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Original Article

Composition, structure and diversity of tree speciesalong an altitudinal gradient in Jammu province of north-western Himalayas, Jammu and Kashmir, India

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Abstract

Community structure and composition are important factors affecting diversity patterns in plant communities. Pertinently, species diversity along altitudinal and latitudinal gradient differs in different layers at different scales. Thirteen community groups characterized by different dominants in the tree layer were distinguished. These include Himalayan subtropical scrub (580-850 m asl), Northern dry mixed deciduous forest (600-1100 masl), Himalayan subtropical pine forest (780-1450 masl), Lyonia / Alnus / Rhododendron forest (1250-1500 masl), Mixed Oak forest (1300-2150 masl), Rhododendron - Oak mixed forest (1600-2200 masl), Pine / Oak mixed forest (1400-1750 masl), Pure Cedrus deodara forest (1450-1700 masl), Taxus wallichiana forest (2000-2580 masl), Deodar / blue pine mixed forest (1900-2600 masl), Fir / Spruce mixed forest (2700-3250 masl), pure Betula forest (3100-3500 masl), and alpine scrub (above 3500 masl). Distribution of importance values of dominants explicitly indicated a vertical pattern of these forest types.The sub-tropical and temperate elements of vegetation reveal predominance of closed canopy forests, wherein the subtropical tree species outnumber the temperate tree flora. The community analysis was performed using stratified random sampling involving 0.01 % of the total area for each community. The pattern of plant diversity as observed by the values of species richness and diversity indices show a decreasing trend from lower to higher altitudes. The study suggests that distribution and species richness are largely regulated by physiography (altitude, latitude, slope, aspect etc.) and climatic factors

Keywords: *community, diversity, richness, gradient, importance values, physiography, vegetation.*

INTRODUCTION

The patterns of biodiversity along altitudinal gradients are well-documented ecological phenomena. Community composition and structure are important factors affecting diversity patterns in plant communities. Furthermore, species diversity along altitudinal gradient differs in different layers at different scales. Understanding how biodiversity is organized across space and time has long been a central concern of ecologists and biogeographers. There exists a gradient of diversity distributions across multiple spatial scales (Brown & Lomolino 1998; Field et al 2009). Latitudinal and altitudinal gradients are the most conspicuous patterns of diversity. However altitudinal patterns of diversity are poorly understood (Sanchez-Gonzalez & Lopez-Mata 2005). Generally, species richness tends to decrease with altitude (Brun et al 2006). Altitude itself represents a complex combination of related climatic variables closely correlated with numerous other environmental properties i.e., soil texture, nutrients, substrate stability etc. (Ramsay and Oxley 1997). Within one altitude the co-factors like topography, aspect, inclination of slope and soil types further effect the forest composition (Holland and Steyn 1975). Austin et al (1996) have analysed association between species, climate, slope protection and soil nutrient status. Along the altitudes the geographic and climatic conditions change sharply (Kharkwal et al 2005). Along an altitudinal gradient, the upperlimit of species richness remains high up to a considerable altitudinal limit (2500 masl) and tree richness increases from increasing moisture in Indian Himalayan region (Rikhari et al 1989). However several other explanations have been given for a linear relationship between species richness and altitude (Givnish 1999). (Saxena et al 1985;Adhikari et al 1992;Sharma et al 2009;Majila and Kala2010)described altitudinal variation in vegetation in western Himalayas and reported that vegetation types differ with change in altitude. A few studies specifically related to plant species diversity, quantitative analysis, species richness their population density and dispersion pattern are available for the Himalayan tract (Relhan et al 1982; Chowdhery and Wadhwa 1984;Singhal et al 1986;Nath et al 2000;Singh and Rawat 2000;Pande et al2001 &2002; Singh and Kaushal 2006;Dash et al 2009;Tynsong and Tiwari 2011and Shameem et al 2011). Several studies have described the vegetation of Jammu province. This includes the works of Sapru (1975), Kaul and Sarin (1976), Kapur (1982), Dhar and Kaul (1986), Kumar (1987), Singh and Kachroo (1994), Kumar (1997), Kour (2001), Singh (2002), Kesar (2002), Sharma (2003), Jhangir (2004), Dutt (2005), Kumar (2007) etc. No studies, however have been reported so far from the Jammu province regarding altitudinal gradation of vegetation. Some important contributions on vegetation analysis,phytosociology and community structure in certain Himalayan forest types are thoseby (Ralhan et al 1982; Saxena & Singh 1982;Singh and Singh 1984; Singh et al 1987; Rao et al 1990;Sharma and Kumar 1992; Verghese and Menon 1998; Pande et al 2002; Ilorkar and Khatri 2003;Negi and Nautiyal 2005; Naithani et al 2006;Sanjeev et al2006). The similar studies have been carried out by Kumar (1987), Kumar (1997), Kour (2001), Singh (2002), Kesar (2002), Sharma (2003), Jhangir (2004), Dutt (2005), Kumar (2007), Kumar (2007)in different regions of Jammu province.

