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Forest Cover Change Detection using Geospatial Techniques in Periyar Tiger Reserve, Kerala, India

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ABSTRACT

The present study evaluates the changes in Forest cover pattern of Periyar Tiger Reserve, Kerala, India. satellite imageries of different time periods, i.e. Land sat 7 and sentinel-2 were obtained from the United States Geological Survey (USGS) Earth Resource Observation and Science Data Centre. Land sat 7 was used for the year 2001 and the sentinel-2b are used for the year 2021. The images of study area were classified into six different classes. The results obtained from the forest cover change, shows that Evergreen (15.19 sq.km), moist deciduous (35.107 sq.km), grassland (35.209 sq.km), thickets (13.53 sq.km) had decreased and the semi evergreen (110.5196 sq.km) had increased. The normalized difference vegetation index (NDVI) analysis has been integrated for improving the classification accuracy.

Key words: *Change detection, Forest cover, Periyar Tiger Reserve, NDVI, Supervised classification*

Introduction

Increasing anthropogenic pressure on the ecosystem has affected and modified the natural land covers resulting in habitat fragmentation, alteration, and degradation. Various studies have shown that habitat modifications severely affect both the floral and faunal biodiversity of the area (Rottenberg, 1999; Roy *et al.*, 2002; Hunter, 2002; Rodewald, 2003; Uezu*et al.*, 2005; Primack, 2006; Sridhar and Sankar, 2008). These modifications have negative impacts on structure and function of forest areas, finally leading to ecosystem instability (Roy *et al.*, 2002; Hunter, 2002; Primack, 2006). Remote Sensing and Geographical Information System (GIS) has become a resourceful tool for assessing and monitoring environmental impacts which are result of natural as well as manmade activities (Joshi *et al.*, 2009; Puri and Atri, 2010).

Timely change detection and assessment is very important as it helps in understanding the relationships and interactions between human and natural phenomena, and thus, helps in better management and use of natural resources (Lu *et al.*, 2004). Application of remotely sensed data has made it possible to study the changes in land use land cover in less time, at low cost and with better accuracy (Kachhwaha, 1985) in association with Geographical Information System (GIS) that provide suitable platform for data analysis, update and retrieval (Star *et al.*, 1997; McCracker *et al.*, 1998; Chilar, 2000). Such information on changing pattern of forests provides inputs for land management purposes also.

To draft and implement conservation plans, understandings of habitat quality and updated resource data is a prerequisite. Landscape ecology metrics added newer dimensions to habitat characteristics and thus land management. It helps in

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understanding the landscape dynamics of the area which is essential for any kind of conservation planning in natural and human dominated landscapes (Lee *et al*., 1999; Apan *et al*., 2002; Leitão and Ahern, 2002). Landscape metrics are the algorithms used for quantifying landscape configuration and compositions depicting the spatial patterning of land cover patches, land cover classes, or entire landscape mosaics of a geographic area (Ji *et al*., 2006; Munsi*et al.*, 2009). Integration of remote sensing and GIS with landscape ecology has huge potential for conservation and land use planning, monitoring, and management purposes (Lee *etal*., 1999; Lillesand *et al.*, 2007).

The present study aims at assessing the forest cover changes that has taken place between the time periods 2001 to 2021 in the Periyar Tiger Reserve (PTR) and quantify the ecological conditions of the tiger habitat using landscape metrics. Periyar Tiger Reserve is located in the districts of Idukki and Pathinamthitta in middle part of Kerala (Figure 1). It is the 10th Tiger Reserve, created in 1979 and covers an area of 925 sq km.The terrain is undulating, with most of the area covered by small hill ranges, steeply sloping on the sides.

Objective

- To identify of Forest cover classes and classify using classification methods and satellite images.
- To prepare the NDVI and forest cover maps for change detection analysis during 2001 and 2021 years.
- To assess the accuracy of forest cover classes to understand the error matrix in mapping.
- The result of study can be useful to forest management and wildlife conservation in the tiger reserve.

