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Land use and land cover change detection through spatial approach: A case study of Mangaluru Taluk, Karnataka

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Abstract: Land cover is a physical appearance of land and represents its ecological status. Land use/land cover changes are due to human intervention, natural disturbance and succession. The present study aimed at monitoring the land cover changes in Mangalore region during the period 1997 to 2017. Remote sensing and Geographical Information System (GIS) techniques were used to determine the land use and land cover changes based on the analysis of temporal Landsat-5 and Landsat-8 satellite imagery. Ground truth observations were performed to check the accuracy of the classification. The present study brought to light that the forest area that occupied 37% of the Taluk's area in 1997 has reduced to 31% in 2017. Other classes like agricultural land, built up area, water bodies and barren land have also experienced changes. Built-up lands (settlements) have increased from 6 per cent to 23 per cent of the total area. The high land vegetation and forest cover areas are disappearing rapidly; water bodies like lakes are also diminishing. Mangalore city is one of the fastest developing cities in India. Proper land use planning is essential for a sustainable development of Mangalore Taluk.

Keywords: Land use, Land cover, Change Analysis, GIS, Mangaluru

1. Introduction

Land Use/Land Cover (LU/LC) is an important component in understanding the interactions of the human activities with the environment and thus it is necessary to understand the changes in it. The land use/land cover pattern of any region is influenced by natural and socio-economic factors and their utilization by human in time and space (Aspinal and Hills, 2008; Feranec et al., 2007). Degradation of land is mainly due to population pressure that leads to intense land use without proper management practices. Over population makes people to relocate themselves towards sensitive areas like highlands. Usually such areas lack planning strategies. The influence of road and other constructions in such terrain will disturb the landscape that intern may lead to landslides/other mass movements. These changes have to be analysed for better understanding of interactions and relationships between human activities and natural phenomena. It also helps us to understand the necessity for improving resource management and decision making (Lu et al., 2004; Seif and Mokarram, 2012).

Proper information on land use/cover and outcome for their optimal use is essential at planning phase to meet the increasing demands of basic human needs and welfare very effectively. Land use and Land cover are inter related i.e., Land use affects land cover and changes in land cover affect land use. Every time changes in land cover by land use do not necessarily imply that there will be degradation of the land. However, many changing land use patterns driven by a variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere (Riebsame et al., 1994). Remote sensing and GIS can be effectively used as a source or tool for rational planning of any area or region. With the invent of these techniques, land use/cover mapping has given a useful, economical and detailed way to improve the selection of areas designed to agricultural, urban and/or industrial areas of a region (Selcuk et al., 2003). Remote Sensing tool has been used to classify and map land use and land cover changes with different techniques and data sets. Remotely sensed data has made it possible to study changes in land cover in less time, at low cost and better accuracy (Kachhwaha, 1985). Various methods of supervised classifications have been applied widely for the land use change analysis throughout the world. These techniques depend on a combination of background knowledge and personal experience with the study area to a greater extent than other areas. Information on LU/LC is important in regional and urban planning and management (Chen et al., 2006; Crainic et al., 2009; Flotterod et al., 2011). An attempt is made in this study to map status and changes in LU/LC of Mangalore region, Dakshina Kannada district of the Karnataka State.

2. Study area

Mangalore region is located at Dakshina Kannada District of the Karnataka state, India and lies in between Arabian Sea towards west and Western Ghats mountain ranges towards east side. The study area (Figure 1) has been divided into three zones by having the river boundary as a reference. It extends between 12°25' N to 13°25' N latitude and 74°25' E to 75°25'E longitude and encompasses an area of 664 km^2. Climatically, the study area experiences humid hot temperate conditions. The annual mean maximum, minimum and average temperature of the study area stands at 36.6, 20.1 and 28.3 °C, respectively. On an average, the study area receives about 4030 mm of rainfall per year. Few rivers flowing in these regions are Nethravathi, Kumaradhara, Phalguni, Shambhavi, Nandini or Pavanje and Payaswini

Rivers. The region has a total population of 20,89,649 (Census of India, 2011).

