Original Research

Assessment of spatial changes in forest cover and deforestation rate in Eastern Ghats Highlands of Odisha, India

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Authors Info

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Abstract

Aim : The spatial changes in forest cover and deforestation rate over eight decades in Koraput district of Odisha, a mountainous part of Eastern Ghats Highland region was studied using remote sensing and GIS. The dynamics of forest fragmentation was also quantified using patch analysis.

Methodology : The multi-source and multi-date mapping was carried out using Survey of India topographical maps (1930's), Landsat MSS (1973), Landsat TM (1990), IRS P6 LISS III (2004 and 2013) satellite images. Radiometric and contrast correction was done to the images using digital image processing software. On-screen visual interpretation of forest cover was done which was aided by unsupervised classification. Ground truthing was done to determine the classification accuracy. Patch analysis was done to quantify forest fragmentation.

Results : The mapping accuracy varied between 71.8% and 93.3 % for different years under study. The results for 1932, 1973, 1990, 2004 and 2013 indicate that the forest cover for the mentioned years were 4413.4 km^2, 3706.0 km^2, 3051.1 km^2, 2554.4 km^2 and 2284.5 km^2, which were 52.7%, 44.2%, 36.4%, 27.3% and 25.8% of the geographical area of the district, respectively. The deforestation rate was 0.38% per year during 1932-1973, 2.04% per year during 1973-1990, 1.71% per year during 1990-2004 and 0.63% per year during 2004-2013. The decline in overall rate of deforestation in recent years indicates increased emphasis on forest conservation. The number of fragmented forest patches was 398 in 1932, 645 in 1973, 688 in 1990, 697 in 2004 and 702 in 2013, which indicates ongoing anthropogenic pressure on the forests. The mean forest patch size decreased from 111 km^2 in 1932 to 65.8 km^2 in 2013.

Interpretation : This study indicates the effectiveness of remote sensing in indentifying the forest and non-forest area. The change analysis of deforestation provides a decisive component for conservation and helpful in long term rational management of the remaining forests of the district for eco-restoration and sustainable development.
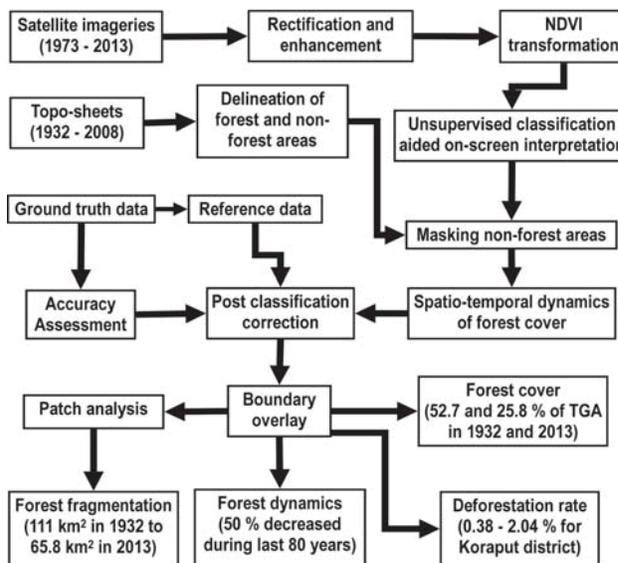
Introduction

Natural forests are one of the most important terrestrial ecosystems of the earth, and are of great interest due to conservation of biodiversity, apart from global carbon cycle. They currently occupy 4.033 billion ha, which is about 31 % of the earth's land surface (FAO, 2010). The human population has increased its ability to manipulate the earth surface mainly because of its increased economic activity (FAO, 2012). This manipulation is most evident in clearing of forests. Clearing of forests (deforestation) to use the land for other purposes, or keeping it as unused wasteland, is very rampant on the surface of the earth. Rapid population growth and the burgeoning demand for food, fodder, fiber and fuel have accelerated the deforestation rate. The world wise average net loss of forest between 2000 and 2010 has reached about 5.2 million ha per year (FAO, 2010). Deforestation has impact on biodiversity, carbon stock, soil, global climatic systems and livelihoods of dependent people, and hence is reason for concern. Although the deforestation rates have been reduced in many parts of the world, but it is still more than 0.1% (0.36%) per year in Southeast Asian countries (FAO, 2010).

