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Assessment of Land Use and Land Cover Changes (1988-2020) through NDVI Analysis and Geospatial Techniques

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ABSTRACT

The present study analyzes the land use and land cover changes in a forested ecosystem of the Eastern Ghats in the Andhra Pradesh state of India. Landsat TM and OLI imageries are classified using supervised classification to find out the land use changes for a span of 32 years (1988-2020). It was found that substantial changes in the scrub forest category with a loss of 177 sq km (out of 842 sq km area) that occurred mainly due to various anthropogenic activities. The classification based on spectral data of Landsat TM and Landsat OLI produced an overall accuracy of about 92.3% for the year 1988 and 86.7% for the year 2020. The normalized difference vegetation index (NDVI) analysis has been integrated for improving the classification accuracy. In the study region, significant changes being occurred in the forested ecosystem and it must be restored for the welfare of the tribal communities who are largely depending upon the natural resources for their livelihood.

Keywords: Land use land cover, Landsat data, Supervised classification, NDVI, Remote sensing, GIS

INTRODUCTION

Satellite imageries are the most important data sources for conducting land use studies on spatial and temporal scales. Sustainable management of natural resources particularly land use and land cover is necessary to understand the process of landscape change as it is a crucial component in understanding the relationship between human beings and the natural environment.[1-3] Satellite data provides an accurate, real time, and reliable information regarding the spatial variables of the land surface to maintain the constant management of natural resources.[4] The conversion of forestland into croplands has now tremendously been increased across the regions.[5-6] The information about land use land cover can be acquired from the various band combinations of raster imageries through the process of image interpretation and classification techniques.[7] Remote sensing and GIS technology offer a quick and efficient approach to the classification and mapping of land use/land cover changes over space and time. The capability of GIS to integrate and analyze, temporal and spatial data, helps in quantifying the land use changes. Land use/land cover change is critically linked to the intersection of natural and human influences on environmental changes. Digital classification techniques through the stratification approach, with limited ground truth, could be used for mapping of broad land cover categories and their spatial distributions. Digital image classification methods like supervised and unsupervised can be used to categorize pixels in an image to obtain a given set of labels or land cover themes. [8-10] Many researchers carried out land cover change detection studies using various algorithms. [11-13] Normalized difference vegetation index (NDVI) is a widely used vegetation index method in studying the environment and climate change, and crop inventory. [14-17]

The main objective of the present study is to identify changes in a part of the Eastern Ghats hilly region of Andhra Pradesh state over a period of 32 years by using remote sensing and GIS technologies. NDVI technique is also applied for cross-checking the accuracy of digital classification of satellite data.

STUDY AREA

The study area, Anantagiri mandal, is a part of the Paderu revenue division of Visakahpatnam district, Andhra Pradesh state, and is also one of the important hilly regions of the Eastern Ghats of India. The study area is located between 17˚ 59' N to 18˚ 22' N latitudes and 82˚ 50' E to 83˚16' E longitudes spreading an area of about 842 sq km (Figure 1). Physiographically, the area is covering with Ananthagiri, Veduruvada, Peddakota and Shankaram Reserve forests distributed in steep mountainous terrain reaching a maximum height of 1635 m. The popular tourist place called 'Borra Caves' which are formed due to the flow of the Gosthani River on the limestone stalactites and stalagmites deposits. These caves are located in the Ananthagiri reserve forest area. The area enjoys tropical humid climate having with an average rainfall of 1400 mm and the temperature ranges from 10˚ to 35˚C. The primitive tribal groups namely Gadaba, Porja, and Khonds are settled along with other tribal groups like Bhagatha, Kondadora, Mannedora, and Valmiki etc. Nearly 278 villages/hamlets with 90% share of scheduled tribe population accommodating about 49,019 inhabitants. [18] The economy of the inhabiting indigenous people is mainly based on agro-forestry.

