(d) 2013

Fig 4: Land Use Land Cpver Classification Maps of ABWLS for the year (a) 1992 (b) 1999 (c) 2006 and (d) 2013

The land use land cover map of the ABWLS area for year 2006 is shown in Fig 4(c). Scrub land forest still remains the major land use land cover consisting of 42.43% of total land (Table 3). A proportional increase in forest cover of 25.04% was recorded during 1999–2006 (8.19 ha). Settlements increased in area occupying 1.50%, while rocky outcrops decreased to 3.67%. The Forest Department, Government of NCT of Delhi undertook a plantation programme through 132 Infantry Batallion (TA) ECO Rajput (Eco-Task Force - ETF) in 2001 over an area of 300 acres. Due to which plantation area was also recorded as 4.59% in this year's image.

Fig 4(d) shows the land use land cover map of the ABWLS area for year 2013. A sharp increase in forest cover was evident during 2006-2013 to 77.96% (25.5 ha) whereas, similar jagged decrease was observed in scrub area and barren land (5.50% and 5.38% respectively of the total area) in 2013 (Table 3). This classification map shows that rocky outcrops still continue to decrease and were recorded 0.8 ha i.e. 2.57% of total area. As compared to 2006 data plantation increased by 5.72% of total area in 2013 (1.87 ha).

Change Detection Analysis

Table 3 shows the rate of change for each land use and land cover classes and for each period of analysis (1992-1999, 1999-2006 and 2006-2013) for ABWLS, representing the land use land cover change trends and indicating the magnitude of change. From the land use land cover change analysis of ABWLS between 1992 and 2013, it was found that the land use land cover structure in 1992 and 1999 is composed mainly of scrub and barren land with total area accounting for 80.16% and 76.18%, respectively. The mining was very recently banned during this time period and the early regeneration was taking place in the area mainly as scrub. But both scrub and barren land reduced subsequently in 2006 having percent cover of 42.43% and 22.32%, respectively and drastically in 2013 with percent cover remaining of 5.5% for both. The reason behind the same may be attributed to faster regeneration of forest due to increased conservation efforts as a sanctuary. However, for forest cover reverse trend was observed during 1999-2006 and 2006-2013 with an increase of 6.76% and 52.92% respectively. An increase of the forest cover in the study area was most noticeable from 2006 to 2013. Whereas, drastic change in the percent forest cover was observed during 1999-2006 and 2006-2013 with an increase of 6.76% and 52.92% respectively. The change detection analysis shows that due to fast regeneration of vegetation in the sanctuary, rocky outcrops in sanctuary faced reduced area by 0.06% during 1992-1996; to 0.61% in 1999-2006; and to 1.10% during 2006-2013. Non-forest area such as settlements within the sanctuary showed a continuous incremental change during 1992 to 2013 reflecting high anthropogenic pressure inside the sanctuary.

Table 3: Changes in land use/ land cover classes (%) during different study years in ABWLS

S.No.	Land Use Type	1992		1999		2006		2013	
		Area (ha)	**Percent Contribution (%)**	**Area (ha)**	**Percent Contribution (%)**	**Area (ha)**	**Percent Contribution (%)**	**Area (ha)**	**Percent Contribution (%)**
1	Forest	4.68	14.31	5.98	18.28	8.19	25.04	25.5	77.96
2	Scrub	17.8	54.42	17.02	52.03	13.88	42.43	1.8	5.50
3	Rocky Outcrops	1.42	4.34	1.4	4.28	1.2	3.67	0.84	2.57
4	Barren Land	8.42	25.74	7.9	24.15	7.3	22.32	1.76	5.38
5	Plantation	0.0	0.00	0	0.00	1.5	4.59	1.87	5.72
6	Water Body	0.1	0.31	0.1	0.31	0.15	0.46	0.08	0.24
7	Settlements	0.29	0.89	0.31	0.95	0.49	1.50	0.86	2.63
Total		**32.71**	**100**	**32.71**	**100**	**32.71**	**100**	**32.71**	**100**

CONCLUSION

Land use land cover trajectory analysis showed the rate of change of LULC during the last two decades (1992-1999, 1999-2006, 2006-2013), which provided useful information of forest regeneration in a mining affected area. The existing remote sensing change detection methods could give better insight for sanctuary resource management and monitoring. From the land use land cover change analysis of ABWLS between 1992 and 2013, it was found that the land use land cover structure in 1992 and 1999 is composed mainly of scrub and barren land with total area accounting for 80.16% and 76.18%, respectively. Mining has been banned since 1986 and the early regeneration was taking place in the area mainly as scrub. But both scrub and barren land reduced subsequently in 2006 having percent cover of 42.4% and 22.3%, respectively and drastically in 2013 with percent cover remaining of 5.5% for both, because of faster regeneration of forest due to increased conservation efforts as a sanctuary. However, for forest cover reverse trend was observed during 1999-2006 and 2006-2013 with an increase of 6.76% and 52.92%, respectively. An increase of the forest cover in the study area was most noticeable from 2006 to 2013. Whereas, drastic change in the percent forest cover was observed during 1999-2006 and 2006-2013 with an increase of 6.76% and 52.92% respectively. The change detection analysis shows that due to fast regeneration of vegetation in the sanctuary, rocky outcrops in sanctuary were reduced by 0.06% during 1992-1996; to 0.61% in 1999-2006; and to 1.10% during 2006-2013. Non-forest area such as settlements within the sanctuary showed a continuous incremental change during 1992 to 2013 reflecting high anthropogenic pressure inside the sanctuary. As remote sensing technology advances, its potential role in monitoring surface mining and reclamation will be enhanced**.** GIS and remote sensing provide land cover information and landscape characterization statistics for assessing habitat diversity and land cover change in a disturbance-dominated post-mining landscape.

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