Vegetation change detection in Barak Basin

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The Barak Basin of northeastern India covers the states of Assam, Manipur, Mizoram, Nagaland and Tripura. The rich and diversified vegetation of the region is facing perturbation in recent years and large tracts of forest are being converted to non-forest. In this study, Moderate Resolution Imaging Spectroradiometer (MODIS) Terra (Vegetation Index) products of 250 m resolution for each year from 2000 to 2006 were used to detect the forest changes. The time series data of Enhanced Vegetation Index (EVI) from 2000 to 2006 were combined into a composite image to observe the changes. The forest change detection map was obtained by performing Principal Component Analysis technique on the EVI composite image. The composite image was classified into a map of forest change showing levels of disturbance in the region. Areas showing significant change were termed as 'hotspots'. Analysis of LISS III and LISS IV satellite data, selected from one of the hotspot sites helped inferring the reasons of perturbation in the region. It is seen that altered patterns of land use, particularly increasing shifting cultivation, seem to be the major causes for large-scale changes in the ecosystem.

Keywords: Change detection, MODIS Vegetation Index, Principal Component Analysis.

THE northeastern region (NER) is regarded as the biogeographical 'gateway' for much of India's biological resources. The NER has been under focus for its biodiversity and has been a region of high priority for investment by leading conservation agencies of the world. But, in recent times the forest ecosystems of the region are being disturbed. Several initiatives were taken for the conservation of the resources in North East India. The Biodiversity Conservation Prioritization Project (BCPP) by WWF-India (1997–2000) was the first exercise of its kind that attempted identifying priority sites and species on the basis of their biological and socio-economic values, and developed strategies for their conservation at a national scale. In the NER, shifting cultivation, illegal felling, forest fire, developmental activities and encroachment of forest lands are principal causes of forest degradation in the region. Mining activities, both in the organized and unorganized sectors, have also been an important factor for forest degradation[1]. Shifting cultivation, locally known as 'jhum', is a widely distributed form of agriculture in the upland areas of the NER. The shortening of the jhum cycle from the traditional 10 years or more to 4–5 years on an average now is indeed a matter of concern[2]. Shifting cultivation has been identified as one of the main human impacts influencing the biodiversity in Tripura, North East India. Over the last few years, a new class of shifting cultivators that has emerged adopts non-traditional forms of jhuming, which has been responsible for the loss of biological diversity in the state[3]. It is further seen that in addition to jhuming, other factors like deforestation without replanting, collection of firewood, conversion of forest land to farm land and overgrazing by cattle also contribute to forest change[4]. Studies conducted in Meghalaya show that the qualitative variation of forest cover is a gift of nature and is related to altitude and climate, while quantitative variation mostly results from human interference. The extent of the existing natural forest cover is inversely proportional to the disturbance caused by man[5]. Several studies were conducted using remote sensing to understand the forest changes. Medium spatial resolution (approx. 20–36 m) satellite images, such as those acquired from Landsat, are well suited for forest disturbance monitoring on a landscape and regional scale[6–11]. Achard *et al.*[12] used AVHRR imagery to locate tropical deforestation hotspots at a global level. Fraser *et al.*[13] suggested that coarse-resolution images can be used to identify the location and timing of large-area vegetation disturbances. Among few studies conducted in the forests of NER using remote sensing and GIS, attempts were made to classify forests using phenological characters as discriminant. Phenological fluxes of forested landscape of North East India have been monitored using temporal IRSIC WiFS data[14]. Models were developed to study the landscape dynamics using remote sensing and GIS. Spatial presentation of landscape dynamics can be used to infer disturbance regimes horizontally[15]. Roy and Tomar[16] used geospatial techniques to characterize biodiversity at landscape level in Meghalaya. Based on the study of biological richness in a part of the Eastern Himalaya, Behera *et al.*[17] observed that the tropical semi-evergreen forests with evergreen and deciduous trees are exposed to large-scale exploitation and destruction owing to shifting cultivation due to their easy accessibility.