Study Area

The Periyar Tiger Reserve is situated in Idukki District of Kerala, India as shown in Figure 1. It is situated in the Cardamom Hills and Pandalam Hills of the Southern Western Ghats between latitudes 9° 17' 56.04" and 9° 37' 10.2" N and longitudes 76° 56' 12.12" and 77° 25' 5.52" E. The major portion of the Reserve forms the catchment of River Periyar and the rest is that of River Pamba. Administratively, PTR falls in Idukki, Kottayam and Pathanamthitta Districts of Kerala. The 'Periyar Wildlife Sanctuary

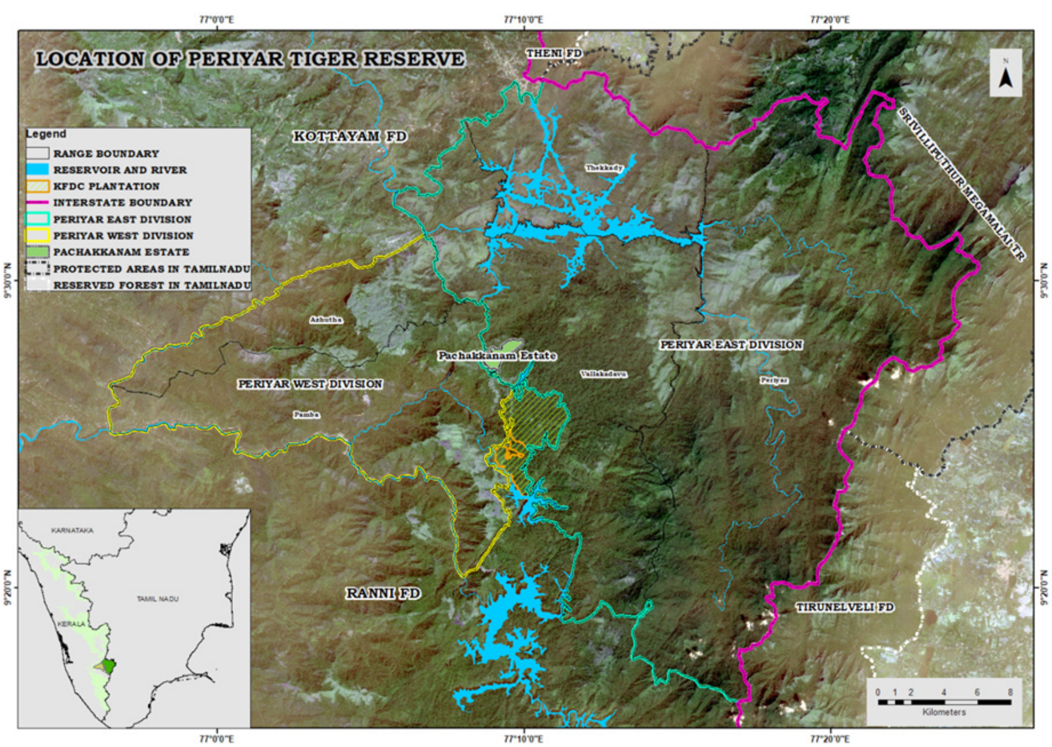

Fig. 1. Study Area

Proper' with an extent of 777 km^2 comprising of Periyar Lake Reserve Forest (600.88 km^2), areas of Rattendon Valley (12.95 km^2) and Mount Plateau (163.17 km^2) was constituted in 1950 as per notification number F1.2854/49/DD dated 11.08.1950. The Sanctuary was brought under Project Tiger in 1978 as the 10th Tiger Reserve in the country and named as Periyar Tiger Reserve. Presently, the total extent of PTR is 925 km^2 of which 881 km^2 is notified core or critical tiger habitat and the remaining 44 km^2 is notified buffer. PTR lies in the range of 76-2017 m above MSL. PTR with adjoining forests forms the largest remaining benchmark climax forest vegetation in the entire peninsular India. This is a representative of Bio-geographic Zone 5-B of the Western Ghats and plays a key role in maintaining regional connectivity in the otherwise fragmented forest tracts. It is contiguous with the forest areas of Theni Forest Division, Megamalai Wildlife Sanctuary, Srivilliputhur Grizzled Squirrel Sanctuary and Tirunelveli Forest Division (in