Indian Journal of Ecology (2022) 49(2): 553-558
DOI: https://doi.org/10.55362/IJE/2022/3560

Manuscript Number: 3560
NAAS Rating: 5.79

Forest Fragmentation Analysis in Part of Kalsubai Harishchandragad Wildlife Sanctuary of Northern Western Ghats, Maharashtra

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***Abstract*:** The Western Ghats is rich in a variety of flora, fauna and specifically about its endemism. The uncontrolled human interference in the area created the problems that leads to environmental degradation. In the Western Ghats, changing land-use patterns caused forest fragmentation, habitat loss, human-wildlife conflict, loss of movement corridor for the wildlife and it became a primary concern for sustainability of biodiversity. To understand the forest fragmentation in the study area, the research work attempts to developed forest fragmentation analysis for the year of 1991 to 2020 using the Landscape Fragmentation Tool (LFT). The result revealed that from 1991 to 2020, non-forest types like water bodies, agriculture land, barren land, scrubland and settlement has been increased by 3.71% (834 ha), 3.36% (755 ha), 2.22% (499 ha), 1.92% (433 ha), and 0.08% (18 ha) respectively. Fragmentation analysis reveals increasing edges by 3.14% (707 ha) and a decrease in the core forest by 6.12% (1376 ha). The result shows that forests are becoming more fragmented and isolated during a period of last three decades. This would help to understand and conserve the forest environments.

***Keywords*:** Forest fragmentation, Landscape fragmentation Tool, Habitat loss, Western ghats

The forest fragmentation causes the loss of biodiversity, loss of animal habitat and aggravated problem of human-wildlife conflict (Badhe and Jaybhaye 2021). The movement of animals is inhibited or restricted when a forest becomes isolated. Several researchers examined landscape fragmentation using geospatial techniques (McGarigal et al 2002, Vogt et al, 2007, Jaybhaye et al 2016, Batar et al 2017). A forest fragmentation study was done and has been implemented in several nations including India, Malaysia, North Korea, the Democratic Republic of Congo, the United Kingdom and the USA (Kupfer 2006, Abdullah and Nakagoshi 2007, Reddy et al 2013, Shapiro et al 2016 and Aditya et al 2018). Some studies emphasize that forest fragmentation is creating problems for ecosystems by fragmenting the forested area and creating edges along the forest area that result in decreasing core forest area. The forest fragmentation problem has diverse dimensions and has been linked to habitat losses and additional environmental issues (Fischer and Lindenmayer 2007). In general, fragmentation is not only dealing with forest fragmentation but also understand the spatial relationship between areas and habitat. Forest fragmentation has two dimensions: forest degradation and forest changes in spatial arrangement (Long et al 2010). The most effective tool for forest cover monitoring by remote sensing data provides a cost-efficient explanation for regular observations to forest cover changes (Potapov et al 2013). In addition, geospatial data is the main current solution for understanding of forest cover and fragmentation (Achard and Hansen 2012, Metha and Singh 2021). Forest fragmentation analysis mapping by geospatial technology provide a clear picture of the deforestation (Stehman 2013).

Deforestation is associated with long term reduction of canopy cover in the area, particularly its transformation to other non-forested land use, significant loss of canopy without either a strong reduction in the forest area that has been effectively tracked on various dimensions for tropical forests using geospatial techniques (Asner et al 2006, DeFries et al 2007). The influence of human activities on forest fragmentation has been addressed in recent studies through several possible analyses (Numata et al 2011, Haddad et al 2015, Molinario et al 2015, Riitters et al 2016) using the available geospatial data on forest cover (Hansen et al 2013, Asner 2014, Rose et al 2015). Recent research has also shown that core forests are becoming more fragmented and isolated.

Study area: The study area of the research work is the part of Kalsubai Harishchandragad Wildlife Sanctuary located on the Sahyadri mountain ranges which is part of the Western Ghats of Maharashtra and is situated between Latitude 19°25'57" to 19°34'04" North and Longitude 73°37'51" to 73°46'25" East covering an area of 225 sq. km (15 km × 15 km dimension) (Fig. 1). The elevation of the area varies from 148 m to 1508 m above MSL while most of the area is situated near the crest line of Western Ghats. Geologically this area is part of the Deccan Trap. The Western Ghats is rich in a diversity of flora and fauna and is declared to be a biological hotspot as biodiversity is adversely impacted by human interference. The Kalsubai Harishchandragad Wildlife Sanctuary is replete with abundant kinds of flora and fauna. This region receives excessive rainfall of about 600 cm. The green landscape is stocked with beautiful vegetation and shrubs like Beheda, Avali, Gulchavi, Kharvel, Siras, Aashind, Parjambhual, Hirda, and Lokhandi under the bracket of trees. The different animals in the study area, like the leopard, jackal, hyena, barking deer, Palm civet, Indian giant squirrel, mongoose, jungle cat, and also many species of mammals and birds. The Pravara River originates on the eastern slope of Sahyadri in between Kulang and Ratangad forts and runs through the heart of the study area. Wilson Dam (Bhandardara Dam) was erected across the Pravara River in 1910.

