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Landscape Metric Modeling - a Technique for Forest Disturbance Assessment in Shendurney Wildlife Sanctuary

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Deforestation and forest degradation are associated and progressive processes result in the anthropogenic stress, climate change, and conversion of the forest area into a mosaic of mature forest fragments, pasture, and degraded habitat. The present study addresses forest degradation assessment of landscape using landscape metrics. Geospatial techniques including GIS, remote sensing and fragstat methods are powerful tools in the assessment of forest degradation. The present study is carried out in Shendurney wildlife sanctuary located in the mega biodiversity hot spot of Western ghats, Kerala. A large extent of forest is affected by degradation in this region leading to depletion of forest biodiversity. For conservation of forest biodiversity and implementation of conservation strategies, forest degradation assessment of habitat destruction area is important. Two types of data are used in the study i.e. spatial and non-spatial data. Non-spatial data include both anthropogenic stress and climate data. The study shows that the disturbance index value ranges from 2.5 to 7.5 which has been reclassified into four disturbance zones as low disturbed, medium disturbed, high disturbed and very high disturbed. The analysis would play a key role in the formulation and implementation of forest conservation and management strategies.

Keywords: *Landscape metrics, GIS, Remote sensing, fragstat, GPS*

1. Introduction

India has been identified as one of the top 12 mega –diversity countries in the world (Chandrashekhar 2003). Among all the natural resources in India, forests are the most important**.** Forest resources are vital for human life. Forests contribute to the livelihoods of about 1.6 billion people worldwide (World Bank 2004). The forests of Kerala are in various stages of degradation under the influence of biotic pressure (Nair 2000). Data on forest area and biotic pressure show that the forest area in the country in general and Kerala in particular is decreasing at quite an alarming rate. Presently the forests of Kerala especially the Shendurney wildlife sanctuary undergo forest degradation due to various natural and anthropogenic reasons. In Kerala a total area of 2395.4 sq. km has been brought under Sanctuaries and National Parks (MoEF 2008) and now these areas are under pressure of degradation.

The concept of fragmentation refers to the transformation of the landscape, often driven by disturbances, from a uniform to more heterogeneous and patchy situation (Kshirsagar 2004, Rossenzweig et al. 2002). The basic variables of disturbance are magnitude, frequency, size and dispersion. At the landscape level, disturbance is related to patch structure and spatial arrangement and determines the fate of patches, their size and duration. Severe disturbance or even a prolonged absence of disturbance generally has a depressing effect on biodiversity, but intermediate disturbance seems to

enhance diversity in a system (Pickett and White 1985). Disturbance is a driver of the landscape dynamics and acts at all spatiotemporal scales. Human induced disturbance differs from natural disturbance especially in extent, severity and frequency. Anthropogenic activities (e.g. development, timber harvest) can disrupt the structural integrity of landscapes and are expected to impede, or in some cases facilitate ecological flows (e.g., movement of organisms) across the landscape (Gardner et al. 1993).

Landscape ecology considers vegetation as a mosaic of patches with unique landform, species composition, disturbance gradient and focuses on the parameters such as patch sizes, patch shapes, patch isolation, interspersion (adjacency of various landuse/landcover), juxtaposition (relative importance of adjacent patches), fragmentation, patchiness, etc. (Coops 2004). All these parameters have a direct bearing on the status of biodiversity within a forest ecosystem, and hence they require ecologists to compute the disturbance index. Field data with respect to species richness, ecosystem uniqueness and biological values, along with these parameters help identify biological richness of the forest types in each region (Brun 2002, Theobald 1999) The concept of fragmentation refers to the transformation of the landscape, often driven by disturbances, from a uniform to a more heterogeneous and patchy situation (Kshirsagar 2004).