Factors affecting deforestation vary widely, within and among countries. According to the Forest Survey of India (FSI) report, in India over 2.62 million ha of forest was lost due to agricultural expansion between 1951 and 1980 (FSI, 1988). This continued with the loss of forest cover of 1,88,900 ha per year between 1991 and 1999 (FSI, 2000). However, forest cover in India has more or less stabilized after 1980 due to ban on clear felling (Reddy *et al*., 2009; FSI, 2013). In recent times, between 2001 and 2013 there was also increase in forest area from 67.55 million ha to 69.79 million ha (FSI, 2013).

Most of the deforestation studies in India have been given priority to the biodiversity rich areas such as North-East India (Roy and Joshi, 2002; Lele and Joshi, 2009), Western Ghats (Jha *et al*., 2000; Krishnaswamy *et al*., 2004) and Andaman and Nicobar islands (IIRS, 2002). Few studies have been conducted in the Eastern Ghats (Sakthivel *et al*., 2010; Reddy *et al*., 2014) region. Most of the studies are focused on mapping vegetation communities, generating data on biodiversity and prioritizing the areas for bio-prospecting. In a study, Reddy *et al*. (2009) mapped the forest cover change in Nabarangapur district of Odisha during 1978-2005. Similarly, Harikrishna *et al*. (2014) has analysed the forest cover change in Andhra Pradesh and reported the occurance of large scale deforestation during 1930-1975 period. The deforestation rates, drivers of deforestation and the Government initiatives for conservation of forests in India were summarized by Reddy *et al*. (2013b). The effectiveness of conservation measures under the ongoing forest management practices in Nilgiri biosphere reserve has been well documented by Satish *et al*. (2014). For determination of long period forest change, long term datasets need to integrate data from large scale historical topographical maps and recent remote sensing datasets.

Remote sensing techniques using satellite images are the most effective and common data source for detection, quantification, and mapping of forest areas and its changes over time (Sakthivel *et al*., 2010), because of its repetitive data acquisition, digital format suitable for computer processing, and accurate geo-referencing procedures. Besides, it provides information to help to resolve controversies about future management directions (Kumar *et al*., 2014). The present study was undertaken to investigate the historical changes that have taken place in forest land in southern parts of Odisha, India. This area is known for extensive shifting cultivation and have degraded due to soil erosion (Adhikary *et al*., 2017). It is believed that this aggressive human activity might have influenced the forest, resulting in a possible impact on the environment. Therefore, the objectives of this study included quantification of recent and historical forest land of the study area through integration of supervised classification, visual interpretation of remote sensing data, use of topographical sheets, and to assess the rate of change in forest cover and forest fragmentation over the time.

Materials and Methods

Study area : The study was carried out in Koraput district of Odisha, a mountainous part of Eastern Ghats Highland region of India, consists of many valleys with scrub and/or deciduous forests on the upper slopes. The study area lies between 82° 05′ to 83° 25′ E longitude and 18° 14′ to 19° 13′ N latitude (Fig. 1), covering an area of 8379 km². It is situated at elevation varying between 123 and 1655 m above mean sea level. The district Koraput is popularly known as the land of aboriginals and is one of the global biodiversity hotspots (Raut *et al*., 2012). It has sub-tropical climate with mean maximum and minimum temperature of 35.8 °C and 7.6 °C and mean annual precipitation of 1452 mm (Adhikary *et al*., 2015). The soils of the study area were been identified as Alfisols and Inceptisols (NBSSLUP, 2005), and both soil depth and texture varied with the topography and become less favourable for cultivation with increasing slope steepness. The hills and hill slopes were mostly dominated by light yellow to brown soils, whereas red sandy to loamy soils were found in the foothills and uplands.

The natural conditions of the district favour a good growth of dry miscellaneous, *Bamboo* and *Sal* forests and allow a rich diversity of fauna and flora. However, due to human interference, the vegetation shows severe signs of degradation, and forest cover has declined within the last decades (FSI, 2013). Agricultural practices extend from valley bottom to hilltop, with variety of cropping systems and management practices. The livelihood practices consisted of activities like timber collection, shifting cultivation, permanent agriculture, mining, etc. The practice of shifting cultivation (called *podu chasa* in local language) is one of the major cause behind deforestation, resulting in conversion of dense forests to open forests as well as degraded forests.