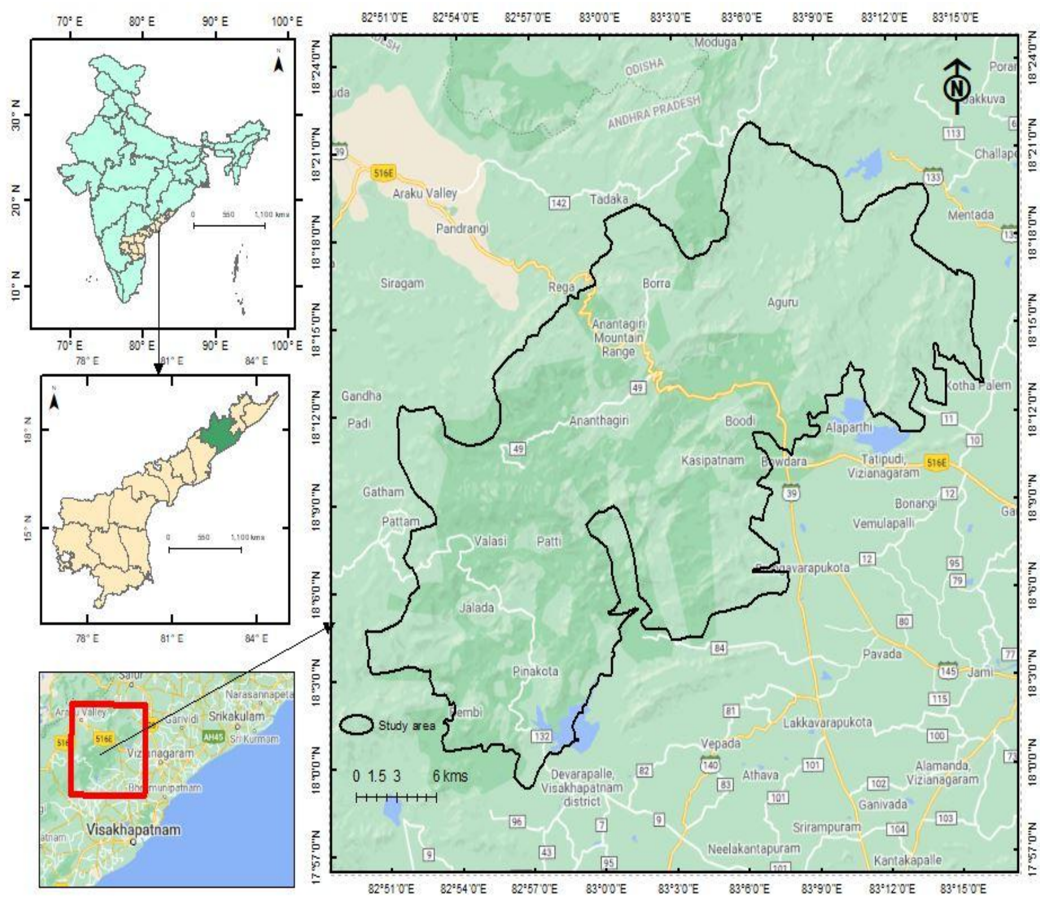

Figure. 1. Location map of the study area.

MATERIALS AND METHODS

For evaluation of land use land cover changes, it is essential to have at least two different time periods data for the purpose of comparison. In this study, Landsat-5 TM data (1988) and Landsat-8 Operational Land Imager (OLI) (2020) in Geotiff (level-1) format were downloaded from USGS Earth Explorer (http://earthexplorer.usgs.gov/) (Table 1). The imageries have further rectified and assigned with UTM-Zone 44N, WGS-84 datum. ERDAS Imagine 2014 for image processing and ArcGIS 10.4 for statistical spatial analysis were used. Supervised classification is more controlled by the user than unsupervised classification. It requires experience by the user about the field and more input, but it can produce better results than unsupervised classification. Maximum likelihood classifier (MLC) is based on the decision rule that the pixels of unknown class membership is allocated to those classes with which they have the highest likelihood of membership. It undertakes the classification of remotely sensed data based on information contained in a set of signature files. The MLC is based on the probability density function associated with a particular training site signature. Pixels are assigned to the most likely class based on a comparison of the posterior probability that belongs to each of the signatures are being considered. [19-22]

Table 1. Specifications of satellite imagery used for the study.

