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Remote Sensing Based Forest Fragmentation Analysis Using GIS along Fringe Forests of Kollam District, Kerala

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Abstract: Remote sensing and GIS has gained momentum in monitoring land use change as well as forest fragmentation due to availability of Landsat satellite data. Kollam Forests sustains extensive deforestation and forest fragmentation, but data and documentation highlighting this transformation of the Western Ghats are limited. The major endeavour of this study is to compute forest fragmentation employing LFT and interpretation of fragmented forest area during the past decade (2001-2017).Two time frame data sets of 2001 and 2017 were used for assessing forest fragmentation. Forest intactness is measured by the proportion of four spatial patterns i.e. core, perforated, edge and patches. Erstwhile tree cover and density was considered as the yardstick to measure forest health and ecosystem but recent studies regarding forest fragmentation has disclosed many harmful impacts of the same. The study intended to develop two land use maps of the experimental area based on maximum likelihood algorithm of supervised classification method and to assess the rate of land degradation. The consequent supervised classified data is subsequently reclassified using reclassify tool of ArcGIS 9.3v. The reclassified image is used as input in landscape fragmentation tool LFT v2.0 to construct a forest fragmentation maps and analyse forest fragmentation pattern during (2001-2017). The results revealed that there was a great spatial variability in the pattern of forest loss and land use change throughout the region which in turn affected the species diversity.
Keywords:Forest Fragmentation, Fragmentation classes, Remote Sensing, GIS

I. INTRODUCTION

Forests refers to those landscapes with natural tree stands of at least 5m in-situ, whether productive or not and excludes the tree stands in agriculture production systems.Forest fragmentation is the process through which formerly large and continuous extensions of forests turn into a set of small and isolated patches, increasingly affected by edge effects (Haila, 1999).Forest Fragmentation encompasses three interrelated process,-reduction in total amount of original vegetation, subdivision of remaining vegetation into fragments, remnants or patches and incorporation of new forms of land use to replace lost vegetation. Three spatial attributes of fragmentation are: core area, shape and isolation of forest fragments. The fragment edges as a range of physical and environmental transitions. Irregular shape of fragments due to forest fragmentation increases length of edges and restrict commutation of native organisms.Forest landscapes are at stake of fragmentation because of changes in land cover due to processes such as agricultural intensification, logging, and infrastructure development. These changes have led not only to the loss of habitat and biodiversity, but also to the modification of natural landscapes and ecosystem functions (Bennet et al., 2010; Abdullah et al., 2007; Wade et al., 2003; Biodiversity Indicators Partnership 2010) revealed that nearly 20% of the world's remaining forest is within 100 m of an edge in close proximity to agricultural, urban, or other modified environments where impacts on forest ecosystems are most severe and more than 70% of the world's forests are within 1 km of a forest edge. Where fragmentation continues, Zhu et al., (2004) observed microclimatic differences which induces buffer effect (edge effect), change of species composition, change in species richness and species (with small population) extinction and parasitic disturbance. Besides Costero (2009), Laurance (2004) and Laurance et al. (2011) discussed about abiotic alteration from forest fragmentation which affects habitats of both floral and faunal community.

Extinction cascades are likely to occur in landscapes with low native vegetation cover, low landscape connectivity, degraded native vegetation and intensive land use in modified areas, especially if keystone species or entire functional groups of species are lost (Fischer et al ., 2007). Broad-scale destruction and fragmentation of native vegetation is a highly visible result of human induced land use change throughout the world (Benettet l 2010). Landscape metrics provide a means of quantifying and describing forest fragmentation. The most common method of calculating these metrics is through the use of Geographic Information System software to analyse raster data, such as a satellite or aerial image of the study area (Meneguzzo et al 2009). Vogt et al. (2007), proposed morphological image identification rather than a fixed-area 'window,' or kernel, is centred over each pixel on a forest map, and an index is calculated according to the amount and adjacency of forest in the window. This result is then assigned to the forest pixel located at the window centre, thus building a new map of the fragmentation index values.

According to Department of Wildlife and Forests (Kerala) report 2014, 8415 Sq.Km of forest land have been changed to non-forest use in Kerala since 1993, which have been converted for the construction of roads, hydro-projects, transmission lines, plantation, farming, and barren land. The fragile nature of the Western Ghats coupled with increasing human activity poses a serious threat to the natural landscape, especially in the forest ecosystem. The contemporary study is designed to provide an epitomize about land cover change and forest fragmentation in Forests of Kollam district of the Kerala state (Figure 1). Kollam district has been continuously experiencing extensive forest loss, due to agriculture expansion and infrastructure development.On the other hand, natural hazards such as floods, landslides, and forest fires have increased over the last few decades and have led to further deterioration of the forest landscape in the study area (Gupta et al 2013).Satellite remote sensing and the use of geographical information systems (GIS) have emerged as powerful tools to create a spatial inventory of natural resources and play crucial roles in monitoring and analysing spatial and dynamic changes of an area (Mondal et al ., 2015). Specifically, the objectives of this forest fragmentation study, which employed remote sensing techniques, are - To produce land use map and compare changes of land uses using Landsat satellite imageries of Kollam Forests from 2001 to 2017 andto identify and assess the change of core, perforated, edged and patched area using two different time frame satellite datasets.

