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EVOLUTION OF CONSERVATION POLICIES ON FOREST COVER CHANGES IN KOYNA WILDLIFE SANCTUARY, MAHARASHTRA, INDIA

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ABSTRACT

Assessing and monitoring changes of forest cover on the Earth's surface is essential to understanding the relationships and interactions between natural and man-made phenomena. Deforestation has created many environmental, economic and social problems on the earth surface. For any country, forest policies are important guidelines for maintaining and restoring forest resources and their interactions with other land utilization. India formulated its first National Forest Policy during the British period and it was revised several times after independence. After the implementation of the Forest Policy, the effects of changes in forest cover should be evaluated. This paper examines the impact of forest conservation policy over the forest cover of Koyna Wildlife Sanctuary in Maharashtra using the geospatial technology. Landsat satellite data of 1977, 1995, 2014 and IRS of 2021 were used for land use/land cover changes mapping. The overall accuracy of the study area is between 85 to 91.25 %. The results shows that forest cover changes were occurred at different rates during study period. The results showed that the policies had a statistically significant positive effect on forest cover change after thirty-six years of implementation and total forest cover gain 2.12 sq. km over the evaluation period. The methods and results of this study will be useful to continue the implementation of these conservation strategies in future.

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INTRODUCTION

Forest ecosystems play a very important role in the global ecological balance and natural environment. Forests are an important natural resource that should be protected as a priority for sustainable environmental management (Panigrahy et al. 2010; Rizwan 2011). Forests provide valuable timber based raw materials for domestic and commercial use in several industries. About 4 million peoples in the world are directly depend on forest products and the rest are indirectly depend on forests. Recently, due to natural and human activities, the forest is threatened and changing continuously (Chandra et al. 2007).

According to the forest study of United Nations, the total forest area of the world was about 7 billion hectares in 1900 and by 2021 it had reduced to 4 billion hectares. Every year we lose 10 million hectors of the world's forests (Global Forest Goals Report 2021). According to Forest Report 2021, the total forest cover of India is 7,13,789 sq km which is 21.71 percent of the total geographical area (FSI report 2021). More than 27 % (275 million) population of India are the lives in proximity of forest and get direct and indirect benefits from forest (CSE Forest in India 2021). Forests play a crucial role in the physical, economic and spiritual life of the population (Byron and Arnold 1999). In terms of biodiversity, India is the rich country in the world and one of the 12 recognized mega-biodiversity areas of world (MoEF 2007). Human and livestock population growth and widespread rural poverty put enormous pressure on forests worldwide, leading to deforestation and degradation. Due to this, a large amount of forest is being destroyed. Forest degradation has many environmental, social and economic consequences, including loss of biodiversity, soil erosion, global warming and loss of livelihoods of forest dwellers. As a result, around the world, countries have adopted various strategies and policies as measures to reduce deforestation, forest management and conservation of forests in response to human disturbance.

In India, the first policy for conservation and forest protection was declared by the British in 1894. The main objective of this policy was to manage state forests for public benefit. After this, Indian Forest Act 1927 was formulated for transit of forest-produce and duties imposed on timber and other forest-produce were consolidated. After independence, forestry comes under the Concurrent List of Schedule VII of the Constitution and both the Central Government and the State Governments create an effective legal and policy framework for the sustainable management of forests. The National Forest Policy 1952, Wildlife Protection Act 1972, Forest Conservation Act 1980, Forest Policy 1988, Joint Forest Management Resolution of 1990, Biological Biodiversity Act, 2002, National Environment Policy, 2006 was introduced the state to exercise exclusive control over forests and their management, conservation and protection (Murthy and Kumar 2019). As a developing nation, India faces a major challenge to increase its forest cover to global standards and meet national policy goals. All forest policies developed so far in India aim to conserve biodiversity, reduce pressure on forests and generate revenue through timber production and sale as well as provide biomass for the large population that depends on forests for their fuel and fodder needs. Policies have evolved over decades and the focus has shifted from production of forestry to protection of forestry and participatory forestry is currently evident. Thus, many policies contribute positively to the adaptation or resilience of forest ecosystems.