Study area

The present investigation was carried out in variable vegetation strata from sub-tropical dry deciduous forests to dry alpine scrub along an altitudinal gradient involvingShiwaliksand PirPanjalrange of Northwestern Himalayas. The main objectives of this paper are to describe the structural attributes i.e., density, species diversity and richness of tree flora; to identify predominating communities of trees and to reveal the influence of altitude on species richness.

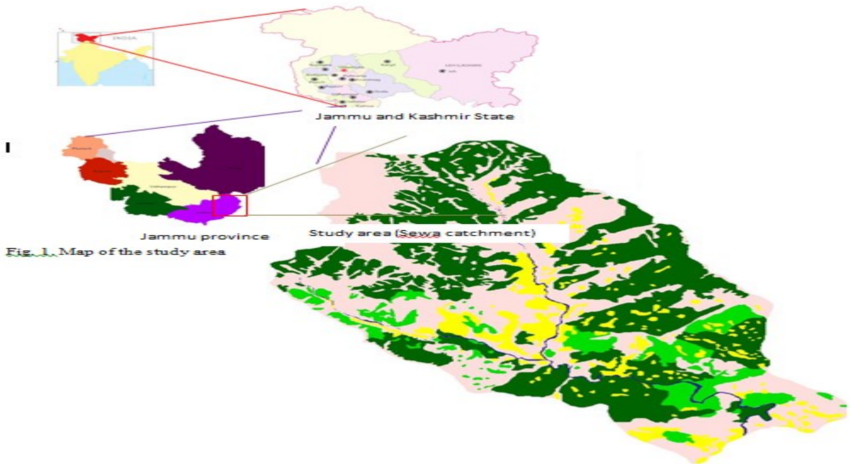

Fig. 1. Map of the study area

The study was conducted in 13 forest stands in Bani and Sarthal areas of district Kathua of Jammu Shiwaliks (32° 36' 38" N to 32° 41' 00" N latitude and 75° 48' 38" to 75° 48' 38" E longitude) covering an area of 381 km² (Fig 1). The tract can be altitudinally divisible into subtropical (580m asl to 1500 m asl), temperate (1500 m asl to 3500 m asl) and alpine (>3500 m asl) zones as reported by Saxena et al. 1985. Mean annual maximum temperature range from 34.5 ± 4.30 ^{0}C, whereas mean annual minimum temperature is recorded as 6.35 ± 2.50 ^{0}C. Average annual rainfall ranges from 1450 mm at moderate altitudes (< 2000 m) and gradually declines to 800 mm beyond 2500 m. The study area is characterized by four major seasons: short spring (February - March); warm and dry summer (mid April to mid July); warm and wet *monsoon* (mid July to mid September) and relatively dry winter (mid-October to February).