Tamil Nadu) and Kottayam, Ranni, Konni, Achenkovil, Punalur and Thenmala Forest Divisions in Kerala. At landscape level, the Periyar Conservation Unit extends right up to the Arienkavu Pass and has tenuous linkages with the Agasthyamalai Conservation Unit comprising of Kalakkad-Mundanthurai Tiger Reserve in Tamil Nadu and Shendurney, Neyyar, Peppara Wildlife Sanctuaries and Thiruvananthapuram Forest Division in Kerala.

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, Multi-temporal Landsat-7 and Sentinel-2B, imageries of 2001 (Fig. 2.) and a high resolution cloud free Sentinel 2b MSI (Multispectral Imager) Level-1C image of 2021(Fig. 3.) was used for mapping forest cover classes of PTR from 2001 to 2021 (Table 1). The main application of both sensors (ETM+ and MSI) is in the areas of forest, agriculture, coastal, inland water resources and LULC mapping and monitoring. All the images were downloaded from USGS earth explorer website

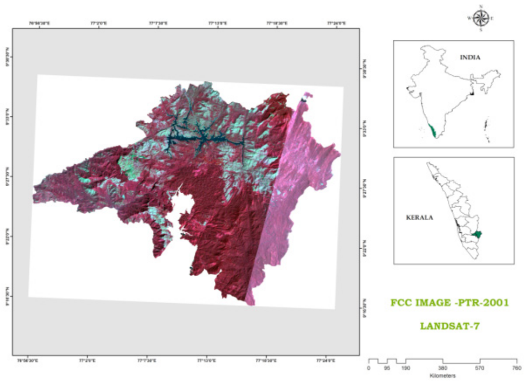

Fig. 2. Landsat image of PTR

The imageries have further rectified and assigned with UTM-Zone 43N, WGS-84 datum. ENVI 5.1 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

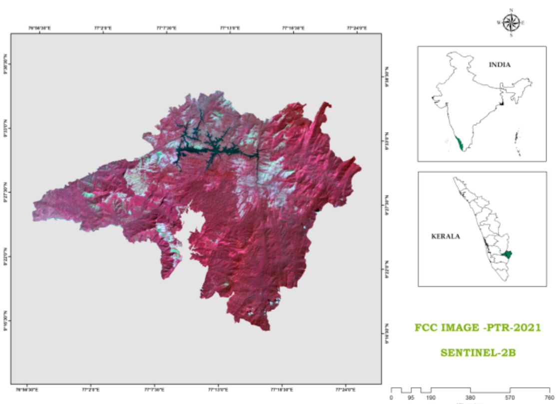

Fig. 3. Sentinel-2 image of PTR

Table 1. Description of the satellite images used in the study

Satellite	Sensor	Acquisition Date	Bands used	Spatial Resolution (m)	Processing
Sentinel-2B	Multi Spectral Imager (MSI)	28-1-2021	B3-Green B4-Red B8-Near Infrared	10	Level 1 C
Landsat -7	ETM+- Enhanced Thematic Mapper	15-5-2001	B2-Green B3-Red B4-Near Infrared	30	Level-1

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.