Data and assessment periods : The data used in this study include both Survey of India (SOI) topographic sheets and multi-date satellite images (Table 1). The forest cover map for the year 1932 was developed using topographic sheets. For other years satellite images such as Landsat MSS (path-151/152 and row-47) for 1973, Landsat TM (path-141/142 and row-47) for 1990, IRS P6 LISS III (path-103 and row-59; path-104 and row-59/60) for 2004 and 2013 were used. The SOI topographic maps of 2008 (scale 1:50,000) were digitized and used for preparing base map and ground truthing after geo-referenced. Finally, during April-May, 2014, a total of 1000 ground truth points were collected from the study area.

Image enhancement, visual interpretation and classification : In this study, ERDAS Imagine 9.2 software was used for digital image processing of satellite images (ERDAS, 2008). First contrast stretching was applied on images to enhance the visual interpretation capability. Prior to image classification, land use features were categorized into four types: dense forest, open forest, non-forest, and water bodies. These four types were identified based on the visual interpretation of satellite imagery on the basis of tone, texture, shape, pattern and association etc. and verified from field inspection. Training samples were then selected for each of the three land use types by delimiting polygons around representative sites. Using the pixels enclosed by these polygons, spectral signatures for the respective land use recorded by the satellite images were derived. Once the spectral signature was deemed satisfactory, the classification process executed, and in this study supervised maximum likelihood method was used as classification method. Finally, accurate forest land use maps were compared with the reference data (the topographic maps, and ground trust points) to assess the classification accuracy.

Classification accuracy assessment : A classification accuracy assessment was performed based on 1000 random points that were identified and located using a random method in ERDAS software to represent the different land use classes of the area. The 1000 points used in the study represented field checkpoints (ground truth data), archived data and topographic maps as reference data. The reference data and the classification results were compared and statistically analyzed using error matrices.

Deforestation rate analysis : Maps were analyzed to identify the magnitude of change. Deforestation rate for successive years of forest cover mapping was evaluated using equation given by Armenteras *et al*. (2006).

Forest fragmentation through landscape matrix : Patch analysis was done using Arc GIS and MS EXCEL spreadsheet. Four landscape matrices were selected and analyzed. (i) Number of patches: It is the number of patches for any particular size class. It measures the extent of fragmentation of the entire landscape. (ii) Patch density: It expresses the number of patches per unit area basis that facilitates comparisons among landscapes of varying size. Patch density can be calculated by

the number of patches in the landscape, divided by total landscape area. (iii) Mean patch size: It is the average patch size within a particular class, or at the landscape level, the average size of all classes. Habitat fragmentation index can be measured through mean patch size. (iv) The largest patch index : It is the measure of the percentage of landscape area occupied by the largest patch of a class.

Results and Discussion

The accuracy of classification results derived from satellite images for change detection of forest cover were verified by creating an error matrix. The generated error matrix is given in Table 2. The classification accuracy for the classified images for the years 1973, 1990, 2004 and 2013 were 71.8%, 85.2%, 90.7% and 93.3%, respectively. Forest cover change is a dynamic process and it changes both spatially and temporally. It is ascertained through time series analysis that there has been a significant change in the forest cover, particularly the conversion of dense forest to open forest and other land uses (non-forest).

Assessment period I : 1932–1973 : The developed forest classes using satellite images such as dense forest and open forest do not find place in the 1930's topographic sheet; instead only the symbols representing the trees are given. Moreover, in the topographic sheets the forest are classified as reserve forest and mixed forest. Hence, because of the varied classification adopted in the topographic sheets and satellite images, it is not possible to compare the forest classes given in these two data sets, readily. Therefore, the total area under forest cover for the assessment period I was compared. In 1932, area under reserve forest was 2786.2 km^2 and area under mixed forest was 1627.3 km^2, which were 33.3% and 19.4% of the study area, respectively. The total area under forest was 4413.5 km^2, which was 52.7% of the study area (Table 3). In 1973, area under dense forest was 2584.7 km^2 and area under open forest was 1121.3 km^2, which were 30.8% and 13.4% of the study area, respectively. The total forest cover was reduced to 3706.0 km^2, which was 44.2% of the study area (Table 3). The deforestation rate in the Koraput district was found to be 0.38% per year for the assessment period I (Fig. 2). Deforestation in the study area started mainly after independence of India because of infrastructure development, construction of dams and population pressure (Reddy *et al*., 2013a). Encroachment on forest lands and converting them in to cultivated area by shifting cultivation played a significant role in deforestation for the period I (Dash, 2006). The areas where changes have taken place are hilly terrains with relatively less slope and easily accessible to villages nearby; whereas the forest cover patches are intact at places where the terrains are inaccessible owing to difficult terrain conditions and high altitude. Other causes behind forest cover changes are illegal timber cutting and extraction of other forest resources. Although, the deforestation rate during the assessment period I was high but that was much lower than the deforestation rate observed in the adjoining Andhra Pradesh state. During same period, the deforestation rate in Andhra Pradesh was 1.62% per year

