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Springer

J. Indian Soc. Remote Sens. (September 2010 : Special issue on Biodiversity and Landscape Ecology) 38 : 453-463

RESEARCH ARTICLE

Geospatial Analysis of Tamil Nadu Eastern Ghats Forest Types at Landscape level with reference to Fragmentation and Species Diversity

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Received: 11 November 2009 / Accepted: 01 April 2010

Keywords Landscape analysis · Forest · Species diversity · Tamil Nadu · Fragmentation · Disturbance

Abstract The present study has generated spatial databases on the vegetation type with plant biodiversity, forest fragmentation and disturbance regimes in Tamilnadu parts of Eastern Ghats (EG), India. These databases have been analysed geospatially with landscape ecology approach. The study also includes ground inventory of plant species based on Remote Sensing (RS) data stratification. The vegetation type map was generated from the visual interpretation of two season IRS LISS III data. The spatial landscape analysis of the remotely sensed interpreted images was carried out using customized software, SPLAM. This is first such study in Tamilnadu Eastern Ghats that provides a comprehensive spatial database on vegetation types, disturbance regime and plant species diversity. The study has shown that the dry deciduous and thorn forests have shown better resistance to disturbance compared to the most disturbed evergreen and semi-evergreen forests. The study outputs are being utilized by forest department and biodiversity boards for conservation action planning and compliance to Convention on Biological Diversity (CBD).

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Introduction

In fast-changing tropical landscapes, effective strategies for conservation must incorporate information on ecosystems and species distribution with that on landscape change (Nagendra, 2001).

While biodiversity is usually considered at the species level, maintenance of biodiversity requires management at higher levels of organization, particularly at the landscape scale. Conservation approach targeted at individual species is difficult and runs the risk of losing on ecosystem functions whereas, a landscape level management provides insight into both landscape diversity and species diversity and suggests a theoretical and practical basis for conservation planning. In many tropical forests a long history of human use has shaped up the current species patterns (Flenley, 1979; Horn and Sanford, 1992). Landscape ecology approach provides a framework to the study of the processes at different scales and time.

Satellite data at various resolutions allow assessing the changes in the forest area which is processed further to quantify and map forest disturbance (Turner and Gardner, 1991; Gustafson, 1998). Vegetation type and land-cover mapping of the entire north-east India, Western Himalayas and Western Ghats of India, were carried out at 1:250,000 scale using IRS LISS data (IIRS 2002). IRS, Landsat or SPOT imagery has provided finer-scale information on forest type distribution and agricultural expansion in India (Roy, 1994; Roy and Ravan, 1996). Satellite based spatial data are useful in many ways in biodiversity monitoring and conservation efforts. Datasets from IRS 1C/1D LISS-III have been used effectively in mapping the pure plant colonies of *Hippophae rhamnoides* in the Spiti region of India with prior knowledge of their occurrence and vegetation types of the area by using remote sensing (Roy *et al*., 2001). Remotely sensed data in conjunction with geographic information system has been successfully utilized to quantify forest loss as well as forest fragmentation (Jha *et al*., 2005). Lovejoy *et al*. (1983, 1984) have carried out a large-scale fragmentation study in Amazon forests.

The present study focuses on the vegetation distribution composition and associated disturbance regimes in the Tamil Nadu parts of Eastern Ghats of India. Very limited information is available on the floristic diversity of the southern Eastern Ghats. The mapping initiatives and phytodiversity of the study area is poorly documented (Rawat, 1997) focusing mostly on a few pockets (Pascal and Ramesh, 1995; Britto and Arockiaswamy, 2001). Ahmedullah and Nayar (1987) and Nayar (1996) have identified areas of endemic significance in peninsular India including the Shevaroy hills in Eastern Ghats of Tamil Nadu. Chittibabu and Parthasarathy (2001) have compared tree diversity in undisturbed and human-impacted tropical evergreen forest sites in the Kolli hills. Kadavul and Parthasarathy (2001) have studied the plant diversity, density, population structure and dispersion patterns in a semi-evergreen forest of Shevaroy hills.