Forest disturbance is a driver of the landscape dynamics and acts at all spatio-temporal scales (Pickett and White 1985, Bansal 1985). Anthropogenic activities can disrupt the structural integrity of landscapes and are expected to impede, or in some cases facilitate ecological flows across the landscape (Gardner et al. 1993, Romme 1982). The fragmentation and isolation of forest habitats have been suggested as an important factor in the decline of plant and animal populations (Robbins et al. 1995; Hagan & Johnston 1992). Large tracts of contiguous forest are broken into smaller fragments through urbanization, logging, and road building. Landscape level analysis attaches importance to assessment of forest fragmentation and due to fragmentation the amount of forest edge increases, the core forest area decreases, and vegetation composition and structure change (Hagan & Johnston 1992, Robinson et al. 1995). A variety of landscape metrics has been developed to allow quantitative assessment of a landscape and its level of fragmentation. Modern techniques like GIS and remote sensing are widely used for the landscape analysis (Pearson 2002).

Remote sensing and GIS have been successfully employed to monitor the disturbance regimes of forest ecosystems and are powerful tools to address the impact due to forest degradation (Jha et al. 2000). The utilization of landscape principles coupled with remote sensing and geographical information system help characterize fragmentation, disturbance regimes and biodiversity. The disturbance regimes assessed across the landscape will allow focusing on the ecosystems which are under 'stresses' (Ramachandra and Nagarathna 2008). Landscape ecology, if not ecology in general, is largely founded on the notion that environmental patterns strongly influence ecological processes (Turner 1989). During the recent few decades forest disturbance in this sanctuary is very high and it is the type locality of several endemic and threatened species (Ravindranath et al. 2006). The present study deals with the landscape level analysis for identification of a forest disturbance region in Shendurney wildlife sanctuary.

2. Study area

The present study is carried out in Shendurney wildlife sanctuary, a part of Agasthyamala biosphere reserve, Western Ghats, Kerala. It is situated in *Pathanapuram* taluk of Kollam district and is a part of Agasthyamalai Biosphere Reserve (ABR), which was notified on the 12th November, 2001 under the UNESCO's Man and Biosphere Programme. Shendurney wildlife sanctuary has an area of 171.32 sq. km and lies between 770 4' and 770 17' east longitude and 80 48' and 80 58' north latitude. The area lies between 100-1785 above from MSL. A total of about 171.5 sq.km area of forests is distributed throughout Shendurney wildlife sanctuary. The lake area extending about 18 sq. km was created after the construction of a dam under the Kallada Irrigation Project. The sanctuary gets its name from a rare timber species called Gluta travancorica locally known as "Chenkurinji". It is also the sanctuary where the concept of ecotourism was implemented for the first time in India with the establishment of the Adventure Park and provisions for trekking and other facilities into the forest. The vegetation types of this sanctuary include evergreen forest, semi evergreen forest, moist deciduous forest, meristica swamp, etc. During the last few decades forest disturbance in this sanctuary is very high. Shendurney wildlife sanctuary is the type locality of several endemic and threatened species.

3. Materials and methods

In the present study an attempt has been made to assess and evaluate the extent of disturbance in Shendurney wildlife sanctuary by using Remote Sensing and GIS. Its forest disturbance status was estimated through remote sensing data and GIS analysis coupled with ground truthing. The data sets used are Landsat MSS image of 1971 (Multi Spectral Scanner), Landsat ETM image of 2000 (Enhanced Thematic Mapper), IRS-P6 LIS III image of the year 2009 and Survey of India (SOI) topographic map of the year 1972 (1: 50,000 scale). The LISS III (March 2009) image was used for land use/land cover classification and the estimation of vegetation vigor of the area. A standard FCC was generated from combining the bands 4-3-2, red -green -blue. The data

were enhanced for easy interpretation of objects, and on-screen visual interpretation using interpretation elements was carried out.

SOI toposheet was used to generate thematic layers including contour lines, drainage, trek path, settlement, etc. The vegetation vigor analysis of the area was done through the Normalized Difference Vegetation Index (NDVI) analysis and the vegetation analysis was done with the aid of the ERDAS Imagine 9.1 version. The landscape analysis, including derivation of parameters such as porosity, fragmentation and patchiness was also performed. Along with these parameters the trek path disturbance and settlement disturbance analysis were also done.