Remote sensing data at different time intervals help in analyzing the rate of change as well as the factors or drivers responsible for the change (Louisa and Antonio 2001). The main advantages of using remote sensing data and methods are potential to play a decisive role in assessing forest degradation and deforestation processes at a much lower cost than any other methods (Mascaro et al. 2010). Changes are usually detected by comparing two or more temporal satellite images, or sometimes by comparing older maps and more recent remote sensing images. The first forest cover assessment in India was done in 1982 by the National Remote Sensing Agency (NRSA) using Landsat MSS data. Biennial Monitoring of forest area was started from 1987 and the latest SFR was published in 2021 (FSI 2021). Many researchers from different countries have recognized the benefits of geospatial technology for mapping, monitoring and detecting forest cover changes. For example, Prakasam (2010) analyzed the forest area of Kodaikanal taluk of Tamil Nadu, Kayet and Pathak (2015) analyzed Saranda forest of Jharkhand, Kaswanto and Arifin (2010) studied the Impact of land use changes on spatial pattern of landscape during two decades (1989-2009) in West Java region. Mengistu and Salami (2007) analysed land use/land cover mapping and change detection in a part of south western Nigeria using remote sensing and GIS. Karande S. V. (2022) analysed the forest degradation of Western ghat in Satara district of Maharashtra.

In this paper, changes in forest cover are evaluated using time-series satellite data of Koyna Wildlife Sanctuary.

STUDY AREA

The area selected for this study is in the south-eastern part of Satara district. It lies between 17°22'18" to 17°46'26" North latitude and 73°33'56" to 73°50'54" East longitude. The total geographical area of the sanctuary is 423.55 square kilometers (Gov. of Maharashtra gazette, dated 10 October 1985), with an altitude in between 634 to 1170 meters above sea level. Average temperatures range is 13°C to 28°C and the region receives an average of 5500 mm annual rainfall. Koyna wildlife sanctuary has been declared as a vide Government of Maharashtra Notification dated 16.09. 1985 under the provisions of Section 18 and section 19 of the Wildlife (Protection) Act, 1972 (53 of 1972) (Gov. of Maharashtra gazette, dated 10 October 1985) The famous Koyna Dam (Shivasagar Dam) is an integral part of the sanctuary and it is named as 'Koyna Wildlife Sanctuary' from the Koyna River. The western boundary of sanctuary was demarcated by Western ghat, northern by Kandati river, eastern by Shembdi, Waghali, Munavale, Kargaon, Nivkane, Ghanbi, Watele, Karwat village and Koyna river. The southern boundaries of the sanctuary are drawn by Rasati, Helwak, Shivdeoshwar, Bopoli villages. The sanctuary is a part of global biodiversity hotspot and eco-sensitive zone of Western Ghats (Sahyadri Mountains) (Mittermeier et al. 2005). It has diverse habitats for various wildlife species and rich in flora and fauna. Western part of the tehsil occupied by the Koyna wildlife sanctuary and it is the one of the parts of the biodiversity hotspot of the Western Ghats (Sahyadri). This area is home to endangered and rare species of mammals, birds and amphibians. 40 mammals, 240 birds, 65 reptiles, 58 fish and 26 amphibian species are found in this area.

