Species richness and diversity along an altitudinal gradient in moist temperate forest of Garhwal Himalaya.

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Abstract: In the present study we have described the impact of altitude on the species richness, species diversity and dispersion behaviour of different tree species in Himalayan temperate forest. We have observed that the values of all the growth indices i.e., Margalef's index (0.17 to 1.14), Menheink's index (0.27 to 0.80), Species diversity (0.99 to 2.34) and Simpson's diversity index (1.49 to 8.73) were maximum at the lower altitudes (2250-1850m asl), medium at mid-altitudes (2600-2400m asl) and lowest at the higher altitudes (2800-2700m asl). Significantly negative correlation of density and species richness with altitude and slope was recorded. The study suggests that the distribution and species richness pattern of different tree species are largely regulated by the altitude and climatic factors. [Journal of American Science 2009;5(5):119-128]. (ISSN: 1545-1003).

Key words: altitude; slope; diversity; species richness; dispersion

1. Introduction

Species richness is a simple and easily interpretable indicator of biological diversity (Peet, 1974). Many types of environmental changes influence the processes that can both augment or erode diversity (Sagar et al. 2003). Ellu & Obua (2005) have suggested that different altitudes and slopes influence the species richness and dispersion behaviour of tree species. Moreover, Kharakwal et al. (2005) have pointed out that altitude and climatic variables like temperature and rainfall are the determinants of species richness. Difference in insolation period may occur according to altitude, thereby forming a range of microclimates in multifaceted landscapes. Diversity of life-forms usually decreases with increasing altitude and one or two life-forms remain at extreme altitudes (Pavón et al. 2000). Altitude itself represents a complex combination of related climatic variables closely correlated with numerous other environmental properties (soil texture, nutrients, substrate stability, etc.; Ramsay and Oxley, 1997). Within one altitude the cofactors like topography, aspect, inclination of slope and soil type further effect the forest composition (Holland and Steyn 1975).

Austin et al., (1996) have analyzed association between species richness, climate, slope position and soil nutrient status. Earlier in a critical literature review on species richness patterns in relation to altitude, Rahbek (1997) viewed that approximately half of the studies detected a mid-altitude peak in species richness and Grytnes and Vetaas (2002) have also reviewed these aspects in Nepalese Himalaya. Along the altitude, the geographic and climatic conditions change sharply (Kharkwal et al., 2005). Bongers et al., (1999) stated that drought indicating factors (length of dry period and cumulative water deficit) were more important for determining species distribution. Veenendaal et al. (1996) showed that elevation above 2000m asl may accumulate snow and have persistent cold temperature in winter. Along the altitudinal gradient, the upper limit of species richness remains high up to a considerable altitudinal level (2500m asl) and tree richness increases with increasing moisture in the Indian Himalayan region (Rikhari et al., 1989). Singh et al. (1994) found that productivity does not change upto and approximately 2500m asl in the Himalayan region. However, several others explanations have been given for a linear relationship between species richness and altitude (Givnish, 1999).

The present investigation was carried out in a moist temperate forest of the Garhwal Himalaya, which comes under district Uttarkashi of Uttarakhand to reveal (i) the impact of altitude on species richness in various temperate forest types and (ii) Assessment and analysis of change in dispersion behaviour of various tree species along altitudinal gradient for proper management, sustainable utilization and conservation of the forest resources in temperate region of Garhwal Himalaya.

2. Materials and Methods

2.1. Study Area

The study was conducted in Chaurangikhal moist temperate forest (30° 39.125' N latitude and 78° 31.156' E longitude) encompassing an area of about 750ha in district Uttarkashi (8016 km^2) of Garhwal Himalaya situated 29 km away from Uttarkashi town, during the years 2006-2007 (Figure 1). The district lies in the upper catchment of two great rivers of India viz, Ganges (called Bhagirathi upto Devprayag) and the Yamuna. Some of the tributaries of these rivers are Jodhganga, Jalandhari, Bhilangana, Duggada and Assiganga. Seven forest types; (i) pure *Abies pindrow*, (ii) pure conifer (iii) mixed *Abies pindrow* (iv) conifer mixed broad-leaved (v) mixed *Quercus floribunda* (vi) mixed broad-leaved and (vii) mixed *Pinus roxburghii*, were selected between 1850 to 2800m asl at various altitudes and slope gradients (Table 1). Broad land use categories of the area include permanent settlements (villages), irrigated and rainfed agricultural fields, scrub land, mixed broad-leaved forests, sub-alpine Oak-Fir forest, summer camping sites and alpine meadows locally known as "Kharaks" and "Bugyals", respectively.