Source: https://dk.nic.in/en/map-of-district/

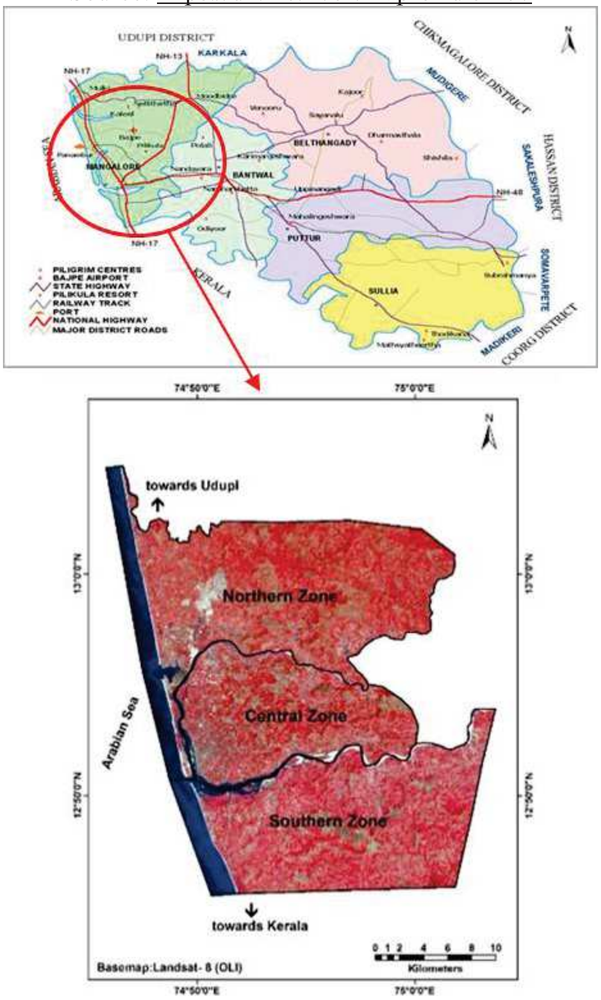

Figure 1: Study area showing the three zones along Mangalore, Dakshina Kannada District.

3. Objectives

The main objective of the present paper is to analyse the nature and the extent of land use/land cover changes in the study area over the past 20 years and to identify the main causes behind the changes.

4. Material and methods

4.1. Satellite data pre-processing

Landsat-5 (Thematic Mapper) and Landsat-8 (Operational Land Imager) satellite imagery with the resolution of 30 m, covering the path-146 and row-51 during February 1997 and January 2017 were used for land use/cover mapping. It was downloaded from the USGS Earth Explorer image database (Landsat Imagery Archive). It has a solar elevation angle of 63.13 degrees and a cloud cover lower than 10%.

4.2. Database preparation

Figure 2 shows the flow chart of methodology adopted for this study. The data sets were imported in ERDAS Imagine version 10.0, satellite image processing software to create a False Colour Composite (FCC). The layer stack option in image interpreter tool box was used to generate FCCs for the study areas. The sub-setting of satellite images was performed for extracting study area from both images by taking geo-referenced out line river boundary of Mangalore region as AOI (Area of Interest). For better classification results, indices such as Normalized Difference Vegetation Index (NDVI) were also used.

