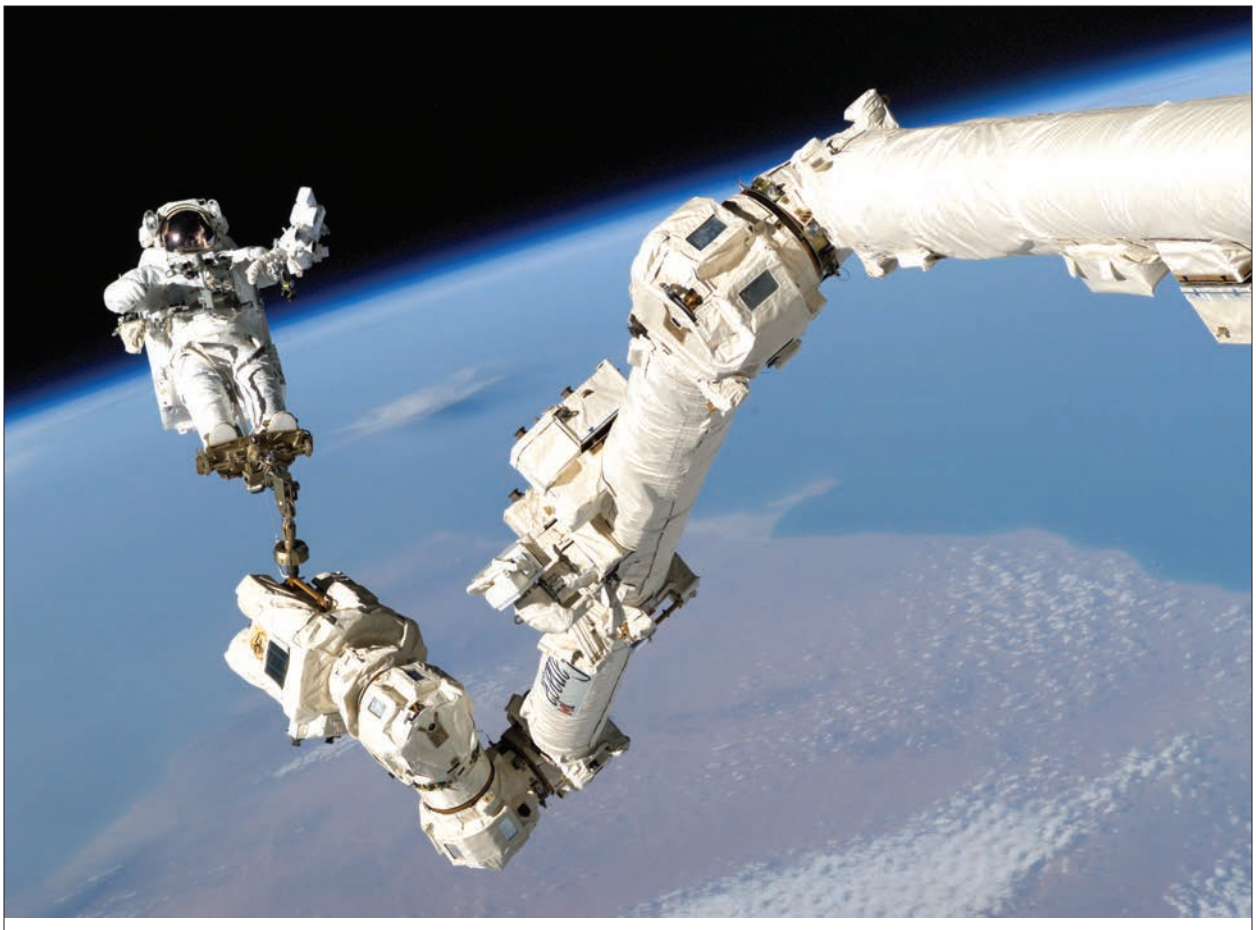

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Vegetation Cover Mapping and Landscape Level Disturbance Gradient Analysis in Warangal District, Andhra Pradesh, India Using Satellite Remote Sensing and GIS

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Abstract: Landscape fragmentation has been identified as fundamental reason for biodiversity loss. Satellite remote sensing data and Geographic Information System have been used to spatially model the disturbance regimes and to integrate the ground based non-spatial data with the spatial characters of the landscape in Warangal district of Andhra Pradesh, India. Disturbance index has been computed for the study area by linearly combining fragmentation, porosity, interspersion, juxtaposition and proximity of road and settlements. Of the eight natural forest types, moist deciduous forests have shown low fragmentation (78.40% of area). Over all disturbance gradient analysis indicates 52.74% of the total forested areas are under low disturbance, followed by 28.04% under medium and 19.22% under high. The present approach of disturbance gradient analysis provides insight into the disturbance status of forest which is useful for forest management.