(Harikrishna *et al*., 2014) which was attributed to the increased anthropogenic pressure on the forest lands.

Assessment period II : 1973–1990 : Between 1973 and 1990, there was also a reduction in the dense forest cover to about 1615.8 km^2 (19.3%). However, there was increase in open forest area (1285.4 km^2) during this period, indicating degradation of dense forest to open forest. Though there was increase in open forest cover, the results indicated that there was an overall reduction of 804.5 km^2 of forest cover, which was 9.6% of the total geographical area of the district (Table 3). The non-forest area increased from 4579.0 km^2 (54.6%) to 5333.4 km^2 (63.7%) in 1990. Considerable increase in the area of water body (94 to 144.4 km^2) was also observed during this period. The deforestation rate was found to be 3.92% per year for dense forest, and the overall deforestation rate was 2.04% per year (Fig.

2). While comparing deforestation rate during period I and II, it was observed that deforestation rate during period II was about 5 times more than that of period I. The reasons may be attributed to the developmental works, shifting cultivation and dam construction. During that period Upper Kolab and Lower Kolab multipurpose dams were constructed to increase the irrigation facilities, which ultimately inundated vast amount of forest land and enhanced the conversion of forest land to agricultural land. The deforestation rate during this period was higher than the other forested area in India. Jha *et al*. (2000) studied the changes in forest cover between 1973 and 1995 in the southern part of the Western Ghats using satellite data that showed rate of net deforestation as 1.34% per year over 22 years. The authors have accounted for the decrease in forest area due to increase in spatial extent of plantations and agricultural fields (Jha *et al*., 2000). In the northern Western Ghats region of

Table 1 : Topographical maps and satellite imageries used in the study

| Type	Period	Scale / Resolution*	Source
SOI topographical maps	1930-1935	1:2,50,000 and 1"=1 mile	US Army Map Service and SOI, Dehradun
Landsat MSS	1973	80 m	GLCF
Landsat TM	1989-1990	30 m	GLCF
IRS P6 LISS-III	2004	23.5 m	NRSC
IRS P6 LISS-III	2013	23.5 m	NRSC

*Scale for topographic maps, and spatial resolution for satellite images

Table 2 : Error matrices and total classification accuracy including producer accuracy and user accuracy for the classified images

Reference data		Land use classes				Classification accuracy (%)		Kappa statistics
		Dense forest	Open forest	Non forest	Water bodies	Producer accuracy	User accuracy	(K̂)
1973 classified data	Dense forest	76	14	7	3	73.8	76.0	0.44
	Open forest	17	59	17	4	64.8	60.8	0.33
	Non forest	6	11	64	12	66.7	68.8	0.34
	Water bodies	4	7	8	81	81.0	81.0	0.45
	Total accuracy					71.8		**0.67**
1990 classified data	Dense forest	192	17	19	0	86.1	84.2	0.84
	Open forest	21	164	14	0	82.0	82.4	0.78
	Non forest	4	12	178	10	82.0	87.3	0.79
	Water bodies	6	7	6	135	93.1	87.7	0.89
	Total accuracy					85.2		**0.84**
2004 classified data	Dense forest	283	11	9	0	92.8	93.4	0.92
	Open forest	18	242	19	0	86.4	86.7	0.85
	Non forest	4	13	237	0	87.8	93.3	0.86
	Water bodies	0	14	5	145	100.0	88.4	1.00
	Total accuracy					90.7		**0.90**
2013 classified data	Dense forest	291	8	15	0	95.4	92.7	0.95
	Open forest	12	254	10	0	90.7	92.0	0.90
	Non forest	2	11	243	0	90.0	94.9	0.89
	Water bodies	0	7	2	145	100.0	94.2	1.00
	Total accuracy					93.3		**0.93**