A. Study Area

Kollam forests has a total areal extent of 971.76602 Km^2 The study area lies between 76° 50' and 77° 20' East longitude and 8° 50' and 9° 10' North latitude (Figure 1). Kollam forests lies 100-1785m above the mean sea level. Kollam forests has a tropical humid climate, with an oppressive summer and plentiful seasonal rainfall (Adityaetal. 2016). The district experiences oppressive summers and cool winters. Temperature is almost steady throughoutt the year. The average temperature is around 25° Celsius to 32° Celsius. Summers usually begin from March and extend till May. The area under forest in Kollam it falls in Thenmala, Punalur (163sq.km) and a portion of Achenkvoil (269sq.km) forest division. Thenmala Range, Aryankavu Range and Shendurni Sanctuary Constitute the Thenmala division (298 sq.km). Achenkovil Range, Kallar Range and Kanayar Range, make up the Achenkovil division while Punalur division includes Pathanapuram and Anchal Ranges (241sq.km). The main drainage basin is the Kallada River which is formed by 3 major rivers Shendurney, Kazhuthuruthy and Kulathupuzha. Amidst Shendurney Wild Life sanctuary lies an artificial lake of 18 sq. km formed by the Thenmala (Parappar) Dam built across the Shenduruny and Kulathupuzha rivers.Achenkovil River originates from the Western Ghats and covers a basin area of 1484 km^2 and the main channel length is 128 km. The River joins Pamba River at Veeyapuram and finally debouches into the Vembanad Lake. Achankovil, Ayirur, Ithikkara, Kallada, Pallikkathodu and Vamanapuram are the major water sheds of Kollam. The vegetation types in these forest ranges include evergreen forest, semi evergreen forest, moist deciduous forest, Myristica swamp, etc (Smitha and Sobha, 2013).About 53 patches of Myristica swamps have been iderntified in Anchal and Kulathupuzha..The study area is a native locality for several endemic and threatened species of Western Ghats.

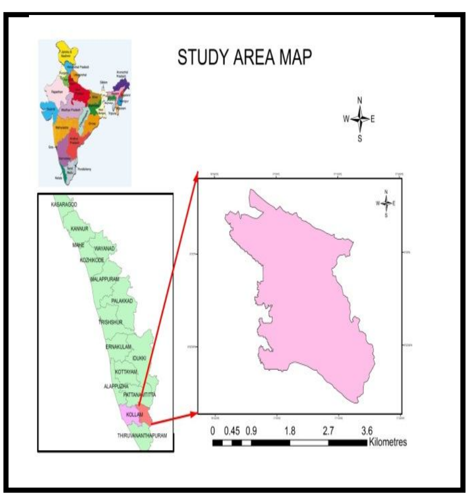

Figure No.1 Location map of study area

II. MATERIALS AND METHODS

Datasets and methods adopted in a bid to fetch supervised classified images and fragmentation maps are portrayed in following sections:

A. *Satellite Data*

For base map preparation of the study area series of satellite imageries were acquainted from Google Earth 7.0v which was combined manually and used as field level investigation for feature recognition. The latest high resolution satellite imagery Landsat 8 OLI-TIRS satellite imagery dated 18th January 2017 having path 144 and row 54, the adjacent scene dated 11th January 2017 with path and row 143 and 54 were downloaded from Earth explorer data search engine owned by USGS**.** and Landsat 7 Enhanced Thematic Mapper +(ETM+) dated7th January 2001 having path 143 and row 54, the adjacent scene dated 28th November 2000 having path 144 and row 54 were downloaded Earth explorer data search engine owned by USGS. The survey of India Toposheets numbered H1 and H5 with scale of 1:50000 covering the study area were used for reference purpose. H1 toposheet contains Kollam whereas H5 contains Tamil Nadu.

SATELLITES	SENSORS	BAND COMBINATIONS	DATE OF ACQUISITION	PATH/ROW	SPATIAL RESOLUTION
Landsat 7	ETM+	NIR, R, G (4,3,2)	07th January 2001	143/54	30m
Landsat 7	ETM+	NIR, R, G (4,3,2)	28th November 2000	144/54	30m
Landsat 8	OLI-TIRS	NIR, R, G (5,4,3)	18th January 2017	144/54	30m
Landsat 8	OLI-TIRS	NIR, R, G (5,4,3)	11th January 2017	143/54	30m

Table No.1 Spatial Data Source

B. *Preprocessing*

The Landsat 7ETM+ and Landsat 8 OLI imageries has been geo-referenced to the Universal Transverse Mercator (UTM) projection zone 43, with a spatial resolution of 30 m. The multispectral satellite image contains seven spectral bands, i.e., bands 1–3 represent the visible part of the electromagnetic spectrum with wavelengths of 0.450– 0.515, 0.525–0.605 and 0.630–0.690 μm, respectively. Band 4 represents the near infrared (IR) with wavelengths of 0.760–0.900 μm and bands 5 and 7 represent mid IR with wavelengths of 1.550–1.750 μm and 2.080–2.350 μm. Band 6 and 8 are present in the thermal IR and panchromatic respectively; however, these bands are not taken into account in this study. Satellite data are distorted by earth's curvature, relief displacement, and acquisition geometry of satellites. Variation in altitude, aspect, velocity and panoramic distortion which is corrected by way of atmospheric and radiometric correction. The remote sensing data obtained were geo-referenced, geo-corrected, rectified and cropped pertaining to the study area. Geo-registration of remote sensing data (Land sat data) has been done using known points (such as road, intersections, etc.) collected from geo-referenced topographic maps published by the Survey of India and Google Earth Images and also from field visits.