In the present study, we adopted the maximum likelihood classifier algorithm for forest cover classification using ENVI 5.1 . A total of Six Forest cover classes, i.e. Evergreen; semi evergreen; grasslands; Moist deciduous forests; thickets and water- bodies (Table 2) 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 forest cover 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. The Kappa coefficient was computed as follows

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

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 forest cover 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

Table 2. Description of different Forest cover categories

Land cover /land use	Description
Evergreen forest	An evergreen forest is a forest made up of evergreen trees. They occur across a wide range of climatic zones, and include trees such as coniferous and holly in cold climates, eucalyptus, Live oak, acacias and banksia in more temperate zones, and rainforest trees in tropical zones.
Semi evergreen forest	Semi-evergreen forests are found in the Western Ghats, Andaman and Nicobar Islands, and the Eastern Himalayas. Such forests have a mixture of the wet evergreen trees and the moist deciduous trees. The forest is dense and is filled with a large variety of trees of both types.
Grasslands	Grassland, area in which the vegetation is dominated by a nearly continuous cover of grasses. Grasslands occur in environments conducive to the growth of this plant cover but not to that of taller plants, particularly trees and shrubs.
Moist Deciduous forest	Moist deciduous forests are the mixture of trees and grasses. These forests are found in areas of moderate rainfall of 100 to 200 cm per annum, mean annual temperature of about 27°C and the average annual relative humidity of 60 to 75 per cent.
Thickets	A thicket is a very dense stand of trees or tall shrubs, often dominated by only one or a few species, to the exclusion of all others. They may be formed by species that shed large numbers of highly viable seeds that are able to germinate in the shelter of the maternal plants.
Waterbody	The area covered with water either along the river bed or man-made dams and ponds

to +1.0. For generating the NDVI, we have used Band 3 & 4 for Landsat ETM+ data and Band 8 and Band 4 for sentinel-2B 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

The following section deals with the forests and various land covers in the study area over the period of 20 yrs. Forests and various land cover categories in 2001 and 2021: The spatial distribution of forests cover in 2001 is vividly shown in Fig. 4. The area under evergreen and Semievergreen in the study area were 532.4 and 129.327 km^2 respectively, i.e., these categories occupied about 57.56 and 13.98 % of the study area respectively. Grasslands, moist deciduous, thickets and water bodies constituted 103.59 sq.km, 109.11 sq.km, 25.46 sq.km and 24.80 km^2 respectively, which is about 11.1 %, 11.8 %, 2.75 % and 2.68 % respectively of the study area. The spatial distribution of forest cover in 2021 is shown in Fig. 5. The area under evergreen and Semievergreen in the study area were 517.2 and 239.8 km^2 respectively, i.e., these categories occupied about 55.9 and 25.92 % of the study area respectively. Grasslands, moist deciduous, Thickets and water bodies constituted 68.38 sq.km, 74.03 sq.km, 11.93 sq.km and 13.50 km^2 respectively, which is about 7.39 %, 8.00 %, 1.29 % and 1.45 % respectively of the study area (Table 3).