4.3. Land use/cover detection and analysis

Acquisition of land use/cover by traditional method takes several months or years; Remote sensing has proved an efficient technique for monitoring the spatial changes in local and global scales (Loveland et al., 2000; Foody, 2002). To work out the land use/cover classification, supervised classification method with maximum likelihood algorithm was applied using the ERDAS Imagine (v.2010) Software. Maximum likelihood Classifier (MLC) algorithm is one of the most popular supervised classification method for analysing satellite data. This method is based on the probability that a pixel belongs to a particular class. The basic theory assumes that these probabilities are equal for all classes and that the input bands have normal distributions. However, this method takes long time of computation, relies heavily on a normal distribution of the data in each input band and tends to over-classify signatures with relatively large values in the covariance matrix. The spectral distance method calculates the spectral distance between the measurement vector for the candidate pixel and the mean vector for each signature and the equation for classifying by spectral distance is based on the equation for Euclidean distance. It takes least computational time among other supervised methods, however, the pixels that should not be unclassified become classified, and it does not consider class variability. Ground verification was done for doubtful areas. Based on the ground truthing, the misclassified areas were corrected using recode option in ERDAS Imagine. The land use Land cover classes were taken as per the International Geosphere Biosphere Program (IGBP) LULC classification scheme.

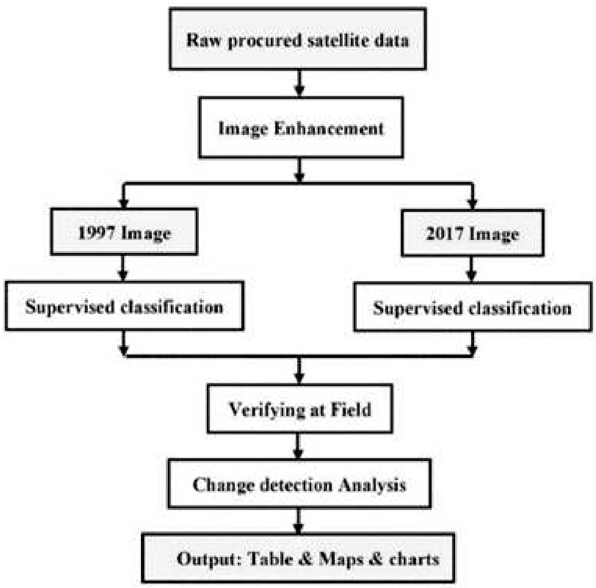

Figure 2: Methodology flowchart

5. Results and discussion

5.1. Land use mapping and distribution

A supervised maximum likelihood classification was implemented for the three images and the final classification products provided an overview of the major land use / land cover features of Mangalore region for the years 1997 and 2017. Six categories of land use / land cover were identified are described in Table 1.

Table 1: Classification scheme used for preparing the decadal land use and land cover datasets

Level - 1	Level - 2	Description
Built-up	Built-up (both urban & rural) BU	Urban, rural, residential, and industrial areas.
Agriculture	Crop Land	These include agriculture area delineable on satellite images in different seasons and the areas which are primarily agriculture but may be fallow.
Mixed Forest	Shrub land (SL)	Stunted height degraded forest.
	Grass Land (GL)	Land covered with grasses, notified or otherwise.
	Permanent wetland (PW)	Water saturated area having land-water interface.
Dense Forest	Forest (FO)	Included evergreen broad leaf forest (EBF), Deciduous Broad leaf forest (DBF), mangrove forest (MF).
	Plantation (PL)	Primarily commercial plantation outside forest, protected areas and wildlife sanctuaries.
Barren Land	Barren Land (BL)	Rocky or exposed rocky areas, Soil filled surfaces.
	Mining (MN)	Mining areas
Water bodies	Water bodies (WB)	Surface water delineable on satellite data in the form of river, lakes, pond, reservoirs/dams, canals.

Based mainly on International Geosphere Biosphere Program (IGBP)

The Figures 3, 4 and 5 illustrate the land use / land cover maps of Mangalore region for the year 1997 and 2017. For each zone separate supervised classification was performed and then the results are analysed. Above mentioned (Table 1) six classes of classification are adopted during supervised classification of three zones.