Sampling procedures and Data analysis:

After the reconnaissance survey, thirteen forest types interspersed in different climatic and physiographic regimes have been identified and recorded. The forest types have been classified as per Champion and Seth (1968) and named according to the composition of dominant trees species as per Ram Prakash (1986), *viz.,* ≥ 75 % as pure; 50 - 75% as mainly; 25-50% as mixed and < 25 miscellaneous. Physiographic factors like altitude and slope aspects across different cover types were measured by GPS. A total of 750 plots each measuring 20 x 20 m were laid for quantitive analysis of tree vegetation. Plots were laid by stratified random analysis with the objective to include at least 0.01 % of the total area and the quadrat area was determined by using species area curve.

Trees were considered to be individuals > 10 cm dbh (Knight, 1963). Total species richness was simply taken as a count of number of species present in the respective forest type. Species richness (number of species per unit area) was calculated as Margalef's Index (1968) using formula SR = S-1/ln (N) and Menhinik's index of richness (Whittaker, 1977) was calculated as Richness = S/√N, where, S = number of species and N = Total number of individuals (of all species in case of Menhinik's index). The diversity (H') was determined by using Shannon-Weiner information index (Shanon and Weaver 1963) as H'= - ∑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. Simpson's diversity index (Simpson, 1949) was calculated as D: I-Cd, Where Cd = Simpson's concentration of dominance = $(\sum ni/n)^2$.

RESULTS

Community structure and composition:

The distinct gradation was observed for different vegetation layers along the altitudinal gradient (Table 1.1). The lower altitudes (580 m asl - 1100 m asl) exhibited the prevalence of sub-tropical dry deciduous tree species with marked dominance of Chirpine community till 1450 m asl. The mid altitudes (1500 m asl- 2200 m asl) exhibited the preponderance of temperate Broadleaved species. Most of the higher ranges (2000 - 3250 m asl) are occupied by gregarious patches of temperate coniferous species like Kail, Deodar, Fir and Spruce. Population structure of encountered species revealed that *Pinus wallichaina* in the mid altitude and *Picea Smithiana* at higher ranges contained an expanding population occupying majority of space in study area. Ban Oak was found dominant among different broadleaved species and found in association with conifers mostly *Pinus wallichiana* at an altitudinal range of 1300 – 1750 m asl. The temperate coniferous stands were encountered on steeper slopes with rocky base.

The quantitative analysis revealed that each forest type except a few reveal a single representative species outweighing the other associates. The dominant temperate coniferous species found included *Pinus roxburghii* (Chirpine), *Pinus wallichiana* (Kail), *Cedrus deodara* (Deodar), *Abies pindrow* (Fir), *Picea smithiana* (Spruce), whereas the dominant broad leaved species included, *Quercus semicarpifolia* (Ban Oak), *Quercus leucotrichophora* (Kharsu Oak), *Betula utilis* (Birch) and *Lyonia ovalifolia.* The subtropical elements were predominated by *Pinus roxburghii*, *Acacia modesta* and *Lannea coromendelica* (Table - 1.1 & 1.2).

Vegetation analysis shows that highest Importance Value Index was exhibited by *Rhododendron campanulatum* (288.53, 96.17%) for alpine scrub. Amongst the temperate forests, the highest IVI values were exhibited by *Taxus wallichiana* (266.43, 88.81%), *Cedrus deodara* (213.54, 71.18%), *Pinus wallichiana* (188.65, 62.88%) and *Picea smithiana* (173.01, 57.67%). Among the temperate broadleaved forests, *Quercus leucotrichophora* (149.82, 49.94%) emerged as the dominant tree species followed by

Lyonia ovalifolia (147.09, 49.03%). *Quercus semicarpifolia* (133.67, 44.55%) and *Betula utilis* (121.24, 40.41%) revealed the least IVI values in their respective forest stands (Table - 1.2).