MATERIAL AND METHODS

The landscape fragmentation tool was used to measure the extent of the fragmentation in part of the Kalsubai Harishchandragad Wildlife Sanctuary. For the research analysis, the geospatial technique is used to have visual output (MacLean and Congalton 2010). This tool was built by the Center for Land Use Education and Research (CLEAR) at the University of Connecticut (Parent et al 2007). The land use land cover (LULC) maps for the study area were generated from the data sources of Landsat satellite images for the years 1991 and 2020. The data set of Landsat 5 TM scenes from February 1991 and Landsat 8 OLI scenes from January 2020 were used to identify the land cover classes. These images were chosen for the study region based on Spatio-temporal concern of the area, images availability and the quality of the datasets. The research method is split into two parts: image classification and landscape fragmentation tool.

Image classification: For the years 1991 and 2020, the change in forest fragmentation and its relationship to human land use type were observed using satellite images of the study area with a spatial resolution of 30 m. During the cloud-free dry season, these satellite images were collected and the images have been corrected atmospherically, geometrically and topographically before the using to measure variations in fragmentation and forest cover. Based on a geospatial approach like satellite image classification using hybrid classification method and extensive fieldwork were conducted for rectification the LULC results (Rahman et al 2016). The classification of satellite image was accomplished as dense vegetation, open vegetation, agriculture, barren land, fallow land, shrubland, settlements, and water bodies.

Landscape fragmentation tool: The landscape fragmentation tool (LFT) was developed by the Center for Land Use Education and Research (CLEAR) at the University of Connecticut using a defined edge width of within 100 m. It categorises and quantifies four different classes of forest fragmentation: core forest, edge forest, patch forest and perforated forest. Furthermore, the core forest was split into small core forest' (<250 acres), medium core forest (250-500 acres) and large core forest' (>500 acres) (Fig. 2). According to peer opinion 100 m width was regarded as edge width for analysis. The landscape fragmentation tool was used to identify the forest fragmentation based on satellite images (Holdt et al 2004, Vogt et al 2007, Parent et al 2007, Hurd and Civco 2010). For the fragmentation analysis using

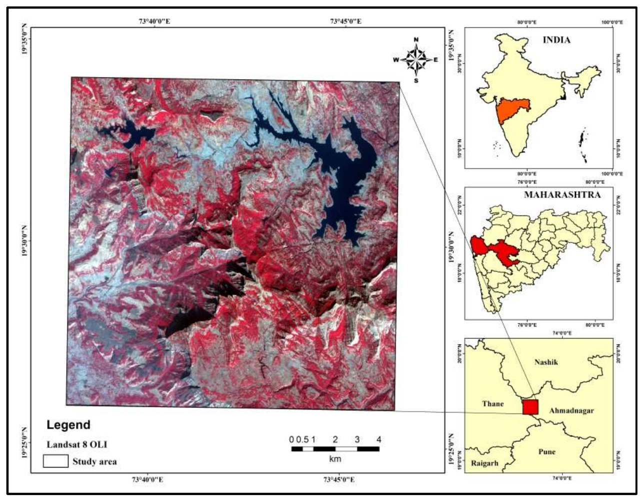

Fig. 1. Study area

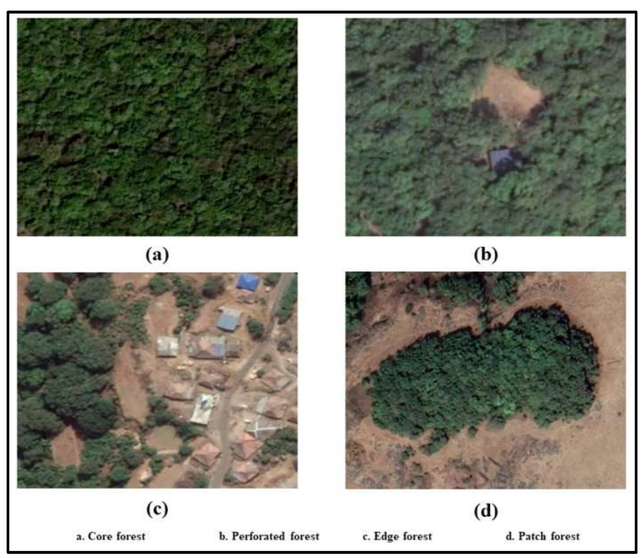

Fig. 2. Classes of forest fragmentation: a. Core Forest, b. Perforated Forest, c. Edge Forest, d. Patch Forest