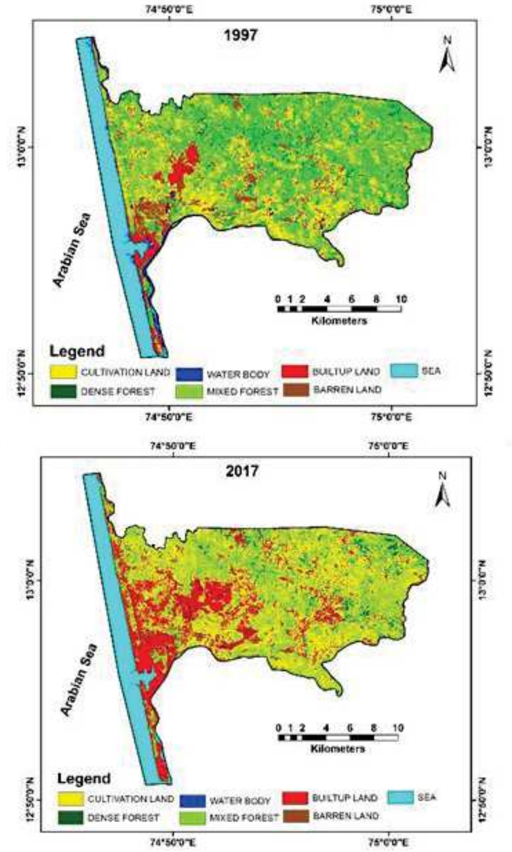

Figure 3: Land use / Land cover in the northern zone during 1997 and 2017

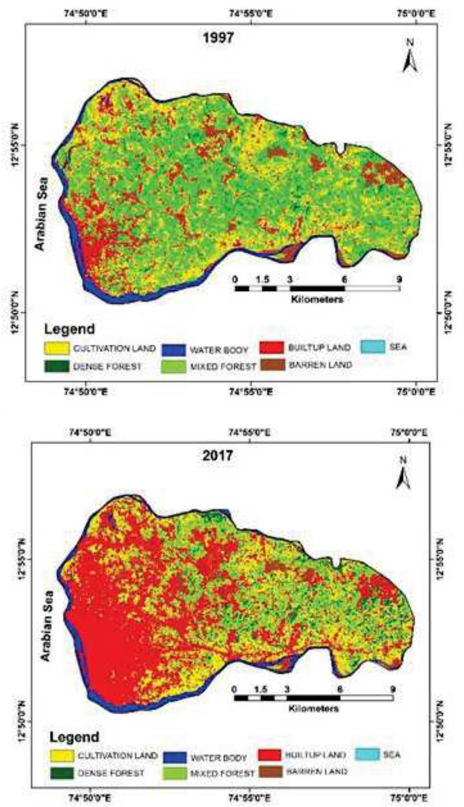

Figure 4: Land use / Land cover in the central zone during 1997 and 2017.

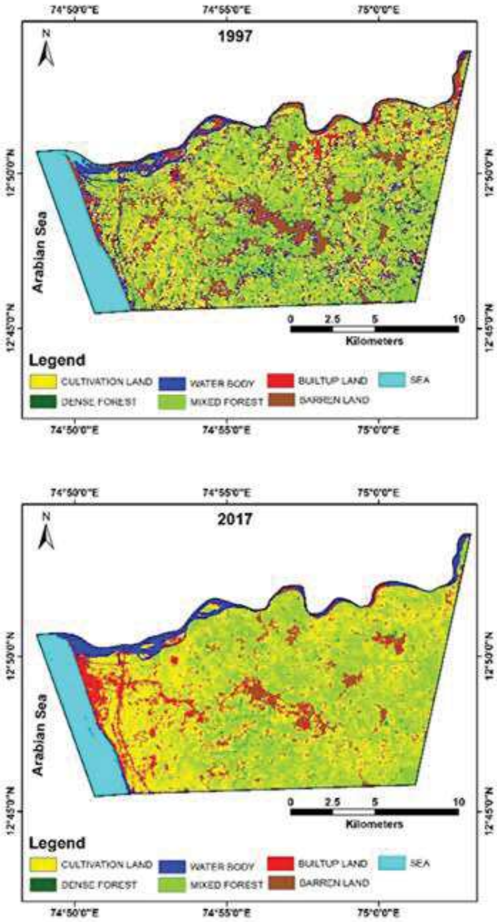

Figure 5: Land use / Land cover in the southern zone during 1997 and 2017.