Table 1.1: The environmental variables across different altitudes

S.no	Forest type	Altitude (in m above mean sea level)	Climate	Aspect	Slope (degrees)	Nature of slope	Position
1)	Alpine scrub	Above 3500	Alpine	Mixed aspect	20	Steep	Upper
2)	Fir / spruce mixed forest	2700-3250	Temperate	Northeast	33	Very steep	Upper
3)	Deodar / blue pine mixed forest	1900-2600		Southeast & northwest	30	Very steep	Upper
4)	*Taxus wallichiana* forest	2000-2580		Northeast	25	Steep	Upper
5)	Pure *Cedrus deodara* forest	1450-1700		Northeast	28	Steep	Middle
6)	Pine / Oak mixed forest	1400-1750		Northwest	30	Very steep	Middle
7)	*Pure Betula forest*	3100-3500		Northeast	22	Steep	Upper
8)	*Rhododendron Oak mixed forest*	1600-2200		Northeast & northwest	25	Steep	Middle
9)	*Mixed Oak forest*	1300-2150		Northwest	28	Steep	Middle
10)	*Lyonia / Alnus / Rhododendron forest*	1250-1500		Southwest	25	Steep	Middle
11)	Himalayan Subtropical Pine Forest	780 -1450	Sub-tropical	Northwest	17	Moderate	Lower
12)	Northern Dry Mixed Deciduous Forest	600-1100		South	16	Moderate	Lower
13)	Himalayan Subtropical Scrub	580-850		South east	14	Gentle	Lower

Table 1.2: Vegetation analysis of tree species in different forest types

Forest type	Climat	SR	Dominant tree species	IVI	Density (tree /Ha)	Mean values	
						Basal area (m^2/ha)	Tree height
Alpine scrub	Alpine	2	*Rhododendron campanulatum*	288.53	150	32.41	2.32
Fir / spruce mixed forest	Temperate	5	*Picea smithiana*	173.01	550	58.55	15.81
Deodar / blue pine mixed forest		6	*Pinus wallichiana*	188.65	625	52.23	21.63
Taxus wallichiana forest		5	*Taxus wallichiana*	266.43	425	41.56	8.71
Pure *Cedrus deodara* forest		6	*Cedrus deodara*	213.54	675	72.80	23.35
Pine / Oak mixed forest		8	*Quercus semicarpifolia*	133.67	500	56.34	21.56
Pure Betula forest		3	*Betula utilis*	121.24	350	52.13	11.24
Rhododendron Oak mixed forest		9	*Quercus semicarpifolia*	123.23	550	62.34	24.34
Mixed Oak forest		10	*Quercus leucotrichophora*	149.82	425	58.78	23.76
Lyonia / Alnus / Rhododendron forest		8	*Lyonia ovalifolia*	147.09	450	43.12	11.33
Himalayan Subtropical Pine Forest	Sub-tropi	14	*Pinus roxburghii*	143.33	625	50.73	12.49
Northern Dry Mixed		28	*Acacia modesta*	98.17	575	65.43	8.34

Deciduous Forest							
Himalayan Subtropical Scrub		23	*Lannea coromendelica*	103.44	475	43.90	8.12

Species richness and diversity parameters:
The highest level of diversity and species richness was recorded for subtropical forests, followed by temperate broadleaved and coniferous forests respectively (Table-1.3).

Table : 1.3 : Total species richness and diversity parameters of tree species along altitudinal gradient

Forest type	Climate	Altitude (in m above mean sea level)	SR	MI	MeI	H'	D
Alpine scrub	Alpine	Above 3500	2	0.613	0.240	0.950	0.710
Pure Betula forest	Temperate	3100-3500	3	0.525	0.342	0.183	0.797
Fir / spruce mixed forest		2700-3250	5	1.021	0.456	1.213	0.810
Deodar / blue pine mixed forest		1900-2600	6	1.980	0.675	2.337	0.835
Taxus wallichiana forest		2000-2580	5	1.654	0.544	2.590	0.753
Pure *Cedrus deodara* forest		1450-1700	6	1.724	0.986	1.801	0.834
Pine / Oak mixed forest		1400-1750	8	1.876	1.023	2.058	0.874
Rhododendron Oak mixed forest		1600-2200	9	1.342	0.694	2.023	0.885
Mixed Oak forest		1300-2150	10	3.184	0.905	2.922	0.866
Lyonia / Alnus / Rhododendron forest		1250-1500	8	3.132	1.078	2.564	0.798
Himalayan Subtropical Pine Forest	Sub-tropical	780 -1450	14	4.945	0.675	2.878	0.876
Northern Dry Mixed Deciduous Forest		600-1100	28	7.342	1.779	4.348	0.988
Himalayan Subtropical Scrub		580-850	23	5.879	1.098	3.793	0.882