Satellite sensor	Data coverage Path/row	year	Details of spectral band	Spectral resolution µm	Spatial resolution m
Landsat-5 TM	141/047	1988	Band 1- Blue	0.45-0.52	30
			Band 2 - Green	0.52-0.60	
			Band 3 - Red	0.63-0.69	
			Band 4 - Near Infrared (NIR)	0.76-0.90	
			Band 5 - Shortwave Infrared (SWIR) 1	1.55-1.75	
			Band 7 - Shortwave Infrared (SWIR) 2	2.08-2.35	
Landsat-8 OLI	141/047	2020	Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
			Band 2 - Blue	0.452 - 0.512	
			Band 3 - Green	0.533 - 0.590	
			Band 4 - Red	0.636 - 0.673	
			Band 5 - Near Infrared (NIR)	0.851 - 0.879	
			Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	
			Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	

In the present study, we adopted the maximum likelihood classifier algorithm for land use land cover classification using ERDAS Imagine 2014 up to the level-II based on NRSA classification system. A total of seven LULC classes i.e. builtup, cropland, plantation, dense forest, scrub forest, degraded forest/wastelands, and water bodies were selected for supervised classification. For each class, ten training areas were selected and giving a total number of 70 training areas for the whole study area. After performing the classification field visit was performed for ground truth verification to refine the LULC classes.

Classification Accuracy Assessment

The accuracy of the map depends on the spatial, spectral resolution, and seasonal variability in vegetation cover types and soil moisture conditions. It is necessary to assess the accuracy of the obtained results through a sample of testing pixels on the classified image. These pixels class identity is to be compared with the reference data (ground truth). The pixels of agreement and disagreement are generally compiled in the form of an error matrix. The error matrix and Kappa coefficient have become a standard method in the assessment of classification accuracy. [23-24] The Kappa coefficient was computed as follows [25]:

$$\hat{K} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+} \cdot x_{+i})}$$

Where
r = the number of rows in the error matrix
xii = the number of observations in row i and column i (on the major diagonal elements)
xi+ = total of observations in row i
x+i = total of observations in column i
N = the number of observations included in matrix

In addition, we used the two raster imageries for finding the Normalized Difference Vegetation Index (NDVI) values for the better evaluation of LULC classification. The NDVI is based on the difference between the spectral radiance of the Red band and the near-infrared bands of raster imageries. In general, the values of the NDVI vary between -1.0 to +1.0. For generating the NDVI, we have used Band 3 & 4 for Landsat TM data and Band 4 and Band 5 for Landsat OLI using the following formula.

NDVI = NIR-RED/NIR+RED

After performing the process of NDVI, the obtained values like minimum, maximum, and mean were used for comparison of LULC classified maps.

RESULTS AND DISCUSSION

Land Use and Land Cover Analysis

Spatial distribution of land use and land cover classes delineated from Landsat 5 (1988) and Landsat 8 (2020) are presented in Figure 2. The areal distribution of LULC classes such as built-up, cropland, plantation, dense forest, scrub forest, degraded forest/wastelands, and water bodies are presented in Table 2. The aerial extent of built-up for the year 1988 was 1.2 sq. km increased to 3.24 sq. km in 2020. As the study area is covered by dense forest, the built-up is mostly confined to the surroundings of agricultural lands. Cropland has covered an extent of 105.4 sq. km ((1988) and 189.5 sq. km (2020) revealing about 22.6 % over the past three decades. Land under dense forest covering was 184.2 sq km in 1988 and 282.78 sq km for the year 2020. It was found that the dense forest area showed an increasing trend with 11% over time. In the study area, the major land use category under scrub forest was 469.7 sq km (1988) which is decreased to 292.8 sq km (2020) showing -21% decreasing rate. The reduction of the scrub forest is mainly due to the expansion of cropland over time. Degraded forest/wasteland also showed a declining trend when in comparison with the year 1988 to 2020 which may be due to afforestation measures taken by the Government organizations after getting hit by major cyclonic storm Hudhud in the year 2014. This cyclonic storm caused extensive damage to the Visakhapatnam district. The two rivers namely Gosthani and Sarada are originating in the hilly ranges of the study area. The Thatipudi reservoir water of Gosthani river is used for irrigation and drinking purpose of the people of Visakhapatnam city. The tribal population of the study area is mainly depending on the seasonal rainfall and spring water for irrigation purposes since the reservoir is constructed at downstream.