C. *Supervised Classification*

The subsequent dated satellite imageries of 2017 and 2001 were mosaicked followed by its subsetting. These two subsets were classified as level 1 using Supervised Classification in ENVI 5.3 + IDL 8.5(64 BIT) with maximum likelihood algorithm using nearest neighbourhood technique. Level 1 classification involves assigning of five different training sets namely- Water, Barren, Built up, Vegetation and Forests, for false colour composite of spectral band combination in satellite image was used with reference to Google Earth

D. *Fragmentation Analysis*

Forest fragmentation was analysed by Reclassification of supervised data and its further processing with LFT.

1) *Reclassification:* Supervised classified imageries were reclassified using reclassify of spatial analyst tool of ArcGIS 9.3 Desktop in to forest (comprising of Vegetation and Forest) and non-forest class (comprising Built up, Barren) zero class for Water. This reclassified image of 2001 and 2017 were used as input features for generating respective forest fragmentation maps using LFT tool.
2) *Landscape Fragmentation Tool Analysis*The input landcover map should contain two classes- 1= land cover types causing fragmentation (non forest- built p and barren), 2 = Landcover types for which fragmentation is to analysed (forest class), 0= no data class will not affect the analysis (water).The edge width parameter is the distance over which the fragmented land cover type of interest (i.e. forest) can be degraded by the fragmenting land cover types (i.e. development). The width of Edge and perforated units will be same as the input land cover raster, edge width must be greater than the grid cell size. A 50 meter edge width was used in this study.

Four classes of forest pattern is considered. 'Core forest' is relatively far from the forest–non forest boundary and 'patch forest' comprises coherent forest regions that are too small to contain core forest. 'Perforated forest defines the boundaries between core forest and relatively small perforations, and 'edge forest includes interior boundaries with relatively large perforations as well as the exterior boundaries of core forest regions.

In this study, core pixels are sub-classified into 2 categories -*small core and large core* – based on the area of a given core patch. The next least-disturbed category, perforated pixels, make up the interior edge of small non-forested areas within a core forest, such as a house built within the woods. These areas, which appear as "holes" or perforations, are shown in light orange. Edge pixels, shown in yellow, make up the exterior periphery of core forest tracts where they meet with non-forested areas. The most disturbed category, patch pixels, are small fragments of forest that are completely surrounded by non-forested areas.

An algorithm to classify forest patterns is defined by a sequence of logical operations such as union, intersection, compleentation, and translation using geometric objects called 'structuring elements' (SE) of pre-defined shape and size.

A verbal description of the algorithm (Holdt et al., 2004) for a formal mathematical language) and consider two SEs: an 8-neighbourhood (SE1) and a 4-neighborhood (SE2). Forest connectivity is defined in cardinal directions only (SE2) and use the following two morphological operations. The 'erosion' operator shrinks regions of forest and the 'dilation' operator expands them; the direction and extent of these operations is defined by the shape and dimension of the SE.

3) *Step 1: Detection of Core forest:* Beginning with the forest map, core forest is obtained by applying an erosion with SE1. The center pixel of SE1 is core forest if all eight neighbors are forest, resulting in all forest regions being shrunk by 1 pixel. The difference between this core forest map and the original forest map defines the pixels that are candidates for the remaining classes of patch, perforated, and edge.
4) *Step 2: Detection of Patch forest :*Patch pixels are forest regions that do not contain core forest. They are identified after their complement, the original forest map without patch pixels, has been found. The latter is reconstructed starting from the set of core forest pixels and adding all forest pixels that are connected to this set which is achieved by repeated dilations with SE2. Here, patch pixels can never be added because they are detached from the core-connected pixels. The first dilation adds forest pixels that are directly connected to core forest, and repeated dilations add forest pixels that are indirectly connected. The dilations stop when all indirectly connected forest pixels have been added. The difference between this map and the original forest map is the set of patch pixels**.**
5) *Step 3: Detection of Edge forest:*The detection of edge pixels starts from the non forest map. By analogy to Step 2, the non forest patches are identified and removed. Edge pixels can then be identified by dilating the current non forest areas in all directions (using SE1) and looking for forest pixels instead of non forest pixels. This step also retrieves the forest patch pixels, which are removed by subtraction.
6) *Step 4: Detection of Perforated forest:* With knowledge of core, patch, and edge pixels, the perforated pixels are obtained by subtraction as the only remaining unlabelled forest pixels.

III. RESULTS AND DISCUSSION

Byemploying foresaid methodologies following results are obtained, which has been listed in following sections.

A. *Forest Fragmentation Analysis*

Forest fragmentation is accomplished by supervised classification, reclassification of classified image into two classes, then further processing in LFT.