Table 2 and 3 illustrate the areas under six classes of three zones (Northern, Central and Southern zone) for the year 1997 and 2017 respectively.

Table 2: Landuse/land cover area (km²) during 1997

Classes	North	Central	South
Cultivation Land	100.59	55.504	84.089
Dense Forest	16.506	4.769	4.607
Water Body	6.659	8.856	46.475
Mixed Forest	99.175	54.404	62.091
Built-up Area	10.557	20.076	9.539
Barren Land	40.129	17.613	22.951

Table 3: Landuse/land cover area (km²) during 2017

Classes	North	Central	South
Cultivation Land	97.506	39.157	100.921
Dense Forest	12.223	10.521	3.104
Water Body	1.503	8.028	9.065
Mixed Forest	82.528	26.656	71.696
Built-up Area	58.529	68.166	22.148
Barren Land	18.735	7.729	11.922

Table 2 and 3 provides data of spatial extent of the land cover in square kilometres for the three zones of study. Cultivation area at the north and central zone was 100.59 km² and 55.504 km² during 1997, but has reduced to 97.506 km², 39.157 km² respectively, in the year 2017. Whereas the cultivation land at the south zone has increased from 84.089 km² (1997) to 100.92 km² (2017). Built-up area at all the zones increased tremendously. During 1997 it was 10.557 km², 20.076 km² and 9.539 km² for north, central and south zone and in 2017 it was found to be 58.529 km², 68.166 km² and 22.148 km² respectively. Also water bodies have decreased drastically at north and south zone and quite stable at central zone since there were no much water bodies existing at central zone. It was found to be 6.659 km² and 46.475 km² (1997) at north and south zone and reduced to 1.503 km² 9.065 km² (2017) respectively. At central zone the water bodies area coverage was 8.856 km² (1997) and 8.028 km² (2017). Likewise, the barren land has reduced in all the zones. It was 40.129 km², 17.613 km² and 22.951 km² (1997) and 18.735 km², 7.729 km² and 11.922 km² (2017) at north, central and south zone respectively. The rapid increase in built-up land in the southern coastal Karnataka is due to the intensive urban growth and industrial revolution (Usha et al., 2014; Silambarasan et al., 2014; Usha et al., 2015; Kale et al., 2016).

Table 4 shows the percentage increase and decrease of land use land cover during 1997 – 2017 for all the three zones. It is observed that there is a large decrease in area of water bodies and barren land by 70.011% and 52.428% respectively. There is slight decrease in areal extent of mixed forest and negligible decrease in area of dense forest i.e., 16.131% and 0.123% respectively. While built up area has tremendously increased by 270.506% whereas the cultivation land has decreased by about 1.078%. Residential and commercial buildings were constructed in the barren land and beside the shores of the river bodies; Farming activities are observed to be stable. This is pictorially depicted in the figure 6.

The figure 7 illustrates the areal coverage of land use/land cover for six classes in the three zones (North, central and South) during 1997 and 2017 respectively. Cultivation area is more on the north and south zone compared to central zone. Also mixed forest cover area is high at north and south when compared to the central zone. Whereas built up area is large at central zone compared to the other two zones. Water bodies are slightly more in the south zone compared to other two zones.

Table 4: Changes in Land use/land cover classes

Classes	Increase (%)	Decrease (%)
Cultivation Land	-	1.0783
Dense Forest	-	0.1236
Water Body	-	70.0117
Mixed Forest	-	16.1311
Built-up Area	270.5068	-
Barren Land	-	52.4289