Change detection is useful in many applications such as land-use changes, habitat fragmentation, rate of deforestation, etc. Several different techniques of change detection have been used from time to time to extract information from remote-sensing imageries. An extensive study was conducted in the Indian sub-continent, covering three major bioclimatic regions, viz. North-East India, Western Himalayas and the Western Ghats, using concepts of landscape analysis to identify biologically rich zones[18]. Such studies have provided details about vegetation-type transitions. These transitions, when coupled with ground-based species databases, help in analysing and quantifying biodiversity losses[19]. Forest-cover changes in the region were observed by geospatial analysis using forest-cover

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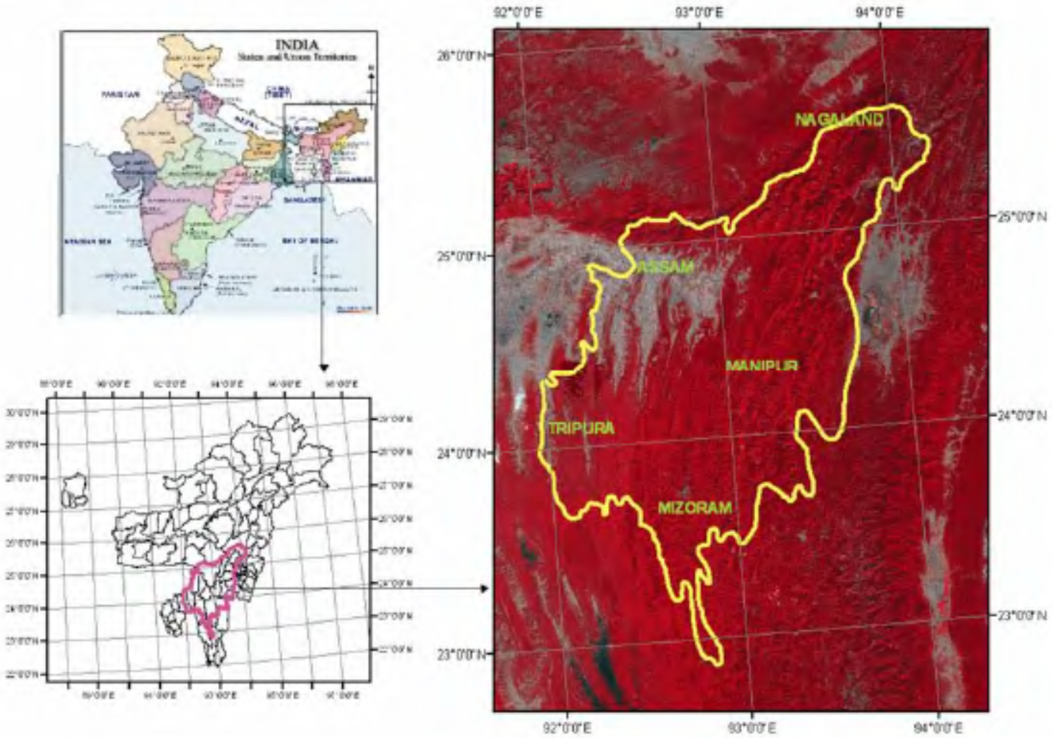

Figure 1. Study area.

Table 1. Satellite data and data products

Data product	Description
MODIS EVI data	The Moderate Resolution Imaging Spectroradiometer (MODIS) 250 m resolution 16-day composite gridded vegetation index data (MOD13Q1), March 2000–06
IRS WiFS	Year 2000, path/row 112/054
IRS-ID LISS III	Year 2000, path/row 112/055
IRS-P6 LISS IV	Year 2006, path/row 101/066

maps from six temporal datasets based on satellite data interpretation and converted to geospatial database since 1972 till 1999 to devise proper management strategies[20]. Temporal Normalized Difference Vegetation Index (NDVI) profile was used to identify distinct growth pattern between the different vegetation cover types[21]. Historical datasets generated from remote sensing data (1972, 1982, 1987, 1989, 1993 and 1999) were used to assess forest cover loss, shape index and entropy to the degree of forest fragmentation over a multi-decadal period[22]. The vegetation cover dynamics in North East India has been analysed by computing temporal fractional vegetation cover (an important factor defining the changes in vegetation cover in temporal domain and the land–atmosphere interaction) using IRS–1C WiFS data[23]. A web-enabled Biodiversity Information System (BIS) has been developed by organizing the spatial and non-spatial data that allows the user to identify gap areas and areas for bioprospecting[24].

