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RESEARCH ARTICLE

LANDSCAPE DYNAMICS IN A SUB-TROPICAL DECIDUOUS FOREST IN NORTH-WESTERN HIMALAYAS, JAMMU AND KASHMIR, INDIA

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ABSTRACT

The present study deals with impacts of fragmentation in vulnerable sub-tropical forest ecosystems of Jammu Siwaliks. The landscape analysis was performed with the objective to estimate and analyze the areas subjected to landscape dynamics by computing landscape indices using remote sensing and GIS techniques. The remotely sensed data derived vegetation map was used as input to fragmentation analysis. The classified map was evaluated for classification accuracy based on 750 field derived points laid separately for northern dry mixed deciduous (370), Himalayan sub-tropical scrub (280) and Himalayan sub-tropical pine forest (100) for quantitative sampling. The landscape parameters *viz.,* fragmentation, porosity, patchiness, interspersion and juxtaposition have been evaluated for disturbance regime *viz-a-viz* biodiversity assessment and to evolve the conservation strategies thereof. The forest cover accounted for about 36% of the total area, whereas 33% of landmass was recorded fallow barren. It was observed that biodiversity levels are different in various fragments and with the changing fragments and patch size there is change in species richness and diversity. The spatial information generated thereof serves a vital input for effective forest management and in developing viable conservation strategies.

INTRODUCTION

Landscape analysis is an important component in determining the diversity of life forms since most of the ecological patterns and processes have unique shaping factors (Roy and Joshi, 2003). Landscape contains all levels of biological hierarchy, from ecosystems to species and genes that are targeted for biodiversity inventories and conservation (Noss and Harris, 1986). It may include agricultural, forestry, protected and ecologically sensitive areas which interact considerably and upon which humans have a major influence (Naveh and Lieberman, 1990; Roy *et al.,* 1997). Of the three basic characteristics of landscapes that affect their diversity, the structure viewed in the form of different landforms, habitats, or vegetation types is the most well understood element of whereas the function is concerned with interactions among spatial elements of a landscape. The third *i.e.,* landscape dynamics includes the characteristics of structure and function both in order to examine changes in pattern and processes over time. It depends on at least four major factors *viz.,* disturbance frequency, rate of recovery from disturbance, the size and spatial extent of the disturbance events and the size and spatial extent of the landscape (Talukdar *et al.,* 2004).

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The habitat destruction is widely considered the most pervasive anthropogenic cause of loss of biodiversity. The fragmentation of original habitat to patches eventually leads to irreversible loss of species. With the persistent disturbance regime the patches become smaller and the edge to interior ratio increases which ultimately reduces the species abundance (Devagiri *et al.,* 2012). The forest fragmentation can be explained in two phases, where the first phase results in the reduction of total extent of forest areas and the second phase leads to the isolation of smaller patches (Wilcove *et al.,* 1986; Saunders *et al.,* 1991). The important consequences for the progressive erosion of biodiversity includes reduction in the number of species, interference in dispersal and migration processes, altered ecosystem inputs and outputs, and exposure of isolated core habitats of forest (Terborgh and Winter, 1980; Tilman and Downing, 1994).

Geospatial modeling of forest disturbance using fragmentation, landscape neighborhood properties, biotic pressures and fire regimes provides spatial patterns of disturbance and facilitates prioritization of conservation measures and ecological integrity (Salem 2003; Ambastha and Jha 2010; Pattanaik *et al.,* 2010; Roy *et al.,* 2010; Sarma *et al.,* 2013; Yadav *et al.,* 2013; Hari Krishna *et al.,* 2014). Land use change can be obtained from multi satellite sensor data using pre-classification or post-classification and pattern recognition algorithms

(Duda *et al.,* 2000). It is known that changes in area, shape and connectivity of the patches cause change in species richness, distribution and persistence of populations and probability of disturbance (Fahring and Gray 1985; Freemark and Merriam 1986; Franklin and Forman 1987; Van Drop and Opdam 1987). Analysis of species richness and diversity indices therefore helps in studying the patterns of biodiversity in different fragments along different levels of anthropogenic influence (Goparaju *et al.,* 2005).