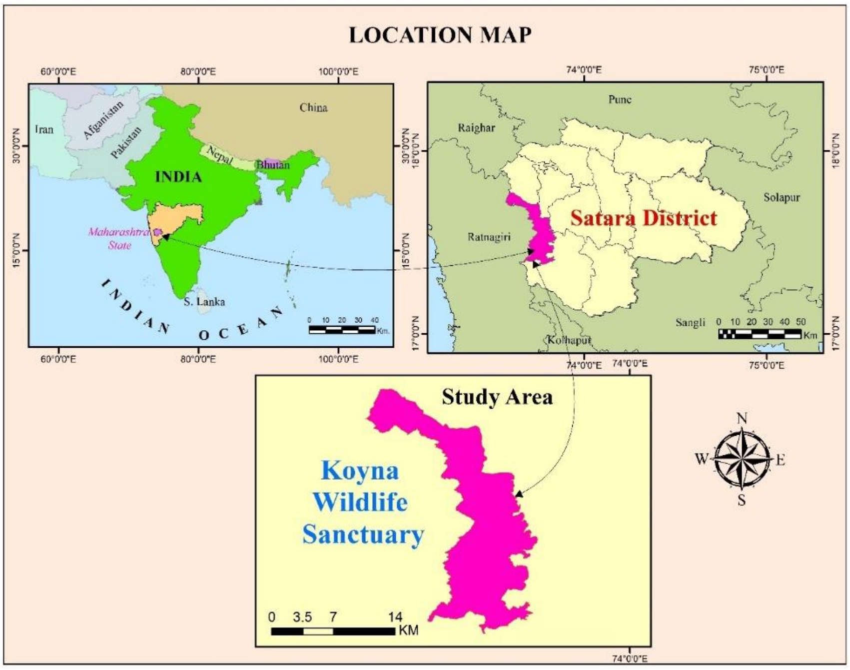

Fig. 1 : Location map

OBJECTIVES

The main objective of this study was to assess the changes of forest cover since the implementation of forest conservation policies over the protected area.

MATERIALS AND METHODS

Remotely sensed cloud-free satellite data used in this study and details of the satellite data shown in Table 1 and Fig. 2. All Landsat satellite images were downloaded from USGS Earth Explorer web portal and ResourceSat-2A, LISS-IV satellite data were purchased from NRSA, Hyderabad. The year 1977 was choose as the base year because the Koyna sanctuary declared as on 1985 and cloud free satellite data before of this year was available from 1977. All five temporal data sets are selected from the same season to avoid differences in signatures of land features. (Boggs 2010).

Table 1: Satellite Data

Sr. No.	Satellite	Sensor	Date of Acquisition	Path	Row/ Scene	Spatial Resolution (m)
1	LANDSAT 2	MSS	19/02/1977	158	47	60
2	LANDSAT 2	MSS	19/02/1977	158	48	60
3	LANDSAT 5	TM	11/01/1995	147	48	30
4	LANDSAT 8	OLI & TIRS	31/01/2014	147	48	30
5	ResourceSat-2A	LISS-IV	31/01/2021	95	60	5.8
6	ResourceSat-2A	LISS-IV	24/02/2021	95	60	5.8