This study aims to map the forest to non-forest changes using the Moderate Resolution Imaging Spectroradiometer (MODIS), Enhanced Vegetation Index (EVI) dataset and Principal Component Analysis (PCA) as a change detection technique. The EVI is an improved vegetation index that accounts for the effects of residual atmospheric contamination and soil background[25]. PCA has been extensively used for change detection analysis of multi-date images[26]. The MODIS, on-board the National Aeronautics and Space Administration, Earth Observing System Terra satellite launched in December 1999, enables researchers to address a broad range of questions associated with biogeochemical cycles, energy balance, and land cover and ecosystem changes at regional and global scales[27]. The objectives of the study are to: (i) prepare a vegetation change map using MODIS 250 m EVI data for the Barak Basin, (ii) map the extent of disturbance, its spatial distribution, location and intensity, and (iii) assess the reasons for the disturbance using LISS III and LISS IV datasets.

The study area (Figure 1) – Barak Basin – lies within geographical coordinates: 91°56′–94°16′E and 22°52′–25°35′N. The southern and western boundaries form the international boundary with Bangladesh. In India, the basin lies in the states of Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. The principal tributaries of the river Barak in India are the Jiri, the Dhaleshwari, the Singla, the Longai, the Sonai and the Katakhal. The major land use/land cover of the basin consists of hills, forests, cultivated land and tea gardens. The basin is rich in floral and faunal diversity. Floods are an annual feature in the valley. Topography is characterized by hills, wide plains, low-lying, waterlogged areas, etc.

Previous studies in North East India have brought out the ongoing changes occurring in the region. Such studies were either location-specific or the region has been studied with a landscape perspective. In the present study, the Barak Basin has been selected due to the fact that it covers many of the north eastern states and the forest changes in one of the State will have an impact on the other adjoining States. The worst impacts could be the severity of flooding, erosion, etc.

Satellite data and data products used in the study area are presented in Table 1.

Using IRS WiFS data, the forests (besides the reserve forests) and non-forest areas (built-up, cropland, wasteland, etc.) were delineated. Only the forested areas have been used for further analysis. The MOD13Q1 product used in the study represents spatial aggregates of the MODIS/Terra vegetation indices 16-day L3 global 250 m ISIN grid. The product contains two vegetation indices, provided by EROS Data Centre Earth Resource Observing System (EDC), viz. the NDVI and EVI. The EVI dataset has been used in the present study to observe the vegetation dynamics, since it is an optimized vegetation index with improved sensitivity in high-biomass regions and has improved vegetation monitoring characteristics via a decoupling of the canopy background signal and reduction in atmospheric influences[28].

EVI was calculated as follows[29]:

$$\mathrm{EVI} = G\frac{R_{\mathrm{NIR}} - R_{\mathrm{VIS}}}{R_{\mathrm{NIR}} + C_1 R_{\mathrm{VIS}} - C_2 R_{\mathrm{Blue}} + L},$$

where R_{Blue} is the blue band reflectance, C_1 and C_2 are the atmospheric resistance red and blue correction coefficients, L is the canopy background correction factor and G is the gain factor. The coefficients adopted in the EVI algorithm are $L = 1$, $C_1 = 6$, $C_2 = 7.5$ and $G = 2.5$.

Image composite of March EVI data has been generated by stacking the seven date EVI data products from 2000 to 2006. It is pertinent to mention that, in this study only March season data have been used, which is the preferred season with respect to data quality (due to cloud cover) and post-monsoon undergrowths in the open areas. PCA was run on this composite image with seven dates, and a new PCA image (Figure 2) was generated with three principal components, which were later treated as separate bands for the interpretation and analysis of the changes within the forest. The first component, which accounts for the maximum individual difference, was put in the red colour; the second principal component is a combination of variables uncorrelated with the first component and was put in the green band, while the third component with least information was given a blue colour. The three PCA components constitute the RGB image. The tonal variation occurring in the PCA image (Figure 3) was considered as the basis for image interpretation and to understand the level of forest dynamics leading to disturbance, in other words, the disturbance zones within the forest. Using supervised classification technique the PCA image was classified into a map showing zones of forest disturbance: (a) disturbed, (b) highly disturbed, (c) less disturbed–open forest and (d) undisturbed–close forest. A site from the classified map was selected for detailed analysis using LISS III and LISS IV images to understand the reasons of vegetation change. The visual interpretation technique was used to map the changes within the forest, in different land-use/land-cover categories utilizing images of IRS LISS III (23.5 m spatial resolution) of the year 2000 and IRS LISS IV (5.8 m spatial resolution) of the year 2006. The area statistics was generated based

