Article

Use of geospatial technology in evaluating landscape cover type changes in Chandoli National Park, India

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Abstract

Monitoring changes in landscape cover types has been a great concern for forest and wildlife managers. Both managers find it very important to know how much area is suitable for wildlife species and what areas are affected due to anthropogenic pressure. To address these concerns, evaluation of Chandoli National Park was done to see the changes that have taken place over the past 28 years. The National Park is situated in India lying within 17^0 04' 00" N to 17^0 19' 54" N and 73^0 40' 43" E to 73^0 53' 09" E. Remotely sensed data procured from satellite IRS-P6, LISS-III (2005) was used. The satellite data was digitally processed and collateral data were generated from topographic maps. The comparative analysis of topographic-map and imagery of 1977 and 2005 revealed that 120.9 km^2 of evergreen forest has been lost during 28 years. Contrary to this an increase of 51.15 km^2 in scrubland and 64.19 km^2 in grasslands were noted. Furthermore, forest cover and land use maps of the study area were prepared from satellite data using supervised maximum likelihood classification technique. The study reveals that Park supports diversified habitats of scrubland (27.47%), grassland (20.13%), rejuvenated (22.17%) and evergreen forest (16.07%). The diversified cover types and improvement in forest density has made the Park suitable for wild animals than the previous one when it was not declared as protected area. The study advocates that if a forest area is protected and conserved from anthropogenic pressure may become more suitable for wild animals.

Keywords remote sensing; GIS; tiger; wildlife; landscape cover change; habitat suitability analysis; Chandoli National Park.

1 Introduction

Over the past 200-300 years humans have been dominant drivers of landscape transformations (Vitousek et al., 1997). During the past 50 years, humans have changed these landscapes to meet the growing demand for food, fodder, timber, fiber, and fuel more rapidly and extensively than in any comparable period of time (Millennium Ecosystem Assessment, 2005).

Recent studies show that environmental, socio-economic, political and technological factors play a great role in landscape change (Burgi et al., 2005). The drivers of landscape change operate at multiple levels that are influenced by regional, national and international/global institutions. According to Lambin et al. (1999), these interactions determine the extent and direction of landscape change.

Biophysical materials and anthropogenic features are often subject to rapid change (Roy et al., 1996a,b; Tahir and Hussain, 2008; Naiman et al., 1999; Rana, 2005; Podobnikar et al., 2009). To fully understand the physical and human processes at work, it is important that such changes be detected and accurately quantified. Landscape changes are of interest because of recognition that changes in land-uses are a major factor affecting global environments (Dale et al., 1993). Wu and Hobbs (2002) considered causes, processes, and consequences of land-use and land-cover changes as one of the main research topics.

In some instances land use / land cover change may result in environmental, social, and economic impacts of greater damage than benefit to the area (Mohsen, 1999). Thus, data on land use change are of value to planners in monitoring the consequences of changes occurring within the region. Such data are of interest to resource management and planning agencies because of their value in assessing current land use patterns and in modeling future developments.

For forest managers, it is of utmost importance to know the precise status of their resources spatially, the location and extent of various vegetation classes within them, the impact and progress of various actions undertaken, and extent of the change along with their trends and patterns. Information about the change is also necessary for updating land cover maps and the management of natural resources.

The tropical region in general is witnessing an accelerated rate of degradation as documented by U.N. (FAO, 1982). The average annual deforestation during the past decade amounts to 15.4 million hectares per year with a compound annual rate of deforestation of 0.8%. The Western Ghats in particular (where the study area is located), characterize many of the conservation problems posed by forest fragmentation. A recent estimate accounts for the loss and conversion of the original natural vegetation of the Western Ghats during 1920–1990 to be around 40%, with an annual rate of deforestation of around 0.57% and a fourfold increase in the number of fragments (Menon and Bawa, 1997). This is a major concern given that forests resources are foreseeable for the human health, ecological balance and economy, hence need continuous monitoring to detect the changes.

Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Anderson, 1977; Ingram and Robinson, 1981; Nelson, 1983). It is useful in such diverse applications as land use change analysis, monitoring of shifting cultivation, assessment of deforestation, study of changes in vegetation phenology, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring and snow-melt measurements.

The literature survey and field visits of the study area revealed that over the span of 28 years (1977-2005) many conservational measures were taken for the improvement of habitats and forests of this protected area (PA). Tree plantation, development of grass lands, evacuation of twenty eight villages, complete ban on commercial exploitation of the forest resource and fishing in the reservoir, restricted entry of local people inside the protected area, etc., were some of the measures taken by the forest department (Anonymous, 2005). Not only this, the government of India has augmented its status from sanctuary to National Park and now as tiger reserve and being a "tiger reserves" it is well protected, well funded and well equipped in comparison to sanctuaries and National Parks (National Tiger Conservation Authority, 2008). These developments have encouraged the author to consider Chandoli National Park as a case study to evaluate the impact of conservation and management measures implemented inside the protected area. Evaluation of temporal changes in landscape cover is one of the best methods to see the impact of conservational and management implications (Abbas, 2010).

The information about the change in landscape may be obtained by visiting sites on the ground and/ or extracting it from remotely sensed data. The studies on landscape change carried out by conventional methods, like gridded mirror technique or ocular estimate of tree canopy cover for evaluating the temporal change in forest crown density (Mueller-Dombois and Ellenberg, 1974; William 2006; Hussain et al., 2008) and multi stage random sampling for vegetation evaluation (Chako, 1965; Ilyas, 2001; Kushwaha et al., 2004), is a formidable task (Adeniyi, 1980).

They are time consuming and do not provide a holistic picture. Monitoring forests from the space or airborne platforms, in contrast, can provide relevant information quickly, as well as repeatedly and at regular intervals of time. This makes it possible to detect changes in the forest environment quickly and efficiently. Considering the importance of remote sensing and geographic information system (GIS) in evaluating the changes in landscape cover, this technique is used for the present study.

Remote sensing offers an important means of detecting and analyzing temporal changes. And since the early 1970s, satellite data have been commonly used for detecting these changes over large landscapes. Many studies have demonstrated the effectiveness of using remotely sensed data as a powerful tool to detect land use change for critical environmental areas, vegetation dynamics and urban expansion. Many eminent remote-sensing scientists have already undertaken several such investigations (Coppin and Bauer, 1996; Victorov et al., 2007; Podeh et al., 2009). Early change detection works focused on the use of aerial photographs or topographical map in evaluating vegetation change. Aerial photographs make sense over historical time periods and are helpful in detailing vegetation land cover (Beaubien, 1986). Pitt and colleagues (1977) described aerial photographs as one of the simplest methods for detecting forest changes because of their easy availability and interpretability.

As time progressed, digital methods were developed for detecting change using satellite imagery to take the advantage of the new repetitive, synoptic digital data (Saint 1980; Howarth and Wickware, 1981). Hame (1988) used visual interpretation techniques to detect forest changes from satellite scanner imagery, whereas Sugumaran et al. (2003) were successful in using satellite imagery to delineate the boundaries of planted forests that were converted under various programmes.