Source: https://bhoonidhi.nrsc.gov.in and https://earthexplorer.usgs.gov

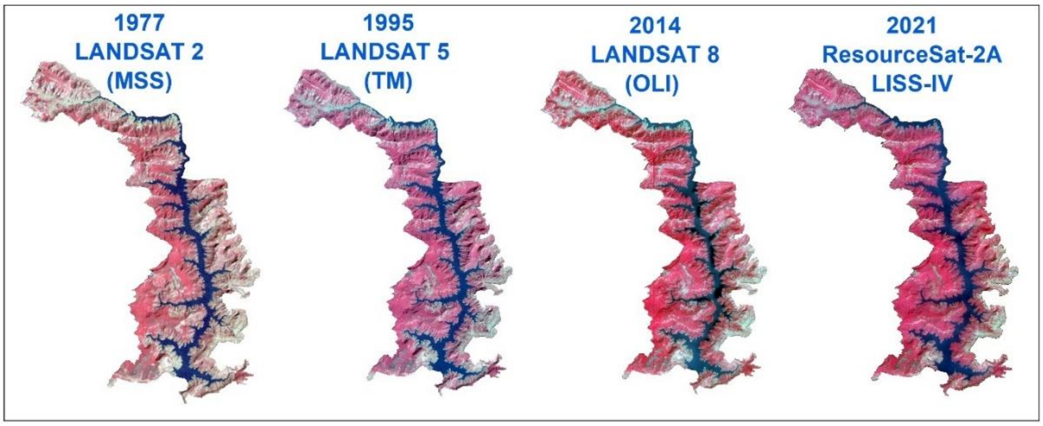

Fig.2 : Satellite data

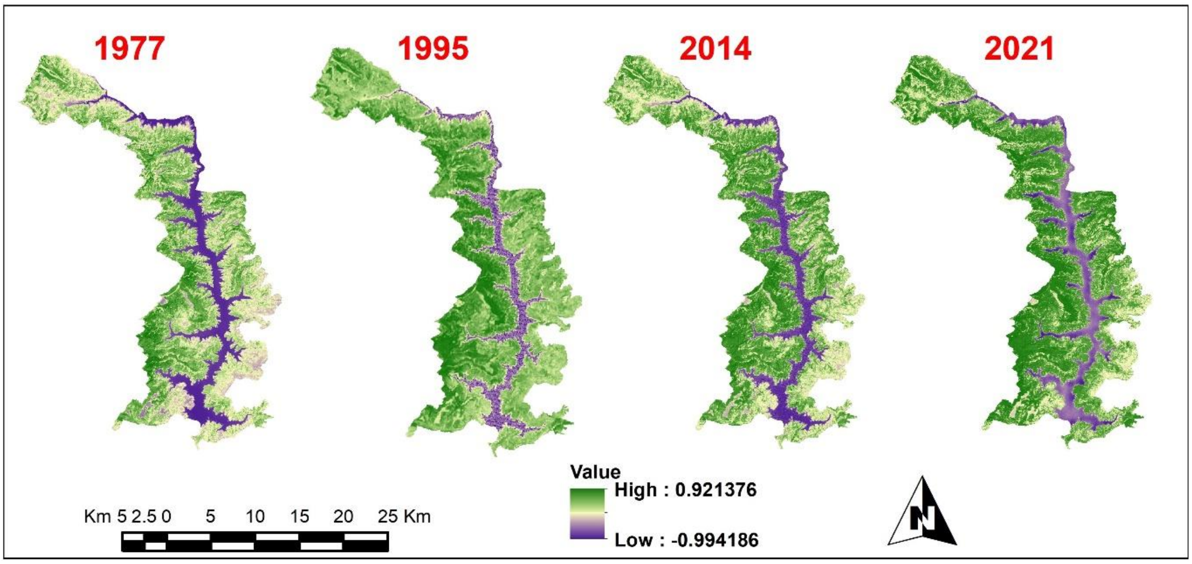

Fig. 3 : Normalized Difference Vegetative Index

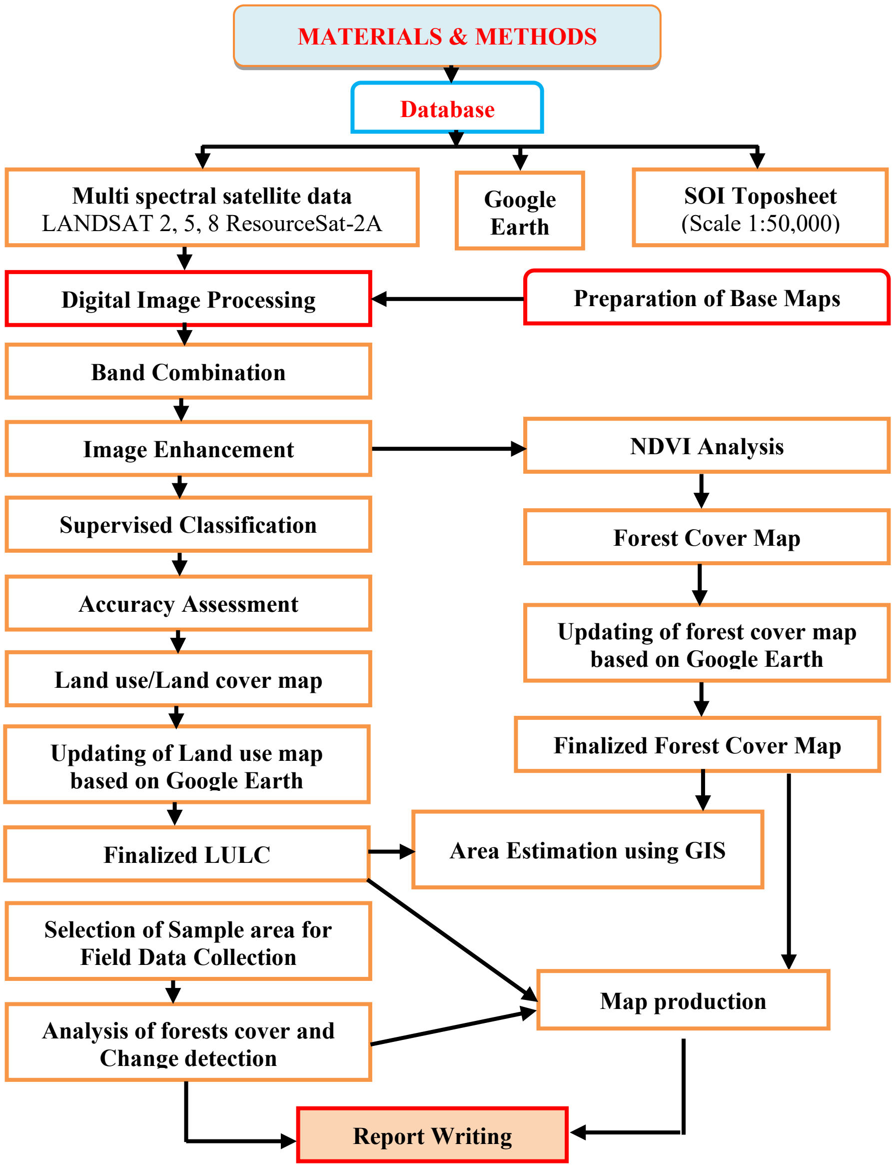

Fig. 4 : Methodology

ERDAS Imagine 2015, Arc GIS 10.8 and QGIS 3.28 software are used to process satellite data and create various maps. The shape file of Koyna wildlife sanctuary was created in ARC GIS 10.8 and QGIS 3.28 based on KML file of Sanctuary prepared by MRSAC, Nagpur, Map of Forest department and Survey of India (SOI) Toposheet No. 47 G/9, 47 G/10, 47 G/11, 47 G/14, 47 G/15. High spatial resolution Google Earth imagery was used to delineate wildlife sanctuary boundaries, visually interpretation of satellite image and accuracy assessment. Climate data was obtained from National Climatic Data Centre, IMD, Pune (Karande 2017). Population data for the study area was gathered from the census of India (Census 2011). The downloaded satellite images were processed in ERDAS Imagine 2015. Radiometric correction was done for data correction in the pre-processing stage and layer stacking for combine multiple lands to create a single image for all observation years (Panchal et al. 2021). All four satellite images were clipped by sanctuary boundary to delineate the study area. Signature was assigned to each class of false color composite (FCC) images with the help of visual interpretation of high-quality Google Earth image.

The NDVI (Normalized Difference Vegetation Index) is highly correlated with the green biome and leaf area (Kumar et al. 2010). NDVI is computed by using the red (visible) and infrared (IR) bands of electromagnetic energy in ERDAS IMAGINE 2014. The NDVI classification of the study area during the study period (1977, 1995, 2014 and 2021) has been done using the Gaussian maximum likelihood algorithm. Forest cover maps of all four assessment years (1977, 1995, 2014 and 2021) are addicted to NDVI analysis of LULC map of the study area (Fig. 3). The raster map is converted into a vector format for calculating the forest area under different class.