The landscape matrix parameters are generated using the software package Fragstat 3.3 (Turner 2003). Habitat fragmentation of the entire area was analyzed at the landscape level through the software package Fragstat 3.3. Fragstat is a spatial pattern analysis program for categorical maps. Fragstat simply quantifies the aerial extent and spatial configuration of patches within a landscape**.** Fragmentation is a measure of forest and non forest polygon per unit area. It was measured by calculating the amount of forest patches occurring in a landscape with respect to non-forest patches. Similarly, using a 100 m radius moving window landscape metrics like patch density, patch richness, perimeter area ratio, the contagion index and similarity index metrics were generated.

The Normalized Difference Vegetation Index (NDVI) is the most widely used technique to help understand the vegetation status of a given area. The basic principle of the NDVI is that healthy vegetation absorbs more red light than the unhealthy or stressed one (Roy and Behera 2005); the basic equation behind this operation can be expressed as:

NDVI = NIR-R / NIR+R

Where:
NIR – near infrared band value,
R – red band value recorded by satellite sensor

An important fact of the obtained values is that for a given NDVI the pixel value always ranges from -1 to +1. Also it is important to note that a negative number or a number close to zero means no vegetation and a number close to a positive number represents luxurious vegetation. The cover density increases as the positive value increases. NDVI was calculated from the satellite image of 2009 using the ERDAS imagine software. NDVI 2009 is reclassified and ranks assigned.