The concept of remote sensing data and its use in evaluating forest change has also taken momentum in India and various works have been done on this aspect. Gupta and Munshi (1985) used aerial photographs and a LANDSAT image to monitor the changes in Delhi (India) during the period 1959-1980. Gautam and Chenniah (1985) were able to detect changes and prepared land use and cover map of Tripura using Landsat imagery data. In 1989, Singh (1989) used Landsat data for detecting the changes in the forests of north-eastern region of India and found it to be an effective tool. Kushwaha (1990) used pre and post imagery Landsat multispectral scanner (MSS) data and detected impacts of 1984 November Andhra cyclone and the ISRO activities on Sriharikota Island and some of the changes noted were even at the micro level. In addition, Kushwaha et al. (2000) evaluated the habitat changes in Kaziranga National Park (Assam) using remote sensing technique, while Karia et al. (2001) studied the temporal changes in forest cover of Kalarani reserve forest of Vadodara (India). Chauhan et al. (2003) carried out the analysis using aerial photographs of 1976 and satellite data -IRS 1C LISS III false colour composite of 1999 and evaluated the changes in density of sal forest. Ramachandra and Kumar (2004) used multispectral sensors data of the Indian remote sensing satellites -1C (of 1998) and IRS -1D (of 2002) to study the changes in land use pattern of Kolar district, Karnataka (India). Panikkar (1999) used topographic maps of 1930, 1960 and satellite imagery of 1990 to see the changes in the landuse/land cover of Dehradun and Mussoorie in Uttar Pradesh, India over a period of 60 years.

In 2005, Lele, et al. used remote sensing data for analysing forest cover dynamics in north-east India while Joshi and his colleagues (2005) identified alpine and arid region in Ladakh. Singh et al. (2006) monitored forest plantations and also assessed the effect of settlements on growing stock in Tahno range of Dehradun Forest Division. Okhandiara (2008) selected medium spatial resolution multi-spectral remotely sensed data of IRS-1D and IRS-P6 LISS-III to detect change in forest landscape of Kannod Forest Subdivision of Dewas district, India between the years 1999 and 2005. In a recent development, Patra et al. (2008) used two multispectral and multi-temporal remote sensing images and semi-supervised technique to evaluate change detection without ground truthing information. Recently, Chakraborty (2009) used moderate resolution imaging spectroradiometer (MODIS) to study the change in forest cover of Barak basin, north eastern part of India.

2 Study Area

Chandoli National Park lies within 17^0 04' 00" N to 17^0 19' 54" N and 73^0 40' 43" E to 73^0 53' 09" E (Fig. 1) in the districts of Satara, Kolhapur, Sangli, and Ratnagiri, Maharashtra state, India. It is mainly stretched along the crest of the North Sahyadri range of the Western Ghats, between the Koyna and Radhanagri Wildlife sanctuaries. Chandoli National Park contains pristine patches of evergreen forest. The origin of the Warna river and almost the entire catchments of the reservoir are protected. Though the reservoir submerged patches of forests, it is now playing an important role in providing effective natural protection to the remaining forests by isolating them from human interference. This area along with others mentioned above was primarily declared a protected area to protect catchments of the dam as well as to conserve biological diversity of the region. There are only a few remaining dense forest patches left in northern parts of the National Park. This area was declared a sanctuary on 16 September 1985 vide notification No. WLP 1085/CR-588/(II)F-5 and later on as National Park on 14th, May 2004. Previously the sanctuary area was 308.97 km^2. Further 10 km^2 was added while declaring it as National Park.

The Chandoli National Park is situated in the bio-geographic province of Western Ghats Mountains. This bio-geographic zone has a chain of hills that run along the western edge of peninsular India and supports 27% (4,000-15,000 species) of all the higher plant species recorded in India, out of that about 1,800 are endemic to this region (Imam and Yahya, 2009). The topography is undulating, with steep escarpments, often with exposed rock. The average elevation is 816.5 msl, with the lowest point at 589 msl and the highest point at 1,044 msl. A distinct feature of the park is the presence of numerous barren rocky lateritic plateaus, locally called the *sadda*. These are usually flat to slightly inclined and have a tremendous amount of loose scattered laterite. These *sadda* have overhanging cliffs on the edges and numerous fallen boulders. Geological foundation of the area is Deccan trap, the soils are mostly lateritic on the plateau and reddish brown with mixed origin on the hill slopes. Before the declaration of this forest area as National Park, some of the forestlands were owned by the villagers as their private property, on which forest department was not having any control. Those forestlands were known as *malki* forest (*malki* means ownership).

The Chandoli National Park experiences a moderate climate with a *maximum* temperature of 38^0C in summer and a *minimum* of 7^0 C in winter. Mean annual rainfall is 3,500 mm (recorded at Chandoli village). According to Champion and Seth (1968) the forest types include, western tropical hill forests, semi-evergreen forests and southern moist mixed deciduous forests, Forests have also been described as tropical semi-evergreen and moist deciduous. Dominant plant species include Anjani (*Memecylon umbellatum*), jamun (*Sygyzium cumini*) with associates Katak (*Bridelia retusa*), Kinjal (*Terminalia paniculata*), Phanasi (*Carallia brachiata*), Ain (*Terminalia alata*), Amla (*Phyllanthus* e*mblica*), Umbar (*Ficus hispida*), Harra (*Terminalia chebula*). Bangala (*Andorpogony*), Dongari (*Crysopogon fulvus*), Kalikusli (*Heetropogon contortus*), Karad (*Themeda quadrivalvis*), Saphet-kusli (*Aristida funiculata*) and bamboo species *Bambusa bamboo* (Kalak) are some of the common grass species. The regeneration of grasses and other plant species are observed in the land evacuated by villagers. Chandoli National Park has very few wild animals, probably due to to anthropogenic pressure prior to being declared a protected area. However, bison (*Bos gaurus*), sambar (*Cervus unicolor*), muntjack (*Muntiacus muntjak*), leopard (*Panthera pardus*), tiger (*Panthera tigris*) are found in the protected area. In addition to Warna River 19 other perennial and 48 seasonal natural water sources are present inside the park (Anonymous, 2005).