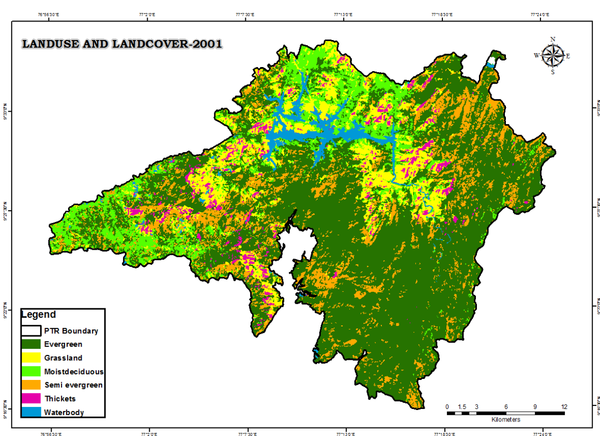

Fig. 4. Forest cover of PTR-2001

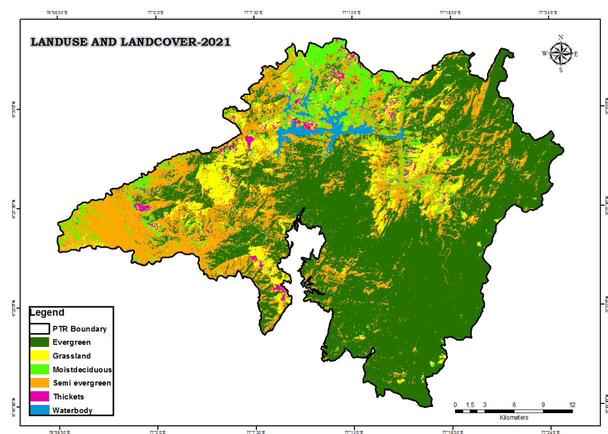

Fig. 5. Forest cover of PTR-2021

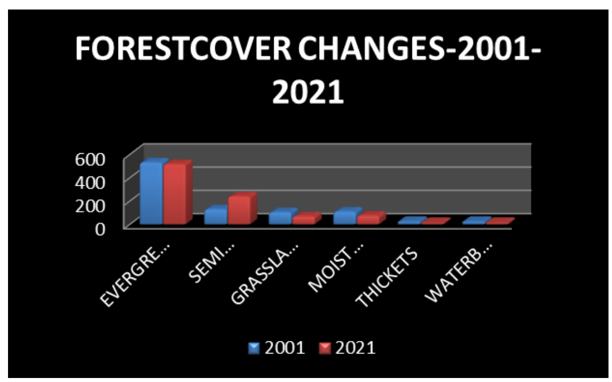

Fig. 6. Forest cover change detection chart 2001-2021

Table 3. Forest cover statistics

Lulc Class (Area)	2001 Sq.km	Percentage %	2021 Sq.km	Percentage %	Changes (2001-2021) Sq.km	Status	Percentage %
Evergreen Forest	3532.4843	757.566291	517.2865	55.922815	15.1983E	Decrease	1.643059
Semi Evergreen Forest	129.3273	13.98143	239.8467	25.92937	-110.5194	Increase	-11.948
Grasslands	103.5968	11.19974	68.3878	7.393276	35.209	Decrease	3.806378
Moist Deciduous Forest	109.1137	11.81778	74.0362	8.003914	35.107	Decrease	3.79535
Thickets	25.46934	2.753462	11.9385	1.290649	13.53084	Decrease	1.462794
Waterbody	24.80855	2.682025	13.5048	1.459978	11.30375	Decrease	1.222027
	100	925	100				

Accuracy Assessment

In the present study, the accuracy of the two raster imageries (2001 and 2021) was assessed through the error matrix. The results of the error matrix for forest cover classes of the study area for both the years are given in Tables 4 and 5. The error matrix summarizes the comparisons between the maps and the reference data collected for pixels. The sample points (60 ground truth-sites for 2001 and 70 truth-sites for 2021) 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 ETM+ and Sentinel-2B produced an overall accuracy of 79.75% and 95.57 % for the years 2001 and 2021, respectively. User's accuracy varied from 81 to 100% for both the years and while the producer's accuracy was from 51 to 100%, respectively. During verification, some of the sample points from grassland areas were confused with thickets. This was due to the habitations are mixed with grassland Furthermore, some forest areas of low density have been identified as grassland and thickets. Water bodies had very high overall accuracy during the ground truth for both the years. Kappa coefficient is for the year 2001 is showed as 94 % and for the year 2021 showed as 84%.