Key words: Landscape, fragmentation, disturbance index, phytodiversity, Warangal, India

INTRODUCTION

Vegetation is very important natural resource which provides basis of life to fauna in one way or the other. Land use and Land cover refers to the physical characteristics of earth's surface, captured in the distribution of vegetation, water, soil and other physical features of the land, including those created solely by human activities (Louisa and Antonio, 2001). The conventional species level approach has limitations in understanding the priorities of biological conservation and management has resulted in policy shift from conservation of single species to their habitats (Kempf, 1993). Mapping the distributions of vegetation cover types and land use/land cover provides critical information for managing landscapes to sustain their biodiversity and the structure and function of their ecosystems.

Landscape analyses at broad spatial scale are becoming increasingly important for biodiversity conservation. Landscape fragmentation has been identified as fundamental reason for biodiversity loss. Fragmentation of ecological units have been well documented at landscape level using patch size, shape, abundance and forest matrix characteristics (Forman and Godron, 1986; Lehmkuhl and Ruggiero, 1991; Shirish and Roy, 1997). The ecosystem degradation and patch characteristics are found to be associated with the degree of spatial fragmentation (Turner, 1987; Ludeke *et al*., 1990; Roy *et al*., 1997).

In India, only limited studies have attempted to establish the relationship between the disturbance and the biodiversity of the landscape (Roy *et al*., 1997). The patchiness or fragmentation of forests is an important consideration in biodiversity characterization. Menon and Bowa (1997) have discussed

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the application of GIS, remote sensing and landscape ecology approach for biodiversity conservation in the Western Ghats. The approach has modeled land cover/land use changes for habitat fragmentation. However, the study did not use important landscape parameters like interspersion, fragmentation, porosity, juxtaposition and disturbance index. Ramesh *et al*. (1997) recommended the landscape approach that takes into account the distribution of vegetation types, tree species richness and uniqueness of the habitats. However, the study did not include the proximity analysis of the source of disturbance, which results in the disturbance regimes at landscape level.

The tropical deciduous forests are threatened ecosystems because of their immense potential value for timber, fuel wood, food and medicine. In the present study efforts have been made to use the remote sensing data and GIS techniques for mapping and study of the tropical deciduous vegetation types and other land use of the Warangal district. Remote sensing data has been used primarily to stratify habitats, vegetation types, land use and their association. Geographic Information System has been used to spatially model the disturbance regimes and to integrate the ground based non spatial data with the spatial characters of the landscape.

The present approach of disturbance gradient analysis using geospatial techniques provides insight into the disturbance status of forests of Warangal district, which is useful for forest management and biodiversity conservation.

MATERIALS AND METHODS

Study Area

The Warangal District of Andhra Pradesh, India lies between 17°19' and 18°13' north latitudes and 78°49' and 80°43' east longitudes, under Deccan Plateau physiographic zone. It is bounded on the north by Karimnagar district and Chattisgarh State, on the west by Medak district, on the south by Nalgonda district, on the East and North East by Khammam district. The total geographical area of the district is 12, 846 km^2 and a population of 3, 246, 004 of which 19.20% were urban. As per state of forest report (Anonymous, 2003), the forest cover of the district is 3,102 km^2 (Dense forest: 2345 km^2 and Open forest 757 km^2).

The Warangal district represents a variety of geological formations and contains rich deposits of economically important minerals. The rock formations are maiuly divided into four geological formations, i.e., Archeans, Gondwanas, Puranas and Recent (Alluviums). The district of Warangal exhibits climatic variation. The district receives South West and North East monsoon rains and summer showers. The district exhibits clear rainfall zonation from West East (764 mm) to North East (1096 mm). There is no remarkable difference in the temperature, as the district on the whole tends to be dry. The maximum and minimum temperatures have been recorded as 42.9 and 16.2°C, respectively. Warangal is predominantly an agricultural district with a large number of artificial lakes and the river Godavari. The predominant crop grown in the district is Paddy, which accounts for 34% of the total cropped area. Cotton, Maize, Chilli, Groundnut, Green grams, Castor and gingelly are other important crops grown in the district, The district represents two protected areas, namely Pakhal Wildlife Sanctuary (839 km^2) and Eturnagaram Wildlife Sanctuary (806 km^2) declared during 1952-53. Earlier, it is a well known *Teak* predominant area (*Tectona grandis*). There is a clear sign in the field that, even remnant teak forests are also under severe threat due to illegal cutting. The number of recorded flowering plant species in the district were 1208 (Reddy, 2001).