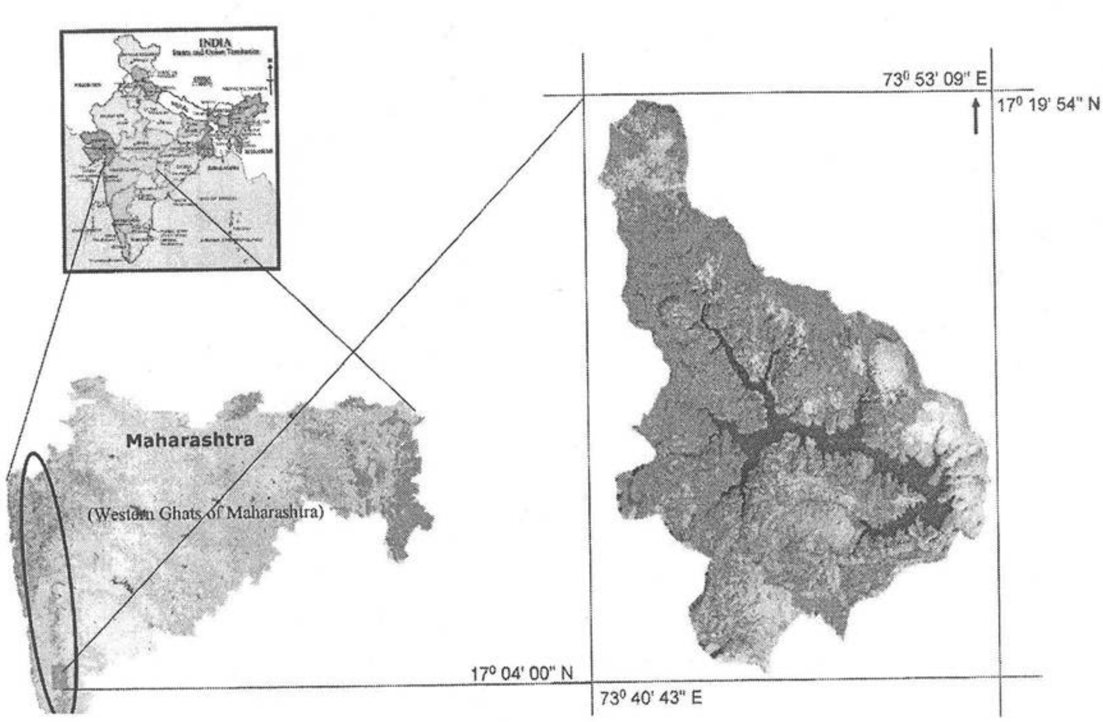

Fig. 1 Location of study area (Chandoli National Park)

3 Methods

The study was carried out in three phases. In the first phase satellite and collateral data were collected and processed, while during the second phase, field survey was conducted for ground truthing to perform hybrid classification (supervised + on-screen digitization). The third phase included database creation and geospatial evaluation of landscape changes. *ERDAS IMAGINE 8.7* (2004) and ArcView 3.2 (1999) computer softwares were used for data processing and GIS analysis.

3.1 Data collection and data processing

Data are generally classified as either primary or secondary. The primary data was obtained by field surveys and by actual measurements recorded during the fieldwork. A global positioning system (GPS), rangers compass, binocular and camera were tools used during the field visit(s). Secondary data was obtained from various sources like National Park maps, topographic maps, and satellite imageries.

3.2 Satellite data

Satellite data of Indian remote-sensing satellite-P6, linear imaging self-scanning satellite-III (IRS-P6, LISS-III) of dated 25th February 2005, Path-95, Rows-060 and 061, swath width 140 km, ground resolution of 23.5m with three spectral bands in visible near-infrared (VNIR) and one in short wave infrared (SWIR) band was acquired from national remote sensing agency (NRSA), Hyderabad, India. Satellite data (imageries) were used for creating False Colour Composite (FCC) that served as the basis to develop the Land Use/Land Cover and Forest Density maps.

The study area lies in two scenes of 095-60 and 095-61 (L1SS III). The satellite data were imported into ERDAS IMAGINE software in an image format for geometric correction. Geometric distortions in a satellite image are introduced by the sensor system. In order to use these data in conjunction with other spatial data, it is needed to georeference the distorted data (raw data) to a coordinate system. The LISS data was co-registered with already rectified enhanced thematic mapper (ETM) satellite data of November 1999 considering it as a reference coordinate system. This method is known as image to image correction, which involves matching of the coordinate systems or column and row systems of two digital images with one image acting as a reference image and the other as the image to be rectified. Distortions can be corrected using ground control points (GCP) and appropriate mathematical models. A ground control point is a location on the surface of the earth (e.g., a road intersection) that can be identified on the imagery and located accurately on a map/rectified image. The image analyst must be able to obtain two distinct sets of coordinates associated with each GCP: (i) *image coordinates* specified in i rows and j columns, and (ii) *map/rectified image coordinates specified in x and y axis*.

The paired coordinates (i, j and x, y) from GCPs can be modeled to derive *geometric transformation coefficient.* These coefficients may be used to geometrically rectify the remotely sensed data to a standard datum and map projection. Polynomial equations are fit to the GCP data using least-squares criteria to model the corrections directly in the image domain without explicitly identifying the source of the distortion (Sabbins, 1987).

In the present study about 20 well distributed prominent features like river, road junctions, drainage bends, drainage junctions, sharp ridge curves, isolated features and some big permanent structures available and identifiable on both the images (LISS and ETM) were considered for GCPs. During the process, GCPs were located in both images (distorted and already rectified) in terms of their coordinates; as column and rows on distorted image (LISS image) and as ground coordinates on already rectified ETM image in terms of universe transeverse mercator world geodetic system -84 (UTM WGS-84). These values were submitted to a least square regression analysis to determine coefficient for two coordinate transformation equations that is used to interrelate the geometrically correct image coordinates (here ETM image) and distorted image coordinates (here LISS image).

All these mathematical notations were processed in *ERDAS IMAGINE.* Once the coefficients for these equations were determined, the distorted image coordinates for the map position were precisely estimated. The precision was measured through root mean square error (RMSE). The RMSE is a measure of precision and used to determine accuracy of the transformation from one system to another system of coordinates. It is the difference between the desired output coordinate for a GCP and the actual. The formula for RMSE is:

$$\mathbf{RMSE} = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(y_j - \hat{y}_j)^2}$$

where the large sigma character represents summation, j represents the current predictor, and n represents the number of predictors.

During the satellite image georeferencing, RMSE is the degree of which the transformation can accurately map all ground control points. It can be measured mathematically by comparing the actual location of the map coordinates to the transformed position in the raster. The distance between these two points is known as residual error. This value describes how consistent the transformation is between the different control points. The units of RMS error are in pixels (Smith and Atkinson 2001). It is common to determine that which of the GCP from the total set contributes the most error, then this point has been eliminated and a new transformation model was recomputed. Considering this, many GCPs were eliminated until the RMS error has not become 0.2 pixels. However, in any case GCPs were never kept below 20. The well distributed 20 GCPs improved the image rectification accuracy and brought the RMSE value as low as 0.2, which is below 1 pixel and can be considered sufficiently accurate (Thakur et al., 2008).

Then the two rectified scenes of 095-60 and 095-61 (L1SS III) were mosaiced using a model present in *ERDAS IMAGINE* software. Image mosaicking is a process in which two or more than two images (already rectified to a standard map projection and datum) are combined into a single seamless composite image. From the mosaiced data, a subset of area of interest (AOI) was made for further analysis. Image was displayed as a False Colour Composite (FCC) using three bands (3, 2, 1) and colour prints were taken to the field for ground truthing.