Spatial information on forest cover and biodiversity are of primary importance for monitoring the efficacy of conservation measures. Given the above scenario, the present study has been carried with the objectives to:

a map major remotely sensed data amenable vegetation types in Tamil Nadu Eastern Ghats
b analyse floristic diversity of forest types through phytosociological inventory
c analyse the disturbance regimes associated with major forest types at a landscape level

Materials and methods

Study area

The southern part of Eastern Ghats comprise a chain of isolated hills running in a west-south-west direction situated between 11^0 13' and 12^0 40' N latitude and 78^0 00' and 79^0 10' E in Tamil Nadu state (Fig. 1). They extend from the borders of Andhra Pradesh to north of river Vaigai meeting the high mountain ranges of the Western Ghats in the Nilgiri belt. The natural vegetation Eastern Ghats is mostly restricted to individual hills namely the Chitteri, Shevaroys, Kalrayans, Javadis, Pacchaimalai, Kolli and the hills of Erode district. The Eastern Ghats range is commonly known as Eastern Ghats granulite belt in the geological nomenclature. The soils are of recent Pleistocene origin and consist of red laterite with loams on hills, ferruginous loam or ferruginous sandy and gravelly soils (Chauhan 1998). The elevation ranges from 240

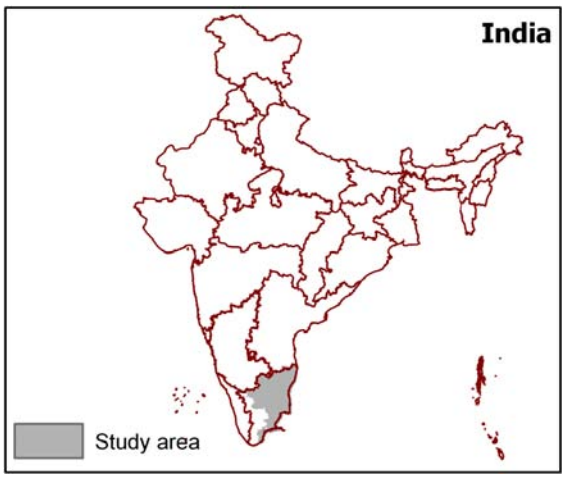

Fig. 1 Study area showing Eastern Ghats and East Coast districts of Tamilnadu

to 1700 m with annual rainfall of 900 to 1500 mm. Most of the rainfall is received from the convection movements and depressions in the Bay of Bengal with peaks in October (Pascal and Ramesh, 1995).

The major forest type is the southern tropical dry mixed deciduous forest occurring throughout the area. There are numerous patches of the tropical semi-evergreen forests, the moist mixed deciduous forests, the tropical riparian fringing forests (Champion and Seth, 1968). Tropical dry evergreen forest, mostly existing as isolated patches of very small sizes is unique to the coastal districts.

Methodology

Vegetation type map

On screen visual interpretation on the basis of image elements, like size, shape, pattern, association, tone and textural variations correlated with ground information were employed for the preparation of vegetation type map (Lillesand and Keifer 1999). The major phenological and physiognomic forest classes were interpreted at 1:50,000 scale using two season satellite data of IRS P6 LISS III for the months of November - December 2004 and February-May 2005 in conjunction with the Global Positioning System locations, Survey of India topo-sheets of and other ancillary information (IIRS, 2002). The Champion and Seth (1968) classification were referred in the vegetation classification scheme for identifying the major phenological types and were suitably rationalized for classes observed in the field and were amenable with the satellite remote sensing data. The interpretation accuracy was evaluated by field checking of the interpreted polygons. Adequate number of ground points were collected all over the study area using Global Positioning System (GPS) for validating the interpretation. Quality assurance and quality control was conducted as per the National Remote Sensing Centre, India, Standard Operational Protocol (2009) and the inputs were incorporated.

Sampling strategy

Stratified random sampling with probability proportion to the size was adopted for analyzing the vegetation composition of all the forest types encountered. Based on biodiversity studies in the area (NRSA 2007) a low intensity sampling of 0.002% of the area was carried out. Nested quadrat method was used for shrub and herb sampling. A total of 501 quadrats of 20×20 m size in proportion to the area interpreted were laid after preparation of forest type maps. For shrubs one plot of 10×10 m, and for herbs five 1×1 m plots were laid within the main plot. All living adult trees with diameter >30 cm girth at breast height (gbh) were identified and measured. Multi–stemmed tree bole girths were measured separately. Lianas were separately enumerated. Individuals with gbh >30 cm were considered as tree and those with gbh >17 cm but <30 cm gbh as saplings.