Ground Data

Field studies were carried out during 2004-2006, to cover overall spectrum of vegetation and land use and also to account species diversity in each vegetation type. A total of 152 phytosociological sample points (each 0.04 ha.) were laid down with sampling intensity of 0.002%

based on stratified random sampling method. Intensive ground truth data has been used to develop the interpretation criteria for stratifying forests into different vegetation types.

Phytosociological data *viz*. relative frequency, relative density and relative dominance have been collected to compute the Importance Value Index (IVI) for each vegetation strata. IVI has been utilized to calculate species diversity using Shannon-Wiener index.

Remote Sensing Data

Indian Remote Sensing P6 (IRS P6) Linear Imaging Self Scanning III two season data acquired on 7th January 2004 and 12th April 2004 have been used in the study (path/row 100/61, 101/61). The orthorectified Landsat Enhanced Thematic Mapper + (Landsat ETM+) data (with UTM projection) downloaded from GLCF website (http://glcf.umiacs.umd.edu/) was used as reference for georectification using ERDAS IMAGINE 9.0. The ancillary data were from field (using Global Positioning System), the Survey of India (SOI) topographical sheets of 1:50,000 scale and Landsat ETM + data of November 1999. The extracted False Colour Composite (FCC) images of study area are shown in Fig. 1 and 2.

This satellite data has been visually interpreted to prepare vegetation and land use map. Vegetation type classification given by Champion and Seth (1968), with some modifications is followed. The different vegetation cover type (forest types and scrub) and land use categories (agricultural fields, barren lands, orchards and water bodies) were delineated on the basis of tone, texture, colour, phenology and physiognomic pattern on 1:50,000 scale.

Landscape Analysis

Spatial Landscape Analysis Model (SPLAM) developed at Indian Institute of Remote Sensing (IIRS), Dehradun (Roy *et al.*, 1999) is portable to all window-based environments. SPLAM is a program generated for the analysis of porosity, interspersion, fragmentation, juxtaposition, terrain complexity, disturbance index and biological richness. SPLAM uses a generic binary image as the input and the output is also written in the same format. It has the flexibility to use a variable grid size.

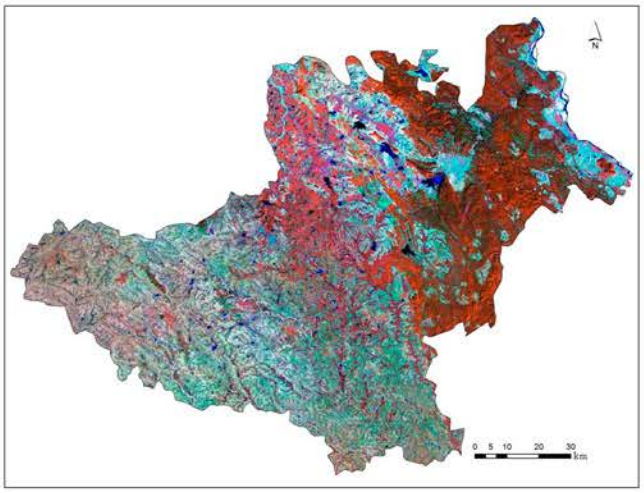

Fig. 1: IRS P6 LISS III False Colour Composite image of Warangal district, Andhra Pradesh, India (7th January, 2004)