The forests of Jammu Siwaliks over the years have been exposed to several degrees of perturbations and the subsequent biodiversity erosion. To better understand the landscape dynamics of the region, a multipronged study was carried out with broader objectives: i) to detect and document changes in major land use in general and forests in representative subtropical forests between year 2000 and 2010, and, ii) to analyze patterns of changes in the landscape of the study area during the period, with special focus on forest fragmentation.

MATERIALS AND METHODS

Study area

The present study was conducted on low-level hill country outside Pirpanjal and between Jehlum and Ravi constituting Jammu hills in Jammu and Kashmir State. The region extends northwards of Pathankote-Jammu national highway covering the erstwhile Jammu district (now districts Jammu and Samba respectively) with an approximate geographical coverage of 2942 sq km with predominance of typical sub-tropical vegetation ranging from 300 m asl to 1675 m asl. The *Kandi* belt includes small dry hillocks and gentle slopes made up of boulder mass. Beset with gorges and ravines, the major part of this zone is under forests and offers but limited facility to agriculture. This undulating tract is criss-crossed by a number of shallow seasonal streams locally known as '*Khads'* with stony beds. The Jammu Siwaliks has a markedly periodic climate characterized by dry and increasingly hot season from March to June, a warm humid monsoon season from July to September and a dry and cold weather from October to December. The normal annual rainfall of Jammu is 1113 mm, 72% of it is received during monsoon months with average number of rainy days per year being 54. June is recorded as hottest month with average maximum 47^0C with January being the coldest month with average 6.8^0C. The foggy winters and scorching summers bear a marked climatic perturbation.

Vegetation mapping and analysis

Indian Remote Sensing (IRS-1C LISS-III) multi season datasets of 2000 have been used for vegetation type classification and land use mapping at 1:50,000 scale using visual interpretation technique. Field information on vegetation type, locality, aspect, slope, geographical location was obtained using GPS (Garmin Rino-130) and the signs of disturbance were recorded for classification and accuracy assessment. The classified map was generated with classification accuracy based on 750 field derived points laid separately for northern dry mixed deciduous (370), Himalayan sub-tropical scrub (280) and Himalayan sub-tropical pine forest (100) respectively for quantitative sampling. IRS-P6 LISS-IV data of 2010 was used for carrying out the change assessment statistics of different vegetation types and land use patterns. Stratified random sampling was adopted for primary and secondary analysis of vegetation. A sample intensity of 0.01 per cent of the total area was adopted covering all vegetation types. The diversity (H′) was determined by using Shannon-Weiner information index (Shanon and Weaver 1963) as $H' = - \sum ni/n \log2 ni/n$; where ni was the IVI value of a species and n was the sum total IVI values of all species in that forest type. A single summary statistic or Importance values was calculated by summing the relative values for species according to Ganesh *et al.* (1996). The equations used is Species Importance Value (SIV %) = relative frequency + relative density + relative dominance.

Landscape Analysis

The landscape analysis was performed in Bio-CAP (1999) software package at Indian Institute of Remote Sensing (IIRS), Dehradun. The major objective was to estimate and analyze the areas subjected to landscape dynamics by computing landscape indices. The entire data handling was taken due care in software package, which is unique bundle of three major components *i.e.* Remote Sensing, GIS and Quarry Shell following Roy and Tomar (2000). The three vital properties *viz*., structure, function and change of a landscape explained in terms of fragmentation, porosity, patchiness, interspersion and juxtaposition were derived as:

Fragmentation

Fragmentation was computed as the number of patches of forest and non-forest types per unit area. Fragmentation extents of different nature, under each forest type were calculated as the fraction of total area under each type. The mathematical representation of the fragmentation is:

$$\text{Frag} = f(nF / n\,NF)$$

where Frag = fragmentation; n = number of patches; F = forest patches; and NF = non-forest patches.