Table 2. Land use and land cover categories and their distribution in the study area.

Class	LULC 1988		LULC 2020		LULC Change (1988-2020)	
	Area		Area		Difference in area	
	km^2	%	km^2	%	km^2	%
Built-up	1.2	0.14	3.24	0.38	2.04	0.24
Cropland	105.4	12.51	189.95	22.56	84.6	10.04
Plantation	0.6	0.07	2.45	0.29	1.87	0.22
Dense forest	184.2	21.87	282.78	33.58	98.6	11.71
Scrub forest	469.7	55.79	292.82	34.78	-177	-21.01
Degraded forest/wastelands	77.7	9.23	63.66	7.56	-14.1	-1.67
Water bodies	3.4	0.40	6.69	0.79	3.28	0.39

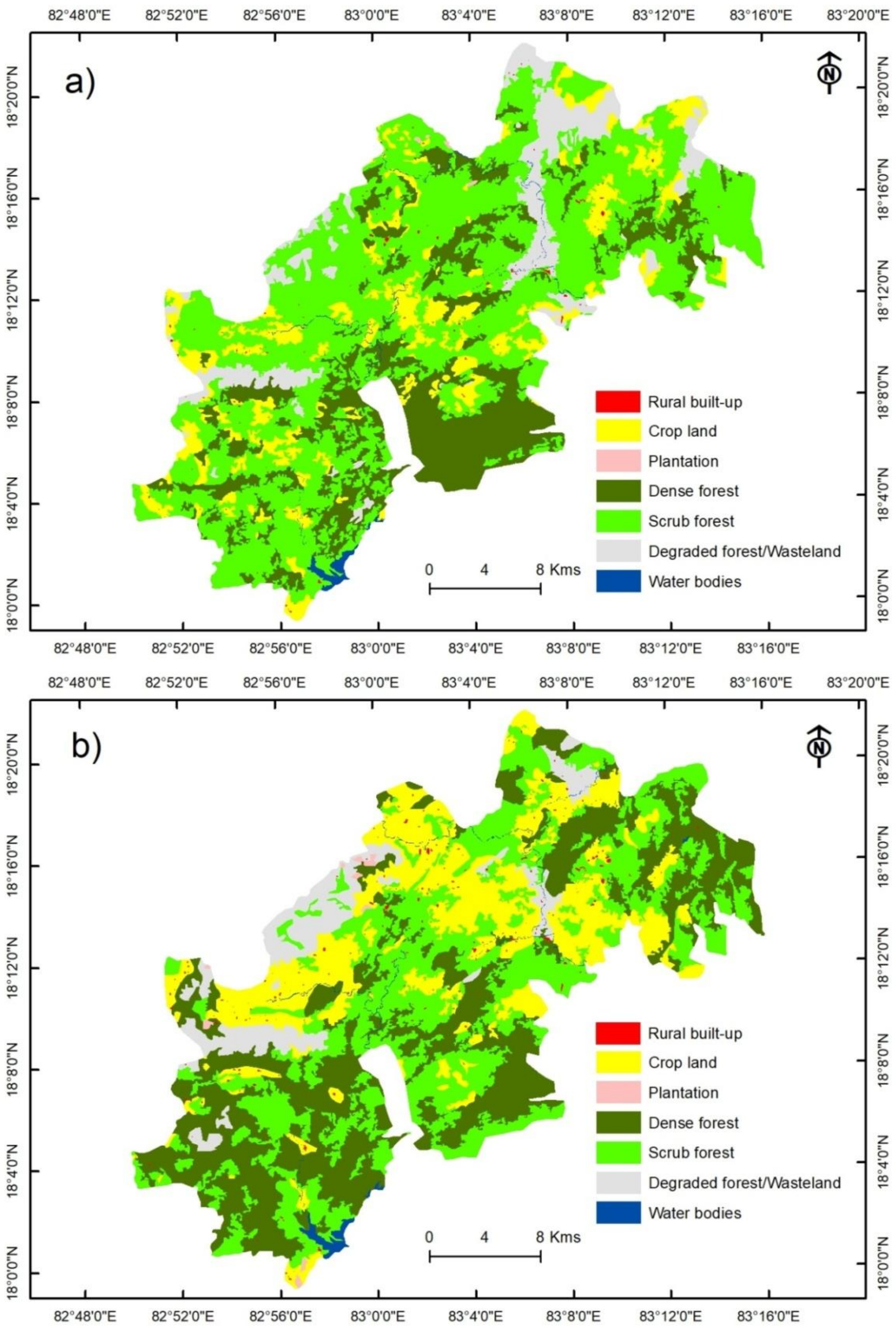

Figure 2. Land use and land cover classes a) year 1988 and b) year 2020.

Accuracy assessment

In the present study, the accuracy of the two raster imageries (1988 and 2020) was assessed through the error matrix. The results of the error matrix for land use/land cover classes of the study area for both the years are given in Tables 3 and 4. The error matrix summarizes the comparisons between the maps and the reference data collected for pixels. The sample points (65 ground truth-sites for 1988 and 75 truth-sites for 2020) were taken into consideration from the field. These sites were chosen with the help of a handheld GPS instrument. The classification based on spectral data of Landsat TM and OLI produced an overall accuracy of 92.3% and 86.7% for the years 1988 and 2020, respectively. User's accuracy varied from 75% to 100% for both the years and while the producer's accuracy was from 71% to 100%, respectively. During verification, some of the sample points from built-up areas were confused with cropland. This was due to the habitations are mixed with cropland Furthermore, some forest areas of low density have been identified as scrub forest