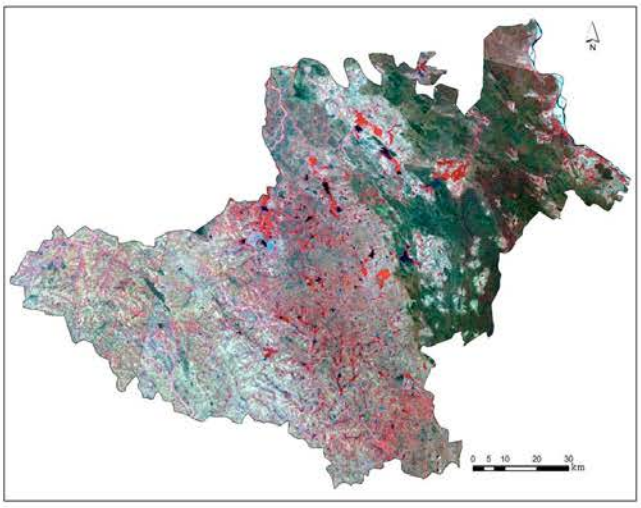

Fig. 2: IRS P6 LISS III False Colour Composite image of Warangal district, Andhra Pradesh, India (12th April, 2004)

The grid size for landscape analysis has been determined by employing a variable grid cell convolution on the spatial data. An initial size of 100 m cell has been used with an increment of 100 m. The grid size, where number of patches becomes constant, is used for the analyses. The grid size of 500 m has been used for landscape analyses in the present study. The various landscape parameters used for the analysis are: fragmentation, porosity, interspersion and juxtaposition. Fragmentation is number of patches of forest and non-forest type in per unit area. It reduces the size and quality of habitat. Porosity is the 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. Interspersion is the measure of spatial intermixing of habitats/land use and is calculated in a non species-specific manner. It is calculated as the number of surrounding grid cells that differ from the central cell. It represents the heterogeneity or homogeneity of the landscape and hence represents landscape diversity. Juxtaposition is the proximity of the patches determines the intensity of disturbance. Hence, the proximity of natural and man made vegetation types have been evaluated through juxtaposition. Juxtaposition is the measure of proximity or adjacency of the vegetation types and hence is a type/species specific measurement. Juxtaposition of the central grid is calculated by comparing the class of the central cell with an adjacent cell as per the weighted preferences of the species and biodiversity values of the vegetation/land use type.

Disturbance Index (DI)

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 at an interval of 500 m for 5 km. For disturbance index analysis negative weights have been assigned to the buffers.

The spatial representation of disturbance has been calculated by combining landscape elements and disturbance sources as per the following expressions:

$$DI = \int \{\text{fragmentation, porosity, interspersion, proximity from disturbance sources (settlements + roads) and juxtaposition}\}$$

$$\text{i.e., } DI = W1i * F + \sum_{j}^{k}(W2i * Pj) + W3i * I + W4i * B + W5i * J$$

Where,

Wsi : (s = 1,5) are the adaptive probabilistic weightages

Pj : (j = 1, k) are the derived porosity values

The final spatial data has been scaled to a range of 0-100 for final preparation.

RESULTS AND DISCUSSION

Mapping of Vegetation and Land Use

From vegetation and land use map, it may be seen that agriculture fields (incl. fallow lands) constitutes 62.22% of total area, while the forest, scrub, water bodies and barren lands covers 24.38, 5.65, 3.47 and 3.28% area respectively (Fig. 3 and Table 1). Among the nine forest types delineated, dry deciduous and moist deciduous forests were distinct phenological formations, riverine forests were locale specific seral formations, savannah is degradational stage, while *Boswellia*, *Cleistanthus*, *Hardwickia* and Teak (*Tectona*) forms gregarious forest formations. Forest plantations are man made category consisting of Teak.

Of the total forest cover of 3,132 km^2, dry deciduous forest type is composed of 82.01% of area. The second most abundant forest type was moist deciduous forest (10.03% of area) (Table 2).