Normalized Difference Vegetation Index (NDVI)

Figure (7 & 8) is showing the reflectance values in the red and infrared channels of different land

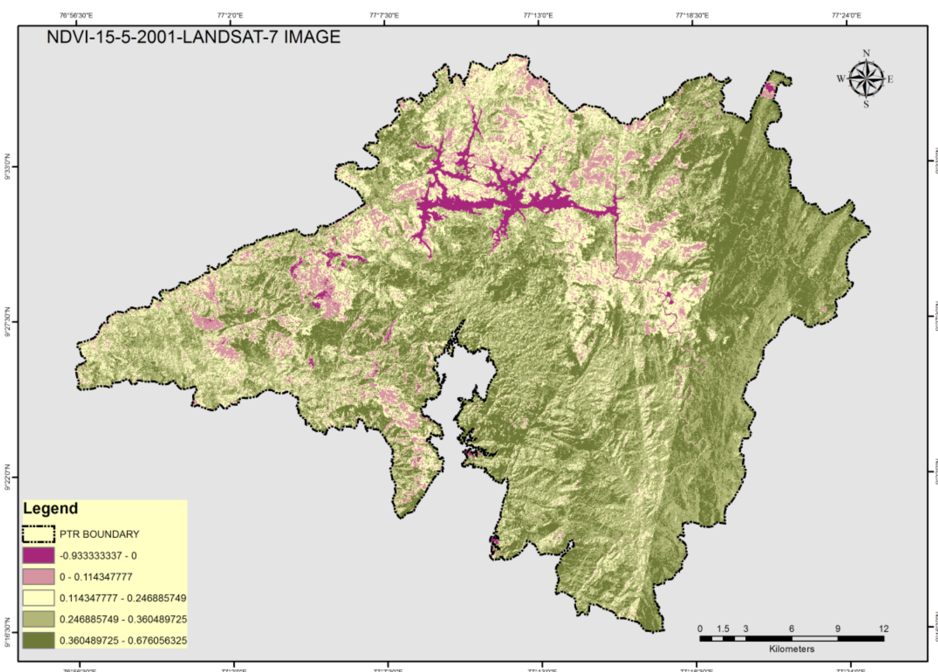

Fig. 7. NDVI of PTR -2001

Table 4. Analysis of error matrix of forest cover classification for the year 2001.

Classification	Waterbody	Moist deciduous	Grassland	Evergreen	Semi evergreen	Thickets	Total
Waterbody	414	0	0	0	0	11	0
Moist deciduous	12	380	105	86	0	434	425
Grassland	30	0	907	0	0	190	1127
Evergreen	0	31	48	2422	4	50	2555
Semi evergreen	0	0	70	199	821	0	1090
Thickets	10	28	75	13	45	732	903
Total	466	439	1205	2720	870	1417	7117
Overall accuracy	79.75%						
Kappa co effcient	0.7402						

cover types. In 2001, the NDVI values are ranging between-0.93 and 0.67 whereas for the year 2021 they are ranging between -0.22 and 0.86. Minimum, maximum and mean NDVI values are presented in Tables 6. The mean NDVI values for water body is ranging from -0.93 to -0.13. 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 0.23 to 0.76, for moderate vegetation values it is 0.42 to 0.95 and for dense vegetation, the NDVI values are ranging from 0.695 to 1.12 respectively (Figure 9).