and cropland. Water bodies had very high overall accuracy during the ground truth for both the years. Kappa coefficient is for the year 1988 is showed as 90% and for the year 2020 showed as 84%. Change analysis of land use land cover classes from 1988 to 2020 were depicted in Figure 3.

Normalized Difference Vegetation Index (NDVI)

Figure 4(a&b) is showing the reflectance values in the red and infrared channels of different land cover types. In 1988, the NDVI values are ranging between0.57 and 0.75 whereas for the year 2020 they are ranging between -0.05 and 0.51. Minimum, maximum and mean NDVI values are presented in Tables 5. The mean NDVI values for water body is ranging from -0.28 to 0.02. Vegetation values are categorized into three classes viz. sparse, moderate, and dense vegetation. In the study area, mean NDVI values of sparse vegetation is ranging from 0.26 to 0.25, for moderate vegetation values it is0.4 to 0.31and for dense vegetation, the NDVI values are ranging from 0.4. to 0.57 respectively (Figure 5).

Table 3. Analysis of error matrix of LULC classification for the year 1988.

Classification	Built-up	Cropland	Plantation	Dense forest	Scrub forest	Degraded forest /wastelands	Water bodies	Row Total
Built-up	8	1	0	0	0	0	0	9
Cropland	0	14	0	0	0	0	0	14
Plantation	0	0	3	0	1	0	0	4
Dense forest	0	0	0	10	0	0	0	10
Scrub forest	0	0	1	1	10	0	0	12
Degraded forest/wastelands	0	0	0	0	1	6	0	7
Water bodies	0	0	0	0	0	0	9	9
Column total	8	15	4	11	12	6	9	65
Producer's accuracy (%)	100	93.3	75	90.9	71.4	100	100	
User's accuracy (%)	88.9	100	75	100	83.3	85.7	100	
Over all accuracy (%)	92.3							
Kappa coefficient	0.90							

Table 4. Analysis of error matrix of LULC classification for the year 2020.