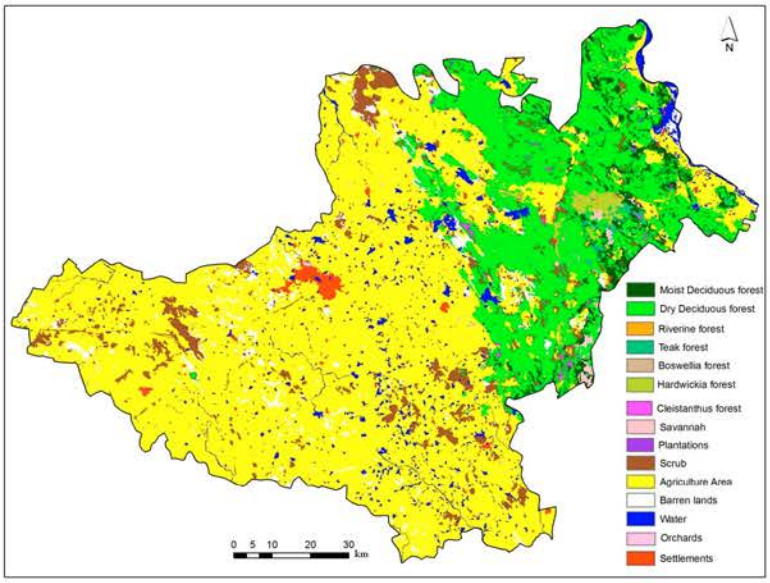

Fig. 3: Vegetation and land use map of Warangal district, Andhra Pradesh, India

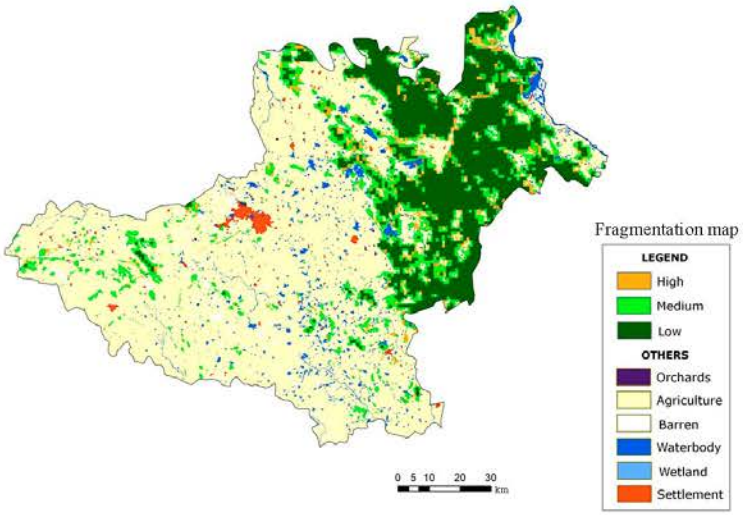

Fig. 4: Fragmentation map of Warangal district, Andhra Pradesh, India

Table 1: Vegetation and land use statistics of Warangal district

Category	Area (km^2)	Area (%)
Forest	3132.00	24.38
Scrub	726.020	5.65
Orchards	10.2500	0.08
Agriculture area	7993.18	62.22
Barren lands	421.440	3.28
Settlements	116.930	0.91
Water	445.910	3.47
Total	12,8460	100.00

Table 2: Forest types of Warangal district

Forest type	Champion and Seth equivalent type	Area (km^2)	Percent of forest area
Moist deciduous forest	Tropical Southern moist mixed deciduous forest	314.10	10.03
Dry deciduous forest	Tropical Southern dry mixed deciduous forest	2568.78	82.01
Riverine forest	Tropical Southern dry riverine forest	22.04	0.70
Boswellia forest	Boswellia forest	4.27	0.14
Cleistanthus forest	-	27.61	0.88
Hardwickia forest	Hardwickia forest	102.28	3.27
Teak forest	Dry teak forest	42.64	1.36
Savannah	Dry Savannah	44.90	1.43
Forest plantations		5.64	0.18
Total		3132.00	100.00

Variability in rainfall pattern of the district from Northeast to South and Southwest, vegetation change is apparent. In the Southern and Westerly directions, rainfall decreases in the rain shadow parts resulting in gradually more drier vegetation formations like *Hardwickia* and *Scrub* types. Importance Value index of dominant species and characteristics of forest types were shown in Table 3 and 4.

Mapping of Disturbance

Landscape analysis in terms of fragmentation, interspersion, porosity and juxtaposition was done using spatial analysis of vegetation type map generated using remote sensing data. Fragmentation analysis was carried out by recoding all the forested classes and non-forest classes into two categories. Figure 4 shows the ground in terms of low to high fragmentation areas on

Table 3: Importance value Index of dominant species of forest types moist deciduous forest