Patchiness

Patchiness is a measure of density of patches of all types or number of clusters in a given mask. The greater the patchiness, the more heterogeneous is the landscape (Murphy, 1985).

$$P = \frac{\sum_{i=1}^{N} Di}{N} \times 100$$

Where, Di = dissimilarity value for i^{th} boundary between adjacent cells; N = number of boundaries between adjacent cells.

Porosity

Porosity is the measure of number of patches or density of patches within a particular type, regardless of patch size

(Forman and Gordon, 1986). Porosity was calculated for subtropical dry deciduous and chirpine forest types occurring in landscape.

$$Po = \sum_{i=1}^{n} Cpi$$

Where, Cpi = is number of closed patches of ith cover class.

Interspersion

Interspersion is the count of dissimilar neighbors with respect to central pixel or measurement of the spatial intermixing of vegetation types (Lyon, 1983). This index is also used to represent the landscape diversity (shape of each category of cover divided by the boundary of the cover). A normalized LUT is made in the range of 0–10.The interspersion image obtained was recorded to four levels and area statistics was calculated as :

$$1 = \frac{\sum_{i=1}^{n} SFi}{n}$$

Where, $$SFi^{\sum_{i-1}^{n}} = \frac{Edge}{2\sqrt{\pi \times Areaj}}$$

is shape factor; Edge = length of edge in both x and y directions; Area j = area of jth polygon by groups of ith cover class.

Juxtaposition

Juxtaposition is the measure of proximity or adjacency of vegetation types. The proximity of edge was determined by the proportion of edge shared by central path with the adjacent patches. Juxtaposition weightage matrix was adopted and weightage was given to each forest type. The weightages were provided based on knowledge base, disturbance of one type or another, species migration, linkages of two associated types etc.

$$J = \frac{\sum_{i=1}^{n} Di(Ji)}{Jmax}$$

Where, Di = shape of desirability weight for each cover type combination determined empirically; Ji = length of edge between combinations of cover types; Jmax = average total weighted edge per habitat unit of good habitat.

Disturbance Index

The primary information on roads, village / settlements etc. was extracted from SOI toposheets and five buffer zones (each of 400 m) were created based on ground reality. Different weightages were assigned to calculate disturbance index.

Shannon-Weiner's index was calculated for all forest types. The road and settlement layers were merged and subjected to obtain a composite layer in Bio-CAP. The disturbance index map was prepared as a combination of different landscape matrices, *viz*., fragmentation, porosity, juxtaposition, and interspersion. The spatial distribution of the anthropogenic/ natural forces on the landscape was used to generate the spatial distribution of disturbance factors *viz.,* proximity to roads, villages, fire intensity and invasive alien species by using ground-based sampling data as well as ancillary databases. Disturbance index was calculated by adopting a probabilistic weightage based on linear combination of defined parameters (Roy and Tomar, 2000).

Disturbance Index = f [Fragmentation, porosity, interspersion, Biotic disturbance buffer, juxtaposition]

$$DI = \sum_{i=1}^{n}\left[Frag_i \times Wt_{i1} + Por_{ji} \times Wt_{i2} + Int_i \times Wt_{i3} + BD_i \times Wt_{i4} + Jux_i \times Wt_{i5}\right]$$

Where, DI = Disturbance Index; Frag = Fragmentation; Por = Porosity; Int = Interspersion; BD = Biotic Disturbance; Jux = Juxtaposition; Wt = Weightages

RESULTS

Vegetation type

The vegetation cover map (Fig. 2) prepared from digital classification of IRS-1C LISS III data depicts seven different categories based on the spectral signatures of ground cover (Table-1, Fig. 1). The overall accuracy and kappa statistics of classified vegetation type map was evaluated at 92.10% and 0.90 respectively. The landscape parameters *viz*., fragmentation, porosity, patchiness, interspersion and juxtaposition have been evaluated for biodiversity assessment. The forests accounted for about 36% of the total area, whereas one third (33.35%) of landmass was recorded as fallow barren (Table-1, Fig. 1).