Classification	Built-up	Cropland	Plantation	Dense forest	Scrub forest	Degraded forest /wastelands	Water bodies	Row Total
Built-up	5	1	0	0	0	0	0	6
Cropland	0	12	1	0	1	0	0	13
Plantation	0	0	6	2	0	0	0	8
Dense forest	0	0	1	14	3	0	0	18
Scrub forest	0	1	0	0	12	0	0	13
Degraded forest/wastelands	0	1	0	0	0	6	0	7
Water bodies	0	0	0	0	0	0	10	10
Column total	8	15	4	11	12	6	9	75
Producer's accuracy (%)	100	80	75	87.5	85.7	100	100	
User's accuracy (%)	83.3	92.3	75	77.8	92.3	85.7	100	
Over all accuracy (%)	86.7							
Kappa coefficient	0.84							

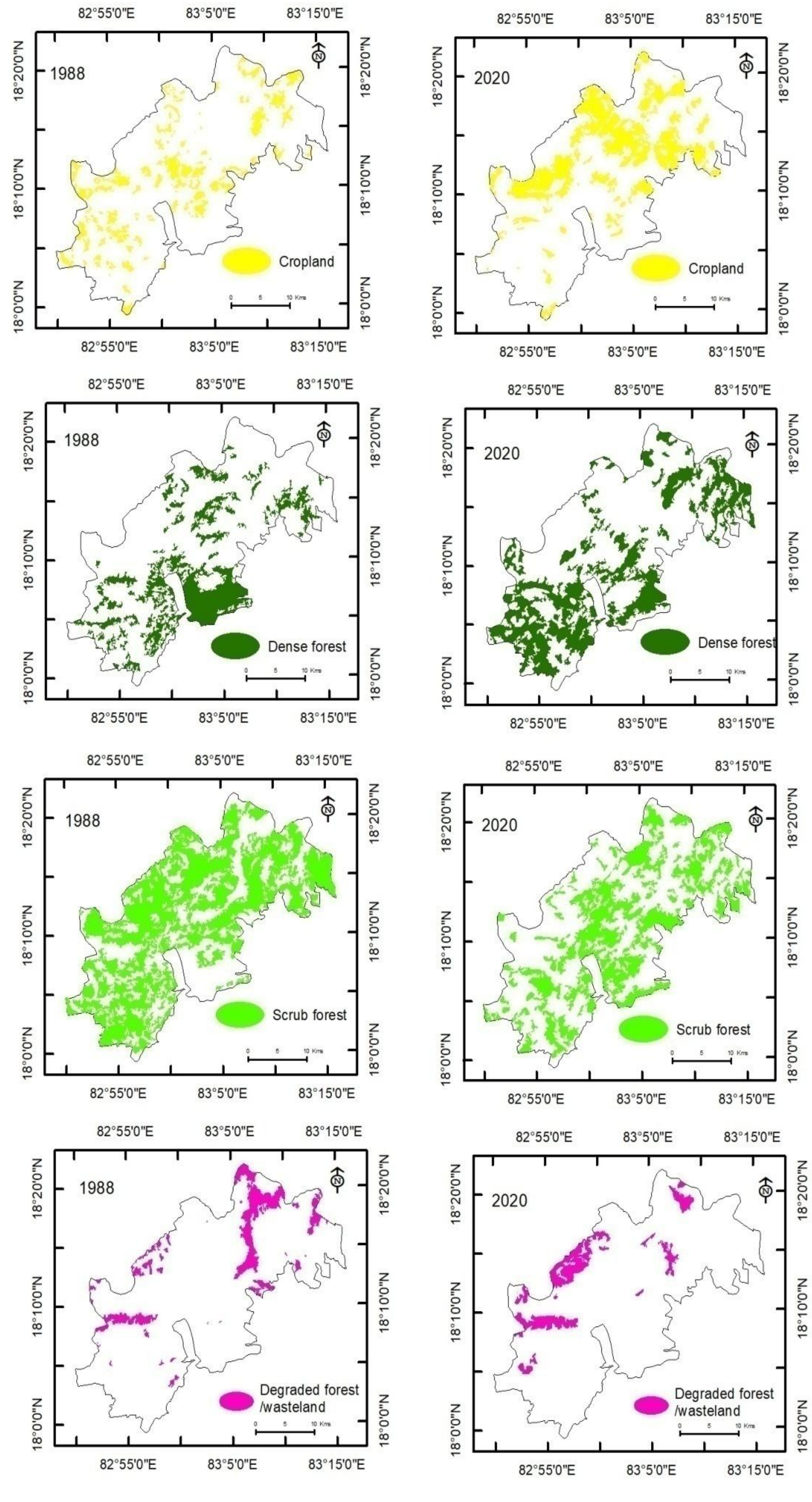

Figure. 3. Change analysis of different LULC classes.