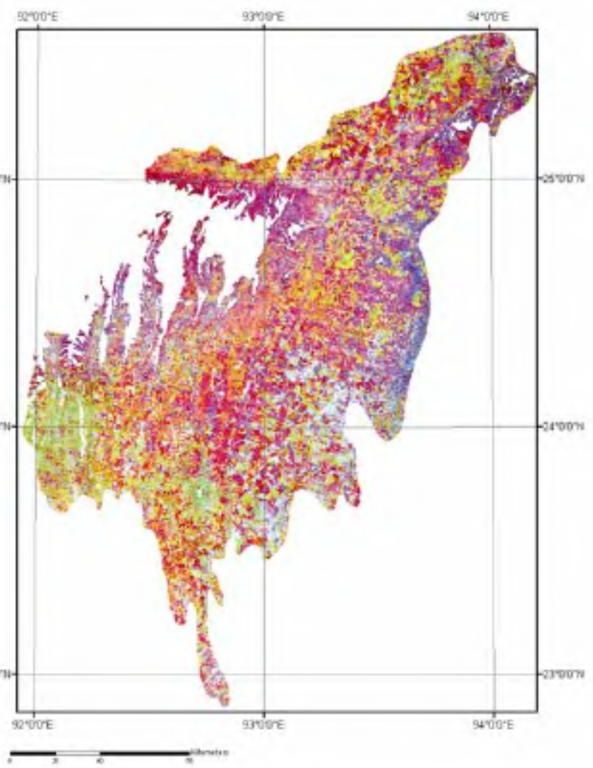

Figure 2. Principal Component Analysis image of Barak Basin.

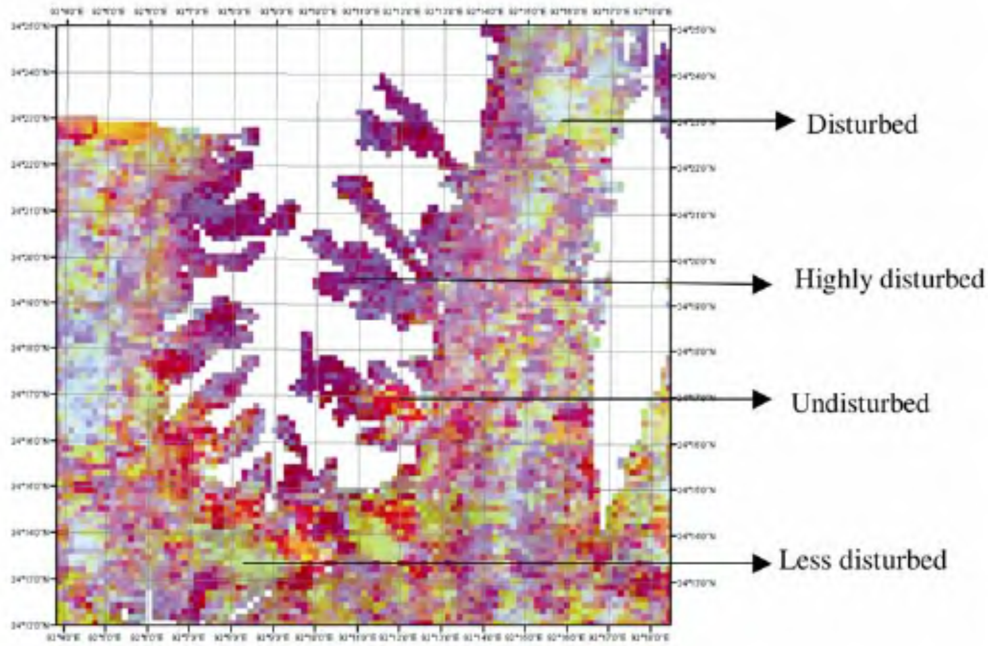

Figure 3. Selected study area from the PCA image showing tonal variation, interpreted into disturbance levels.