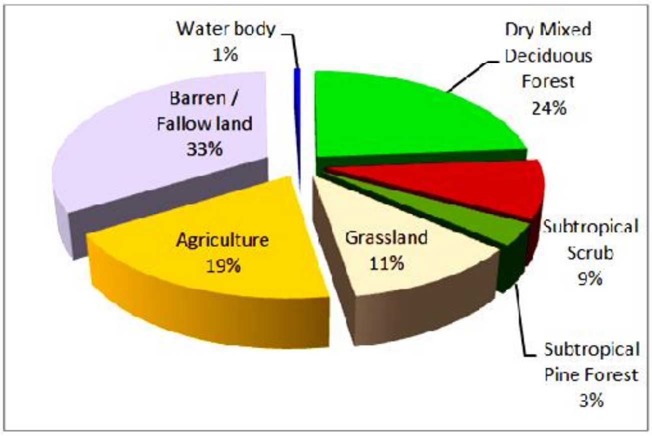

Figure 1. Landuse / landcover statistics of study area (year 2010)

The forests have been categorized into three major types *i.e.,* Northern dry mixed deciduous forests, Himalayan subtropical scrub and Himalayan subtropical Pine forest (Fig. 2) as per

Champion and Seth, (1968). No significant changes have been noticed in the spatial extent of vegetation and land cover during year 2000 to year 2010. Though, there has been a virtual decline in the green cover with forest / agriculture area been transformed into fallow / urban built up. The forest area alone has reduced to the tune of about 5% from year 2000 to 2010 (Table-1). The vegetation analysis revealed the dominance of *Mallotus philippensis* (SIV %, 6.4), *Acacia modesta* (10.44 %) and *Pinus roxburghii* (24.27%) as over storey elements in northern dry mixed deciduous forests, Himalayan subtropical scrub and Himalayan subtropical Pine forest respectively. Other dominant trees included *Grewia optiva*, *Dalbergia sissoo*, *Toona ciliata*, *Flacourtia indica*, *Ficus palmata*, *Lannea coromandalica*, *Albezia lebbeck*, *Zizyphus mauritiana*, *Flacourtia indica, Acacia catechu, Phyllanthus emblica, Ougenia oogeinensis* etc. whereas the under storey was dominated by *Lantana camara*, *Carissa opaca*, *Mimosa rubicaulis*, *Zizyphus oxyphylla*, *Dodonaea viscosa*, *Woodfordia fruticosa*, *Colebrookia oppositifolia*, *Punica granatum* etc. The northern dry mixed deciduous forests occupying 27.3 % of the study area revealed maximum species richness and diversity as indicated by the higher values obtained for Shannon-Wienner's index (1963). Most of the forest landscapes are influenced by human disturbances and thus necessitates the need for immediate conservation action plan to ensure sustainable utilization and better management of forest.

Landscape analysis

Fragmentation image (Fig. 3a) indicated four levels of fragmentation. Out of the total, 1279 sq. km. *i.e.* 43.48% area of the study area falls under pure non-forest class indicating it as a highly fragmented landscape. 26 % of the area falls in high and very high classes of fragmentation (Table-2). Areas dominated by chirpine forest showed medium to high level of fragmentation which is owed to frequent forest fires in Kalidhar, Jammu and Bahu-Mahamaya ranges. The patches revealed more or less uniform pattern of vegetation over the landscape (Fig. 3b). Most of the areas receive a dense network of patches indicating a higher degree of interactions among vivid life forms. 75.23% of the total area falls under low to moderate levels of patchiness indicating higher degree of heterogeneity of the landscape whereas 23.92% of the remaining area falls under medium to high levels of patchiness. Fifteen per cent of the total area indicates very high degree of interspersion followed by 51.60% of medium to high level. Only 33.40% of the area showed least interspersion values (Table-2).

The juxtaposition image (Fig. 3c) reflects higher interaction between subtropical dry deciduous forest and subtropical scrub followed by Chirpine forests. This trend may be related to medium to large-scale disturbance in last two vegetation types.