Species richness

For species diversity the Importance Value Index (IVI), and the Shannon-Wiener Index (H′) was calculated based on the IVI value, of plant species in different categories (Shannon and Weaver, 1963).

$$H' = -\sum_{i=1}^{S} pi \ln pi \quad (1)$$

where, '$p_i = n_i/N$', where n_i is importance value or number of species and 'N' is total IVI or total number of species in that habitat type.

Disturbance Regime analysis

Disturbance regimes and their impact on communities and landscape can be well understood by analyzing spatial and temporal architecture of disturbance (Moloney and Levin, 1996). At landscape level, disturbance is related to patch structure and spatial arrangement and determines the fate of patches, their size and duration. Measurements of landscape diversity are analogous to common measurements of species diversity (Whittaker, 1960, 1972). The disturbance Index was computed by adopting a linear combination of the following parameters on the basis of probalistic weightages (however equal weightage was given for all the parameters as default value in the software)

Disturbance Index (DI) = Σ {Fragmentation × Wti1 + Porosity × Wti2 + Interspersion × Wti3 + Biotic disturbance buffer × Wti4 + Juxtaposition × Wti5}

All these parameters excepting human disturbance were derived through GIS analysis of vegetation type map. Fragmentation is the number of patches of forest and non-forest type per unit area. Porosity is the measure of number of patches or density of patches within a particular forest type. Interspersion is a count of dissimilar neighbors with respect to central pixel or measurement of the spatial intermixing of the vegetation types.

Juxtaposition is defined as measure of proximity of the vegetation. Available maps (Survey of India) were used to extract information on roads, village/ settlements, etc. to create a biotic disturbance buffer. ERDAS Imagine 8.7, Arc GIS 9.0, EstimateS (Colwell 2005), MS Excel, SPSS 10.0 and SPLAM software packages (IIRS 2002) were used for vegetation type mapping and analysis of phytosociological data.

Results and discussion

Land cover and land use

Figure 2 shows the vegetation type map of the study area and covers 20 districts of the Eastern Ghats and East Coast area of Tamil Nadu. A total of 93121 km^2 of area was interpreted of which 15.85% of total geographic area is under forests, scrub and plantation. Among the rest 4.04% of total geographic areas are under orchards/tree groves, 67.82% under agriculture, 5.98% barren, 4.63% water bodies and 1.66% settlements.

Forest types

A total of 14,760 km^2 or 15.85% of total geographic area is under forests, scrub and plantation. Dry mixed deciduous is the dominant vegetation type comprising 19.25% of the total forest area. Another major class is the dry deciduous scrub forest. Moist deciduous forests comprise 7.78%, semi-evergreen with 1.81% and grasslands with 2.00%. Tropical Evergreen comprises 1.63% of the above category. Tropical evergreen forests encountered in the study area are an inferior edition of the tropical wet evergreen (1A/C_3), as described by Champion and Seth (1968), in structure and composition. The canopy was low without significant stratification. Tropical semi-evergreen forests are prominent on shallow red soils on flat plateaus atop hills and appeared as intermediate between the tropical wet evergreen and moist deciduous forms. Undergrowth was more copious as compared to evergreens. Moist deciduous forest existed in areas conducive for dry deciduous forest but still retained an evergreen under storey. The forest had somewhat irregular top storey of predominantly tall deciduous trees. Bamboo undergrowth as plantation and naturally occurring was characteristic.

Floristic diversity and dominance of species

This present study has contributed comprehensively in terms of inventorying the large number of herb, shrub and tree species for the entire Tamil Nadu part

Table 1 Phytosociology of different vegetation types from inventory plot data

	Evergreen	Semi-Evergreen	Moist Deciduous	Riparian	Dry Mixed Deciduous Forest	Southern Thorn Forest
Tree density ha^{-1}	500	418	327	227	315	127
Basal area ha^{-1}	36.86	18.05	18.03	19.83	11.39	2.33
No. of tree species	35	60	142	30	266	50
Shannon-Weiner Index	4.486	4.695	6.059	3.941	4.071	2.803