Where **SR**: Species Richness; **MI**: Margalef's Index; **MeI**: Menhinik's index; **H':** Shannon-Weiner's index, and **D**: Simpson's diversity index.

Maximum value of species richness and Margalef's index was recorded for Northern dry mixed deciduous forests (28 and 7.342) followed by Himalayan sub-tropical scrub (23 and 5.879), Himalayan sub-tropical Pine forests (14 and 4.945), Mixed oak forest (10 and 3.184), Rhododendron-Oak mixed forest (9 and 1.3420) and the least values were depicted by Alipne scrub (2 and 0.613). However, steady levels of species richness (8 - 9) and (5 - 6) were recorded for the temperate forest communities at an altitudinal range of 1250 to 2200 m asl and 1450 to 3250 m asl respectively. The Margalef's index (1.021 - 1.980) also did not vary considerably in the given altitudinal range. Above 3100 m asl, both the parameters decreased abruptly with the species richness dipping to 2-3 and Margalef's index valuing 0.525 to 0.613.

Menhinik's index was recorded with a maximum value of 1.779 for Northern dry mixed deciduous forests followed by Himalayan sub-tropical scrub (1.098), *Lyonia* / *Alnus* / *Rhododendron* forest (1.078), Pine Oak (1.023), Pure *Cedrus deodara* (0.986), *Rhododendron* - Oak mixed forest (0.694). Minimum value of 0.240 was observed at highest elevation for alpine scrub above 3500 m asl.

Maximum species diversity was observed for sub-tropical forests at an altitudinal range of 580-1450 m asl, wherein maximum value of Shanon Wieners' index was recorded for Northern dry mixed deciduous forests (4.348) followed by Himalayan sub-tropical scrub (3.793) and Himalayan subtropical pine forests (2.878). The uniform pattern of species diversity was encountered in the latitudinal range of 1500 – 2600 m asl with Shanon Wieners' index varying between 2.023 to 2.992 except for a dip (1.801) in case of pure *Cedrus deodara* forests at an altitudinal range of 1450 - 1700 m asl. However the species diversity (1.213 to 0.950) falls exponentially with the increase in elevation beyond 2700 m asl.

The maximum value for Simpson's diversity was recorded for Northern dry mixed deciduous forests (0.988). However the values of Simpson's diversity indicated a uniform pattern (0.876 – 0.885) at an altitude of 1450 to 2600 m asl, whereas a small dip in the values was observed beyond 2600 meters till 3500 m from wherein the values further fell (0.835 to 0.797) with the minimum recording of 0.410 for alpine scrub at an elevation beyond 3500 m asl.

DISCUSSION

The study reveals that tree species found in this part of Himalayas exhibit varying patterns of distribution along different altitudinal and climatic gradients. Distributional ranges of several species were segregated along the widened altitudinal ranges (Kharakwal et al 2005). Pausas and Austin (2001) also suggested that over any large region the distribution of species richness is likely to be governed by two or more environmental factor and not by a single factor.