Species	Relative density	Relative frequency	Relative dominance	IVI
Moist deciduous forest				
Dillenia pentagyna	8.68	4.44	15.71	28.83
Terminalia alata	8.85	6.14	13.57	28.57
Lannea coromandelica	1.39	1.37	4.70	7.45
Nyctanthes arbor-tristis	3.99	1.71	1.17	6.87
Bridelia retusa	2.08	2.39	1.60	6.08
Dry deciduous forest				
Terminalia alata	8.86	4.99	10.43	24.28
Diospyros melanoxylon	7.61	5.65	10.51	23.77
Anogeissus latifolia	6.52	4.61	9.05	20.18
Xylia xylocarpa	6.93	5.27	7.38	19.58
Lagerstroemia parviflora	7.17	4.71	5.81	17.69
Riverine forest				
Terminalia arjuna	9.91	8.33	30.67	48.91
Barringtonia acntangula	23.42	8.33	12.56	44.32
Syzygium cumini	14.41	5.56	11.51	31.48
Strychnos nux-vomica	2.70	5.56	5.63	13.89
Strychnos potatorum	7.21	5.56	0.98	13.74
Boswellia forest				
Boswellia serrata	40.82	11.11	54.64	106.57
Chloroxylon swietenia	16.33	11.11	5.90	33.34
Lannea coromandelica	6.12	5.56	4.50	16.18
Sterculia ureus	6.12	5.56	3.46	15.14
Albizia odoratissima	4.08	5.56	3.36	13.00
Hardwickia forest				
Hardwickia binata	30.84	14.29	41.50	86.63
Anogeissus latifolia	14.95	10.71	19.87	45.54
Dalbergia paniculata	10.28	7.14	3.30	20.72
Lannea coromandelica	6.54	7.14	2.06	15.75
Givotia rottleriformis	2.80	3.57	7.63	14.01
Teak forest				
Tectona grandis	37.27	12.50	19.21	68.98
Terminalia alata	13.04	3.57	6.05	22.67
Lagerstroemia parviflora	4.35	5.36	2.40	12.10
Lannea coromandelica	0.62	1.79	9.11	11.52
Diospyros melanoxylon	4.35	3.57	1.43	9.35
Cleistanthus forest				
Cleistanthus collinus	29.60	5.13	7.40	42.13
Diospyros melanoxylon	24.80	4.26	2.54	31.59
Morinda pubesceus	4.80	4.26	5.08	14.13
Buchanania lanzan	3.20	4.26	5.64	13.09
Miliusa tomentosa	3.20	2.13	1.38	6.71
Savannah				
Chloroxylon swietenia	8.44	5.13	14.23	27.80
Benkera malabarica	12.11	8.12	5.54	25.77
Gymnosporia heyneana	4.10	8.04	5.09	17.23
Helicteres isora	5.78	4.09	6.64	16.51
Ochna obtusata	3.76	3.99	2.78	10.53

Table 4: Forest type characteristics of Warangal district

Forest type	No. of tree species	Basal area ha^{-1}	Stems ha^{-1}	Shannon-wiener index
Moist deciduous forest	129	25.26	576	5.42
Dry deciduous forest	112	20.97	509	5.04
Riverine forest	20	24.78	396	3.88
Boswellia forest	22	24.06	412	3.35
Cleistanthus forest	29	18.85	525	3.02
Hardwickia forest	35	24.63	553	3.64
Teak forest	42	12.48	475	3.14
Savannah	14	4.18	242	2.21

a qualitative basis. The fragmentation aualysis statistics for different forest types was analyzed and categorized into high, medium and low fragmentation areas (Table 5).

Of the eight natural forest types, savannah, teak and dry mixed deciduous forests represent high proportion of area under high fragmentation category. It is directly attributed to the prevailing