Supervised classification of satellite image based on maximum likelihood classification technique was used to generate eight different land use/land cover classes (i.e., dense forest, medium forest, agriculture, scrub, fallow, settlement, road and water). Supervised classified images are converted into vector format for change detection analysis in ERDAS Imagine. The LULC change detection are prepared in ARC GIS 10.8 using the geoprocessing tool and field calculator. All the steps used in this research are shown in figure 4. Different colour codes are assigned to the classified scene for easy identification in ArcGIS 10.8

Accuracy assessment is required to validate remotely sensed data against ground truth data (Owojori and Xie 2005). Ten randomly distributed points of each class and total 80 were selected from each of the four observation years for accuracy assessment.

Reference data and classification results were compared using a statistical error matrix. Producer and user accuracy of each class, overall accuracy and kappa coefficient of each satellite image were calculated to assess the accuracy of satellite data (Lu et al. 2004).

The table 2 shows overall accuracy and Kappa coefficient values for images in different years. The result shows that the overall accuracy of all four LULC data was 85 %, 87.50 %, 90 % and 91.25 % for the years 1977, 1995, 2014 and 2021 respectively (Table 2). Kappa coefficient was found to be highest for 2021 (0.79), followed by 2014 (0.78), 1995 (0.75) and 1977 (0.73). All classified images have overall accuracy is 85 to 91.25 % and kappa coefficient is 0.73 to 0.79. The present study shows acceptable agreement with LULC analysis (Lins and Kleckner 1996).

Change detection analysis using pixel-by-pixel comparisons was used to identify and quantify transitions in classified time-series images. Classified images from 1977 were first compared to 1995 and then 2021. 1995 was compared to 2014 and 2014 was compared to 2021. Showing change statistics and using transitions between images is achieved.

(i) The overall classification accuracy $= \frac{\text{No.of correct points}}{\text{total number of points}} X\ 100$

(ii) Kappa coefficient $= \frac{(\text{Reference point x Total points}) - \text{sum of all correct points}}{(\text{total points})^2 - \text{sum of all correct points}}$

Table 2: Accuracy assessment

Year	Overall accuracy	Kappa coefficient
1977	85.00	0.73
1995	87.50	0.75
2014	90.00	0.78
2021	91.25	0.79

DISCUSSION

Table 3: Land use and Land cover (1977 to 2021)

Sr. No.	LULC Classes	Area in Sq. Km							
		1977	**%**	**1995**	**%**	**2014**	**%**	**2021**	**%**
1	Dense forest	109.41	25.83	110.51	26.09	112.20	26.49	116.02	27.39
2	Medium forest	189.0	44.62	188.89	44.60	187.41	44.25	184.52	43.57
3	Scrubland	24.06	5.68	22.13	5.23	21.00	4.96	19.84	4.69
4	Agriculture	6.78	1.60	7.41	1.75	7.60	1.79	7.67	1.81
5	Fallow land	16.29	3.85	16.49	3.89	17.07	4.03	16.93	4.0
6	Road	0.30	0.07	0.37	0.09	0.44	0.10	0.55	0.13
7	Settlement	0.07	0.02	0.11	0.03	0.17	0.04	0.16	0.04
8	Waterbody	77.64	18.33	77.65	18.33	77.65	18.33	77.85	18.38
Total Area		**423.55**	**100**	**423.55**	**100**	**423.55**	**100**	**423.55**	**100**

Table 4: LULC Change matrix (Area (sq. km)

LULC Classes	1977	%	2021	%	1975 to 2021
Forest Area (Sr. 1,2)	298.42	70.46	300.54	70.96	2.12
Scrubland	24.06	5.68	19.84	4.69	-4.21
Non forest area (Sr. No. 4,5,6,7)	23.44	5.53	25.32	5.98	1.88
Waterbody	77.64	18.33	77.85	18.38	0.21
Total Area	**423.55**	**100**	**423.55**	**100**	