3.3 Collateral data

The topographic maps; 47G/6, 47G/10, 47G/11 and 47G/14 (1:50,000 scale) of the study area, were collected from forest department, Kolhapur (wildlife wing), Maharashtra and park boundary was marked with the help of forest officials. The topographic maps are a graphic form of visual communication. In India these maps are published by the government agency, Survey of India (SOI). The topographic map is a selective, idealized, symbolized and generalized representation of the whole or part of the earth on the plane surface. It has scale, direction, latitudes and longitudes. The purpose of a topographic map is generally to present the distribution of geographic phenomenon of the earth surface and the arrangement of major land forms and land-use. The topographic maps are large scale maps showing the location and shape of both natural and man made features. It provides information viz: (i). Marginal information-on the margins of topographic maps information about name of state(s), name of district(s), latitudes, longitudes, scale, contour interval, year of publication are given; (ii). Physiographic information- it provides information on nature and types of landforms (mountain, plateau or plain), average height, general slope, important hills, peaks, ridges, valleys etc; with their height and locations, important rivers, their tributaries and drainage pattern. Topograhic maps also provide information on areas covered by vegetation, types of forest (protected forest, reserve forest) and other types of vegetation and their distribution; (iii). Cultural information- Topographic maps bear a sufficient information pertaining to cultural aspects, which includes land-use (cultivated land, waste land, other use of land), means of irrigation, occupational structure of the population (mining, cultivation, forestry, etc), settlement (urban centre, rural settlements, etc., Ishtiaq, 1994). Topographic maps are also used in detecting the landscape changes. Parikkar used GIS and topographic maps of 1930 and 1960 to evaluate the changes in land use/land cover of Dehradun, India.

The study area is covered by four different topographic sheets (as mentioned above), therefore, all these maps were scanned and exported to *ERDAS IMAGINE 8.7* in image format (.img) for geo-referencing. Georeferencing is needed if topographic maps are used in conjunction with other spatial data. The topographic map of "survey of India" is gridded into nine equal quadrangle grids and information regarding coordinates (latitudes/longitudes) is present at the margins/corners of the map in coordinate system of "geographic" in degrees/minutes/seconds. The values of latitudes/longitudes of quadrangle (grid intersections) was calculated manually and used as GCPs. For each topographic map, sixteen GCPs (12 from margins/corners and 04 from grid intersections) were picked up by placing "crosshair" over corners and quadrangle grid crossing of topographic map. These known coordinate data were entered into the model as; longitude of topographic map in X field and latitude of topographic map in the Y field in degree minutes seconds (DD MM SS) format, which is automatically converted to decimal form. Similarly, the other three topographic maps were georeferenced. The RMS error (discussed on previous page) was maintained up to one-third of a pixel by placing the crosshair over accurate position of known coordinates (on topographic maps). The map was resampled using the nearest neighbourhood method and re-projected into universe transverse mercator world geodetic system-84 (UTM-WGS 84) projection for further analysis. Nearest neighbour is a resampling method used in remote sensing. It is an interpolation that determines the grey level from the closest pixel to the specified input coordinates, and assigns that value to the output coordinates. This method is considered to be the most efficient in terms of computation time, because it does not alter the digital number (grey level) value (Lillesand and Kiefer, 1994).

Then the four rectified topographic maps were mosaiced (method discussed in previous page). This mosaiced map was overlayed/swapped on rectified LISS image and its accuracy was checked by seeing overlapping of the features like roads, railway lines, crossing of canal etc. on each other. From the mosaiced data a study area of interest (AOI) was built around the park boundary to produce a rectilinear map for extracting information on various aspects of landscape cover, park boundary, etc.

3.4 Field survey

Field surveys were carried out over a 15 days period from the 18th to the 30th October 2005. Ground truthing was done by matching the pattern, texture association, shape and size of the features from the FCC for a particular topographic feature using GPS locations. Initially it was decided to use "line transects method" for collecting data for ground truthing. But later changed for a "opportunistic transect method" as forest areas were not always accessible due to high density of under growth and absence of accessible tracks and roads. The forest area on both sides of the reservoir was traversed on foot and GPS locations were noted.

3.5 Database creation using remote sensing and GIS

The geocoded FCC of IRS-P6 L1SS III dated 25th February 2005 was digitally analyzed. The Land Use/Land Cover map of the study area was prepared through digital analysis of satellite data using supervised maximum likelihood classification technique. Supervised classification is a procedure for identifying spectrally similar areas on an image by identifying 'training' sites of known targets and then extrapolating those spectral signatures to other areas of unknown targets. Supervised classification relies on the *previous* knowledge of the location and identity of land cover types that are in the image. This can be achieved through fieldwork study of aerial photographs or other independent sources of information. Training areas, usually small and discrete compared to the full image, are used to "train" the classification algorithm to recognize land cover classes based on their spectral signatures, as found in the image. The maximum likelihood classifier (MLC) assumes that the training statistics for each class have a normal or 'Gaussian' distribution. The classifier then uses the training statistics to compute a probability value of whether it belongs to a particular land cover category class. This allows for within-class spectral variance. In this the image analyst uses a prior knowledge to weight the probability function. The MLC usually provides the highest classification accuracies (Lellesand and Kiefer, 1994). This digitally analysed forest cover and land use map was left for further on-screen digitization, known as hybrid classification.

Normalized difference vegetation index NDVI was used to prepare a forest density map that was categorized into four canopy density classes: <10% (non forest), 10-40% (open), 40-70% (medium) and >70% (dense). Image elements like tone, texture, shape, size, shadow, location and association were also evaluated to aid in the class delineations. NDVI is a method of measuring and mapping the density of green vegetation. For its measurement scientists use satellite sensors that observe the distinct wavelengths of visible and near-infrared sunlight which is absorbed and reflected by the plants, then the ratio of visible and near-infrared light reflected back up to the sensor is calculated. The ratio gives a number from minus one (−1) to plus one (+1). An NDVI value of zero means no green vegetation and close to +1 (0.8–0.9) indicates the highest possible density of green leaves. The 'normalized difference vegetation index' is calculated by the formula: $NDVI = (IR-R)/(IR + R)$, where IR = infrared light and R = red light (Lellesand and Kiefer, 1994). The group of pixels having NDVI values from 0 to 0.3 were categories under canopy density class of <10%, 0.3-0.5 as canopy density class of 10-40%, and 0.5-0.7 were categorised as 40-70%, whereas, the group of pixels having NDVI value 0.7-0.9 were kept under the canopy density class of >70%.

3.6 Evaluation of changes in landscape covers type

The change in landscape cover type was evaluated by comparing multi-date data sets. One set of data was topographic maps of 1977 (1:50,000), whereas another one was satellite data of LISS-III (of 1995).

The geo-referenced topographical map was brought within the geospatial environment of ArcView software for the visual interpretation and on-screen digitization. Similarly, digitally analyzed and already classified forest cover/landuse map (supervised classification of LISS imagery, as discussed earlier) was brought within the geospatial environment of ArcView software as a base map/image for the visual interpretation and on-screen digitization (i.e. hybrid supervised classification). The hybrid classification of LISS image was done in order to provide similar methodological treatment to topographic map as well satellite imagery while preparing the forest cover/landuse map. A hybrid classification is an approach in which generally supervised /unsupervised classification is coupled with on-screen digitization to generate a layer/map. This method is considered to be more efficient and accurate than maximum likelihood classifier (Ranga et al., 1999). The hybrid classification method can be used for generating Land Use/Land Cover map employing supervised classification, on-screen digitization technique and ground truthing (Kamusoko and Aniya, 2009).