The data reveals that maximum density, basal area and average height are exhibited by conifer species. This is attributed to their gregariousness and high girth. Moderately low values of basal area and tree height as exhibited by Himalayan subtropical scrub, *Lyonia* / *Alnus* / *Rhododendron* forest, *Betula* forest, *Taxus wallichiana* forest are attributed to heavy lopping of multipurpose tree species for fuel, food, fodder and medicines. It is well observed that mixed broadleaved coniferous forests are under high biotic pressure to meet daily requirements of local inhabitants resulting poor and stunted growth. The variation in quantitative parameters, species richness as well as composition between different communities is also due to elevation, bioclimatic and edaphic factors. All the above information is in parallel with the findings of various ecologists for moist Himalayan temperate forests (Relhan et al 1982; Saxena and Singh, 1982; Singhal et al 1986, Kadavul and Parthasarthy, 1999; Rawat, 2001; Pande et al 2002; Singh and Kaushal, 2006; Sharma et al 2009).

Shanon Weiner's index values ranging from 0.950 to 2.922 is in accordance with the values reported for other temperate forests (Monk, 1967; Risser and Rice 1971; Relhan et al 1982; Pande et al 2001; Rawat, 2001, Pande et al 2002, Singh and Kaushal 2006; Sharma et al 2009). Low diversity in some areas could be due to the lower rate of diversification of communities (Fisher, 1960) and severity in the environment (Connel and Oris, 1964). It can be observed that diversity and density, both decreases with the increasing basal area in the localities, which are dominated by conifers. Similar trend has been observed by Hara et al (1997) in Taiwan; Kadavul and Parthasarthy (1999), Chauhan et al (2001) and Singh and Kaushal (2006) in India.

The diversity indices reveal that north aspects presents more favourable opportunities for growth of tree species, which has also been reported by Rawat and Pant in the year 1999. The present study revealed that maximum species richness is encountered at lower elevations, compared by higher elevations is in consonance with the findings of Kumar and Ram (2005) and Sharma (2009). Burns (1995) and Austin et al (1996) have found that the total species richness was greatest at lower elevation and warmer sites. More than two thirds of plant species were encounters at the elevation range of 580-1450 m asl with the temperature fluctuating between 8^{o}C to 37 ^{o}C. The low elevational sites were relatively densely populated probably because human interference in these areas facilitates the introduction and establishment of non-native species as also reported by Rawal and Pangtay (1994).

Species richness shows a general pattern of intermediate altitude peak (Whittaker 1977, Whittaker et al 2001, and, Brown and Lomolino, 1998). This is mainly due to the double gradient of temperature and precipitation. In the temperate forests, the species richness was found maximum in mixed board leaved forests as also reported by Kumar and Ram (2005) and Sharma et al (2009). The occurrence of *Quercus leucotrichophora*, *Quercus semicarpifolia, Lyonia ovalifolia* and *Alnus nitida* almost on almost all the sites along the temperate altitudinal gradient suggests their tolerance to biotic pressures and wider ecological amplitude. *Pinus roxburghii* is an early successional species and Oak a climatic climax (Champion and Seth, 1968)

The quantitative relationship between dominant and rare species is an important structural property of the community. In present study, density / ha of trees varied from 150 to 675 where the basal area (m^2/ha) varied from 32.41 to 72.80 (Table - 1.2). The density values did not vary very much and the values reported by other authors (Singhal and Soni, 1989; Adhikari and Tiwari, 1991; Mishra et al 1993; Ilorkar and Khatri, 2003) are more or less similar. A heterogeneous tree population was found at an elevational range of 580-1100 m asl. Similar observations were recorded by Sarma (1990), Gogate and Kumar (1993), Singh et al (1991) and Ilorkar and Khatri (2003). The high Importance Value Index (IVI) of species indicated their dominance and ecological success, good power of regeneration and ecological amplitude.

CONCLUSION

The present study highlights the poor status of species richness especially for the temperate and alpine forests. The investigations revealed that lower and comparatively warmer elevations revealed higher species richness and diversity than the cold and higher elevational cover types, which implies that temperate and alpine forests need effective monitoring and conservation. The study suggests that the distribution and species richness pattern of different tree species are largely regulated by altitude and climatic factors.

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