LFT, was necessary to reclassify the LULC into non-forest and forest classes using spatial analyst tools in ArcGIS for identification (Table 1). Agriculture, barren land, fallow land, scrubland, settlement and water body were excluded from the analysis as the non-forested area only dense vegetation and open vegetation will remain as core forest.

RESULTS AND DISCUSSION

The land use land cover classification was done for the years 1991 and 2020. For the year 1991 Landsat 5 TM image was analysed by using a combination of bands 4, 3 and 2. For understanding contemporary LULC pattern, Landsat 8 OLI satellite image of the year 2020 used by a combination of bands 5, 4 and 3. Image classification for LULC was done based on supervised image classification, ISO cluster unsupervised classification using ArcGIS and ERDAS imagine 14 software. During the supervised image classification process of pattern recognition prior ground knowledge was used. The identified pattern of these LULC of the selected period was validated in a cross-examination manner to recognize the change notified over the period.

Table 1. Reclassification of LULC

LULC categories	Reclassified class
Agriculture	Non-forest
Barren land	Non-forest
Dense vegetation	Forest
Fallow land	Non-forest
Open vegetation	Forest
Scrub land	Non-forest
Settlement	Non-forest
Water body	Non-forest

LULC pattern of the study area in 1991: In the year 1991 based on LULC classification, most of the study area was occupied by forest area. The area under the forest was about 13582.71 ha (Hectare) (60.40 %) of total land and the remaining 8906.31 ha (39.60 %) of the land occupied by non-forest land use land cover pattern (Table 2). Among the non-forest land use activity, agriculture is the dominant activity, as covered nearly 2859.84 ha (12.72 %) of the area. The remaining LULC classes among the non-forest area have occupied in descending manner such as fallow land 2161.89 ha (9.61 %) and barren land 1601.82 ha (7.12 %), water bodies (5.73%), scrubland (3.88%), and settlements (0.54%). The forest area is shown by light green and fir green patches on the LULC maps of the two selected periods. Land cover classes, agriculture, barren land, fallow land, scrubland, water bodies and settlements are shown respectively by yellow, light sienna, pale brown, grey, red, and blue colour (Fig. 3a).

The LULC map has been distributed into forest and non-forest to understand forest fragmentation (Fig. 3b). The study area covered 13582.71 ha of forest land in 1991, accounting for 60.40% of the total area and is seen in shades of green colour on the map. The forest fragmentation categories were generated using the LFT are patch, edged, perforated and core is shown by dark orange, yellow, light orange and green colour respectively (Fig. 3c). Forest fragmentation map of year 1991 reveals that 40% area among total forest land was occupied by core forests, 28% by perforated forests, 24% by edge forests and only 8% by patch forest area (Fig. 3d). To identify fragmentation, edge pixels are coded yellow and identify the external edge of core forest areas where non-forest areas intersect (Fig. 3c). The highest disturbing

Table 2. LULC classes and distribution

Major class	Sub-classes	Area in 1991		Area in 2020	
		(ha)	(%)	(ha)	(%)
Non-forest (a)	Agriculture	2859.84	12.72	3614.67	16.07
	Fallow land	2161.89	9.61	2053.44	9.13
	Barren land	1601.82	7.12	2101.14	9.34
	Water body	1289.70	5.73	2123.55	9.44
	Scrub land	871.47	3.88	1304.19	5.80
	Settlement	121.59	0.54	139.77	0.62
Total (a)		8906.31	39.60	11336.76	50.41
Forest (b)	Patch	1026.90	4.57	1010.52	4.49
	Edge	3300.84	14.68	4007.97	17.82
	Perforated	3855.42	17.14	2109.87	9.38
	Core	5399.55	24.01	4023.90	17.89
Total (b)		13582.71	60.40	11152.26	49.59
Grand total (a+b)		22489.00	100.00	22489.00	100.00

classes are edge and perforated pixels and that shown in map respectively by yellow and light orange colour indicate that this region has the maximum fragmented forest and that maximum of the forest fragmentation zones are susceptible to shift into non-forest classes.