On-screen digitization grants a higher level of accuracy (Anonymous, 2010). It captures data from digital images or scanned maps by using the mouse instead of the cursor. In addition, on-screen digitizing provides zoom facility. It also allows for editing features when enough information is available from the image. This method is commonly called "heads-up" digitizing because the attention of the user is focused up on the screen. This technique is used to trace features from a scanned map or image to create new layers or themes by adding labels during tracing (Anonymous, 2010). This method can make full use of an analyst’s experience and knowledge. Texture, shape, size and patterns of the images are key elements useful for identification of changes in Land Use/Land Cover through visual interpretation. However, this method is time consuming for a large-area change detection application. Jensen (1996) used on-screen digitization to distinguish mangrove forest from non-mangrove forest, whereas, Stone and Lefebvre (1998) used visual interpretation and on-screen digitization to evaluate selective logging in Para, Brazil. Loveland et al. (2002) used this technique on fine resolution data to detect United States land-cover changes and estimate the change rates. Recently, Lu et al. (2004) used visual interpretation of multi-temporal colour composite images for quantifying the land-cover changes.

In the present study on-screen digitization technique was used and the satellite imagery (after supervised classification) was delineated and classified into six categories of evergreen forest, scrub land, grass land, *Malkiland* (secondary/rejuvenated forest), *sada* (laterite rock) and river (water). The topographic map was delineated and classified into only five categories; evergreen forest, scrub land, *malkiland* (overexploited), *sada* (laterite rock), and river (water). Grass lands were not shown on the topographic map, so not considered for classification. The spatial distribution of “*malkiland*” (on topographic map) and “secondary/rejuvenated forest” (on satellite imagery) was identified almost on the same location; however, two were distinguished on the basis of forest’s status, like degraded or rejuvenated.

The different classes were digitized on-screen with the help of mouse in the polygon form and stored as a vector file in shapefile format in ArcView. During the delineation of features, the vector files (in shapefile format) were displayed over the original topographic map/satellite image to see the accuracy of digitization. After creation of shapefile (the format Arc View uses)"attributes’ were attached. Each class was given unique identity and assigned a particular colour to make them separate from each other. The vector maps were polygonized using a clean-build operation. The aggregated area of different classes were calculated and verified with the total area of the national park.

After preparation of Land Use/Land Cover maps from topographic map (1977) and satellite imagery (2005), area of each class were compared to analyze the changes in the landscape cover type (Table 1 and Fig.2).

4 Results and Discussion

A comparative analysis of topographic map and satellite imagery revealed that over the 28 years (1977-2005) major changes took place in landscape cover types within the Chandoli National Park (Fig. 3 and 4).

A detailed analysis of toposheets and other secondary information shows that the study area was initially covered with about 178.14 km^2 of evergreen dense forest, mixed forest and open forest. Originally, 32 villages

Table 1 Changes in Wildlife habitats of Chandoli National Park during 1977-2005

SN	Habitat type	Area during 1977 (in Km^2)	Area during 2005 (in Km^2)	Changes	Description
1	Evergreen forest	172.14	51.24	-120.9	1. Decrease in forest area up to 120.9 Km^2 2. Some of the forest patches submerged into reservoir after dam construction
2.	Scrub land	36.45	87.60	+51.15	1. Increase in scrub land up to of 51.15 km^2 2. Area increased as some of the agriculture land evacuated by villagers are converted into scrubland
3.	Grass land	NA	64.19	+ 64.19	1. As such no grass land was marked on toposheet of 1977 2. After evacuation of the villages some of the agriculture land developed into grass land 3. Grass plantation were also done in some of the area by forest department
4	*Malkiland*	97.66 (over-exploited)	70.70 (Secondary/ rejuvenated) forest	-26.96	1. Area decreased to 26.96 km^2 2. As some of the area developed into secondary/rejuvenated forest 3. some area converted into scrub land
5.	River (Water)	3.0	35.52	+32.52	1. Increase of 32.52 km^2 2. After dam construction, a reservoir with backwater submerged approx 32 km^2
6.	*Sada* (Laterite rock),	9.75	9.75	No change	1. No change 2. Change in rock is very slow process and may takes thousands of years

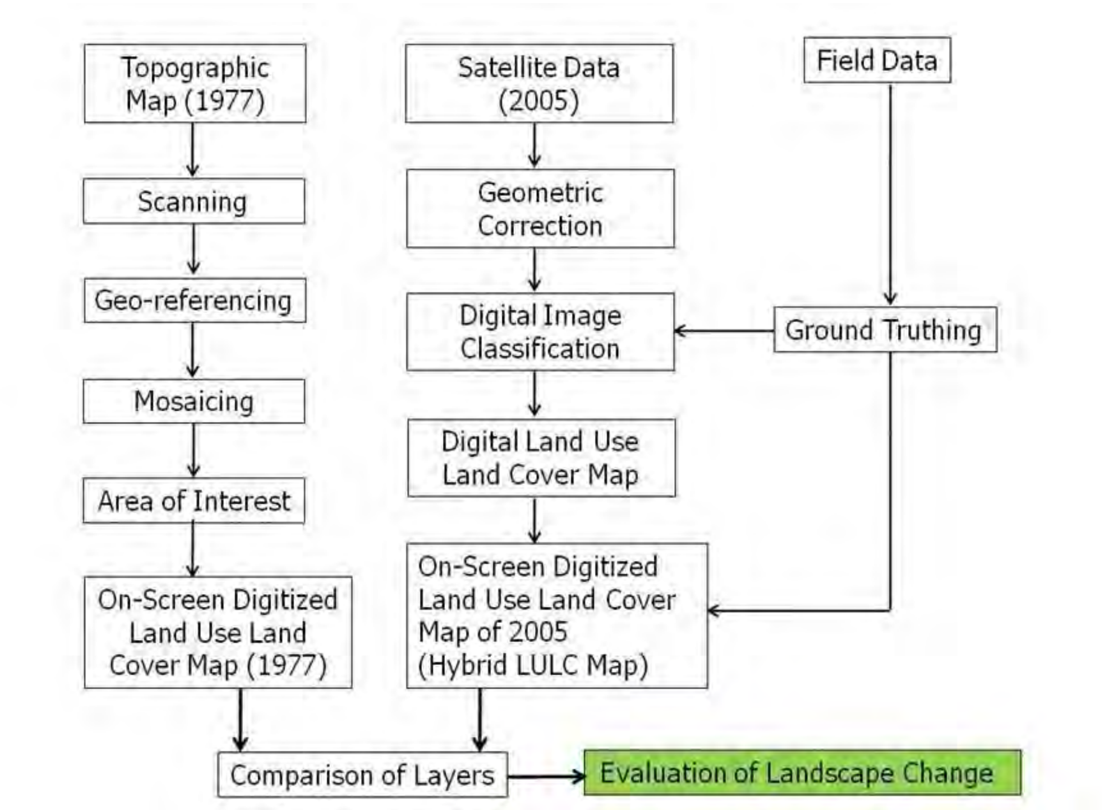

Fig. 2 Paradigm of landscape cover type change evaluation for Chandoli National Park, India (1977-2005)

