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PHYTODIVERSITY ANALYSIS : A GEOSPATIAL APPROACH

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ABSTRACT

Stratified random sampling with probability proportion to the size (PPS) is adopted for analyzing vegetation composition of all types. Vegetation cover type map derived using satellite remote sensing data have been considered as prime input for phytodiversity analysis of forest ecosystem. Geographic Information System (GIS) has been used to derive landscape indices such as fragmentation, porosity, patchiness, patch density, interspersion and juxtaposition, which depict landscape characteristics. Phytodiversity richness map generated for the Shiwalik hills of Punjab state is based on the disturbance index, terrain complexity, species richness, biological value and ecosystem uniqueness. The resultant maps highlight areas that are rich in phytodiversity. Forests of Shiwalik hills of Punjab state are moderately rich in some fragmented pockets. Deciduous forest showed high degree of richness (55.09% and 12.86% in high and very high categories respectively) followed by moist deciduous forest (17. 92% in high and 16.19% in very high categories). Deciduous scrub shows least richness (13.96 % in high and 1.61 % in very high categories) as compared to pine forest (16.72% in high and 4.55% in very high categories). Phytosociological data collected from field sampling was analyzed to derive species richness, biodiversity value and importance value of various forest types.

INTRODUCTION

The anthropogenic interventions in natural landscape have brought in enormous change in species composition and their distribution pattern in time and space. Though, with the technological and human expansion, the similar activities are now flattering progressively more invasive, giving Shiwalik forests little opportunity to recuperate. In most of the cases change in species, the composition and distribution is the result of forest fragmentation, which is the consequence of social, political and economic forces controlling the land use. The conventional species-to-species level approach for phytodiversity conservation has major limitations, and has resulted in a policy shift from conservation of single species to their habitats at landscape level. Understanding landscape spatial pattern is important since it contains all levels of the biological hierarchy, from ecosystems to species and genes, which

are targeted for phytodiversity conservation. Tropical communities are often more susceptible to loss of biological diversity than temperate communities because tropical species occur in lower densities and are less widely distributed and often have weaker dispersal capabilities. Increasing human intervention and excessive exploitation of resources have resulted in great changes and provide alarming signals of accelerated biodiversity loss. A significant change in understanding the priorities of biodiversity conservation and management has resulted in a policy shift from conservation of single species to their habitats through interactive network of species at landscape level (Orians, 1993; Edward *et al.*, 1994). Calls for the conservation of biodiversity are an explicit recognition that biological loss occurs at all levels, and that attempts to maintain this diversity-conservation effort must be applied to all levels and not just to endangered species (Noss, 1991; Scott *et al.*, 1991). Species composition, abundance and assemblage structure changes with forest disturbance. The rapid biodiversity assessment techniques for sampling are designed with a view to identify the rich sites in order to investigate the relationship between biodiversity and forest ecosystem processes. There is a growing need for better understanding of the biodiversity distribution pattern vis-à-vis human interventions. India has very varied environmental conditions and is among the 16 mega biodiverse countries in the world. The flowering plants, which provide maximum direct benefit to mankind, comprise about 19395 taxa, which is about 7% of the described species in the world (Karthikeyan, 2000). The great heights and complex terrain of the Himalayan region, which change frequently, provide endless microclimatic conditions suitable to the species to grow and evolve. The Himalayas have more than 5 micro-endemic centres. Shiwalik ranges are one such mirco-endemic centre. About 125 wild relatives of crop plants have been reported in the western Himalayas, and Shiwaliks ranges are part of these. These ranges are among the youngest hills in the world and are active as well as fragile. Shiwalik hills of Punjab state have rich biological diversity and act as major natural green belt of the state. The state is well known for agricultural produce and industries. But the degradational activity coupled with the destruction of forests in the name of developmental activities has altered the natural landscape of the region to a great extent. It is facing threat for its very existence again from mankind in the name of development.

Satellite remote sensing has been used to map and classify land use and vegetation cover classes in various remote, inaccessible areas and mountainous regions (Frank, 1988; Lal *et al.*, 1991). Remote sensing technology is being widely used world over for the quick assessment of the Earth resources. In this study, vegetation type map derived from satellite data was considered as prime input for landscape ecological analysis of forest ecosystem. Phytosociological data collected from field sampling was analyzed to derive species richness, biodiversity value and ecosystem uniqueness of various forest types. Ancillary databases such as proximity from the roads / villages, terrain complexity, etc. were derived in GIS domain.