1) *Supervised Classification:* The results obtained from supervised classification showed that there is a decrease in forest cover due to anthropogenic and physical factors. The dominating landcover type in 2001 land use image shows vegetation, followed by forest, barren areas are found most widely than built up, water body. The vegetation area has been increased in 2017 image mainly by artificial forestry plantations. This discloses the fact that much of the fragmentation took place forming edge and patch forest as in 2017 land use image

LAND COVER TYPE	CATEGORIES INVOLVED	RECLASSIFIED LANDCOVER
Water Bodies	Stream, Pond, Lakes, Tanks, Reservoir	Non forest
Barren and Built up	Grazing Land, Vacant Land ,Bush Land, Deforested and Degraded Forest Land, Rocks, quarry, pits, open ground at building sites, Kaccha roads	Non forest
Vegetation	Horticultural land, Betel leaf, Sun grass, Cropland, Nurseries, Social Forestry Plot, Govt. afforestation	Non forest
Forest	Natural patches, Mixed Forest,	Forest

Table No.2 Aggregation of land classes into forest and non-forest classes for fragmentation analysis

Table No:3Aealexent of Land use classes in the study area in Km^2

LAND COVER TYPE	2001	2017
Water Bodies	20.7848	20.8089
Barren and Built up	91.7919	103.9707
Vegetation	448.4419	702.5841
Forest	415.9566	144.4248

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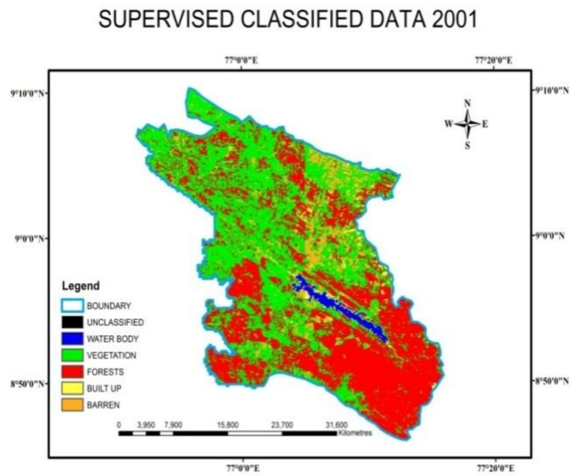

Figure No.2 Supervised classified data 2001

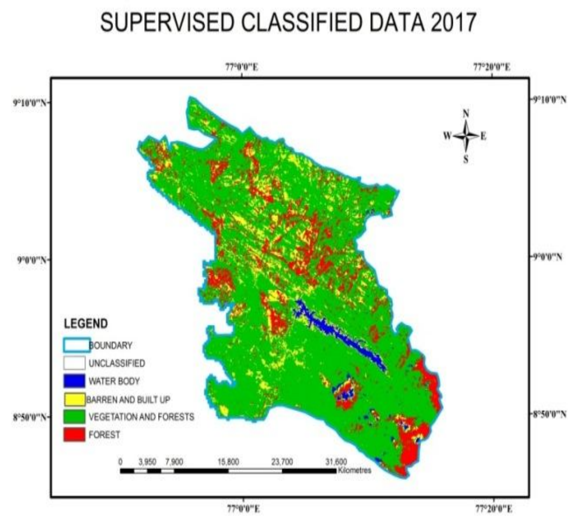

Figure No.3 Supervised Classified data 2017

2) Fragmentation Classes: The reclassified image of supervised datasets of 2001 and 2017 is processed in LFT V2.0 tool yielding following observations:

a) Core Forest: Forest pixels that are relatively far from the forest-no forest boundary. Essentially these are forested areas surrounded by more forested areas. The core forest into 3 categories to indicate the viability of the core patches with respect to the size of the patch. These three categories – small (< 250 acres), medium (250-500 acres), and large (>500 acres) based on edge effect - total forest cover within a landscape has a greater role in maintaining biodiversity than forest patch size .Small core area covered 4.084 km2 in 2001 fragmentation map which includes core zone of Thenmala Division and Anchal Range , while it reduced to 2.9925 km2 in 2017 fragmentation map which includes shrinking of core region of ThenmalaDivison , Punalur range and Anchal Ranges.. Large core area comprised 800.7273 km^2 in 2001 involving core regions of all the four forest divisions which is lowered to 764.2701 km2 by 2017, proximate dip in larger core area took place in Thenmala range.. Medium core area is absent due to the inclusion of water pixels in to zero class.Despite being intact, 37 sq.km of core forest has been fragmented within a span of 17 years. This number includesnotonlcore forest lost to development, but also core degraded to one of the other three (impacted) categories. Most probable causative factors include alien plant invasion, setting up of nature centric worship places, construction of Thenmala reservoir, agriculture, planting agroforestry. Formation of patch forests and edge forests increases the pace of edge effect, making core areas prone to further fragmentation.

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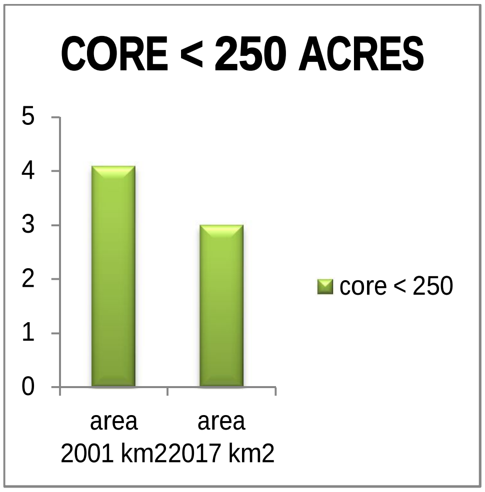