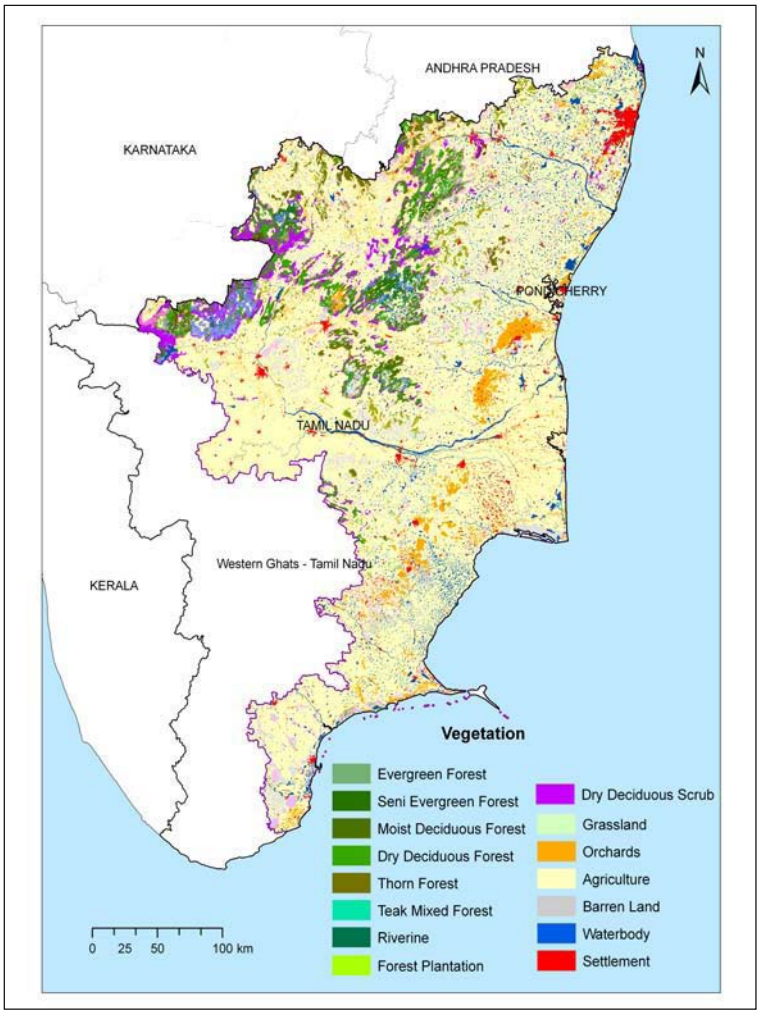

Fig. 2 Vegetation type and land cover of Eastern Ghats and East Coast districts of Tamil Nadu

of Eastern Ghats. The moist deciduous forest type with a total of 412 species and 142 tree species exhibited maximum species diversity. A total of 35 tree species were inventoried from the phytosociological data from the evergreen plots. Though evergreen forest had very small area coverage, it had a high stem density of 500 stems ha^{-1} and also had the highest basal area of 37 m^2 ha^{-1} (Table 1). Similarly, semi-evergreen forest recorded next highest stem density (418 stems ha^{-1}). However, its basal area was in the same range as of the moist deciduous and riparian forest. Due to luxuriance of moisture conditions, trees in the riparian forest had developed thick boles and thus a larger basal area. The evergreen system in the study area was relatively species poor. Still, the evergreen and semi-evergreen forests showed high values of Shannon-Wiener index *viz.,* 4.49 and 4.67 respectively. This indicated high evenness even with less number of species. 44 out of 119 species were singletons in case of the evergreen forests.

Landscape analysis

The landscape metrics provides an understanding in order to quantify different aspects of landscape structure (Haines – Young and Chopping, 1996). Table 2 gives the area statistics along with the indices such as the number of patches, the average patch size. The largest average patch size is that of by southern thorn and the least area is occupied by evergreen forest patches. Similarly the dry deciduous has the maximum size of the patch and the evergreen has the least. The statistics shows that the dry deciduous/southern thorn has the maximum resilience to disturbance and the evergreen has the least. The spatial distribution of qualitative fragmentation levels (Fig. 3) and qualitative disturbance (Fig. 4) resulted from the landscape analysis. The evergreen forests covered an area of 240 km^2 that was 0.26 % of the total geographic area of the Eastern Ghats of Tamil Nadu. Maximum area of 3,815 km^2 was covered by dry deciduous forest which showed comparatively less disturbance. 50% of the area of evergreen forests was found to be highly or moderately disturbed (Fig. 5).