A geospatial approach for phytodiversity conservation also addresses some of the limitations of conventional random sampling. To overcome this limitation, stratified random sampling with probability proportion to the size (PPS) was adopted for analyzing vegetation

composition of all the types encountered. In the present study, vegetation cover type map derived from satellite remote sensing data have been considered as prime input for phytodiversity analysis of forest ecosystem. Geographic Information System (GIS) has been used to derive landscape indices such as fragmentation, porosity, patchiness, patch density, interspersion and juxtaposition, which depict landscape characteristics. Phytodiversity richness map generated for the Shiwalik hills of Punjab state is based on the disturbance index, terrain complexity, species richness, biological value and ecosystem uniqueness. The resultant maps highlight areas that are rich in phytodiversity.

Study Area

The study was carried out in the Shiwalik hills of Punjab state (Fig.1) having geographical area of *ca* 9448.97 km^2 and situated in north eastern part of the state. It lies between 30° 34' and 32° 33' N latitude and 74° 50' and 76° 52' E longitude. It is broadly divided into sub-mountainous Himalayas and the eastern and western alluvial plains. The important rivers draining the region are the Sutlej and the Beas. The average annual rainfall varies between 400 to 600 mm and the mean annual temperature ranges from 22.5° C to 25.0°

Land Use Pattern

The recorded forest area (including dry deciduous scrub) of Shiwalik hills of Punjab state is 1599.42 km^2, which constitutes 16.93% of total geographic area. The major forest types are dry deciduous, moist deciduous, dry deciduous scrub and coniferous forest. The non-forest area, such as agriculture, grassland, water body, canals, settlements, riverbed and barren land, contributes 7849.55 km^2 which constitutes 83.07% of the total geographical area.

Vegetation type

Deciduous forest, moist deciduous forest, dry deciduous scrub and pine in small pockets are the main vegetation of the region. Champion and Seth (1968) described 6 forest types

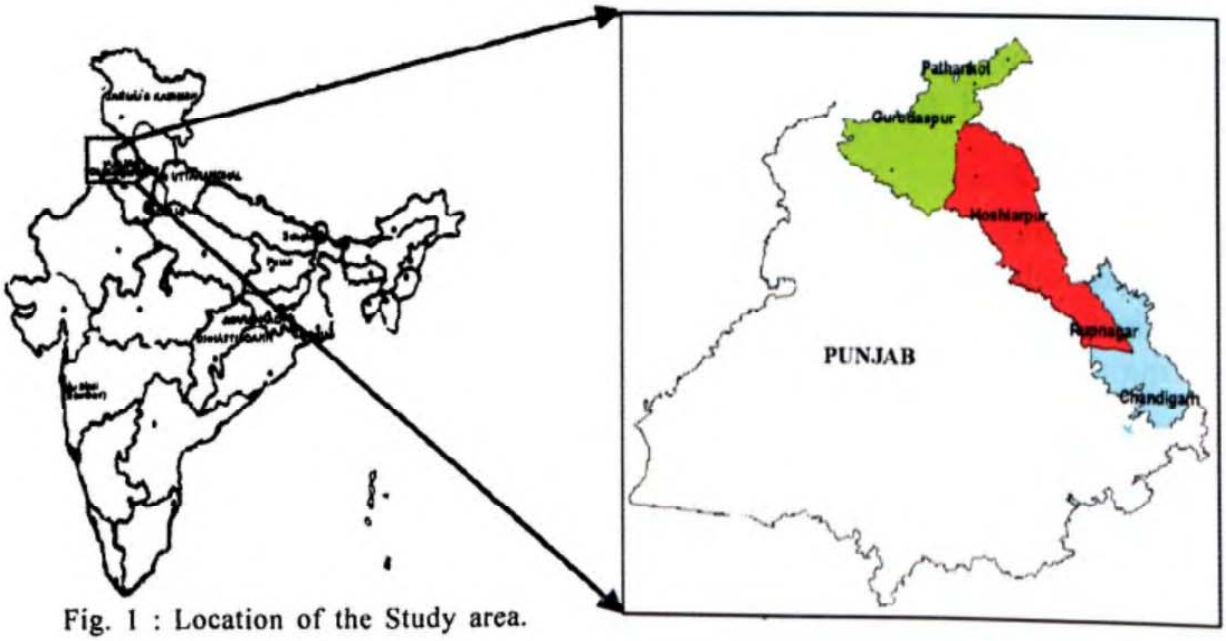


Fig. 1 : Location of the Study area.

viz., Northern dry mixed deciduous forest (5B/C2), Dry bamboo brakes (5E9), Dry deciduous scrub (DS1), Khair-Sissu forests (5/1S2), Shiwalik chirpine forest (9/C1) and Subtropical *Euphorbia* scrub (9/C1/DS2).

MATERIALS AND METHODS

Remote Sensing data

Following satellite remote sensing data have been used for land cover and land use classification of the area (Table 1).