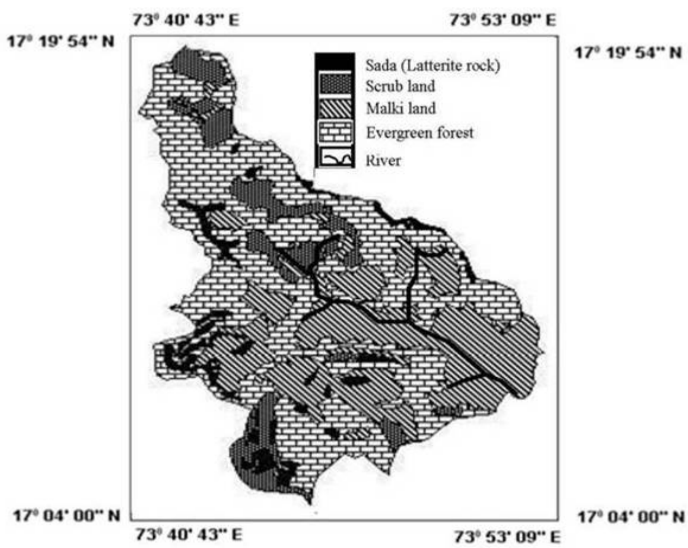

Fig. 3 Status of Chandoli National Park during 1977

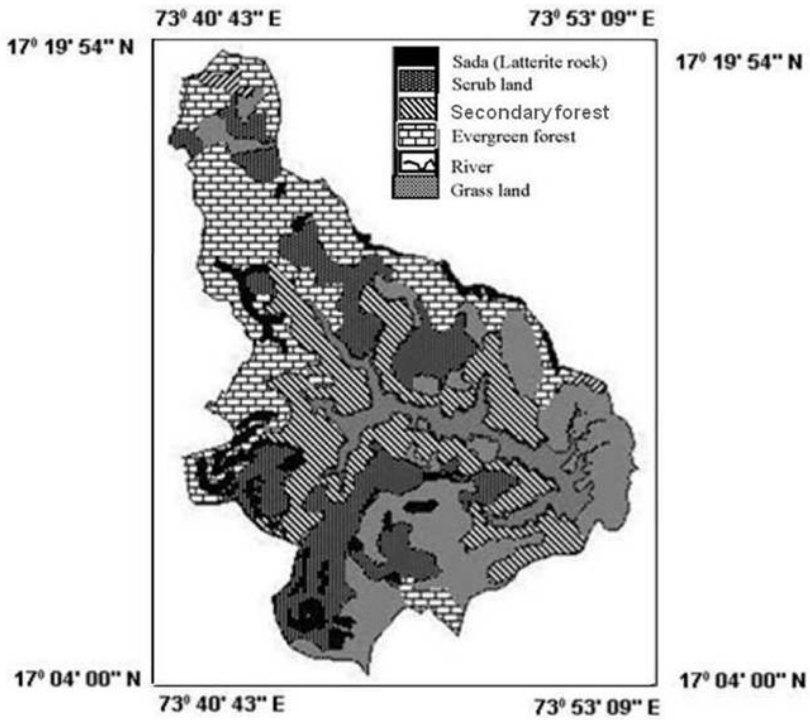

Fig. 4 Status of Chandoli National Park during 2005

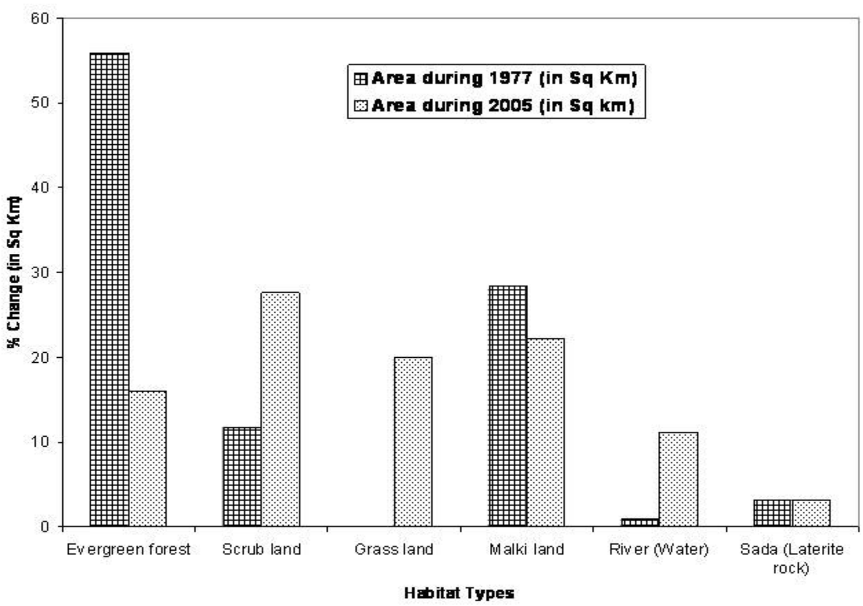

Fig. 5 Change in wildlife habitat of Chandoli National Park during 1977-2005

with several hamlets were present inside the protected area and contained a human population of 7,900. Whereas, within a 10 km radius of National Park, about 78 villages with a human population of 10,150 (1981 census) were also present. It is reported that most of the villagers were either labourer or marginal farmers depending partially or fully on the forest resources to meet their requirements of fuel, timber, habitation and fodder for their livestock. The total number of livestock present in the protected area accounted for 2800 with another 75,000 found within a 10 km radius of the National Park (Anonymous 2005). The dependency of such a large number of human population and livestock on the protected area has led to the depletion of forest resources resulting in a loss of 120.9 Km^2 of evergreen forest (Table 1, Fig. 5).

In contrary, an increase of 51.15 km^2 of scrubland was recorded during 28 years (1977-2005). This increase might be in part attributed to the conversion of lost forest into scrubland caused by either the indiscriminate cutting of the trees that reduced the open forest into an early stage i.e. scrubland or by the development of evacuated area into scrubland due to protection from overgrazing.