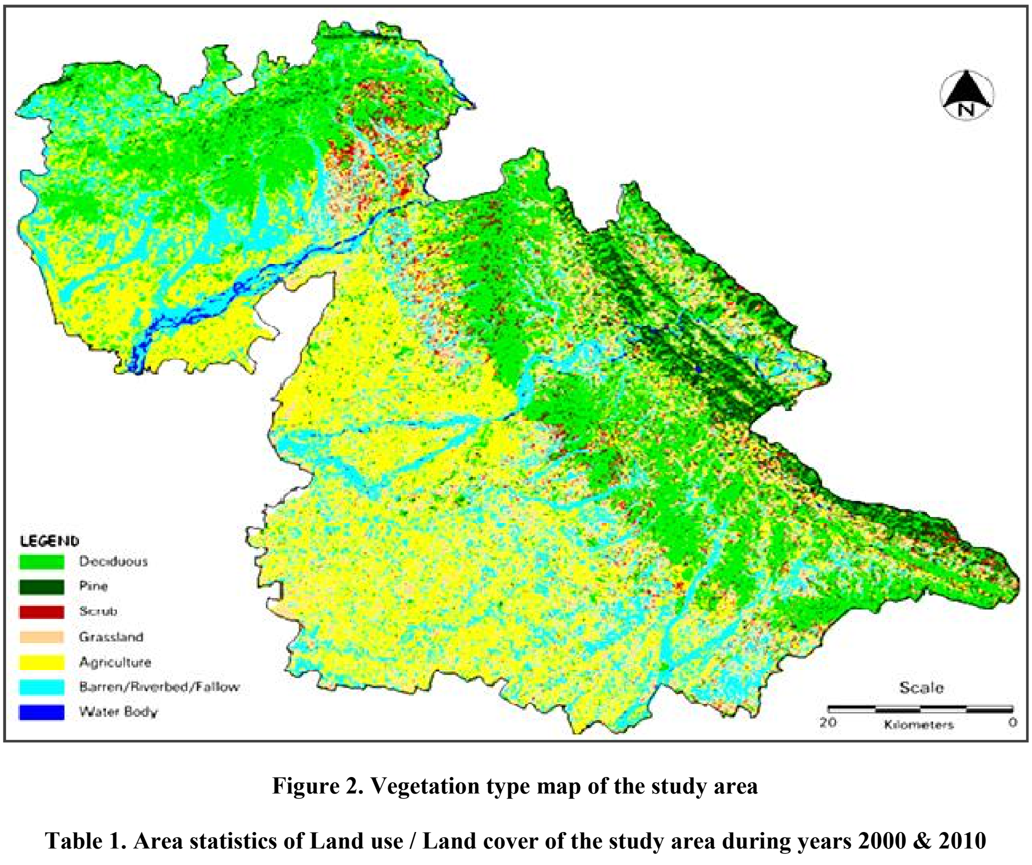

Figure 2. Vegetation type map of the study area

Table 1. Area statistics of Land use / Land cover of the study area during years 2000 & 2010

S.No	Vegetation type	2000		2010	
		Area (Km^2)	% age	Area (Km^2)	% age
1.	Northern Dry Mixed Deciduous Forest	804.46	27.3	701.58	23.84
2.	Himalayan Subtropical Scrub	296.80	10.1	267.37	9.08
3.	Himalayan Subtropical Pine Forest	99.85	3.4	89.17	3.39
4.	Grassland	345.45	11.7	334.03	11.35
5.	Agriculture	606.80	20.6	553.72	18.82
6.	Barren / Fallow land	769.46	26.2	981.17	33.35
7.	Water body	17.85	0.6	14.69	0.50

Table 2. Area statistics of fragmentation, patchiness, interspersion, juxtaposition, porosity and overall disturbance image of study area (Year 2000)