Table 1: Details of satellite data used

Satellite ID	Path	Row	Date
IRS-1D LISS III	93	48	12 Oct. 2000
IRS-1D LISS III	94	48	03 Nov. 2000
IRS-1D LISS III	94	49	03 Nov. 2000
IRS-1D LISS III	95	49	31 Oct. 2000
IRS-1D LISS III	95	50	31 Oct. 2000

Preprocessing of satellite data

IRS-1D LISS-III data (October 2000 and Novenber 2000) were used to prepare vegetation cover type map. Total five scenes were loaded and each scene was rectified with respect to 1:50,000 scale (SOI) toposheet (Total 32 toposheets were used, geometrically corrected and mosaiced to a single image). A second order transformation was followed. Average root mean square error within one pixel was maintained while preparing transformation model. Lambert Conformal Conic projection (LCC) was used during rectification of image. Each rectified scene was subjected to radiometric correction before mosaicing it to a single mosaic image. After extraction of required area from this single mosaic image, it was subjected to Supervised Maximum likelihood classification using the ground truth information collected during the fieldwork.

Ground truthing

Reconnaissance survey was carried out in the area to acquire the knowledge of the vegetation and other broad land uses. During reconnaissance information on the correlation of image elements with that of ground features was also obtained. Interpretation key was formulated and classification was performed.

Field data

Information on plant species is further processed for evaluating other parameters like, Total Importance Value, Ecosystem Uniqueness, Biodiversity value, etc. It is important that well distributed samples are taken for information on species occurrence. Classified vegetation cover type has been used for finding the sample size. Sampling intensity of 0.021 % has

been done. Higher sample intensity is adopted in view of variability in the area.

Approach

Ground observations are taken through stratified random sampling in all the forest types. Their economic uses have been found from literature. Total Importance Value (TIV) of each plant is established for its value for food, fuel wood, charcoal, timber, medicine, etc. Ecosystem uniqueness is established from the list of the species found during survey based on its representativeness, endemism, etc. Biological richness is obtained after integrating species richness, biological value, disturbance index, ecosystem uniqueness and terrain complexity.

Sampling design

The probability proportionate stratified random sampling was adopted and the optimal sample plots for each floristic type were calculated @ 0.002 % sampling intensity. Detailed inventory was done in 74 sample plots covering four major vegetation cover classes for trees, shrubs, seedlings, saplings, epiphytes, climbers and other growth forms including herbs (Table 2). Cumulative species-area curves were plotted for all forest types sampled by sequential arrangement of plots. For sampling, various strata of vegetation, nested quadrat sampling mode was followed. A 20 × 20 m plot for trees (CBH ^{3} 15 cm), within which a 10 × 10 m nested plot at the center for shrubs were laid. For herbs/seedlings 1 × 1 m plots of which, five were laid at the four corners and one at center of the 20 × 20 m plot (Fig. 2). The epiphytes, creepers, climbers and other lianas and their host/symbiotic plants were also noted as a special attribute in a view to take an account of all the above ground floral components present in a particular site of sampling pertaining to that forest type.

Table 2 : The distribution of sample points in each of the forest type

Forest Type	No. of sample plots
Moist deciduous	32
Dry deciduous	31
Deciduous scrub	7
Pine forest	4
Total :	74

The data was collected on following parameters in each of the sample plot.

— Description of ecosystem and forest type including phenology.

— Species name and number of individuals for every species.

— Girth at breast height (gbh) in centimeters.

— Economic importance such as grazing, medicinal, human food, fuel, timber, charcoal and other uses such as industrial use, rope making, tanning leather, etc. This importance value was collected by interviewing local people wherever possible and from literature.