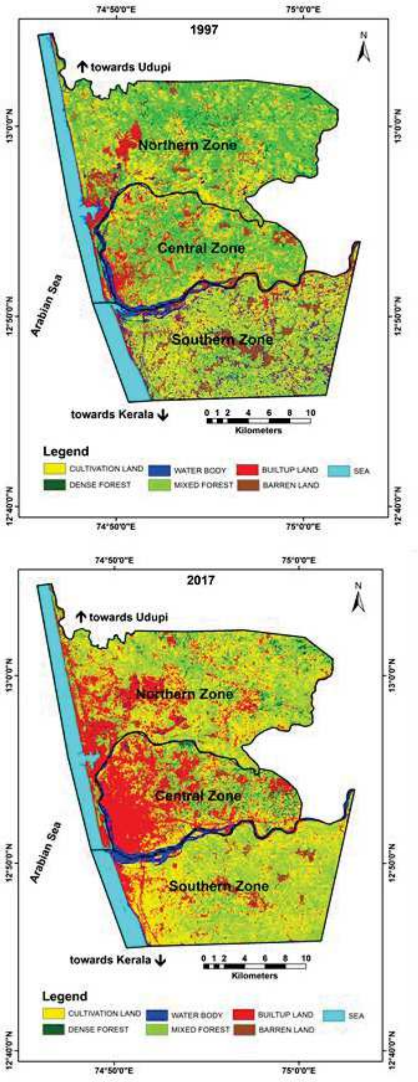

Figure 6: Land use / Land cover in the study area during 1997 and 2017

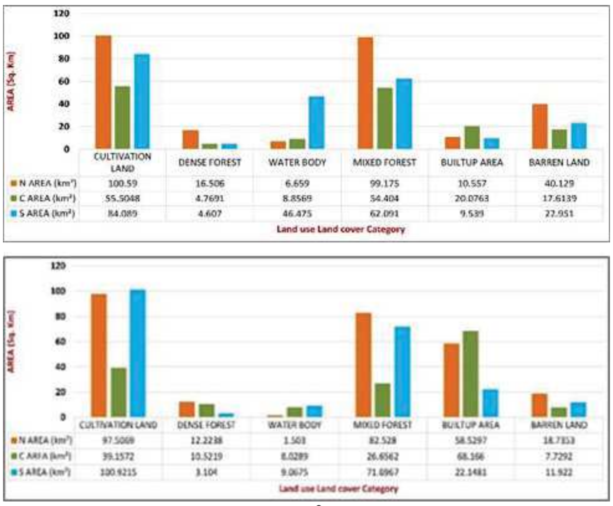

Figure 7: Areal extent (km²) of land use and land cover in the three zones during 1997 and 2017

Each zones discrete study was conducted to understand evidently the land use/land cover change in respective three zones of interest. The data list of the increase and decrease in area of land use/land cover classification for the 20 years span of study is given in Table 5. It is clearly observed that the built up area have increased tremendously in all the three zones (North, Central and South). There is enormous increase in built up area at North zone by 454.45%. The noticeable change is increase in dense forest area at central zone region by 120.63%. North and south zone regions have significant decrease in water body's area of 77.43% and 80.49% respectively compared to central which is almost same for year 1997 and 2017. At all zones the barren land area in 2017 has decreased by half in its occurrence of 1997. Mixed forest has decreased by 16.79% and 51.01% at North and central zone and 15.47% a slight increase in area at south zone region.

The effect of increasing human population on land cover can be clearly noticed in the study. More the populations mean more the changes taking places in order to support the human activities and needs. Hence these activities will lead to land cover changes that was also similar to the result of this study. The population of Mangalore Taluk was 2,73,304 in 1991 and 4,25,725 in 2001 and recent Census of India, (2011) says it was 9,94,602 with an average Annual growth rate of ~ 4.55% and ~ 8.85% per year during the years 1991-2001 and 2001-2011 respectively. It could be suggested that population has an effect on land cover change to meet their need for pace and land in order to support human life such as development settlements and agricultural lands including rice fields. The figure 8 illustrates the decrease and increase in land use/land cover area with graphical representation for the year 1997 and 2017 respectively.