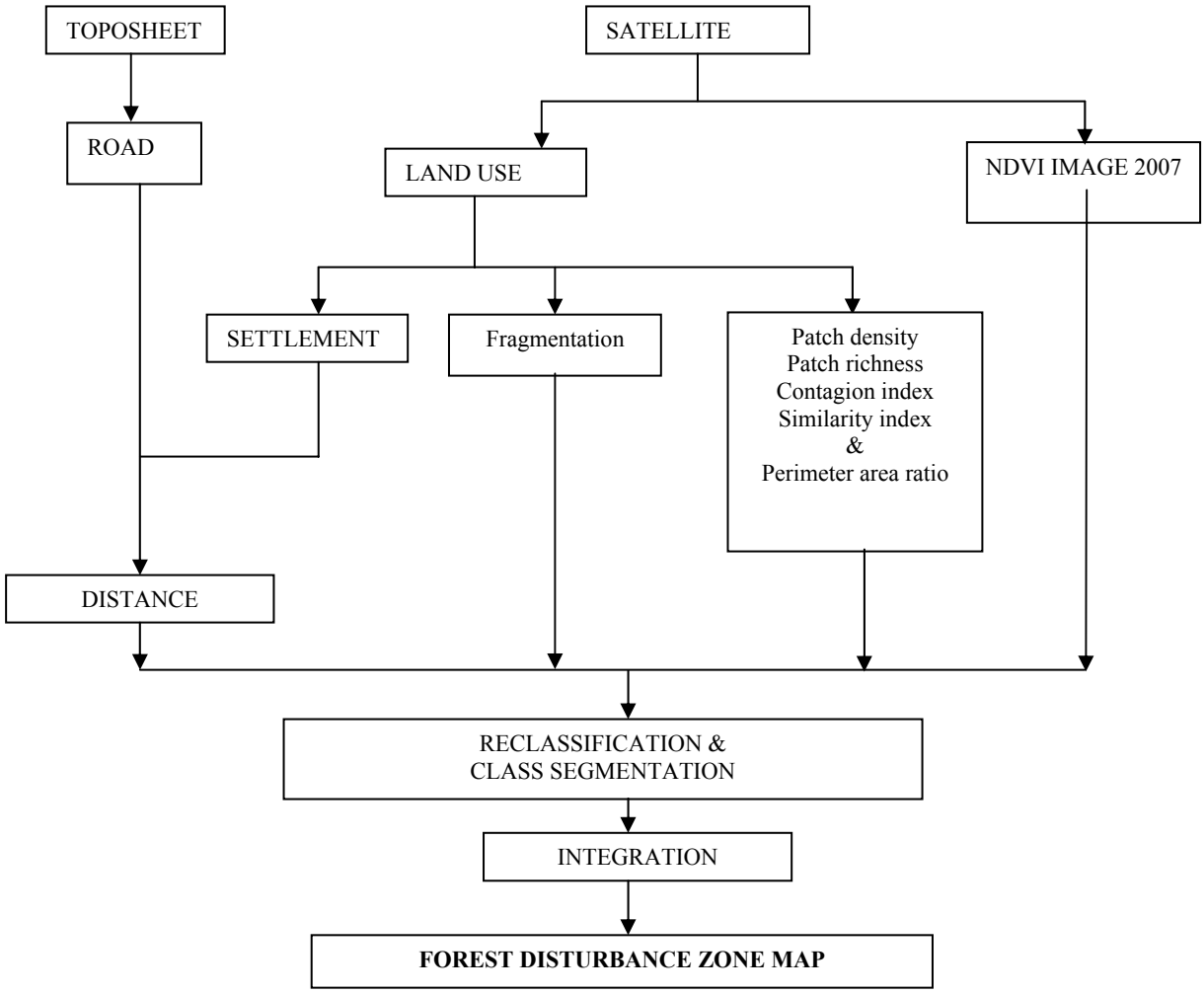

Fig. 1. Flow diagram for forest disturbance analysis

For the purpose of distance analysis available maps (SOI) were used to extract information on roads, village/settlements, etc. A variable buffering with respect to the radial distance from the point of disturbance is performed by imposition of a condition that "greater the distance lesser the weight", in other words, weight is set inversely proportional to the distance. Disturbance due to biotic/anthropogenic aspects was modeled in the GIS domain as biotic zoning. Integration of these inputs was modeled in ArcGIS for deriving a disturbance index. The road and settlement distance analysis was performed in this methodology.

A disturbance index has been computed for the study area by linearly combining fragmentation, porosity, interspersion, juxtaposition and proximity of road and settlements. Proximity analysis has been performed to correlate the spatial interrelationship in a horizontal plane. This relationship has been obtained from the analysis of buffer operations. Buffers have been generated for roads as well as village locations of the study area.

The thematic layers generated were subjected to raster calculation in the Spatial Analyst extension of ArcGIS 9.3 and by giving proper weights to each layer. The formula used for the analysis and integration of layers is expressed as:

DI = (Fragi x Wti1 + Porji x Wti2 + pati x Wti3 + peri x Wti4 + contag x Wti5+ sim x Wt6+ BDi x Wti7+ndvi x Wti8 +Prox sttle x Wti9 + road x Wti10) (1)

DI - disturbance index,
Frag - fragmentation,
Por - porosity,
Pat - patchiness,
Sim - similarity index,
Contag - contagion index,
Peri - perimeter area ratio,
Sttle - settlement disturbance.

The detailed methodology is given in the flowchart below.

4. Results and Discussion

The vegetation analysis and NDVI analysis of Shendurney wildlife sanctuary show that drastic forest cover changes occurred from 1971 to 2009. A large amount of evergreen forest has changed to semi evergreen and moist deciduous forests and this indicates that the sanctuary underwent severe disturbances during that period. Different types of disturbances affect the sanctuary, anthropogenic activities being the major ones. The periodic occurrence of forest fire and land cover change also contributed to disturbances. The forest cover change in the area is explained in Table 1.

Table 1. Land use land cover changes in Shendurney Wild Life Sanctuary in the period of 1971 - 2009

Land use type	Changes			
	1971		2009	
	Area (Km^2)	Area %	Area (Km^2)	Area %
Evergreen forest	62.46	36.42	39.7	23.17
Semi evergreen forest	6.91	4.03	9.79	5.71
Moist deciduous forest	58.7	34.23	69.35	40.47
Dry deciduous forest	16.37	9.55	22.44	13.09
Scrub forest	2.41	1.41	1.67	0.97
Open forest	0.19	0.11	3.34	1.95
Forest plantation	8.08	4.71	6.65	3.88
Water body	13.44	7.84	16.12	9.41
Built up	2.93	1.71	2.31	1.35

Results of the landscape matrices have revealed that Shendurney wildlife sanctuary is undergoing high disturbance. The results are classified into four classes viz, low, medium, high and very high. The role of different landscape parameters and their results are explained below.