S.No	Extent	Fragmen - tation	Patchi - ness	Intersp - ersion	Juxta - position	Porosity (% age)		Disturbance	
		% age				Broad leaved	Chirpine	Area	%age
1.	Low	13.87	36.13	33.40	39.85	29.16	6.30	508.98	17.30
2.	Medium	16.42	39.10	27.85	16.85	16.87	4.80	437.25	14.87
3.	High	14.67	16.75	23.75	22.00	8.09	0.96	475.93	16.17
4.	Very high	11.56	7.19	15.00	21.30	2.74	0.83	261.57	08.90
5.	Non-forest	43.48	-	-	-	43.14	87.11	1258.00	42.76
6.	Shadow	-	0.83	-	-	-	-	-	-
	Total				100			2941.73	100

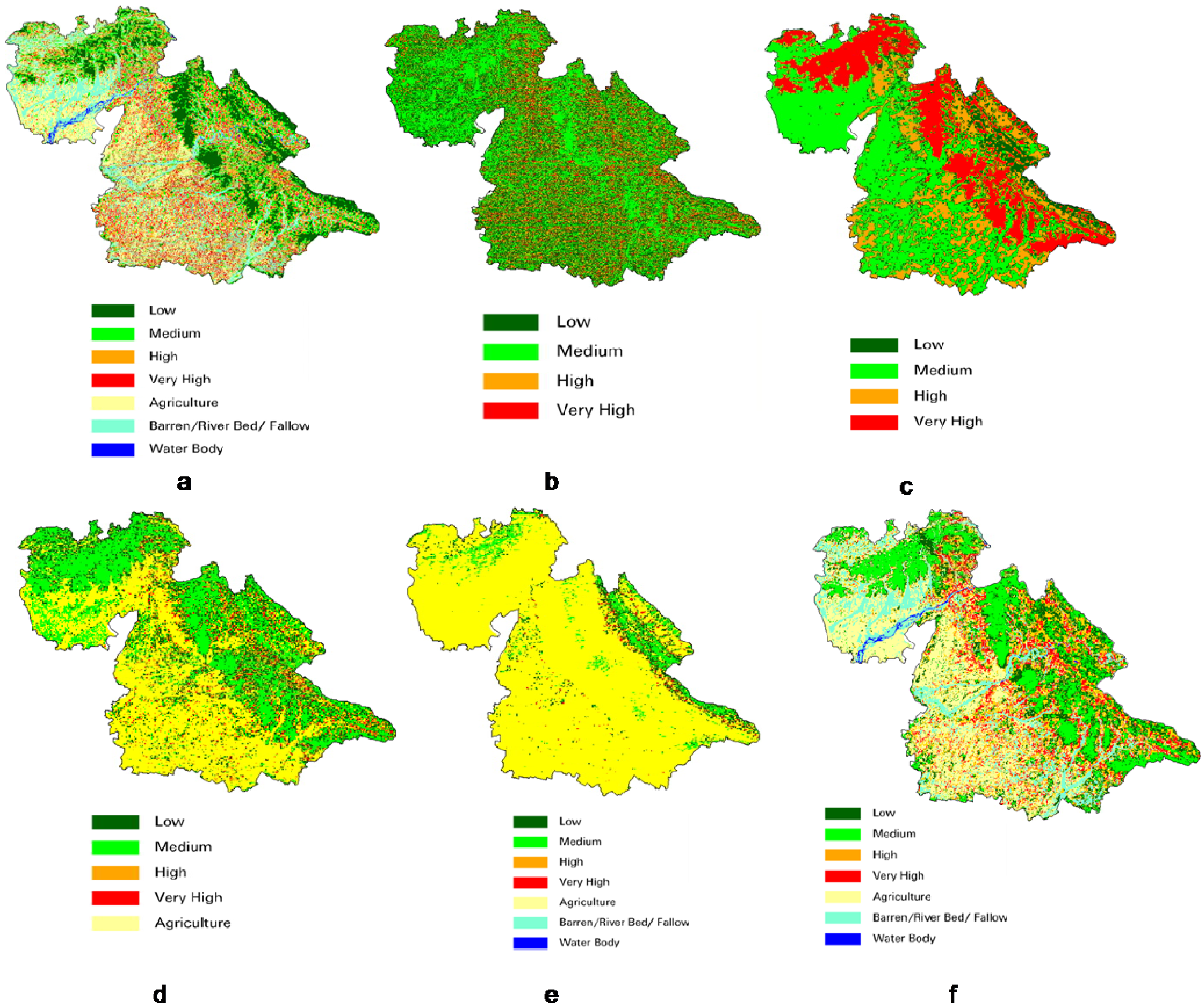

Figure 3. a) Fragmentation map, b) Patchiness map, c) Juxtaposition map, d) Porosity map of subtropical dry deciduous forest, e) Porosity map of subtropical pine forest, and f) Disturbance map of the study area