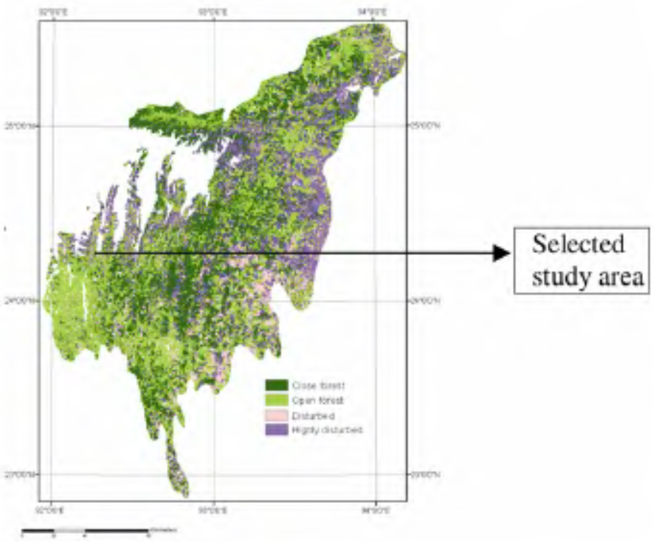

Figure 4. Classified map (of PCA image) showing disturbance regimes.

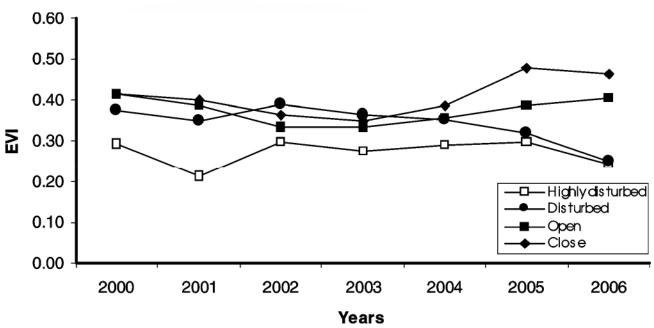

Figure 5. Profile of vegetation changes (based on Enhanced Vegetation Index) from 2000 to 2006 in Barak Basin.

on the visually interpretated maps. The interpreted map was verified by ground-truthing exercise carried out in the site.

The classified map (Figure 4) derived from the PCA image shows the disturbance regime for the whole basin based on the PCA image. It can be seen that large tracts are under the disturbed and highly disturbed areas.

The EVI profile (Figure 5) drawn shows the response of the vegetation to the disturbances in the region throughout the year and this further helped in understanding the disturbance map. It can be seen that the highly disturbed areas show a low profile throughout the year; these are actually the areas lying adjacent to the settlement areas. The disturbed areas show good vegetation status, but are being degraded gradually, indicating high rate of deforestation activities in the last few years. The open forests are areas showing good vegetation status in the year 2000, but are now being degraded. The close forest and open forest to some extent show an improvement in the EVI profile that may be attributed due to conservation measures being taken up and the ongoing plantation activities.

From the PCA image and the classified map, a study site (one of the dynamic sites) covering parts of Dharmanagar and Kailashsahar in North Tripura District has been selected for detailed investigation. The mapping has been done within the forested areas, so that the reasons for forest change can be clearly understood. During the mapping, the season of the datasets was strictly taken into consideration. Interpretation of satellite images (Figure 6) of two dates showed large-scale changes occurring within the forest (Figure 7).

Table 2. Statistics and reasons for large-scale changes within forests in the selected study area

	2000	2006	Observed change
Forest categories (area in km^2)			
Evergreen forest	127.57	96.11	–31.46
Deciduous forest	48.02	31.70	–16.32
Rubber plantation	9.09	9.21	0.12
Deforestation (timber extraction)	0.54	1.61	1.07
Non-forest categories (area in km^2)			
Current shifting cultivation	13.71	17.00	3.29
Abandoned shifting cultivation	0.36	19.41	19.05
Scrub forest	27.22	20.40	–6.82
Land with scrub	14.33	19.22	4.89
Land without scrub	7.79	31.54	23.75
Settlement (others)	12.20	14.15	1.95
Water body (others)	4.89	5.28	0.39