Landscape mapping in terms of fragmentation, patchiness, interspersion, porosity and juxtaposition was done by running a spatial grid over vegetation type map. The fragmentation statistics was analyzed forest type wise and categorized into high (H), medium (M), and low fragmentation (L) areas. The disturbance map also has been qualitatively categorized into high, moderate and low areas. The area statistics under various vegetation types has shown high disturbance in evergreen forests of 13.79% followed by 10.51%, 10.29%, 9.62% and 4.4% for moist deciduous, southern thorn, semi-evergreen forests and dry mixed deciduous forests respectively.

Discussion

Vegetation mapping provides relevant information for effective management of natural resources, especially for the conservation of biodiversity (Stoms, 1992). The vegetation map shows the presence of evergreen, semi-evergreen forest types in numerous isolated and fragmented patches on the hills. The evergreen in the area includes elements typical of both the tropical wet evergreen forests as well as the tropical dry evergreen forests.

Our ground inventory based on satellite data based stratified sampling design has recorded large number of plant species in different forest types. The results have contradicted the general belief about the study area as being species deficient as the forest types exhibited high species diversity. The number of coexisting species in an area is both a function of local and regional processes whose relative influence varies over time (Mouquet *et al*., 2003). Many tree species as *Memecylon edule, Canthium dicoccum, Strychnos nux-vomica, Anogeissus latifolia, Chloroxylon swietienia,* etc. were distributed across nearly all forest types and disjunct set of hills. Since limit to local species richness is set by the degree of regional heterogeneity and the dispersal between communities (Mouquet and Loreau, 2002), it is evident that low elevation of the hills failed to form an effective barrier for the dispersal of species. The high species richness is a reflection of the diversity of the regional

Table 2 Patch features of major forest types of Eastern Ghats of Tamil Nadu

	Evergreen	Semi-Evergreen	Moist Deciduous	Dry Deciduous	Southern Thorn
Number of patches	183	121	659	1458	466
Maximum size of patch (km^2)	24.2	58.9	84.5	329.1	92.5
Average size of patch (km^2)	1.3	2.2	2.0	2.6	3.2
Total area (km^2)	239.9	265.5	1340.5	3815.0	1490.2
Standard deviation	2.9	5.9	6.0	10.6	7.5