The area statistics of juxtaposition image revealed medium interaction (56.70%) among the vegetation types therein. These areas mostly fall in agriculture dominated southern flank of the region. The rest of the area (43.30%) mainly dominated by subtropical vegetation along Jammu foothills and *Kandi* belt indicated high and very high levels of juxtaposition (Table-2).

Porosity image was obtained for two major vegetation types with varying levels of porosity. The porosity image obtained for northern dry mixed deciduous forest revealed that 43.15% of area falls in non-forest category (Fig. 3d). Of the remaining 29.16% was found to be least porous, leaving 27.67% of area exposed to medium, high and very high level of porosity whereas the porosity image (Fig. 3e) obtained for sub tropical pine forest indicated that only 12.89% of the total area falls in this category. Out of this, 6.30% was found least porous whereas 6.59% area indicated medium, high and very high levels of porosity (Table-2). This leads to an indication that half of the area under this forest type is homogenous and non-fragmented. These areas fall in wildlife sanctuaries, reserve or protected forests in Kalidhar, Nandani and Bhamyal. Highest level of porosity as revealed by Mansar-Surinsar ridge is attributed to complex topographic features and edaphic factors which controls the vegetation distribution therein.

The disturbance index image (Fig. 3f) was obtained by linear combination of its correlates *i.e.* patchiness, porosity and interspersion. The image exhibited four levels of gradients from least to highest. The area statistics of the image revealed that 17.30% of area is least disturbed *i.e.,* it is characterized by low level of fragmentation, patchiness, porosity, interspersion and high levels of juxtaposition. 31.04% of the area indicated medium to high levels of disturbances, whereas only 8.90% of the area was found highly disturbed (Table 2, Fig. 4). The medium to high levels of disturbance is seen in and along Jammu foothills and whole of the *Kandi* belt. The fragile terrain, rocky slopes and geological dips in this region also contribute to varying degrees of natural fragmentation. Highest level of fragmentation is seen along the fast expanding suburbs and townships along national highways and railway tract. On the whole the disturbance index image of the area revealed the onset of increased number of anthropogenic atrocities to the landscape.