Figure No.4 CORE <250 ACRES

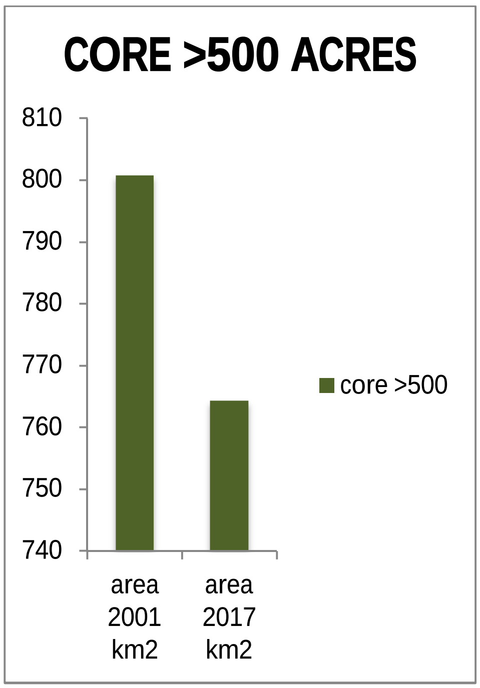

Figure No.5 CORE >500 ACRES

b) Patch Forest: Small fragments that are completely degraded by the "edge effect".Patch forests do not contain any forest pixels that are more than 100 meters from non-forest – they are entirely encompassed by the edge-effect. Forest pixels that comprise a small forested area surrounded by non-forested land cover. Patch forest pixels must be completely isolated from core forest pixels. A patch forest must be within 300 feet from a non forest land cover feature. It is the commencing stage of forest fragmentation. Patch forest covers an area of 0.3456 km^2 in 2001 image involving Thenmala Range and Anchal Range, which is increased to 0.495 km^2 in 2017 which got dissipated to Punalur Range and Anchal Range including Thenmala Range and Shendurney Wildlife Sanctuary. This slight increase in patch forest area reflects higher conversion rate of forest to non-forest areas. Most of the patch formations is evident outside protected areas, substantially in transition zones followed by buffer zones and core regions. The driving forces behind this is livelihood dependence of native people on timber, forestry operations, forest fire and other infrastructure developments. It is the most disturbed category of forest classes.

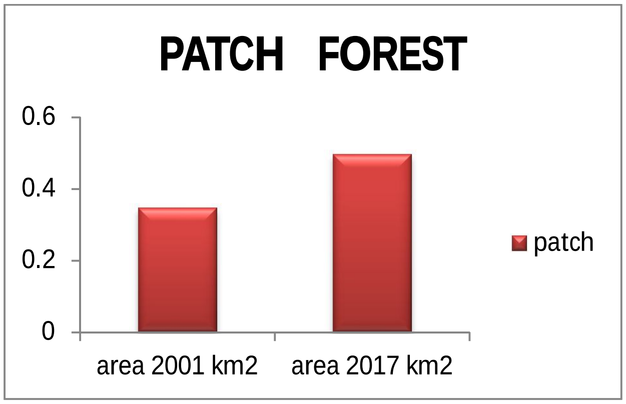

Figure No.6 PATCH FOREST

c) *Edge Forest:* Forest pixels that define the boundary between core forest and large non-forested land cover features. The edge forest must be within 300 feet of a large no-forest land cover feature and adjacent to core forest. Edge Forest comprised an area of 48.2634 km2 in 2001 involving Thenmala forest Range and Anchal Range, which is further extended to 59.95988 km2 in 2017 included Thenmala Range , Pathanapuram range, Punalur Range and Anchal range . The factors triggering edge forest formation involves construction of Kallada Hydroelectric power station and sabarigiri hydroelectric power stations next to Thenmala Reservoir, establishment of Roads and urban settlements. Of all the three impacted categories Edge Forest formation is at peak rate.

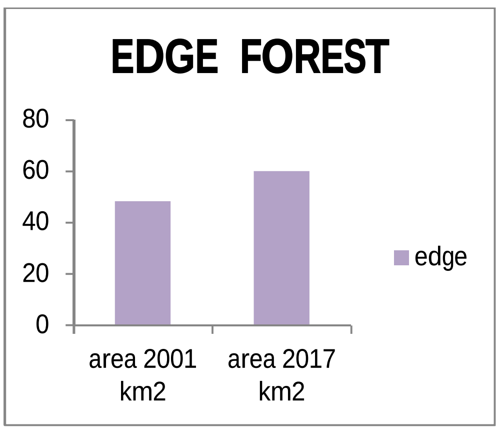

Figure No.7 EDGE FOREST

d) *Perforated Forest:* Least-disturbed category, perforated pixels, make up the interior edge of small non-forested areas within a core forest, such as a house built within the woods. Forest pixels that define the boundary between core forest and relatively small clearings (perforations) within the forested landscape. The perforated forest must be within 300 feet of a relatively small forest clearing and adjacent to core forest. Perforated forests extended 1.9791 km2 in 2001 involved Transition and buffer zone Thenmala Forest range, Transition zone of Shendurney Wildlife Sanctuary which increased to 19.2915 km2 by 2017, includung Transition and buffer zone Thenmala Forest range, Transition zone of Shendurney Wildlife Sanctuary, Core area of Anchal Forest range. Private enclosures with their associated agriculture and plantation activities, Acacia and Eucalyptus plantation at the primary ends of plots, which retreated into forest core, the spatial extent of perforation depends on areal extent of artificial forestry. As the perforation intensifies, patch forest formation rises, followed by edge forest, which further gets fragmented into non-forest areas.