The most important development that occurred in the National Park is the expansion of grasslands. The satellite imagery shows that grasslands have been created in the south-east, south-west as well as in the National Park's extreme northern part. These grasslands cover an area of 64.19 km^2 (Imam 2005). However, the 1977 topographic map shows no such areas as grassland. It is reported that development of grasslands occurred due to the planting of grasses over 6.9 km^2 and because of natural growth in agricultural lands that were evacuated by villagers. During the field visit, I observed that 28 villages (out of 32) that were evacuated had played a major role in the recovery of this cover type. The *Malkiland* covers an area of 97.66 km^2 and was previously owned by the villagers and over-exploited; this land has now reclaimed and parts have rejuvenated into "secondary forest". Inspite of protection and conservation, only 51.15 km^2 of *Malkiland* has been restored as "secondary forest" and the rest has either been converted into scrublands or grasslands. In my opinion, this is probably due to loss of fertile top soil making it unsuitable for supporting large size trees, and because a portion of the *Malkiland* was also submerged by the reservoir after construction of the dam.

A comparative study of the topographic map and satellite imagery of the study area over two time periods has revealed that no change has been noticed in *Sada* (Laterite rocks) located inside the National Park. Basically without human intervention, it is a well known fact that changes to rock is very slow process that takes thousands of years to make any noticeable alterations. So this finding is not surprising. However, the congruency between the products (of proportions and areas mapped as rock outcrop on the map and image classification) will increase the researcher's confidence not only in land cover changes results but also on remote sensing and GIS techniques.

My final assessment shows that in 2005 the Chandoli National Park supports the following landscape cover types: scrubland (27.47%), grassland (20.13%), secondary/rejuvenated forest (22.17%), evergreen forest (16.07%), *Sada* (3.06) and water (11.10%) (Table 1). Additionally, 16.61% of forested areas are covered by crown density of more than 70%, and 22.97% with the density class of 40-70% (Table 2). The diversified cover types and improvement in forest density has made the National Park more suitable for wild animals than previously, when it was not declared as protected area.

Table 2 Crown Density of Chandoli National Park during 2005

Density Class (in %)	Area (km^2)	Area (%)
0 – 10	83.50	26.08
10 – 40	109.35	34.31
40 – 70	73.20	22.97
More than 70	52.90	16.61

These landscape changes also support Imam (2005) habitat suitability analysis that suggested that the forest area of Chandoli National Park is suitable for tigers, and their prey base (herbivores like sambar, muntjack, and bison). Specifically, the habitat suitability analysis revealed that 136.37 km^2 (42.75%) of the forested area is suitable for tiger in the Park.

5 Conclusion

Finally, my study suggests that if a forest area is protected and conserved from anthropogenic pressure, landscape cover type changes can occur that appear to be conducive as suitable wildlife habitat. In the future by declaring specific areas as a National Park, and providing them additional protection, appears to be a strategy to enhance desirable landscape cover types for wildlife. Our present time tells us of a scenario whereby we are losing tiger habitats continuously, thus declaring additional National Parks as Tiger Reserves may be a big step towards achieving tiger conservation.

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References

Abbas II, Muazu KM, Ukoje JA. 2010. Mapping land use-land cover and change detection in Kafur Local Government Katsina, Nigeria (1995-2008) using remote sensing and GIS. Research Journal of Environmental and Earth Sciences, 2: 6-12

Adeniypi O. 1980. Land-use change analysis using sequential aerial photography and computer technique. Photogrammetric Engineering and Remote Sensing, 46:1447-1464

Anderson JR. 1977. Landuse and land changes: a frame work for monitoring. US Geological Survey Journal of Research, 5(2): 143-153

Anonymous. 2005. Management Plan of Chandoli National Park. Kolhapur Forest Division, Maharashtra, India, 190

Anonymous. 2010. On-screen digitizing. http://wwwiapadorg/p3dm_process/ step_04b htm

ArcView 3.2. 1999. Environmental System Research Institute's GIS version 3.2. Environmental Systems Research Institute, Inc Redlands CA, USA

Beaubien J .1986. Visual interpretation of vegetation through digitally enhanced Landsat MSS images. Remote Sensing Reviews, 2: 11-43

Burgi M, Hersperger AM, Schneeberger N. 2005. Driving forces of landscape change: current and new directions. Landscape Ecology, 19: 857–68

Chako VJ. 1965. A manual of sampling Techniques for forest surveys. Managers Publication, Delhi, India

Chakraborty K. 2009. Vegetation change detection in Barak Basin. Current Science, 96: 1236-1242

Champion HG, Seth SK. 1968. A Revised Survey of the Forest Types of India Dehradun. Forest Research Institute, India

Chauhan PS, Porwal MC, Sharma L, et al. 2003. Change detection in Sal forest in Dehradun forest division using remote sensing and geographical information system. Journal of the Indian Society of Remote Sensing, 31: 211-218

Coppin PR, Bauer ME. 1996. Change detection in forest ecosystems with remote sensing digital imagery. Remote Sensing Reviews, 13: 207-234

Dale VH, O'Neill RV, Pedlowski M, Southworth F. 1993. Causes and Effects of Land Use Change in Central Rondonia Brazil. Photogrametric Engineering and Remote Sensing, 59: 997-1005

ERDAS IMAGINE 87. 2004. Leica Geosystems GIS and Mapping. Gisleicageosystems.com

FAO. 1990. Survey of Tropical Forest Cover and Study of Change Processes. Forest Resource Assessment, Forestry Paper, FAO

Gautam NC, Chennaiah GC. 1985. Land-use and land-cover mapping and change detection in Tripura using satellite LANDSAT data. International Journal of Remote Sensing, 6: 517-528

Gupta DM, Munshi MK.1985. Urban change detection and land-use mapping of Delhi. International Journal of Remote Sensing, 6:529-534

Hame TH. 1988. Interpretation of forest changes from satellite scanner imagery. In: Satellite Imageries for Forest Inventory and Monitoring; Experiences, Methods, Perspectives, Research Notes, No. 21, Department of Forest

Howarth PJ, Wickware G M. 1981. Procedures for change detection using Landsat digital data. International Journal of Remote Sensing, 2: 277-291

Hussain MS, Sultana A, Khan JA, et al. 2008. Species composition and community structure of forest stands in Kumaon Himalaya Uttarakhand India. Tropical Ecology, 49: 167-181

Ilyas O. 2001. Status and conservation of ungulates in the Kumaon Himalayas with special reference to aspect of ecology of barking deer *Muntiacus muntjak* and goral *Nemorhaedus goral.* PhD Thesis, Aligarh Muslim University, India

Imam E. 2005. 2005. Habitat suitability analysis for tiger in Chandoli National Park Kolhapur using Remote Sensing and GIS. Dissertation, Indian Institute of Remote Sensing, India

Imam E, Yahya HSA. 2009. Primates of India. Sadguru Publication, India

Ingram K, Knapp E, Robinson JW. 1981. Change detection technique development for improved urbanized area delineation. Technical Memorandum. Computer Sciences Corporation (CSCITM-81/6087), Silver Springs Maryland, USA

Ishtiaq M. 1994. Practical geography. Jawahar Publishers and Distributors, New Delhi, India

Jensen JR. 1996. Introductory digital image processing: A remote sensing perspective. Prentice Hall, USA

Joshi PK, Rawat GS, Padilya H, et al. 2005. Land use/land cover identification in an alpine and arid region. Nubra valley Ladakh using satellite remote sensing. Journal of Indian Society of Remote Sensing, 22: 371-380