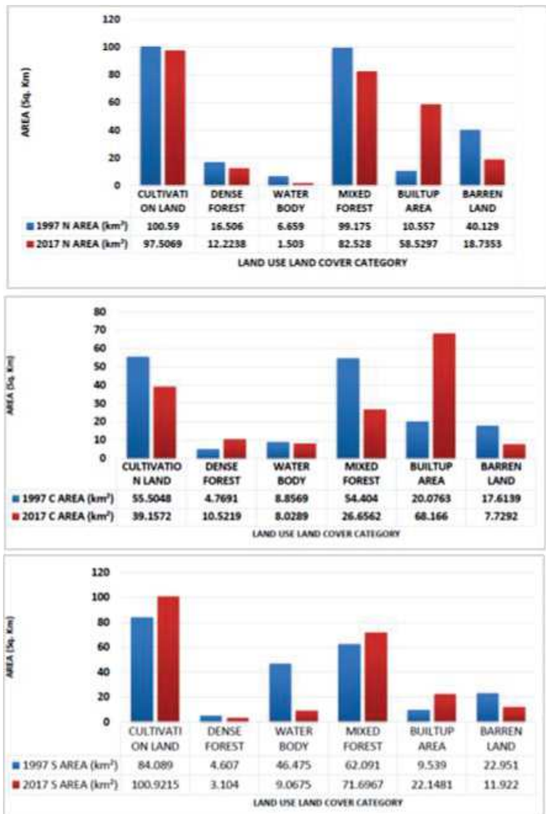

Figure 8: Areal extent (km²) of land use and land cover in north, central and south zones during 1997 and 2017

The mean changes per year was also analysed to examine how fast the increase or decrease took place each year (Table 6). The mean increase per year of cultivation land, dense forest, water body, built-up area and barren land were analysed for the three respective zones. In north zone mean increase of built-up area was 2.40 km^2/year and mean reduction of land cover class of cultivation land, dense forest, water bodies, mixed forest and barren land were 0.15 km^2/year, 0.21 km^2/year, 0.26 km^2/year, 0.83 km^2/year and 1.07 km^2/year respectively. Similarly, in central zone mean increase of dense forest and built-up area were 0.29 km^2/year and 2.40 km^2/year respectively and mean reduction of land cover class of cultivation land, water bodies, barren land were 0.82 km^2/year, 0.04 km^2/year and 1.39 km^2/year respectively. In South zone the mean increase of land cover of cultivation land, mixed forest and built-up land were 0.84 km^2/year, 0.48 km^2/year and 0.63 km^2/year respectively while the mean reduction of land cover class of dense forest, water bodies and barren land were 0.08 km^2/year, 1.87 km^2/year and 0.55 km^2/year respectively.

The graphical representations of the mean changes per year was also examined to understand how fast the increase or decrease took place every year (Figure 9). The representation of mean was obtained by considering all six classifications in the same order as mention in table 6. The six classes represented in x-Axis are 1- CL, 2 - DF, 3 - WB, 4 - MF, 5 - BL, 6-BA. The peak variations in areal extent and the mean changes per year in built up area and barren land could be clearly observed through this representation.