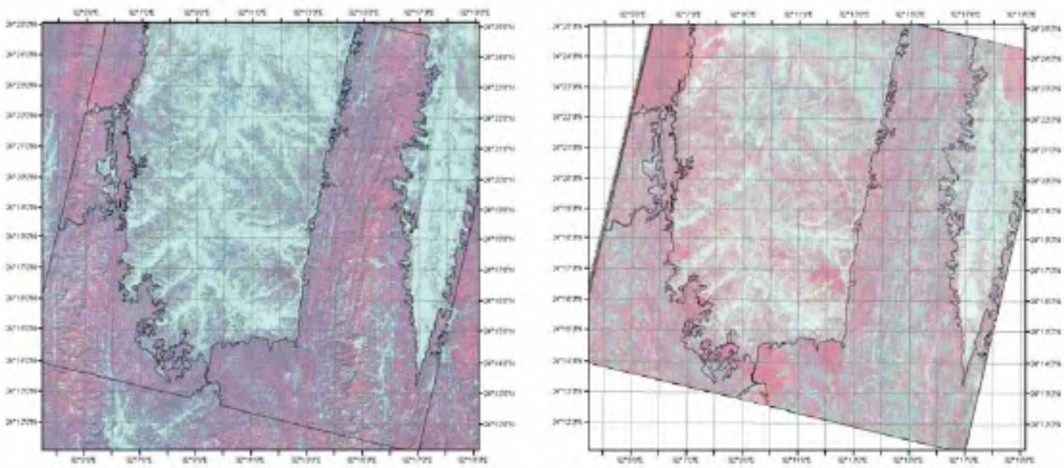

Figure 6. The selected study area.

The area statistics (Table 2) shows that there is a loss of ~31 km^2 of evergreen forest followed by ~16 km^2 loss in deciduous forests. It can be mentioned that the forests of the region, particularly the evergreen forests, are facing higher rate of transformation. The disturbance factors leading to such changes are attributed to the increasing areas under shifting cultivation, both current and abandoned, as seen in the statistics. The forested areas are being converted to the other nonforest categories of land use/land cover, as shown by the marked increase in the land without scrub category. The visual interpretation map (using LISS III and LISS IV) and its verification during the field visit help us to understand the PCA image and its validation. It has been found that the region is facing severe pressure from the increasing jhum practice and the reduced fallow period. The areas mapped as disturbed, which are distributed in several pockets, are the jhum lands. Such regions are located in the tribal-dominated areas, where the extent of jhum (shifting cultivation) is high. Disturbance in the forest is also clearly seen in the EVI profile. Areas appearing as highly disturbed in the map are the settlement areas with least vegetation and they show a constant, low EVI profile throughout the year.

There are large tracts of open and dense forests, but there are several areas under the highly disturbed category. It appears from the PCA image that the forest (dominated by evergreen and moist deciduous) in the region is facing severe disturbance mainly due to shifting cultivation, particularly in the Manipur–Mizoram bordering areas and parts of Tripura. Widespread deforestation activities are prevalent in the region, leading to large-scale depletion of forests.

The valuable information provided by MODIS EVI on the vegetation status is useful in change detection studies over larger natural units, like a basin. Application of changed detection methods like PCA is found effective in mapping the vegetation changes and in disturbance monitoring. Based on the inferences drawn from this study area (in Dharmanagar), the forest dynamics has been understood for the whole basin. It has been found that several pockets of the basin are facing high rate of forest