Table 3 : Total area and area-wise changes of different land use classes from 1932 to 2013 in Koraput district

Land use class	Total area (km^2)					Area (%)				
	1932	1973	1990	2004	2013	1932	1973	1990	2004	2013
Dense forest	2786.2	2584.7	1615.8	1109.1	964.7	33.3	30.9	19.3	13.2	11.6
Open forest	1627.3	1121.3	1285.4	1175.3	1193.8	19.4	13.4	15.3	14.0	14.2
Water body	75.0	94.0	144.4	196.2	201.7	0.9	1.1	1.7	2.3	2.4
Non forest	3890.5	4579.0	5333.4	5898.4	6018.8	46.4	54.6	63.7	70.5	71.8
Total	8379.0	8379.0	8379.0	8379.0	8379.0	100.0	100.0	100.0	100.0	100.0
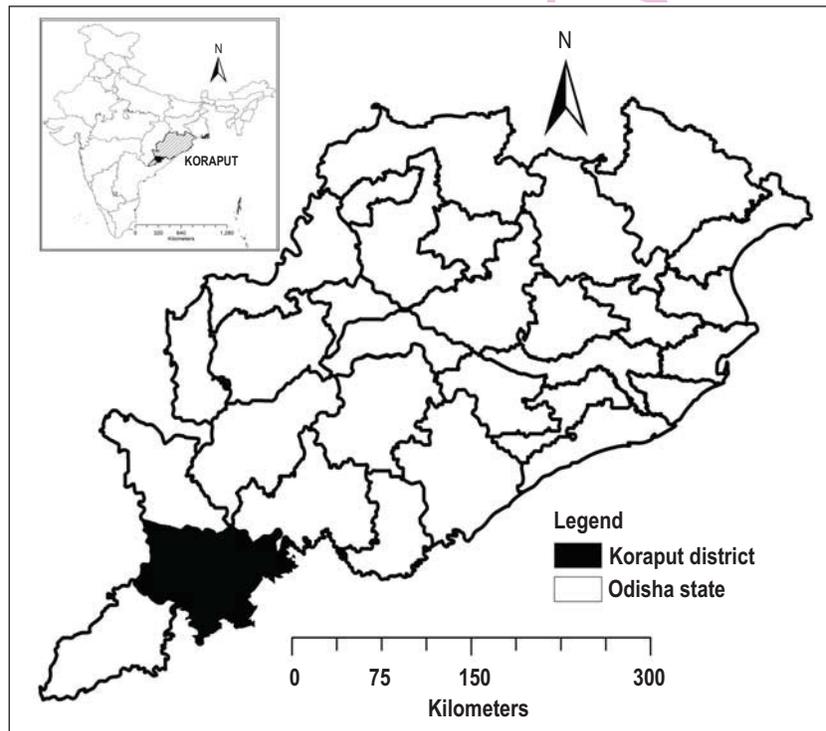
Fig. 1 : Location map of the study area (Koraput district of Odisha, India)

Maharastra, the deforestation rate was nearly 0.37% per year (Panigrahy *et al*., 2010).

Assessment period III : 1990–2004 : During this period, there was also a reduction in the dense forest cover to about 1109.1 km^2 (13.2%). In case of open forest, decreasing trend was also observed. Area under open forest decreased to 1175.3 km^2 (14.0%). There was an overall reduction of 616.7 km^2 of forest cover, which was 7.4 % of the total geographical area. The non-forest area increased from 5333.4 km^2 (63.7%) to 5898.4 km^2 (70.4%) during 1990-2004 (Table 3). The deforestation rate was found to be 2.69% per year for dense forest, and the overall deforestation rate was 1.71% per year (Fig. 2). During the assessment period III, the deforestation rate in Koraput was found to slow down a little but still remained higher than many