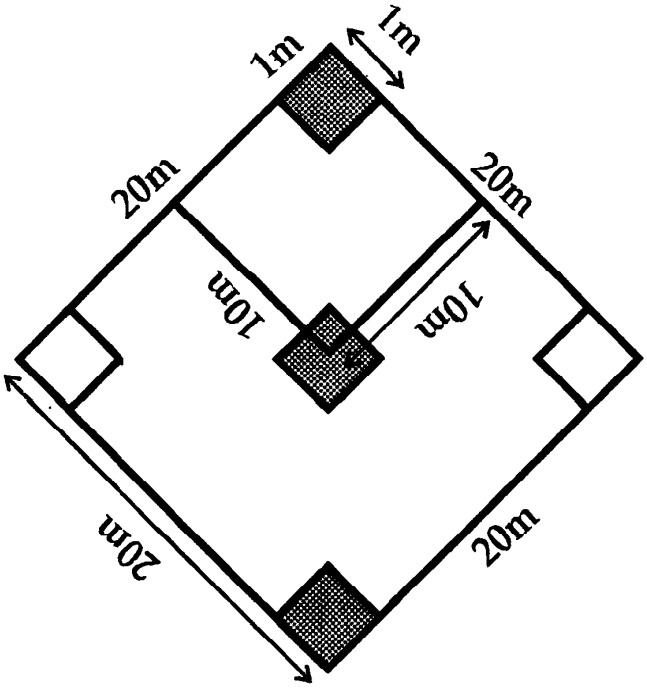


Fig. 2: Layout of nested quadrat sample plot

Database Creation in GIS

In geo-spatial analysis integration of spatial and non-spatial data or vector data is important. As discussed earlier the biotic disturbance had played a very significant role in existing biodiversity of today. Database in GIS domain provides opportunity to analyze their impact zones. Therefore, village locations (point and polygon features) transport networks (Road and railway) and contour lines with 20m intervals were digitized in ERDAS 8.4 software. The road and settlement maps were used as input in further analysis for deriving disturbance gradient.

Vegetation Classification

Based on the prior knowledge supervised classification method was followed. Training sites were selected and processed. The classified output was finally subjected to hybrid classification approach to prepare vegetation type map of the study area showing various vegetation types (Fig. 3). The accuracy of the image was evaluated using field knowledge and the ground truth information. Along with the different types of forest, other general land use/land cover classes were also classified so as to understand the landscape of the region. Following forest classes have been delineated and a comparison with Champion and Seth's (1968) classification scheme is given below (Table 3).

Phytodiversity analysis

Phytodiversity analysis was carried out to understand the floristic and vegetation pattern in the region. For this purpose, the vegetation types were grouped into four major types. The phytosociological database was created and computed for the basic structural parameters, viz. frequency, basal area and density, etc. Importance value index (IVI) was calculated to assess the ecological importance of the species with respect to the community structure.