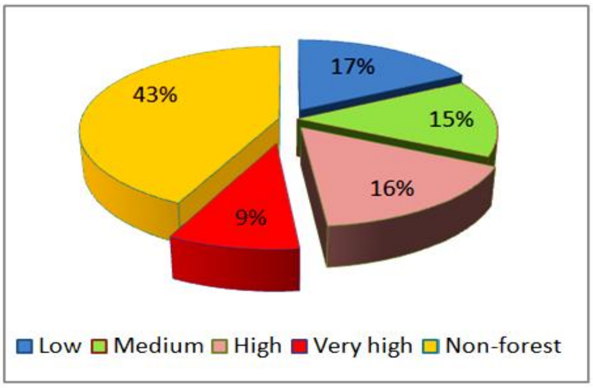

Figure 4. Disturbance index (%age) of study area

DISCUSSION

Subtropical moist deciduous forests are found highly diverse among other types with more species diversity and individual count. This is because of more congenial conditions prevailing in tropics/subtropics than alpine/subalpine areas (Khoshoo, 1993). The less species diversity in Himalayan subtropical scrubs has been partly attributed to the pronounced dry season and relatively low annual precipitation as also reported by Gentry (1992). The intermediate level of disturbances may also leads to higher species diversity (Pickett and White 1985; Behera 2000; Anonymous 2002; Roy *et al.,* 2002; Kale *et al.,* 2010). No significant changes have been noticed in the landuse / land cover statistics of the study area over the span of ten years. Similar results were obtained for sub-tropical forests in their studies conducted by Hari Krishna *et al.* (2014); Subin *et al.* (2014) respectively. However substantial land use changes have been detected within the same time span (Ramachandra and Kumar 2011; Sarma *et al.,* 2013). Fragmentation, an indicator of anthropogenic perturbations on landscape elements has been seen in moderate to high levels in almost one third of the study area. Maximum fragmentation levels are seen in *Kandi* belt which is attributed to varied biotic influences. Behera (2000); Goparaju *et al*. (2005), concluded that fragmentation was higher in the areas closer to the habitations and roads. Inaccessible areas at higher altitudes possess nearly undisturbed forests due to least biotic interferences. The loss and fragmentation of natural habitats, overexploitation of plant and animal species and the impact of exotic species are the major factors contributing to the loss of biodiversity (Balaji and Rai, 1999). Mandal *et al.* (2000) revealed that anthropogenic perturbations are responsible for rapid decline in natural resources. Debra *et al.* (2001) noticed that extrinsic factors like human transformation of landscape include deforestation and reforestation, urbanization, corridor construction and agricultural conversion influence the landscape dynamics to a considerable extent. Several workers revealed that deforestation and land clearing are the complex and multifaceted factors for biodiversity erosion (Ghazoul and Evans 2001; Lele and Joshi 2009; Ningthoujam and Mutum 2010; Devagiri *et al.,* 2012). The disturbance index map was generated as a function of heterogeneity, adjacency of the vegetation type and the proximity to the biotic interferences. It was observed that the disturbance level was high in areas prone to easy anthropogenic access.

Several authors have integrated Remote Sensing and GIS to provide reliable means of ecosystem monitoring and biodiversity conservation (Goparaju and Jha 2010; Ningthoujam and Mutum, 2010; Ramachandra and Kumar, 2011; Sarma *et al.,* 2013; Yadav *et al.,* 2012; Chawla *et al.,* 2012; Devagiri *et al.,* 2012; Roy, 2013; Hari Krishna *et al.,* 2014). The geospatial disturbance analysis in other regions of India reveals interesting results. Highly disturbed forests in Sunderbans of West Bengal occupied 10.41% of forest area (Nandy and Kushwaha 2010). The study by Pattanaik *et al.* (2010) reported 13% of forests under high disturbance in Kuldiha wildlife sanctuary of Odisha. Subin *et al.* (2011) reported 2.76% area under high disturbance in Shendurney wildlife sanctuary of Kerala. Karanth *et al.* (2006) revealed that 8-10% of the Bhadra Wildlife Sanctuary, Karnataka falls in high disturbance category whereas the results obtained for geospatial analysis of disturbance regimes indicates that 61.75% of the total protected areas in Rajasthan are under moderate disturbance index followed by 28.64% and 9.61% under low and high categories respectively (Hari Krishna *et al.,* 2014). The environment of the fragments and forest landscapes reveal the unprecedented growth of weeds especially *Lantana camara.* Janzen (1986); Goparaju *et al.* (2005) in their studies concluded that weedy species sprawl in the forest interiors eliminated the species contained therein. in the present context most of the forest fringes have been found heavily infested with Invasive Alien Species with *Lantana camara* the most gregarious among others. The species richness and diversity among the forests fragments varied across the anthropogenic gradient.

Conclusion

Finally it can be concluded that the landscape dynamics of sub-tropical vegetation of north western Himalayas follow a critical combination of different environmental drivers ranging from rugged topography, edaphic environment, weather and climate to anthropogenic land cover modification. The study reveals moderate to high disturbance around the forest edges, which implies high anthropogenic pressure at forest interfaces. It has also been found that species on forest edges have higher tolerance to climatic factors and disturbance regimes. Further, the reduction of anthropogenic pressure around forest edges by providing alternate resources to the local inhabitants will help in further checking the loss of edge biodiversity.

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