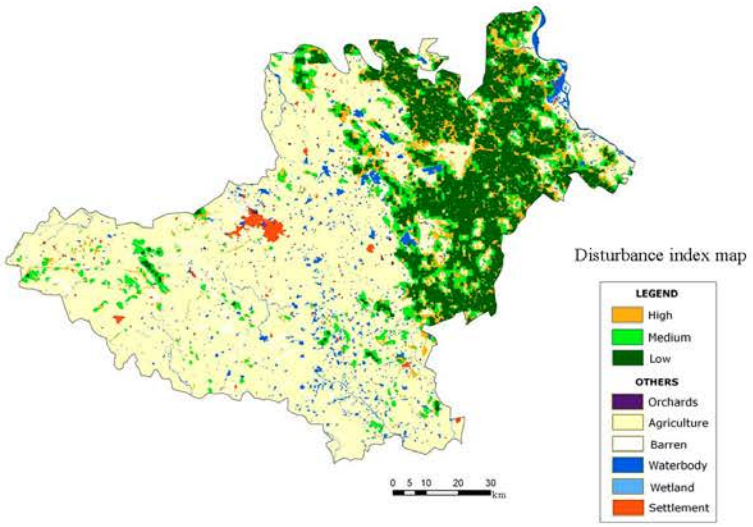

Fig. 5: Disturbance Index map of Warangal district, Andhra Pradesh, India

Table 5: Fragmentation scenario in different types of forests

	Fragmentation (%)			
Forest type	Low	Medium	High	Total
Moist deciduous forest	78.40	15.56	6.04	100
Dry deciduous forest	48.16	40.84	11.00	100
Riverine forest	35.40	57.60	7.00	100
Boswellia forest	36.70	52.80	10.50	100
Cleistanthus forest	31.10	62.00	6.90	100
Hardwickia forest	39.20	56.00	4.80	100
Teak forest	39.16	49.79	11.05	100
Savannah	29.16	55.79	15.05	100

anthropogenic pressure. The moist mixed deciduous forests have shown very less fragmentation and 78.4% of the area falling under the category of low fragmentation. It depicts that moist deciduous forests harbor maximum intact area. It may be important to note that *Boswellia* forests which in principle set in remote inaccessible area should show least fragmentation, in fact, shows an opposite trend. The trend may be because of heavy perforations and forest blanks on hill tops. Spatially higher extent of fragmentation have been recorded in forest edges.

Modeling of disturbance index considers various landscape parameters as derived from forest/non-forest maps as well as spatial alignments of various vegetation types. In addition, it also integrates the disturbance agents as proximity functions. Overall observation of the disturbance shows that low disturbance regimes cover 52.74% of the total forested tracts followed by 28.04% under medium and 19.22% under high (Fig. 5). Disturbance regimes across the forest types have been assessed and shown in Table 6. Savannah, Teak mixed and dry deciduous mixed forests show maximum area under high disturbance regimes compared to the other forest types. Savannah is a typical degradational forest type consists of *Phoenix acaulis* as indicator shrub species with abundant growth of grasses and sparse representation of tree cover. High disturbance regimes have been found in the edges of all forest types and isolated hills.

The forest type-wise ground based sample point location data have provided properties of the habitats. Trends across forest types were consistent with phytosociological principles and disturbance gradient. It is evident that species diversity (shannon-weiner index value 5.4) and mean basal area per

Table 6: Disturbance gradient in different types of forests

	Disturbance index (%)			
Forest type	Low	Medium	High	Total
Moist deciduous forest	65.05	28.44	6.51	100
Dry deciduous forest	52.20	27.63	20.17	100
Riverine forest	21.50	64.70	13.80	100
Boswellia forest	45.30	37.80	16.90	100
Cleistanthus forest	51.30	31.20	17.50	100
Hardwickia forest	54.65	36.12	9.23	100
Teak forest	50.29	25.81	23.90	100
Savannah	44.60	26.50	28.90	100

ha. (25.26 km^2) are high in moist deciduous forests (Table 4). It indicates most of the moist deciduous forests were still under low disturbance regime. Mean basal area per ha. is quite low in the case of teak forests shows that high commercial exploitation. The ground cover in the areas of high disturbance index shows predominance of invasive exotic flora mainly represented by *Hyptis suaveolens*, *Lantana camara*, *Cassia tora*, *Cassia uniflora*, *Mimosa pudica* and *Parthenium hysterophorus*.

CONCLUSIONS

Warangal is one of the tribal districts in Andhra Pradesh, India should be prioritized for conservation in view of representation of diverse forest types and phytodiversity. These forests were providing subsistence to tribals in the form of non timber forest produce mainly constitutes of Kendu (*Diospyros melanoxylon*), Amla (*Phyllanthus emblica*), Kovel (*Sterculia urens*), Mohua (*Madhuca indica*). The present study is helpful in understanding the structure and composition of forest types under various disturbance levels. Analysis of phytosociological data, fragmentation and disturbance index reveals high anthropogenic pressure in Savannah and Teak forest. The main causes of the disturbance in the forested tracts of Warangal district are primarily illegal cutting of wood, recurrent forest fires, grazing pressure, invasion of exotic species and encroachment of land for cultivation.

The results show that the low disturbance regimes cover 52.74% of the total forest area followed by 28.04% under medium and 19.22% under high. Ecological restorative efforts should be applied to the highly disturbed forest patches. The present approach stands unique due to the representation of results in spatial form useful in preparation of management plans based on scientific information. The study also demonstrated potential of satellite remote sensing and Geographical Information System in conservation studies.

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