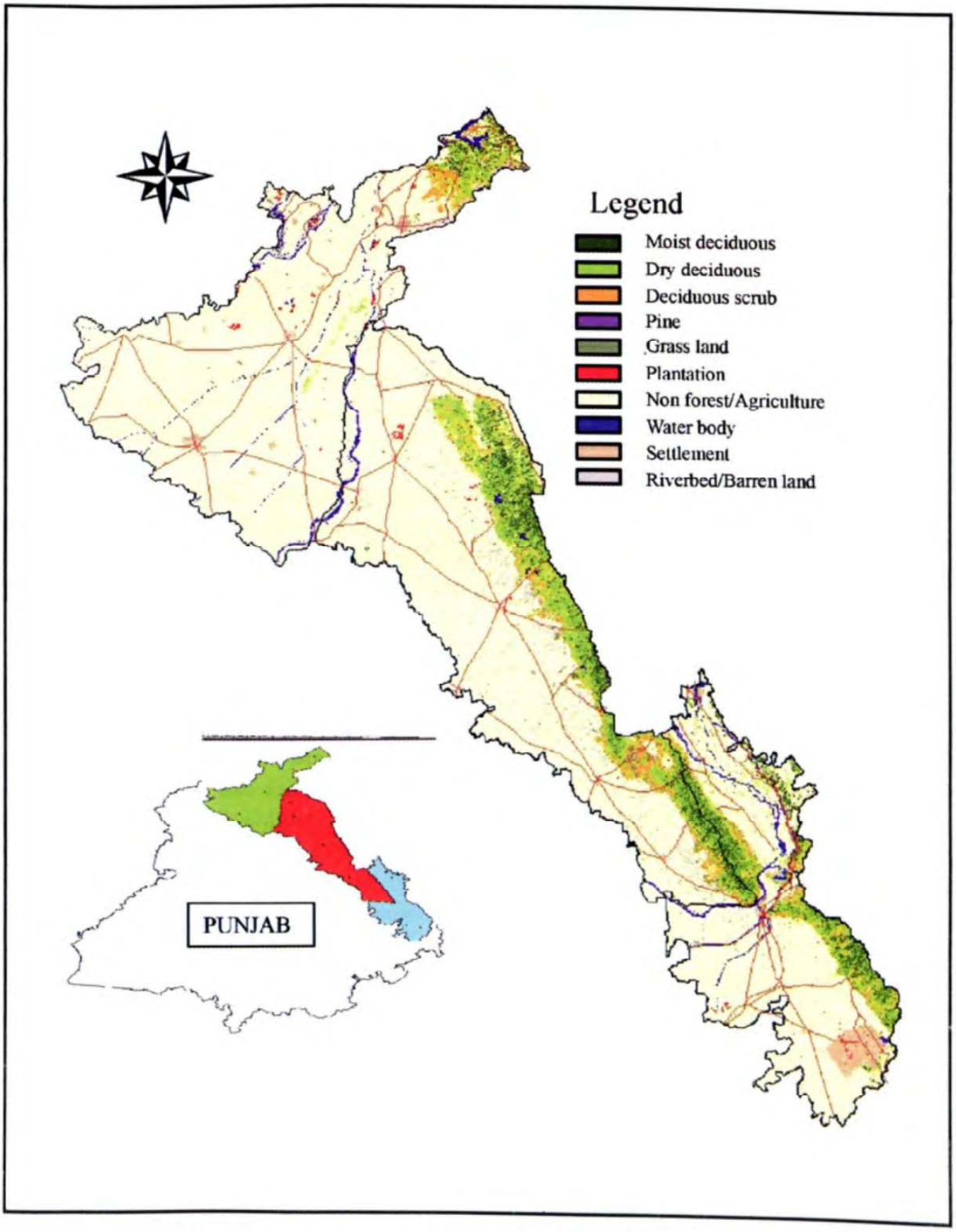


Fig. 3: Vegetation Cover Type Map of Punjab Shiwaliks.

Table 3 : Vegetation classes compared with Champion and Seth's Classification:

Satellite based classification of vegetation types	Champion and Seth Classification (1968)
Moist deciduous forest	Dry bamboo brakes, Khair-sissu forest
Dry deciduous forest	Northern dry mixed deciduous forest Dry deciduous forest
Dry deciduous scrub	Subtropical *Euphorbia* scrub, Dry deciduous scrub
Pine	Shiwalik chirpine forest

***Importance Value Index* (IVI):** IVI is a statistical quantity, which gives an overall picture of the importance of the species in the plant community. Since the above relative parameters give clues individually, all the parameters are summed up in order to provide the total picture of sociological structure of a species in a community, and called as importance value index (IVI).

Species richness (Shannon-Wiener Index)

It is probably the most widely used index in community ecology. The index represents the average degree of uncertainty in predicting to which particular species, an individual chosen at random from a sample will belong. Species richness can be described as the number of species in a sample or habitat per unit area. Higher the value greater the species richness. Species richness (Shannon-Wiener Index) was calculated for all forest types using the formula:

$$H' = - \sum [(ni/N)^* \log e(ni/N)]$$

Where n_i = number of individuals or amount (e.g. biomass) of each species (the *ith* species) and N = total number of individuals (or amount) for the site, and e = the log base of 10.

RESULTS AND DISCUSSION

Vegetation Classification

The Shiwalik hills of Punjab have four major vegetation types of the seven described by Champion and Seth (1968). These are, moist deciduous, dry deciduous, pine and dry deciduous scrub, and together constitute about 1404.06 km^2, which is about 14.65 per cent of the total geographical area of the region. In addition to these, non-forest classes

such as agriculture, plantation, riverbed, barren land, settlement, grassland and water body makes up for about 85.35 per cent of the geographical area. Amongst the forests, dry deciduous forest has wide distribution in the region from Chandigarh to Pathankot and covers an area of 775.85 km^2. Dry deciduous scrub is the next dominant forest type of the region which is mainly constituted with *Lantana* scrub distributed throughout the region and then followed by moist deciduous forest found in Dhar, Pathankot, Dholbaha, Talwara, Nangal, Noorpur in fragmented patches. The coniferous forest covers an area of 6.51 km^2 and is localized on the higher ridges or slopes in the northern part of Pathankot district.

Table 4 : Area under different land cover / land use classes in the region

Land use / cover class	Area in km^2
Moist deciduous forest	276.46
Dry deciduous forest	775.85
Dry deciduous scrub	345.24
Coniferous forest	6.51
Grass land	38.24
Plantation/Avenue trees	211.04
Agriculture	7443.22
Water body	78.94
Settlement	178.46
Riverbed/Barren land	238.19
Total	9592.15

Phytodiversity Analysis

Total 315 species were encountered in this study. The importance value indices have been calculated for those species and it expresses the importance of individual species in a plant community. The total basal area, mean basal area and tree density calculated for each forest types clearly defines the structure, composition and density of each forest type. Species diversity has been calculated for all forest types prevailing in the region (Table 5).

Moist deciduous forest

Out of 74 sample plots, 32 were laidout in this forest type. Out of 161 individuals encountered, 42 are trees, 24 are shrubs and rest belong to herbaceous categories. The total basal area including trees and shrubs occurring in moist deciduous forest was calculated to be 22.95m^2/ha. This forest type is most predominated with *Acacia catechu* and *Mallotus philippensis*.

Table 5 : Biodiversity status in the Shiwalik hills of Punjab state.