Kamusoko C, Aniya M. 2009. Hybrid classification of Landsat data and GIS for land use/cover change analysis of the Bindura district Zimbabwe. International Journal of Remote Sensing, 30: 97-115

Karia JP, Porwal MC, Roy PS, Sandhya G. 2001. Forest change detection in Kalarani round Vadodara Gujarat- a remote sensing and GIS approach. Journal of the Indian Society of Remote Sensing, 29: 129-135

Kushwaha SPS. 1990. Forest-type mapping and change detection from satellite imagery. Journal of Photogrammetry and Remote Sensing, 45: 175-181

Kushwaha SPS, Khan A, Habib B, et al. 2004. Evaluation of Sambar and muntjak habitats using geostatistical modeling. Current Science, 86: 1390-1400

Kushwaha SPS, Roy PS, Azeem A, et al. 2000. Land area change and habitat suitability analysis in Kaziranga National Park Assam. Tigerpape, 27: 9-17

Lambin EF, Baulies X, Bockstael N, et al. 1999. Land-Use and Land-Cover Change (LUCC): Implementation Strategy. IGBP Report 48, Stockholm, Sweden

Lele NV, Joshi PK, Agarwal SP. 2005. Remote sensing for forest cover dynamics in North-East India. Indian Journal of forestry, 28: 217-224

Lillesand TM, Kiefer RW. 1994. Remote Sensing and Image Interpretation. John Wiley and Sons, New York, USA

Loveland TR, Sohl TL, Stehman SV, et al. 2002. A strategy for estimating the rates of recent United States land-cover changes. Photogrammetric Engineering and Remote Sensing, 68: 1091–1099

Lu D, Mausel P, Brondi'Zio E, et al. 2004. Change detection techniques. International Journal of Remote Sensing, 25: 2365–2407

Menon S, Bawa KS. 1997. Applications of Geographic Information Systems, remote-sensing and a landscape ecology approach to biodiversity conservation in the Western Ghats. Current Science, 73: 134-145

Millennium Ecosystem Assessment. 2005. Overview of the Millennium Ecosystem Assessment.

Mohsen A. 1999. Remote Sensing and Image Interpretation. John Wiley Sons Inc, USA

Mueller-Dombois D, Ellenberg H. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, New York, USA

Naiman RJ, Elliott SR, Helfield JM, O'Keefe TC. 1999. Biophysical interactions and the structure and dynamics of riverine ecosystems: the importance of biotic feedbacks. Hydrobiologia, 410: 79-86

National Tiger Conservation Authority. 2008. Ministry of Environment and Forest, Government of India

Nelson RF. 1983. Detecting forest canopy change due to insect activity using Landsat MSS. Photogrammetric Engineering and Remote Sensing, 49: 1303-1314

Okhandiara RR, Rajub PLN, Bijkerc W. 2008. Neighborhood correlation image analysis technique for change detection in forest landscape. The International Archives of the Photogrammetry Beijing: Remote Sensing and Spatial Information Sciences Vol XXXVII Part B8

Panikkar SV. 1999. http://wwwgisdevelopmentnet/magazine/gisdev/1999/sep-oct/ fcd shtml

Patra S, Ghosh S, Ghosh A. 2008. Change detection of Remote Sensing Images with semi-supervised multilayer perceptron. Fundamenta Informaticae, 84: 429-442

Pitt AJ, Jakimoff AW, Evans BJ. 1977. The land in the Heytesbury settlement scheme. Soil Conservation Authority Kew, An interim report, http://wwwdpivicgovau /dpi/vro/ coranregnnsf /pages/soil_landform_map

Podeh SS, Oladi J, Pormajidian MR, et al. 2009. Forest change detection in the north of iran using TM/ETM+Imagery. Asian Journal of Applied Science, 2: 464-474

Podobnikar T, Schoner M, Jansa J, et al. 2009. Spatial analysis of anthropogenic impact on Karst geomorphology (Slovenia). Environmental Geology, 58: 257-268

Ramachandra TV, Kumar U. 2004. Geographic Resources Decision Support System for land use land cover dynamics analysis. FOSS/GRASS Users Conference, Bangkok, Thailand

Rana SVS. 2005. Essentials of ecology and environmental science. Prentice-Hall of India, New Delhi, India

Ranga RV, Thomas EB, Shekhar S, et al. 1999. An Efficient Hybrid Classification System for Mining. Multi-spectral Remote Sensing Imagery Guided by Spatial Databases. http://www-userscsumnedu/~vatsavai/papers/prrs0

Roy PS, Dutt CBS, Jadhav RN, et al. 1996a. IRS-1C utilization for forestry applications. Current Science, 70: 606-613

Roy PS, Sharma KP, Jain A. 1996b. Stratification of density in dry deciduous forest using satellite remote sensing digital data- An approach based on spectral indices. Journal of Bioscience, 21: 723–734

Sabbins F. 1987. Remote sensing: Principles and interpretation. WH Freeman and Co, New York, USA

Saint G. 1980. Multitemporal remote sensing: satellites provide a new tool for Earth resources management. Acta Astronautica, 7: 373-383

Singh A. 1989. Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing, 10: 989-1003

Singh IJ, Mizaurahaman M, Kushwaha SPS. 2006. Assessment of effect of settlements on growing stock in Tahno range of Dehradun Forest Division using remote sensing and GIS. Journal of Indian Society of Remote Sensing, 34: 209-217

Smith DP, Atkinson SF. 2001. Accuracy of rectification using topographic map versus GPS Ground Control Points. Photogrammetric engineering and remote sensing, 67: 565-570

Stone TA, Lefebvre P. 1998. Using multitemporal satellite data to evaluate selective logging in Para Brazil. International Journal of Remote Sensing, 19: 2517–2526

Sugumaran R, Pavuluri MK, Zerr D. 2003. The use of high-resolution imagery for identification of urban climax forest species using traditional and rule-based classification approach. Geoscience and Remote Sensing, 41: 1933-1939

Tahir M, Hussain T. 2008. Environmental Geography. Jawahar Publishers and Distributors, New Delhi, India

Thakur AK, Sing S, Roy PS. 2008. Orthorectification of IRS-P6 LISS-IV data using Landsat ETM and SRTM datasets in the Himalayas of Chamoli District Uttarakhand. Current Science, 95: 1459

Victorov S, Kildjushevsky E, Sukhacheva L, et al. 2007. Multi-temporal coastal zone landscape change detection using remote sensing imagery and in situ data. In: Use of Landscape Sciences for the Assessment of Environmental Security (I Petrosillo et al., eds). Springer, Netherlands, 155-164

Vitousek PM, Mooney HA, Lubchenco J, et al. 1997. Human domination of Earth's ecosystems. Science, 277: 494-499

William JS. 2006. Ecological Census Techniques: A Handbook. Cambridge University Press, USA

Wu J, Hobbs R. 2002. Key issues and research priorities in landscape ecology: an idiosyncratic synthesis. Landscape Ecology, 17: 355-365