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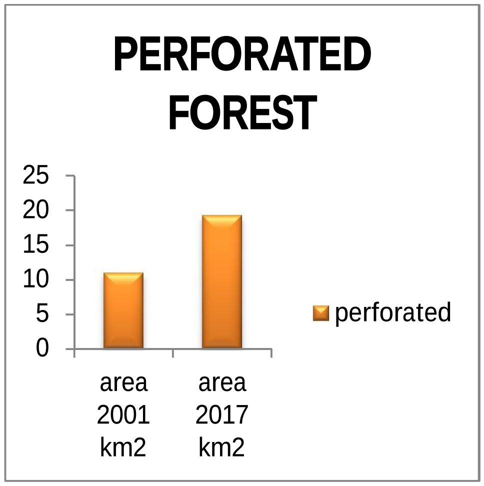

Figure No.8 PERFORATED FOREST

FOREST FRAGMENTATION CLASSES	2001	2017
PATCH	0.3456	0.495
EDGE	48.2634	59.9598
PERFORATED	10.9791	19.2915
CORE < 250 ACRES	4.084	02.9925
CORE > 500 ACRES	800.7273	764.2701

Table No: 4 Areal Extent of forest fragmentation classes in Km^2

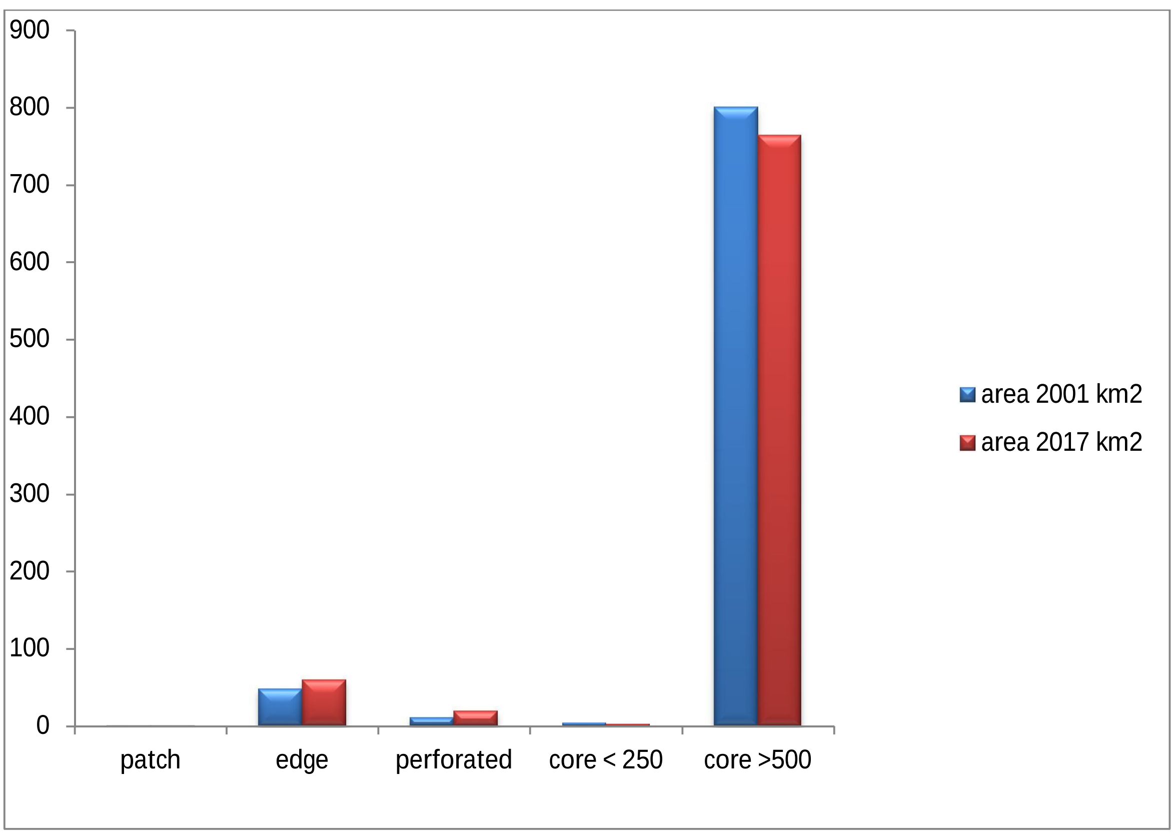

Figure No. 9 Areal Extent of Fragmentation classes 2001-2017

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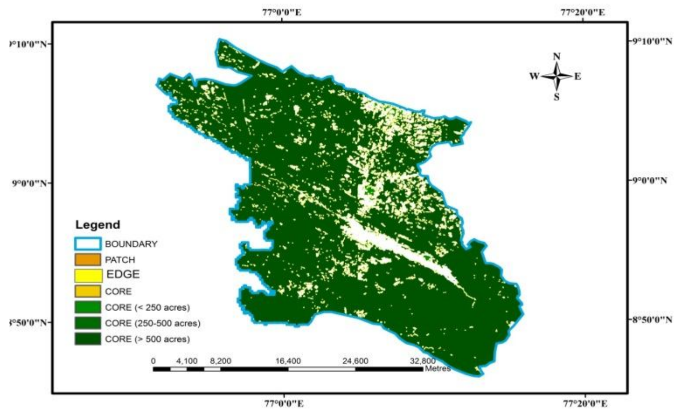
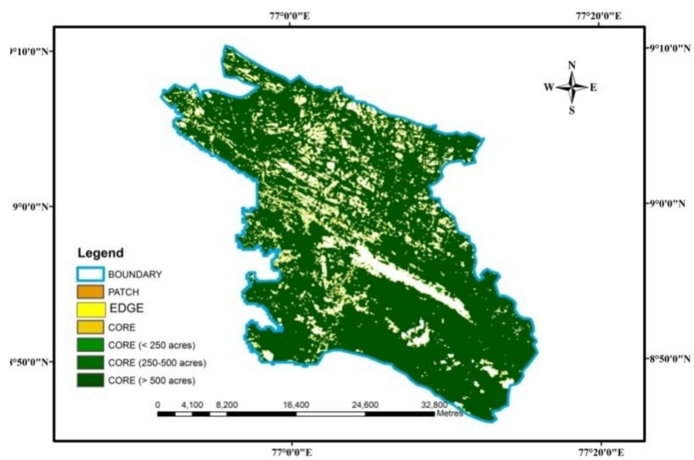
FRAGMENTATION MAP 2001



FRAGMENTATION MAP 2017



Similar studies using LFT were executed by Rouse et al., 1974 implemented LFT for analysing Forest Fragmentation in Colarado Forests. They compared the watershed fragmentation maps over the 15-year period, revealing results such as amount of urban area increased from 9% overall to 13% overall , The amount of interior forest decreased substantially from 1985 to 1999, with the lowest period of change between 1995 and 1999; As the interior forest levels decrease, the amount of perforated forest increased, while the edge, patch, and transitional areas remained fairly constant.

LFT was used by Fazzel et al., 2009 Foddy et al., 1994 to Hoekman et al., Amit et al 2017, to map spatial patterns in Val Grande National Park in North Italy, to determine Land use changes of Chunati WLS, forest fragmentation in Connecticut and Gharwal region Of Himalayas for a specific period of time. Ultimately generating a fragmentation map from which forest cover loss is detected and quantified. Forest cover loss has been quantified in terms of three fragmentation classes –Perforated, Edge and Patch.

B. Aftermath of Forest Fragmentation

Forest fragmentation is one of the greatest threats to biodiversity in forests, especially in the tropics. The problem of habitat destruction that caused the fragmentation in the first place is compounded by:

1) The inability of individual forest fragments to support viable populations, especially of large vertebrates
2) The local extinction of species that do not have at least one fragment capable of supporting a viable population
3) Edge effects that alter the conditions of the outer areas of the fragment, greatly reducing the amount of true forest interior habitat. The effect of fragmentation on the flora and fauna of a forest patch depends on the size of the patch and its degree of isolation. Isolation depends on the distance to the nearest similar patch, and the contrast with the surrounding areas. For example, if a cleared area is reforested or allowed to regenerate, the increasing structural diversity of the vegetation will lessen