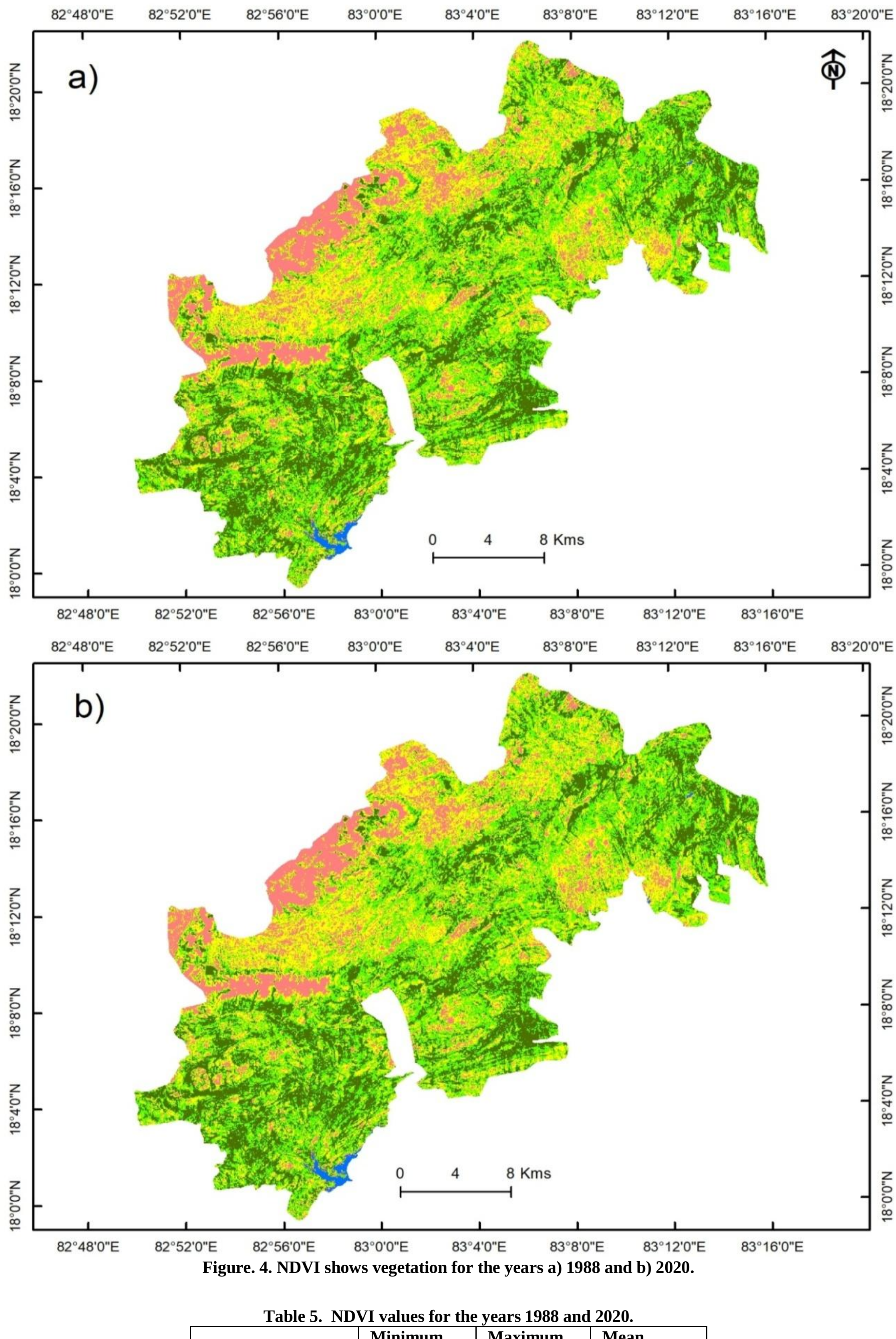

Figure. 4. NDVI shows vegetation for the years a) 1988 and b) 2020.