Classified land use/land cover (LULC) change maps of the study area for 1977, 1995, 2014 and 2021 are given in figures 5 and tables 3. During the assessment year of 1977, 1995, 2014 and 2021, the area under dense forest was 109.41 sq. km, 110.51 sq. km, 112.20 sq. km and 116.02 sq. km respectively. The area under medium forest was 189 sq. km, 188.89 sq. km, 187.41 sq. km and 184.52 sq. km respectively. The area under scrub land was 24.06 sq. km, 22.13 sq. km, 21 sq. km and 19.84 sq. km respectively. The area under fallow land was 16.29 sq. km, 16.49 sq. km, 17.07 sq. km and 16.93 sq. km respectively. The area under agriculture was 6.78 sq. km, 7.41 sq. km, 7.6 sq. km and 7.67 sq. km respectively. The area under waterbody was 77.64 sq. km, 77.65 sq. km, 77.65 sq. km and 77.85 sq. km respectively. The area under road was 0.30 sq. km, 0.37 sq. km, 0.44

sq. km and 0.55 sq. km respectively. The area under settlement was 0.07 sq. km, 0.11 sq. km, 0.17 sq. km and 0.16 sq. km respectively. The dense (evergreen) and medium (semi-evergreen) forests occupied more than 70 % of the total geographical area of the study region. However waterbody occupied more than 18 % area, scrubland occupied 5 % area and non-agriculture occupied 6 % area of the study region.

LULC of 1977 was used as a baseline and compare with the year of 1995, 2014 and 2021 for forest cover change analysis. LULC distribution showing the forest cover has been changed in Koyna wildlife sanctuary during the study period. The average proportion of land covered by dense forest, which in 1977 was 109.41 sq. km (25.83%), it increased to 116.02 sq. km (26.49%) in 2021, it shows a 6.61 sq. km forest cover is increased. The proportion of land covered by scrubland has decreased from the original 24.06 sq. km (5.68%) in 1977 to 19.84 sq. km (4.69%) in 2021. It must be noted that 10.88 sq. km medium forest cover converted into dense forest canopy and 9.84 sq. km scrub land changed into the medium forest cover (Fig 5). The results of this study indicate that the implementation of forest conservation policies has been fully effective for the controlling of forest degradation and enhanced forest recovery (Fig 5).

The observed pattern of forest cover change and the rate of change reported during the current study period is different to studies of ISFR 2021 (FSI 2021) for example, we observed an annual average gain of forest cover is 0.37 % while ISFR 2021 reported 142.77 % for the total forest area from 1995 to 2021. During the study period, forest area was significant increased (38.22 %) on the western side of the Koyna (Figure 4) but significant decline (10.37 %) of the east side during study period. Forests of the eastern side of the Koyna dam may face higher human pressures than those in the eastern side of dam. Moreover, results showed that demographic factors (Occupation, Construction etc.) are important determinants of forest cover changes, having significantly negative effects. The area covered non -agriculture (settlement, road, agriculture) lands also increased gradually during the observation period. It has about 23.44 sq. km (5.53%) in 1977 and increased up to 25.32 sq. km (5.98%) in 2021. In support of this, historically, various studies reported that the most changes in forest cover result from human activities (Houghton 1991; Meyer and Turner 1992; Jorgenson and Burns 2007; Carr 2008; Jha and Bawa 2006). A higher percentage of agricultural population may also cause greater dependency on fuel wood for cooking and heating (Krutilla et al. 1995). In the study area 3.01 sq. km forest area was converted in non-agriculture land use. After 1985, Koyna wildlife sanctuary declared by Government of Maharashtra and illegal activities are strictly banned. After 2002 fifteen villages from core zone of the sanctuary were rehabilitated to the other places, it shows that the settlement area in the sanctuary was reduced from 0.17 sq. km to 0.16 sq. from 2014 to 2021. Road is an indicator of development, it also had a significantly negative impact on forest covers (Nagendra et al. 2003; Soares et al. 2004; Fearnside 2008). The area covered by road has increased from the original 0.30 sq. km in 1977 to 0.55 sq. km in 2021. About 0.22 sq. km forest land was losses for widening of old roads and construction of new roads.