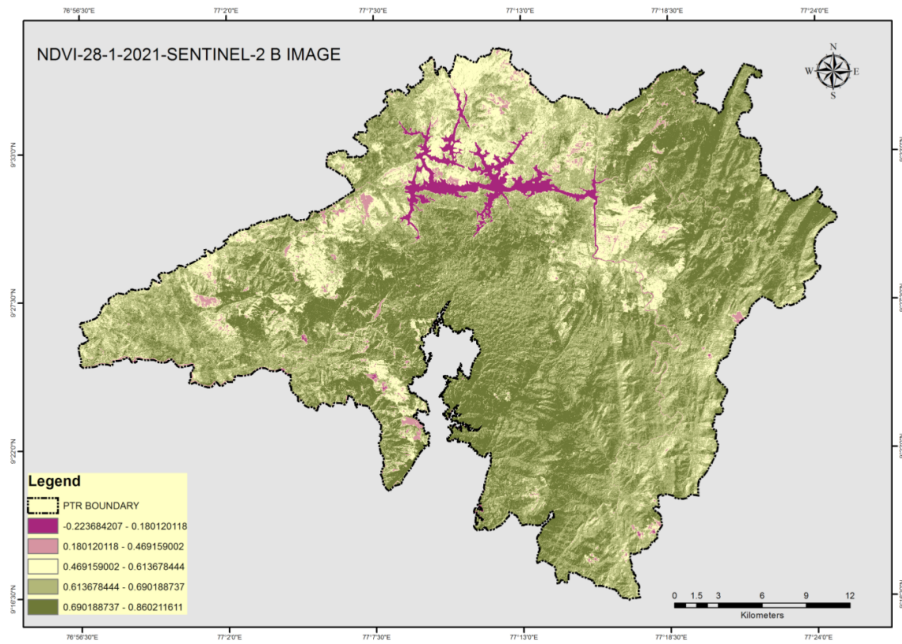

Fig. 8. NDVI of PTR -2021

Table 5. Analysis of error matrix of forest cover classification for the year 2021.

Classification	Waterbody	Moist deciduous	Grassland	Evergreen	Semi evergreen	Thickets	Total
Waterbody	2985	0	0	0	0	0	2985
Moist deciduous	0	2323	85	0	0	1236	3644
Grassland	0	0	8428	0	0	145	8573
Evergreen	0	0	0	20389	45	18	20452
Semi evergreen	0	0	0	0	5995	0	5995
Thickets	0	651	64	0	26	8858	9599
Total	2985	2974	8577	20389	6066	10257	51248
Overall accuracy	95.57%						
Kappa co effcient	0.9413						

Table 6. NDVI values for the years 2001 and 2021.

Forest Cover	Minimum		Maximum		Mean	
	2001	2021	2001	2021	2001	2021
DENSE FOREST	0.36	0.69	0.67	0.86	0.695	1.12
MODERATE FOREST	0.24	0.61	0.36	0.69	0.42	0.955
SPARSE FOREST	0.11	0.46	0.24	0.61	0.23	0.765
BARE SOIL	0	0.18	0.11	0.46	0.055	0.41
WATERBODY	-0.93	-0.22	0	0.18	-0.93	-0.13

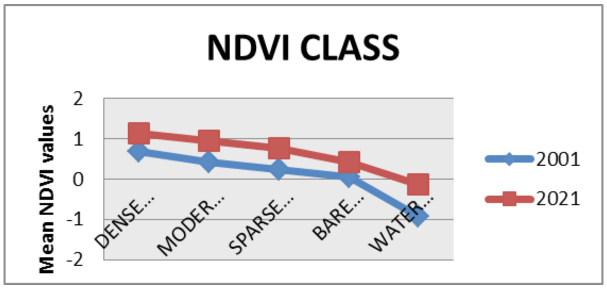

Fig. 9. Graph showing the mean values of NDVI.

Conclusion

The monitoring of forest cover changes is very much needed for forest and wildlife conservation activities. Nowadays these are studied by utilizing the classification procedures along with NDVI indexing. Forest cover 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 forest cover changes between 2001 and 2021 in a densehilly range of the Western Ghats of India. From the identified classes, the area under grassland, evergreen, moist deciduous and thickets showed a declining trend from 2001 to 2021 with a net change of 35.209 sq. Km, 15.19 sq.km, 35.107 sq.km and 13.53 sq. km, respectively. Whereas semievergreen was showed an increasing trend with a net positive change of 110.51sq km. The results revealed that the overall classification accuracy of 79.75 % for the year 2001 and 95.57 % for the year 2021. 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 climatic activities including heavy rainfall, flood, forest fire and landslide are significantly affected the changing pattern of forest cover. The results we obtained may help to analyze, study the future changes and find a solution to overcome the future problems.

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