Forest type	No. of Families	No. of species			Total No. of Species	Total Importance Value
		Trees	Shrus	Herbs		
Moist deciduous	36	42	24	95	161	10.46
Dry deciduous	31	141	75	147	363	10.53
Deciduous scrub	25	7	12	58	77	9.75
Pine 11	7	15	36	58	8.01	

Dry deciduous forest

Thirty one sample plots were laid in this forest type. A total of 363 species were encountered of which 141 are trees, 75 are shrubs and rest belong to herbaceous vegetation. The total basal area of the trees was calculated to be 38.41 m^2/ha. The tree density was observed to be 916 per ha. This forest type is most prominently dominated by *Acacia catechu* (IVI = 108.86) of which relative density contributes a major share of 30.72 followed by relative dominance of 69.83. Major association of dry deciduous was composed of *Anogeissus latifolia, Lannea coromandalica, Aegle marmelos, Mallotus philippensis,* etc.

Deciduous scrub forest

Out of 74 plots, 7 plots were laid in this forest type. A total of 77 species were encountered of which 7 are trees, 12 are shrubs and 58 herbaceous species. The total basal area of the trees was calculated to be 8.133 m^2/ha. Deciduous scrub forest is dominated by *Lantana camara, Woodfordia fruiticosa, Carrissa opaca,Capparis decidua* with some association of *Acacia modesta, Dodonaea viscosa, Aegle marmelos,* etc.

Pine forest

Pine forest was distributed only in northern part of the Gurdaspur district of the region with small pockets in ridges and side slopes. Only 4 plots were laid in this type. The total basal area of the trees was calculated to be 6.531 m^2/ha. A total of 58 species were encountered of which 7 are trees, 15 are shrubs and 36 herbaceous species. The vegetation is dominated by *Pinus roxburghii* (IVI=183.61 and relative density: 68.57) associated with *Syzygium cumini, Wendlandia heynei, Pyrus pashia, Syzygium cuminii,* etc.

Species diversity

Dry deciduous forest shows highest diversity (3.5361) with total number of 363 species followed by moist deciduous (3.0959), dry deciduous scrub (2.2666) having 77 species and coniferous forest showing least diversity (1.6207) with 58 species

Economically Important Species

Economically Important plants are the species, which have social and economic value. In the Shiwalik hills of Punjab state 240 economically important plants were recorded. The

Table 6 : Forest type wise Shannon-Wiener Index and mean basal area.

Forest Type	Mean Basal Area (m^2)	Shannon Wiener Index (SWI) (H')
Moist deciduous	22.948	3.0959
Dry deciduous	38.412	3.5361
Deciduous scrub	8.133	2.2666
Pine	6.531	1.6207

total importance value (TIV) for each species was calculated .considering 10 important uses. The parameters considered are (1) Food (2) Fuel (3) Fodder (4) Fiber (5) Timber

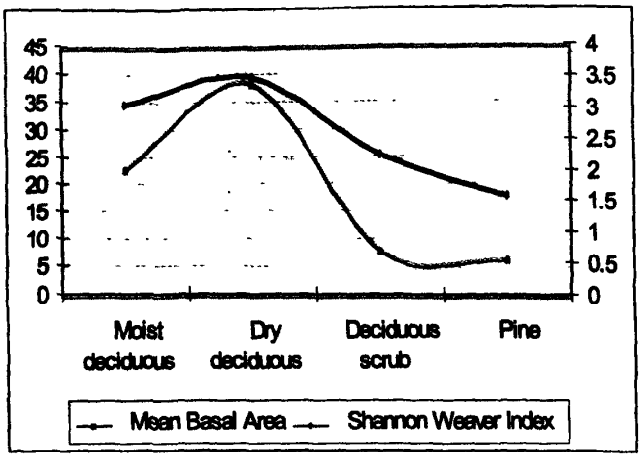


Fig. 4. Graph showing positive correlation between mean basal area and species diversity.

(6) Medicinal (7) Oil (8) Gums/Resins (9) Tannin and (10) Others. These 10 parameters have been weighted for a scale of 1 to 10 wherein maximum value represents highest economic value. Maximum total importance value was observed in dry deciduous type (TIV of 10.53) and coniferous type has the least value (TIV of 8.01). Some of the economically important species are *Acacia catechu, Achyranthes aspera, Justicia adhatoda, Ageratum conyzoides, Azadirachta indica, Cannabis sativa, Moringa oleifera*, etc.

Table 7 : Total Importance Value of different vegetation types.

Forest Type	TIV %
Moist deciduous	10.46
Dry deciduous	10.53
Deciduous scrub	9.75
Pine	8.01

Medicinal Plants

About 132 medicinally important species have been recorded during the sampling Medicinal usage of these plants occurring in Shiwalik hills of Punjab have been compiled from available literature sources. Some of the medicinally important plants are *Justicia adhatoda, Aegle marmelos, Azadirachta indica, Bacopa monnieri, Cordia dichotoma, Terminlaia chebula, Terminalia bellirica* etc. Table-8 provides an overview of the per cent utilizable species.