Table 5. NDVI values for the years 1988 and 2020.

Land cover class	Minimum		Maximum		Mean	
	1988	2020	1988	2020	1988	2020
Water body	-0.57	-0.05	0.01	0.09	-0.28	0.02
Baresoil	0.01	0.09	0.21	0.22	0.11	0.16
Sparse Vegetation	0.21	0.22	0.3	0.28	0.26	0.25
Moderate Vegetation	0.3	0.28	0.38	0.33	0.34	0.31
Dense Vegetation	0.38	0.33	0.75	0.51	0.57	0.42

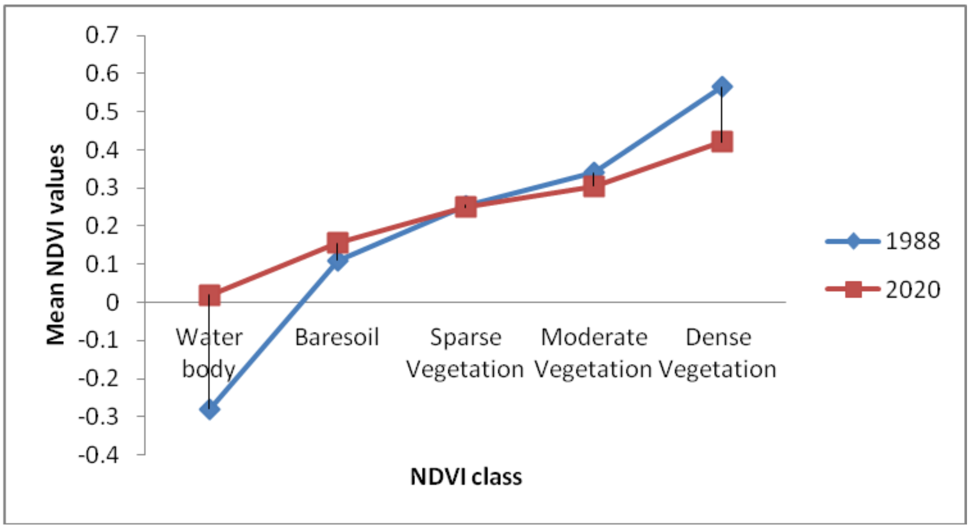

Figure. 5. Graph showing the mean values of NDVI.

CONCLUSIONS

The monitoring of land use land cover changes is very much needed for development activities. Nowadays these are studied by utilizing the classification procedures along with NDVI indexing. Land use changes are effectively captured by satellite sensors with various spectral, spatial, and temporal resolutions. The present study was carried out to identify the pattern of land use and land cover changes between 1988 and 2020 in a dense hilly range of the Eastern Ghats of India. From the identified classes, the area under scrub forest and degraded forest/wastelands showed a declining trend from 1988 to 2020 with a net change of -176.90 sq. km and -14.07 sq. km, respectively. Whereas other classes such as built-up, cropland, plantation, dense forest, and water bodies are showed an increasing trend with a net positive change of 2.04 sq km, 84.58 sq km, 1.87 sq km, 98.61 sq km and 3.28 sq km, respectively. The results revealed that the overall classification accuracy of 92.3% for the year 1988 and 86.7% for the year 2020. NDVI analysis has been integrated for cross-checking of the classification accuracy. The analysis revealed that NDVI values are almost identical to the derived land cover classes. Various anthropogenic activities including shifting cultivation and clearing of forest area for agriculture practices by the indigenous people of the study area are significantly affected the changing pattern of land use and land cover. The study is suggested that the policymakers and researchers may need to create awareness among the indigenous people and encourage them for effective and eco-friendly land use practices to sustain the ecological balance and conservation of natural resources.

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