parts in India. During 1973–2004, in the neighbor district, Malkangiri, the net rate of deforestation was 1.83% per year (Pattanaik *et al*., 2011). Various factors with varying intensities like over-grazing, illegal encroachments, unsustainable cultivation practices, forest fires, shifting cultivation and indiscriminate logging were responsible for the ongoing deforestation. In another adjoining district, Nawarangpur, the net and gross rate of deforestation was 3.2 and 4.11% per year, respectively during the period 1973 to 2004 (Reddy *et al*., 2009). The main causes of forest change were identified as encroachment for agriculture and settlements, illegal logging, construction of multipurpose dams and other infrastructure development. Another study in R.V. Nagar range, Visakhapatnam, Andhra Pradesh during 1988 to 2006 showed a net deforestation rate of 0.81% per year and a gross
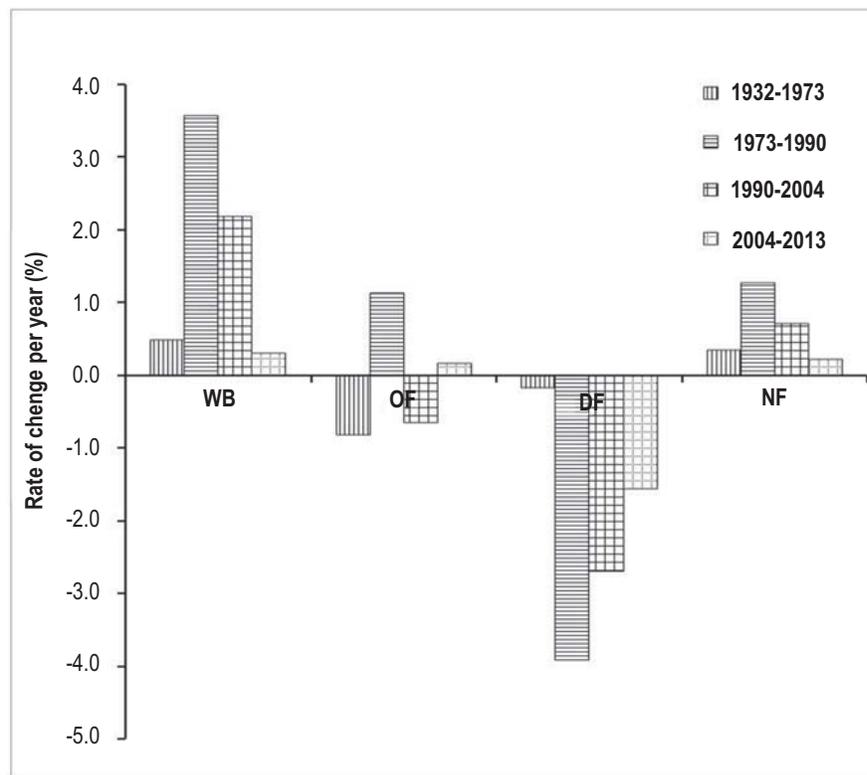
Fig. 2 : Rate of land use changes in Koraput district during the four assessment periods. WB: Water bodies; OF: Open forest; DF: Dense forest; NF: Non-forest

deforestation rate of 1.04% per year (Reddy *et al.*, 2010). Anthropogenic activities, mainly shifting cultivation and expansion of agricultural fields were identified as driving force for deforestation in that area.

Assessment period IV: 2004–2013 : During the last decade (2004-2013) the deforestation rate was slower than the previous two assessment periods which was 0.63% per year. There was a loss of 144.4 km^2 dense forest area during this period; however, there was an increase in open forest area, indicating conversion of dense forest to open forest and other land uses. Total area under deforestation was found to be 125.9 km^2 (Table 3). Although the deforestation rate during the assessment period IV showed a decreasing trend (0.63% per year) still it was higher than the national average (FSI, 2013). The cause may be attributed to awareness among the people, and initiative taken by the state forest department, Odisha, to protect and manage the forest land. The result of the present study was in close proximity of another study focusing on the monitoring of deforestation in Ranchi, Jharkhand. It was found that from 1996 to 2008, the net rate of deforestation was 0.95% per year mainly due to urbanization (Kumar *et al.*, 2010).