Fragmentation is a measure of forest and non-forest per unit area (Radeloff et al. 2005). The fragmentation value ranges from 1 to 4 and it is reclassified into four zones. Moderately disturbed zone with their respective 84.67 km² and 25.61 km² zones is classified into low fragmented, medium fragmented and highly fragmented. The majority of the sanctuary lies in the low fragmented i.e. 130.93 km² area. There are 3.76 km² areas in the medium fragmented zone and 10.23 km² of the area fall in a highly fragmented zone.

Porosity is a measure of the number of patches or density of patches within a particular type. It provides an overall clue to the degree of species isolation present and to the potential genetic

variability present within flora and fauna population in a landscape.

Patchiness is a measure of density of patches of all types. In the area of Shendurney wildlife sanctuary the patches are uniform .The denser patchiness in an area, the lesser is biodiversity of the latter. The patch density value of the study area ranges between 1 to 4 and it was then reclassified into four classes: low patchiness class covering 129.28 km² and medium patchiness class covering 36.78 km² of the study area while high and very high classes cover 5.94 and 0.1, respectively

Perimeter-area ratio is a measure of the ratio of the patch perimeter to the area of a given mask. The perimeter area ratio value of the sanctuary ranges between 550-1250 and was then reclassified into four classes: low perimeter area ratio class covering 115.62 km² of the study area, medium and high class covering 28.75 km² and 26.22 km², respectively, while 1.91 km² area falls under a very high perimeter ratio.

Contagion index reflects dispersion (i.e. the spatial distribution) and intermixing of patch types. The contagion index value ranges from 0 to 120 and it was then reclassified into 4 classes. Low Contagion index class covers 93.84km² and medium class covers 37.23 km² of the study area where high and very high classes cover 35.94 km² and 4.56 km², respectively.

Similarity index quantifies the spatial context of a habitat patch in relation to its neighbors of the same or similar class and the similarity value is being assigned as per given weight. The similarity index value of the study area ranges from 0 to 7.5 and it was classified into 4 classes. Very low similarity index class covers 137.01 km² of the study area, medium class covers 6.25 km² and high class covers 9.81 km².

Disturbance index or biotic disturbance is due to human activity and its interaction with different land use affects forest disturbance (Ravan 2005). It is assumed that the villages and transportation network act as a catalyst, as the point source of disturbance. Therefore, proximity from the transport network and settlements is one factor for deriving the disturbance index. Table 2 shows the details regarding the result of different landscape parameters.

Table 2. Results of landscape analysis in Shendurney Wild Life Sanctuary

SL no:	Landscape metrics	Classes	Area (km2)	Area %
1.	Fragmentation	Low	151.66	88.43
		Medium	12.77	7.45
		High	6.95	4.05
		Very high	0.123	0.07
1	Patchiness	low	109.46	63.82
		medium	53.36	31.11
		high	8.51	4.96
		very high	0.18	0.10
2	Patch richness	low	109.46	63.82
		medium	45.32	26.42
		high	15.33	8.94
		very high	1.40	0.82
3	Perimeter area ratio	low	135.10	78.77
		medium	24.38	14.22
		high	11.12	6.48
		very high	0.91	0.53
4	Contagion index	low	120.57	70.30
		medium	18.27	10.65
		high	29.97	17.47
		very high	2.65	1.54
5	Similarity index	low	115.27	67.19
		medium	17.64	10.29
		high	11.16	6.50
		very high	9.06	5.28

Figure 2 shows the disturbance map of the study area. The disturbance index obtained is recorded in four levels of a gradient from low to moderate to highest. The disturbance ranged from 55 to 412 (Figure 2, Table 3). The majority of the sanctuary lies in the low disturbed and moderately disturbed zone with 84.67 km² and 25.61 km², respectively. The total of 17.36 km² area falls in a disturbed zone and 2.36 km² area falls in a highly disturbed zone. Low disturbance areas are characterized by low fragmentation, low porosity, low interspersion, low perimeter - area ratio, low patchiness and far from biotic disturbance. High disturbance areas are those where fragmentation is high with high porosity, high interspersion and proximity to biotic disturbance zones.