Table 8: Per cent utilizable species for Total Importance Value (TIV).

Forest type	USES									
	Food	Fuel	Fodder	Fiber	Timber	Medi-cinal	Oil	Gums/ Resin	Tannin	Others
DD	11.15	0.79	9.09	9.8	10.2	31.66	5.02	3.5	5.18	9.83
MD	12.7	2.36	6.94	7.91	2.6	32.1	0.65	0.86	1.3	8.45
DS	10.05	2.21	9.06	9.31	9.55	31.61	6.37	3.18	6.61	8.09
PN	0	0	8.52	0	0	20.78	0	0	0	2.35
Total	33.9	5.36	33.61	27.02	22.35	116.15	12.04	7.54	13.09	28.72

Ecological importance:

The species recorded during the field data collection were screened for their uniqueness with the help of RED DATA BOOK and many other references. All the species recorded were abundant in nature. However, two species were found to be rare, viz., *Delphinium danudatum* and *Peristylus constrictus.*

Biological Richness :

Floristic variability is caused by the several factors and the environmental conditions prevailing in the past or present. Biodiversity conservation, therefore, seeks overall knowledge of the biodiversity and human dimensions. Thus, Biological richness (BR) has been considered as the function of disturbance index, terrain complexity, species richness, biological value and ecosystem uniqueness (Fig. 6). This encompasses various aspects governing the biodiversity of any area. Geospatial analysis was carried on the dataset. Four classes defined for the purpose are class 1 (Low); class 2 (Medium); class 3 (High) and class 4 (Very high). In order to generate the biological richness map, the above inputs were assigned probabilistic weightages. In the context of landscape characterization, forests of Shiwalik hills of Punjab state are moderately rich in some fragmented pockets. Deciduous forest showed high degree of richness (55.09 per cent and 12.86 per cent in high and very high categories respectively) followed by moist deciduous forest (17. 92 in high and 16.19 in very high categories). Deciduous scrub shows least richness (13.96 per cent in high and 1.61 per cent in very high categories) as compared to pine forest.

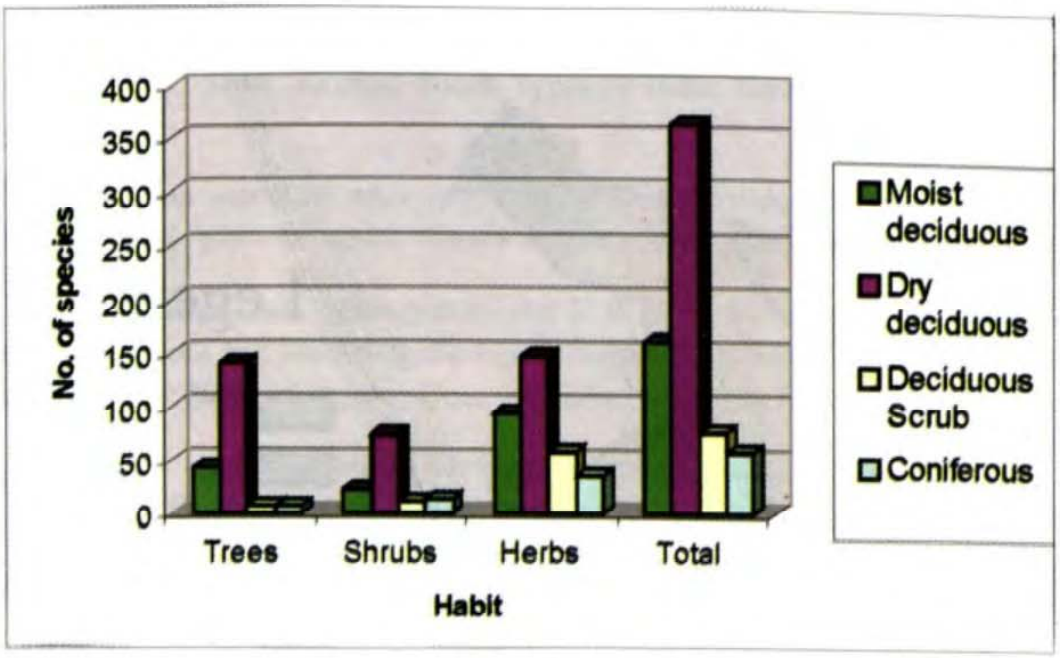


Fig. 5. Species distribution in each habit type.