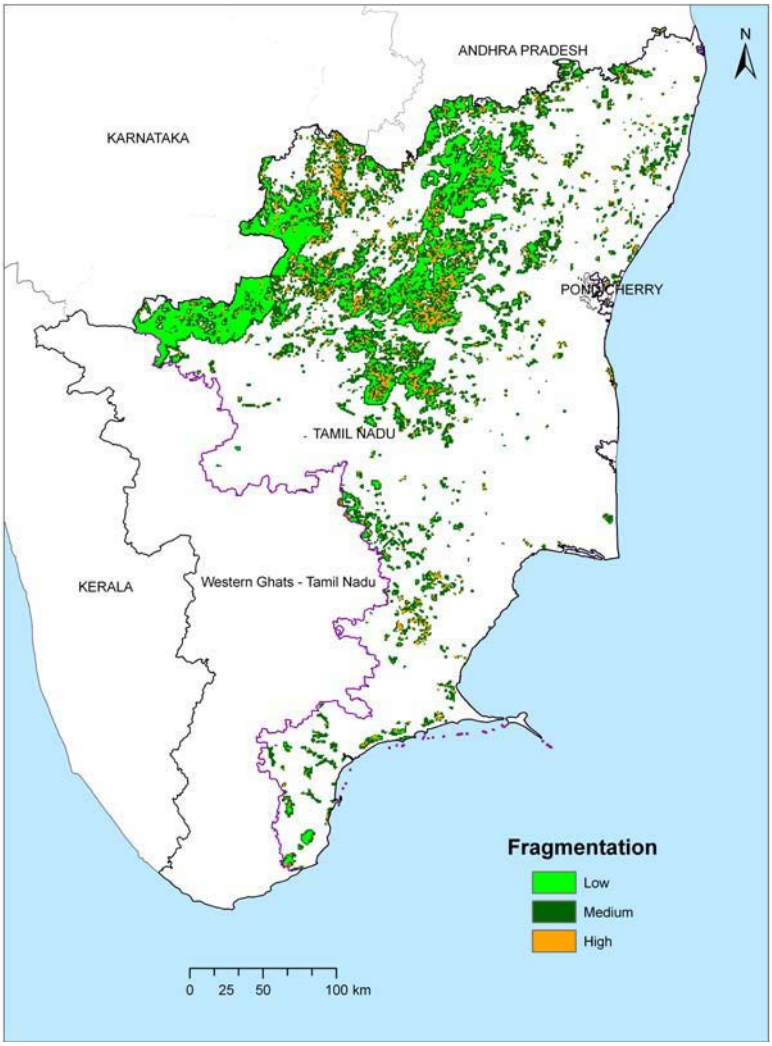

Fig. 3 Qualitative forest fragmentation map of Eastern Ghats and East Coast districts of Tamil Nadu

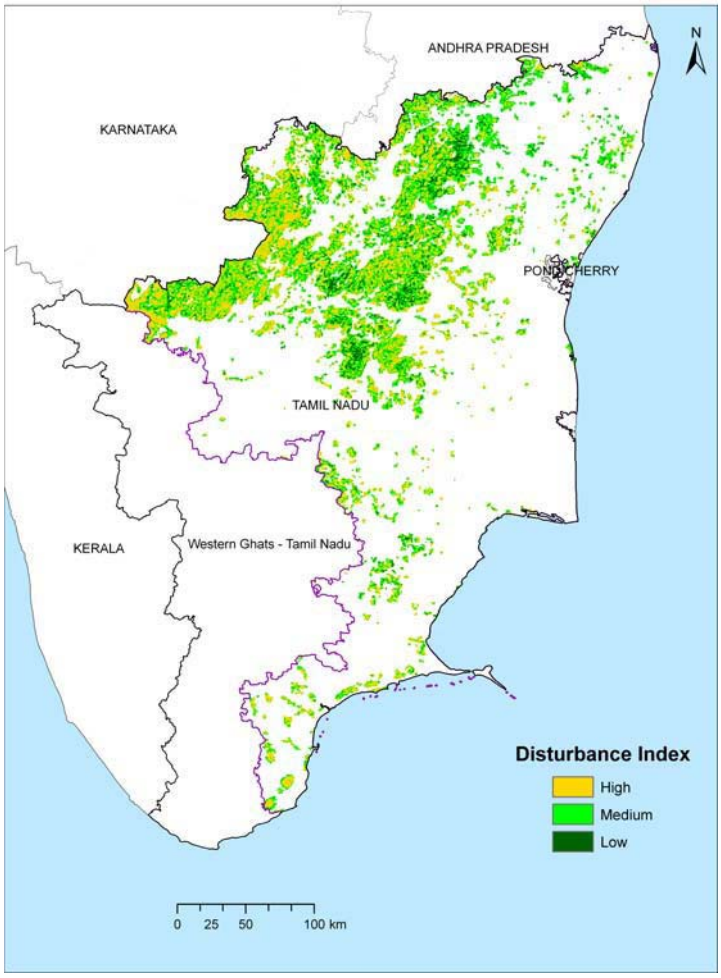

Fig. 4 Qualitative disturbance regime map of Eastern Ghats and East Coast districts of Tamil Nadu

pool, which comprises the existing species of the Eastern Ghats and the East Coast. It can be presumed that high levels of disturbance in the area have prevented local scale saturation particularly in case of moist deciduous systems (Karlson and Cornell, 2002).

The dry mixed deciduous and moist mixed deciduous systems have shown higher species rich and less disturbed or disturbance resistant systems as compared to the evergreen and semi-evergreen systems. The analysis suggests the moist deciduous forests being the transitional zones recorded high and very high levels of biological richness. This may be due to higher degree of species flow in this type because of the possibility of large number of niches.