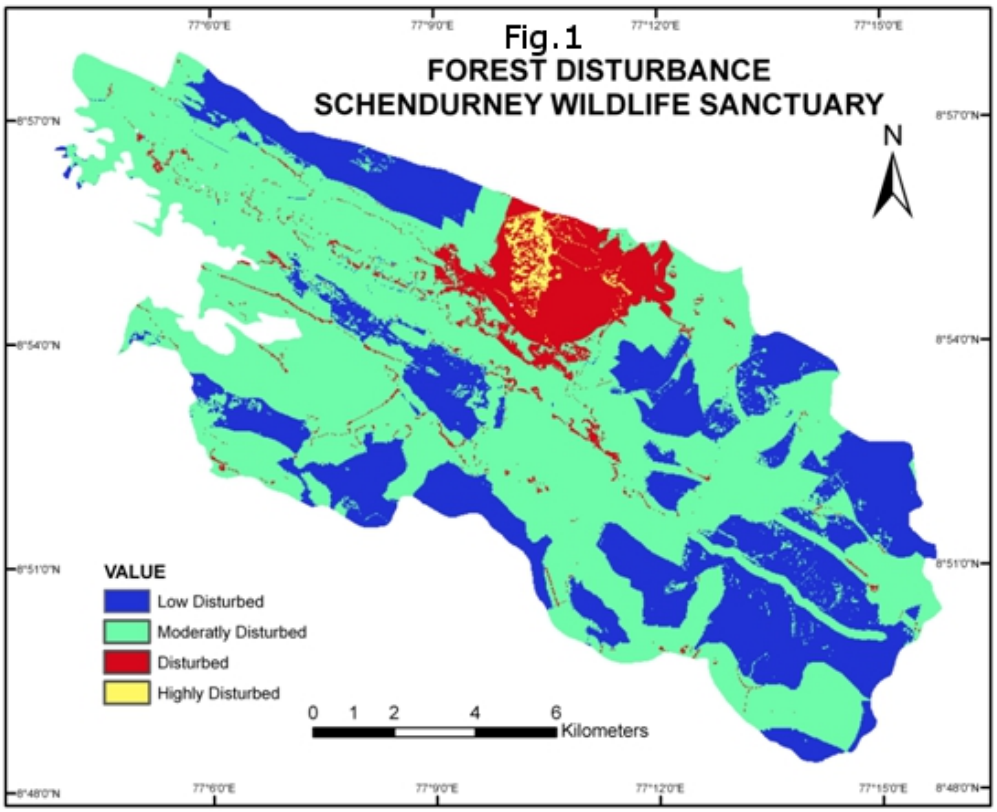

Fig. 2. *Forest disturbance Schendurney wildlife sanctuary*

Table 3. *Forest disturbance analysis*

Sl No	Classes	DI - Value range	Area In (Km)	Area In (%)
1	Low disturbed	55.0to 233.75	64.37	37.63
2	Moderately disturbed	233.75 to 412.25	79.04	46.21
3	Disturbed	412.5 to 591.25	22.61	13.22
4	Highly disturbed	591.25 to770	4.72	2.76

5. Conclusions

The loss of biodiversity has been attributed to habitat loss and fragmentation of forest ecosystem; the fragmentation analysis of the study area has revealed that 0.07% (0.123 km2) of the study area is highly fragmented. This means the sanctuary area is under pressure of forest fragmentation and in near feature the extent of fragmentation increases if no conservation practices are implemented. The study illustrates the stress on vegetation cover and helps understand the structure and composition of forest types at various disturbance levels. The final forest disturbance map generated for the sanctuary has revealed that 2.76 % (4.72 km2) of the forest area falls within a disturbed zone and only 37.63% (64.37 sq. km) area remains undisturbed. Anthropogenic disturbance greatly impacts the forest of the study area and this contributes to disturbance. The disturbance zone map has shown that much of the disturbance occurred adjacent to the settlement and road network.

The present study reveals that for sustainable management of Shendurney wildlife sanctuary preventive measures should be taken to reduce forest disturbance. The study has created an information base, which will help design conservation schemes for long term maintenance of biodiversity. Disturbed and highly disturbed zones in the sanctuary delineated by this study should have special management programs and measures should be taken to improve the vegetation cover in this region. Conservation and protection of the remaining evergreen forest patches should be the prime goal. The outcome of the analysis is useful for forest officers to plan management strategies toward sustainable forest management.

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