CONCLUSION

Biodiversity of Punjab Shiwaliks is facing threat due to various developmental activities. Satellite remote sensing data provide much needed qualitative information on the land cover and land use pattern of the region. Efforts directed towards conservation of one or a few species have limitations and, therefore, it is essential to consider biodiversity conservation in its entirety, i.e. at landscape level. Disturbance is one of the major factors for biodiversity loss, and the forest patches represent biodiversity depending on the existing environmental conditions and associations. Landscape principles like fragmentation, porosity, interspersion, juxtaposition, etc. allow us to establish the disturbance gradient. The analysis done through remote sensing and GIS and phytogeographical analysis revealed that majority of the area is highly disturbed and therefore it is matter of great concern for biodiversity conservation. Shiwalik hills are faced with increasing anthropogenic activities and humans in the name of development invade forest landscape. Large areas are under scrub and need protection to avoid further site degradation. The region has a large number of medicinal plants. Biorich areas are restricted to certain areas and fragmented pockets. These biodiversity 'refugia' in the unique and fragile ecosystem of Shiwaliks need to be protected on priority for future prosperity.

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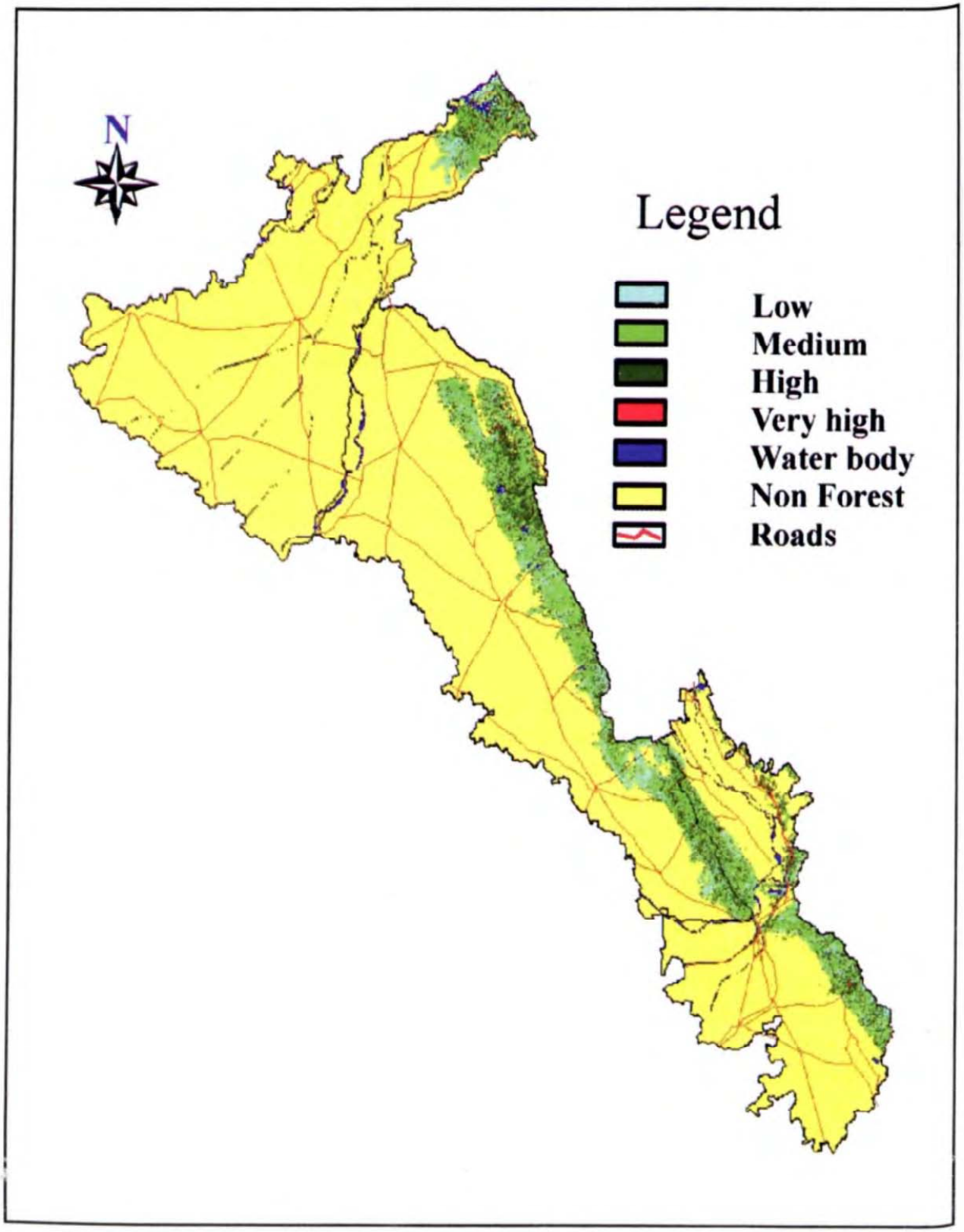


Fig. 6. Biological richness map of Punjab Shiwaliks.

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