the isolation of the forest fragments. However, when formerly forested lands are converted permanently to pastures, agricultural fields, or human-inhabited developed areas, the remaining forest fragments, and the biota within them, are often highly isolated.Forest patches that are smaller or more isolated will lose species faster than those that are larger or less isolated. A large number of small forest "islands" typically cannot support the same biodiversity that a single contiguous forest would hold, even if their combined area is much greater than the single forest. However, forest islands in rural landscapes greatly increase their biodiversity. The loss of forest cover not only directly results in habitat loss, but it also contributes to increased water run-off quantity (Bosch and Hewlett, 1982) and associated water-quality concerns. Forest birds are often used as indicators of the quality of the landscape because they are more easily surveyed, and more is known about their habitat requirements and distribution than any other group of wildlife. Much less is known about the sensitivity of invertebrates, amphibians, reptiles, plants, and small mammals to forest fragmentation.

C. Diminution Measures

2017 dataset sketches that forest fragmentation has slightly risen compared to 2001 dataset. Following are well practiced mitigatory measures for fixing forest fragmentation.

1) Increasing amount of vegetation by afforestation and reforestation technique along linear structure like roads, and provision of green belts of 2Km width in between power stations
2) Prevention, to keep exotic species from becoming established or spreading farther.
3) To prevent wildfire through fuels reduction, to prevent disease and insect damage through hazard reduction.
4) Integrated management, to deal with exotic agents now firmly established, to re-establish appropriate levels and functions of native insects and diseases
5) Restoration, of damaged watersheds, of fire in the ecosystem, of tree species and structures that have become scarce
6) Monitoring, to track broad vegetation trends, to evaluate the effectiveness of treatments, make adaptations to learn, and to detect emerging problems.
7) Reducing human intervention in buffer and core areas, thereby improving habitat quality for wildlife.
8) Reducing settlements within the core areas , thereby reducing perforated forest formations
9) Minimising overgrazing inside the sanctuary, these activities nay be confined to buffer and core areas.
10) Prolonged monitoring for innate degradation such as landslides, and forest fires.
11) Implementation and planning of long term conservation programmes and effective eco-tourism strategies within the sanctuary.
12) Effective implementation of strict legal measure in converting forest to non-forest areas.