Forest fragmentation through patch analysis : In order to estimate the level of isolation of forest fragmentation, patch

analysis was done. The forest patches were categorized under seven classes, i.e. <1, 1–5, 5–10, 10–20, 20–50, 50–100 and >100 km^2 (Table 4) and the number of forest patches falling under each class across the spatial extend of forest cover was analysed. During 1932, out of 398 forest patches, 256 (64.2 %) belonged to <1 km^2 patch size category. The number of <1 km^2 patches was 493, 552, 569, and 576 in 1973, 1990, 2004 and 2013, respectively. Patches of >100 km^2 contributed to highest forest area of 3439 km^2 in 1932, while it was 1503 km^2 in 2013 (Table 5). The total number of forest patches increased from 398 in 1932 to 702 in 2013 (Table 6). Patch density increased from 6.4 to 6.7 per km^2 during 1930–2011. The mean patch size of forest varied across time periods. The mean patch size showed a severe reduction in area of 111 km^2 in 1932 to 97.4 km^2 in 1973, 89.1 km^2 in 1990, 89.3 km^2 in 2004 and reached to 65.8 km^2 by 2013. Largest patch index of forest landscape in 1932 was estimated at 28.5%, whereas 7.3% of the forest area was concentrated in a single large patch in 2011.

The deforestation rate was also clearly visible from the forest matrix analysis. There was an extensive increase of number of forest patches from 1932 to 1990. Clearing of forest to adjust population pressure and construction of some water reservoirs were the main reasons. The increase of small sized patches and decrease of bigger forest patches over time was a

Table 4 : Size class distribution of forest patches and its changes from 1932 to 2013 in Koraput district

Patch class (km^2)	1932		1973		1990		2004		2013	
	Count	%	Count	%	Count	%	Count	%	Count	%
<1	256	64.2	493	76.5	552	80.2	569	81.7	576	82
1-5	62	15.7	69	10.7	61	8.8	57	8.2	57	8.1
5-10	33	8.4	47	7.3	45	6.6	45	6.4	45	6.4
10-20	23	5.8	20	3.1	17	2.5	15	2.1	13	1.9
20-50	14	3.4	8	1.2	6	0.9	5	0.7	5	0.7
50-100	5	1.3	3	0.5	3	0.4	3	0.4	3	0.4
>100	5	1.2	5	0.7	4	0.6	3	0.5	4	0.5
Total	398	100	645	100	688	100	697	100	702	100

Table 5 : Area wise (km^2) and temporal change of forest patches from 1932 to 2013 in Koraput district

Patch class (km^2)	1932		1973		1990		2004		2013	
	Area	%	Area	%	Area	%	Area	%	Area	%
<1	49	1.1	52	1.4	122	4.2	103	4.5	106	4.9
1-5	84	1.9	100	2.7	119	4.1	112	4.9	112	5.2
5-10	124	2.8	122	3.3	102	3.5	85	3.7	82	3.8
10-20	181	4.1	163	4.4	131	4.5	94	4.1	89	4.1
20-50	247	5.6	204	5.5	160	5.5	116	5.1	112	5.2
50-100	291	6.6	233	6.3	209	7.2	167	7.3	155	7.2
>100	3439	77.9	2831	76.4	2060	71	1608	70.4	1503	69.6
Total	4414	100	3706	100	2901	100	2284	100	2159	100

Table 6 : Different forest fragmentation indices and their temporal change from 1932 to 2013 in Koraput district

Landscape matrices	1932	1973	1990	2004	2013
Number of patches	398	645	688	697	702
Patch density (per km^2)	6.4	10.7	5.7	6.8	6.7
Mean patch size (km^2)	111.0	97.4	89.1	89.3	65.8
Largest patch (%)	28.5	15.2	7.6	7.8	7.3

clear indication of anthropogenic pressure on forest, lead to its fragmentation. It is evident that there has been extensive decline in the size of the largest forest patches due to deforestation. Large-scale deforestation in Koraput has led to a decline in forest patch area and increase in the number of patches.

The deforestation rate over eight decades was studied using both topographical sheets and satellite images. This clearly revealed the magnitude of deforestation in Koraput. If such massive levels of deforestation remain unchecked, there is a chance that the district will retain a little forest cover in near future. This will ultimately lead to biodiversity loss. Comprehensive spatial analysis about the status of forests is useful in formulating the policies related to sustainable use and biodiversity conservation. The change and landscape matrix analysis of deforestation provides a decisive component for conservation and helpful in long term rational management of the remaining forests of the district.

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