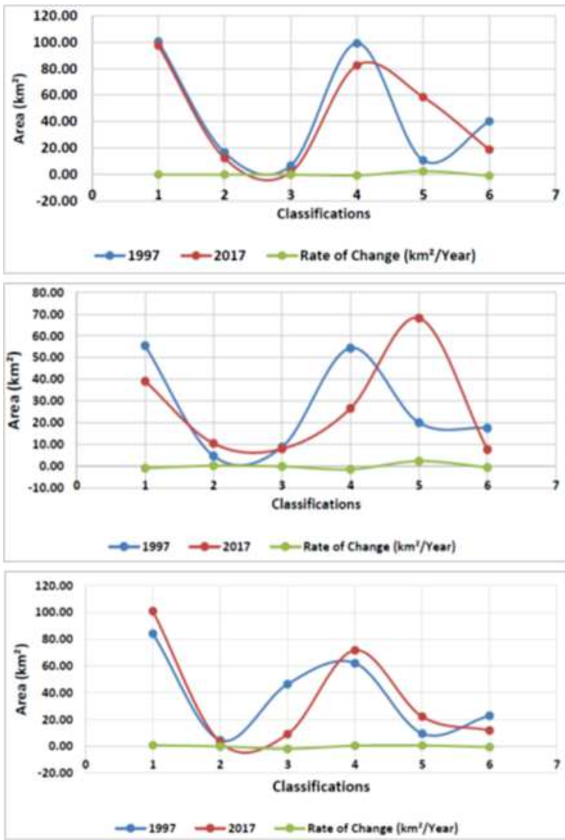

Figure 9: Mean changes in areal extent (km^2) of land use and land cover per year at north, central and southern zones during 1997 and 2017

Table 5: Increase and decrease in land use and land cover classes in all the three zones (km²)

	NORTH				CENTRAL				SOUTH			
Class .	1997	2017	I (%)	D (%)	1997	2017	I (%)	D (%)	1997	2017	I (%)	D (%)
CL	100.59	97.51	-	3.07	55.50	39.16	-	29.45	84.09	100.9	20.10	-
DF	16.51	12.22	-	25.94	4.77	10.52	120.63	-	4.61	3.10	-	32.62
WB	6.66	1.50	-	77.43	8.86	8.03	-	9.35	46.48	9.07	-	80.49
MF	99.18	82.53	-	16.79	54.40	26.66	-	51.01	62.09	71.7	15.47	-
BL	40.13	18.74	-	53.31	17.61	7.73	-	56.12	22.95	11.92	-	48.05
BA	10.56	58.53	454.45	-	20.08	68.17	239.53	-	9.54	22.2	132.2	-

CL- Cultivation Land, DF- Dense forest, WB- Water bodies, MF- Mixed forest, BL- Barren Land, BA- Built up area, I – Increase, D – Decrease.

Table 6: Rate of land cover change per year (1997-2017)

	1997	2017		1997	2017		1997	2017		
ZONES	N AREA (km²)	N AREA (km²)	Rate of Change (km²/Year)	C AREA (km²)	C AREA (km²)	Rate of Change (km²/Year)	S AREA (km²)	S AREA (km²)	Rate of Change (km²/Year)	Overall Changes in entire Area
CULTIVATION LAND	100.59	97.51	-0.15	55.50	39.16	-0.82	84.09	100.92	0.84	-1.0783
DENSE FOREST	16.51	12.22	-0.21	4.77	10.52	0.29	4.61	3.10	-0.08	-0.1236
WATER BODY	6.66	1.50	-0.26	8.86	8.03	-0.04	46.48	9.07	-1.87	-70.0117
MIXED FOREST	99.18	82.53	-0.83	54.40	26.66	-1.39	62.09	71.70	0.48	-16.1311
BUILTUP AREA	10.56	58.53	2.40	20.08	68.17	2.40	9.54	22.15	0.63	270.5068
BARREN LAND	40.13	18.74	-1.07	17.61	7.73	-0.49	22.95	11.92	-0.55	-52.4289

6. Conclusion

The study has revealed that remotely sensed data (imageries) are important and extremely useful in mapping and monitoring the dynamics of land use / land cover changes. GIS analysis has shown the capabilities to analyse spatial data and to provide information that aid in the decision making. Northern and central zone of the study area has experienced drastic increase in built up area thereby decreasing the mixed and dense forest. Southern zone has very slow rate of change in land use / land cover. Necessary action has to be taken in order to restrict the rapid growth of built up area leading to the distraction of fertile Agriculture / Forest land.

7. Recommendation

Settlement expansion, subsistence farming and illegal logging are the major factors behind the land use/land cover changes observed in the area. These findings highlight the need for comprehensive assessment of human activities and adaptation of sustainable forest management practices such as close supervision of forest reserves and making more arable lands available through restoration of already degraded and impoverished lands.

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