IV. CONCLUSION

Forest fragmentation is not random, the present study indicates that the forest areas has been affected by surrounding urban areas in varying magnitude. Altered physical processes and impacts of human land use has a profound influence on forest patches and their biota, particularly on fragment edges. It is evident from the result increased edge and patch forest formation, makes Kollam forests highly vulnerable to forest fragmentation in future. It can be concluded that, anthropogenic pressure due to higher pace of tourism activities, agricultural expansion and over grazing are the major provoking factors of forest fragmentation.

Forest Fragmentation Map generated notifies that Patch forest formed in 2001 is approximately 0.0376 %, Edge forest accounted for 4.97%. Perforated forest formed is 1.130% of total forest area. However, forest fragmentation map of 2017 reflects that patch forest formed is 0.0517%, Edge Forest formed is 6.175%, and perforated forest formed is 1.986% of total forest area. It can be concluded that almost 20.158 Sq.Km or 2.0751 % of forest area is converted to non-forest purpose with in a span of 17 years. Moreover smaller core region present during 2001 was 0.4205% and larger core region present is 82.38% of total forest area. Incase of 2017 fragmentation map smaller core area covered is 0.3081% and larger core area present is 78.68% of total forest area. Therefore it can be derived that 37.5487 sq.Km or 3.91 % core area has been either lost to development or any of the three impacted regions.

But the irony part is Thenmala range despite being healthiest forest is more subjected to fragmentation, as more Edge forest formation has been witnessed in Thenmala range. If Edge forest formation continues unchecked, by 2030 Kollam forest will be completely wiped off or gets replaced by more non-forest areas.

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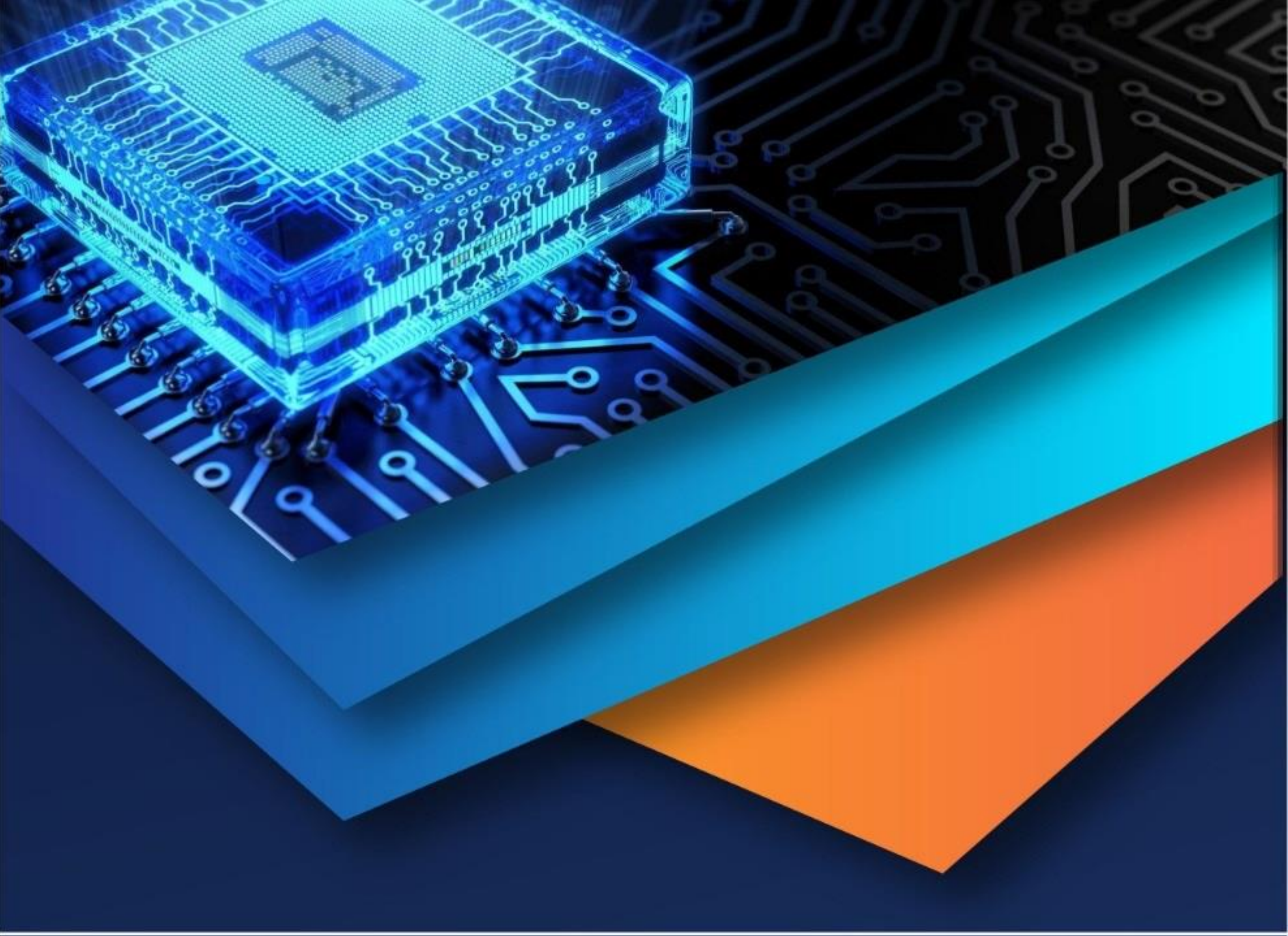

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