Disturbances, both human-induced and natural, shape forest systems by influencing their composition, structure, and functional processes and leads to the processes like fragmentation, migration, local and regional extinction. Fragmentation has a strong influence on the dynamics and fate of the material and energy moving across a landscape. There

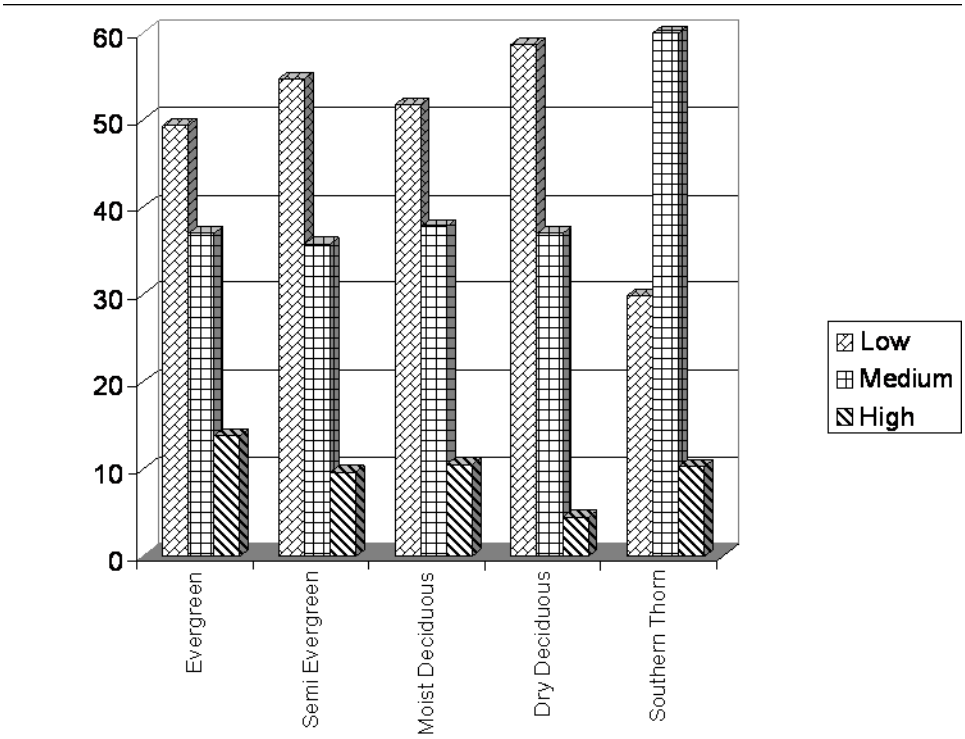

Fig. 5 Disturbance Index in major forest types of the study area

is a paucity of basic information on the frequency, intensity, and spatial extent of some disturbances and their impacts on forests. Currently ecosystem-based approaches to practical problems in conservation suffer from vagueness and circularity (Goldstein, 1999). Landscape models focus on disturbance as well as ecological processes. The transitional dynamics of the landscape can be incorporated into assessment of viability and threat by combining methods of landscape prediction with those of metapopulation simulation. Forest fragmentation patterns and species diversity can be analysed for various plant communities in temporal domain (Goparaju and Jha 2010). The high levels of disturbance indicate that major conservation efforts are required for saving evergreen and semi-evergreen ecosystems of the study area.

Conclusion

The Eastern Ghat hills in Tamil Nadu harbors diverse flora. Though endemicity is not high, the forest ecosystems particularly the evergreens found here are unique as they are found at low elevations receiving low rainfall. A number of factors such as climate change, forest fires, grazing, etc. act in conjugation so as to effect the progressive drying of the environs. The area has been long colonized by human beings and the native flora and has faced much destruction and exploitation over the years. Study of various abiotic factors in relation to biodiversity and their ecological relationship with each other helps in the analytical assessment of the status of vegetation. This in turn would result in the formulation of suitable measures for *in situ* conservation and management plans. It is important to consider ways in which

impacts to forest systems can be mitigated under likely changes in disturbance regimes. The knowledge of how climate affects disturbances and how forests respond to them should lead to better ways to predict and cope with disturbance-induced changes in forests.

Acknowledgments

This research was funded by the Department of Biotechnology and Department of Space, Government of India project on Biodiversity Characterisation at Landscape level in Eastern Ghats and East Coast using RS and GIS. We are grateful to V. Jayaraman, Director, NRSC, P.S. Roy, Dean, IIRS and Associate Director, NRSC; and Project Director, DBT-DOS project, NRSC for the direction and necessary facilities to carry out the project. We thank R.S. Dwivedi, GD (LRG) for encouragements and technical support. We acknowledge the contributions of M.S.R. Murthy, Head Forestry and Ecology Division, NRSC and project coordinator, (EG) for his contribution in landscape analysis and overall project work progress. We thank Sudhakar Reddy and Shivam Trivedi Scientists at NRSC, for their help in database creation.

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