LULC pattern of the study area in 2020: For the year 2020, the LULC classification of Landsat 8 OLI image of the study area has been carried out. The derived LULC result for the year 2020, forest and non-forest areas have almost occupied the equivalent quantity of land. It almost covered 50 % of each of them i.e. non-forest land use covered about 11336.76 ha (50.41 %) of land and forest land use occupies a remaining 11152.26 ha (49.59 %) of land (Table 2).

Other than forest area, land use patterns show some minor changes during the three decades in the categories of non-forest land-use patterns. The agriculture category remained dominant by increasing its area up to 3614.67 ha (16.07 %). The other categories of land use land cover among the non-forest area as given in descending manner. The water bodies comprising approximately 9.44 % of the total area and covering 2123.55 ha of the area was the second-highest category (Table 2). The remaining LULC classes such as barren land occupied 2101.14 ha (9.34%) of total land, fallow land covered 2053.44 ha (9.13%) and scrubland 1304.19 ha (5.80%) and settlements 139.77 ha (0.62%) are covered (Fig. 4a).

The temporal satellite image analysis of the study area shows that the forest area had substantial forest fragmentation over the last three decades (Fig. 4b). The study area covered 13582.71 ha of forest land in 1991, representing 60.40 % of the total area, and reduced up to 49.59 % of forest land in the year 2020 (Table 2). The forest fragmentation categories were generated using the LFT are patch, edged, perforated and core is shown by dark orange, yellow, light orange and green colour respectively (Fig. 4c). Forest fragmentation map of the year 2020 revealed that 36% of the total forest land was occupied by core forests, 36% by edge forests, 19% by perforated forests and only 9% by patch forest area (Fig. 4d). Growing patches in the study area mean forest condition has disturbance and it leads to increase forest fragmentation.

Changing LULC from 1991 -2020: The changing scenario

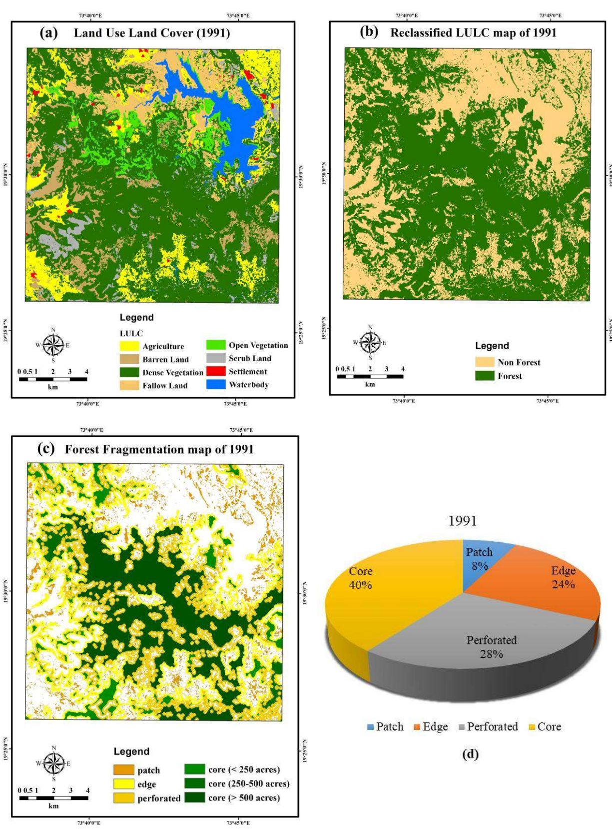

Fig. 3. a. Land use map of Study area-1991, b. Reclassified LULC (forest Non-forest) map -1991, c. Forest Fragmentaion map- 1991 d. Forest fragmentation classes cover in 1991