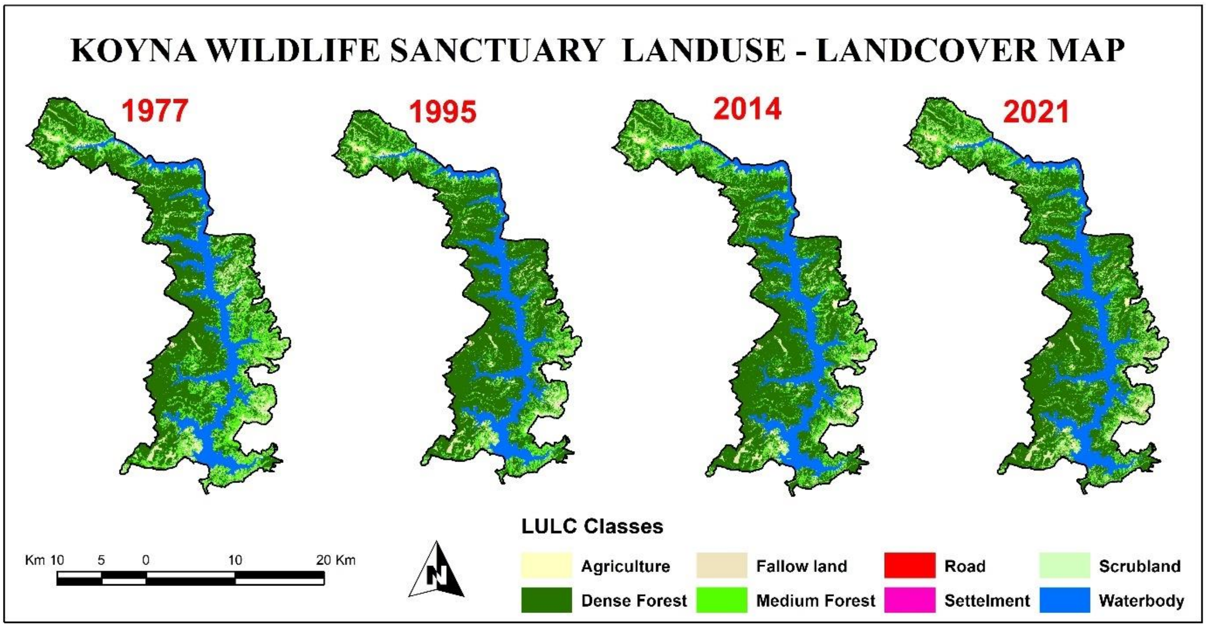

Fig. 5 : LULC Map

CONCLUSION

After 36 years of declaration of Wildlife sanctuary, conservation policies seem to be achieving their goals of restoring forest cover and conserving natural forests (He et al. 2008). Continuous conservation efforts through the forest department therefore important for preventing deforestation and forest degradation in KWLS and during the study periods the area under forest cover was increased in 2.12 sq. km. (Table 4). The forest cover rapidly decline of the eastern part of the sanctuary shows that demographic factors have significant negative effects on forest cover change. In addition, as a proxy of development, road network also had significantly negative effects on forest cover change. Forest transition in India is not a unique case in Asia. China and Vietnam have also undergone forest transition during the last decade (Foster and Rosenzweig 2003). In addition, many other developing countries around the world have slowed down deforestation and may step into a forest transition within the near future (Henson 2005; Wannitikul 2005). Finally, although conservation policies have shown positive effects on forest cover not only in the study area, but also in India as a whole (Liu et al. 2008). The use of modern technologies such as satellite remote sensing and GIS are very useful for the accurate measurements of the forest cover changes.

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