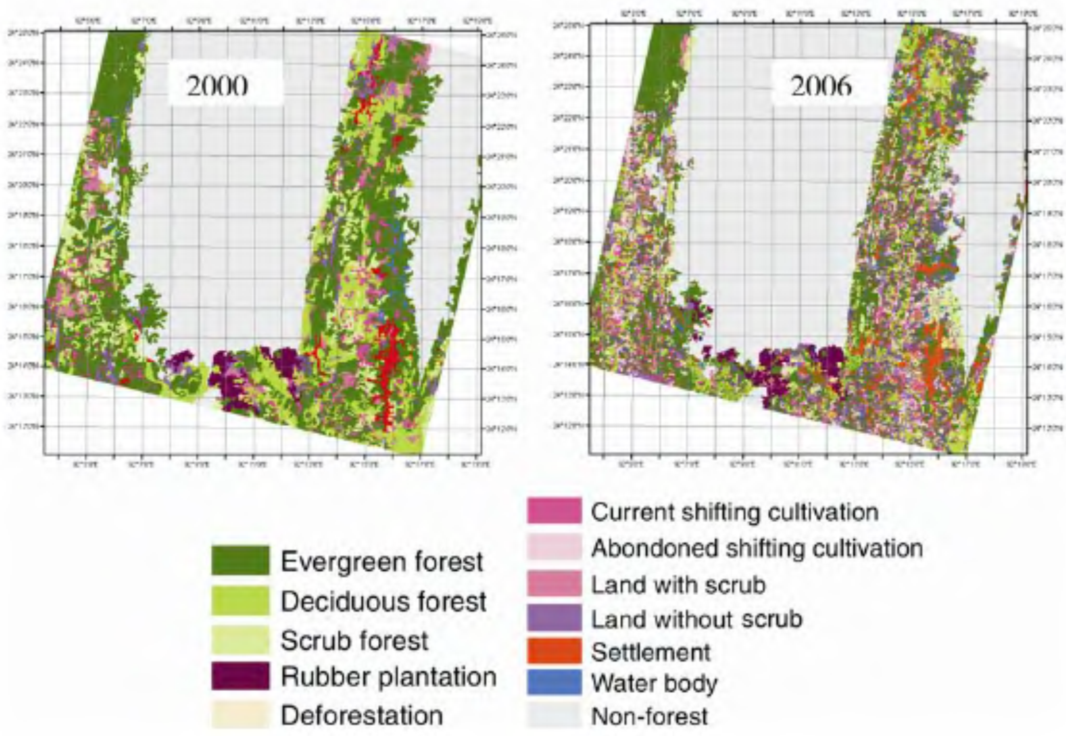

Figure 7. Land-use/land-cover change within the forested region in the selected study area.

dynamics due to disturbances owing to practices like shifting cultivation, and increasing areas under land with scrubs.

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Measurement errors in participatory GIS: role of individual workers

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The internet, with high resolution images from 'Google Earth', has facilitated detailed earth observations by common man/indigenous societies. This study analyses human errors in elementary steps of map preparation and compares different workers doing similar work. The objectives of the study are to determine variation in observations (point and length) made by an individual at different scales of working, and to determine user-dependent variations in mapping and measurement of the same task (multiple users). A common set of methodology was adopted by different students to accomplish a similar procedure. The role of scale (size of object) on observations was minimal to affect an individual's ability in determining the precise location of a point. Individual workers may contribute significant errors in the Geographical Information System (GIS) work, where multi-user task is assigned to complete a project. In participatory GIS, additional support by the leader/supervisor to the workers may produce better results with higher accuracy.

Keywords: Geographical Information System, map preparation, measurement error, multiple users.

REPRESENTATION by mapping an earth feature acts as a vital information tool for the development of human society. The internet has opened new horizons for the common man. Free services like 'Google Earth'[1], with high resolution images, has facilitated detailed earth observations and creation of maps for various purposes by different stakeholders to generate information which otherwise does not exist or is expensive to develop (e.g. detailed city map, small patches of vegetation in surrounding, land parcels, etc.). Certain limitation does exist (images are only of recent time, all the areas are not covered, information on time and season not available, etc.). High resolution images in Google Earth provide an opportunity to create maps on participatory Geographical Information System (GIS) by common people/indigenous societies/citizens, which invites consequences of data integration and multiplication of errors during the process. The word 'error' includes not only 'mistakes' or 'faults', but also statistical concept of error[2], i.e. 'variation'. Similarly, in professional GIS it has been realized that geographical data are not of homogenous quality, and may have errors and uncertainty that need to be recognized and addressed accurately[3–5].

Visual methods of map interpretation include formation of various shapes (different boundaries) by interpreting maps. This process requires determining a point location to initiate line drawing and judgement to realize a boundary to be marked as a line. However, various image/map-related factors (which remain the same for all workers using that map) contribute in this judgement, which is also influenced by one's own ability to determine the location and control the precise movement of his/her hand. Thus we hypothesize that the scale of observation (distance from the object) may act as a source of error by affecting an individual's ability to determine the precise location of a point and also initiating the creation of a polygon or line during mapping. Hence different users may also act as sources of errors while contributing to the same work. The objectives of the present study are to determine the

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