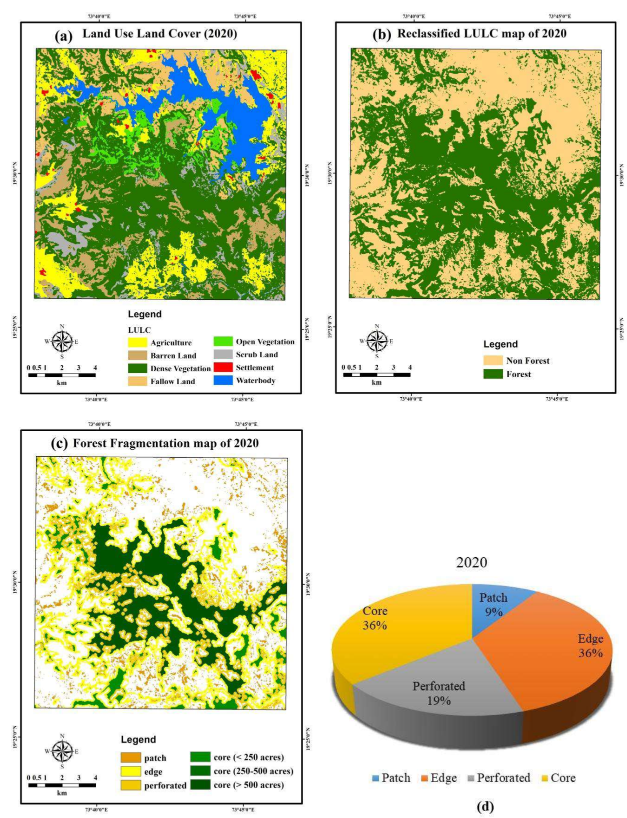

Fig. 4. a. Land use map of Study area-2020, b. Reclassified LULC (forest Non-forest) map -2020, c. Forest Fragmentaion map- 2020. d. Forest fragmentation classes cover in 2020

of LULC shows that forest area has been considerably reduced by 2430 ha area from the year 1991 to 2020. Thus, the forest areas have been fragmented and are converted into other non-forest areas. Consequently, in the temporal range of the study, the other non-forest areas have been progressively increased. The area of water bodies, agricultural land, barren land, scrubland and settlement increased 834 ha, 755 ha, 499 ha, 433 ha and 18 ha respectively. The area under the forest region decreased due to deforestation for commercial and fuelwood and agricultural purposes. Other reasons are increasing dispersed settlements, infrastructure development such as roads, dams etc.

Forest Fragmentation from 1991-2020: In 1991, under the dense and open vegetation, there was about 13582.7 ha of forest land, holding about 60.40 % lands. But at the other edge, 8906.31 ha (39.60%) of the land was occupied by the non-forest land classes. However, forest cover area has been reduced in 2020 (11152.26 ha) and forest coverage has been swapped by other non-forest land classes. In 1991, across three forest fragmentation categories, the core area shared 5399.55 ha of land and in 2020 the core area was drastically reduced to 4023.9 ha of land. Under these spatial scales, the core area deficit was 1375.65 ha (6.12%). After the core area, the perforated area becomes less prone to forest fragmentation. The perforated area in 1991 was 3855.42 ha and the area was 2109.87 ha in 2020, resulting in a gross perforated area loss of 1745.55 ha (7.76%). The edge field, on the other hand, increased from 3300.84 ha to 4007.97 ha, resulting in an overall growth of around 707.13 ha (3.14%). Finally, the patches appeared mostly the same. In 2020, the study region lost about 2430.45 ha of forest land to a variety of non-forest uses. Core forest losses were around 1375.65 ha and the core region is not only affected but other categories are affected as well. If we are not concerned about it, there will be bitter consequences for both the present and future generations. The outcome of the study suggests that the cease of forest fragmentation become a primary concern for biodiversity sustainability.

CONCLUSION

The main problem is deforestation which consequently leads to the decreasing area under forest and results in the increasing area under other land use land cover categories. The research work has a temporal range of three decades and quantified the change of deforestation through the measuring process of fragmentation from 1991 to 2020. The result revealed that non-forest types like water bodies, agriculture land, barren land, scrubland and settlement has been increased by 3.71%, 3.36%, 2.22%, 1.92% and 0.08%, respectively. Fragmentation analysis reveals increasing edges by 3.14% (707 ha) and a decrease in the core forest by 6.12% (1376 ha). The main drivers of forest fragmentation are agriculture expansion, commercial logging, fuelwood, settlement expansion, forest fire and infrastructure development like road and dam construction etc. The other form of forest fragmentation such as patch edged and perforated resulting a serious threat to the local biodiversity. The work has relevance to make aware about future generations regarding sustainable human-environment interaction. It suggests executing existing indigenous sustainable practices through government initiative with effective people participation.

ACKNOWLEDGMENTS

The authors are thankful to the Savitribai Phule Pune University, Pune under the Rashtriya Uchchatar Shiksha Abhiyan (RUSA/CBS/TH1.3) programme, for providing financial support to carry out this research.

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Received 21 November, 2021; Accepted 12 March, 2022