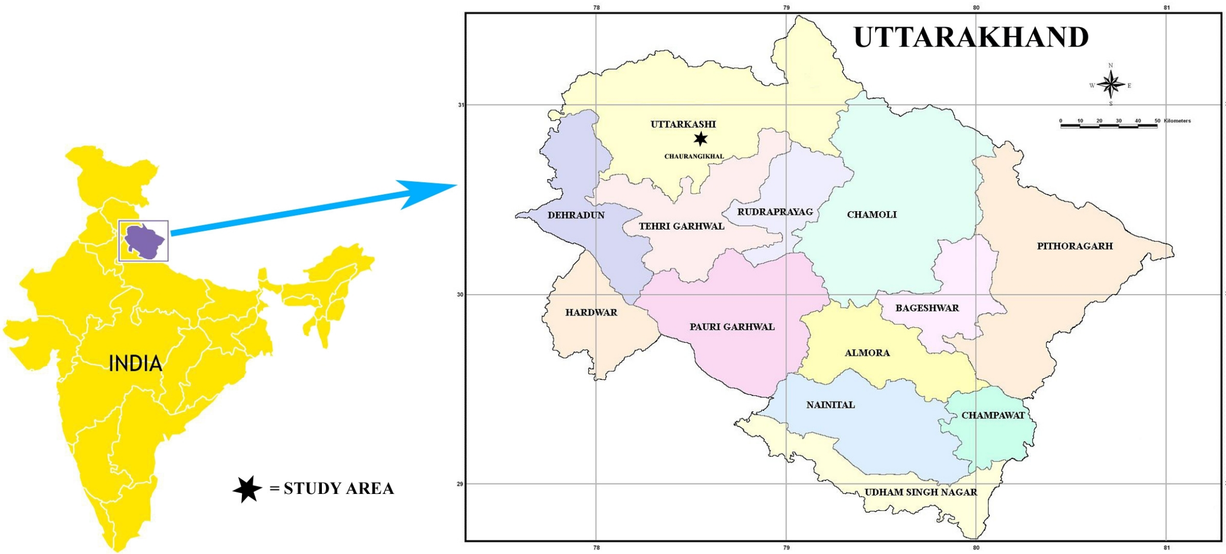

Figure 1. Map of the study area.

Table 1. The environmental variables across different altitudes

FT	Forest Type	Altitude (m asl)	Slope Aspect	Slope (Degree)	Nature of slope	Position
1	Pure *Abies pindrow* forest.	2800-2700	South-East facing.	38	Very steep	Upper
2	Mixed *Abies pindrow* forest.	2800-2650	North-East facing.	30	Very steep	Upper
3	Conifer mixed broad-leaved forest.	2700-2600	South-East facing.	25	Steep	Upper
4	Mixed broad-leaved forest.	2700-2600	South-West facing.	25	Steep	Upper
5	Pure *Abies pindrow* forest.	2600-2500	South facing.	28	Very steep	Middle
6	Pure *Quercus semecarpifolia* forest.	2600-2500	West facing.	18	Moderate	Middle
7	Conifer mixed broad-leaved forest.	2600-2450	North facing.	14	Moderate	Middle
8	Mixed *Quercus floribunda* forest.	2600-2400	South facing.	16	Moderate	Middle
9	Mixed broad-leaved forest	2400-2250	South-West facing.	15	Moderate	Lower
10	Pure *Pinus roxburghii* forest	2250-1850	South-West facing.	15	Moderate	Lower

The climate of the study area is moist temperate type, which receives moderate to high snowfall from December to February. Meterological details (1998-2007) of the study area are given in Figure 2. Mean annual maximum temperature was 18.51 ± 3.70 °C, whereas mean annual minimum temperature was 5.71

± 1.81 °C. Mean annual rainfall was 1825.39 ± 417.54 mm. Mean Relative humidity round the year in the study area ranged from 15 % to 86 %. The rainy season accounts for about three-quarters of the annual rainfall. In the study area the year is represented by three main seasons; the cool and relatively dry winter (December to March); the warm and dry summer (mid-April to June); and a warm and wet period (July to mid-September) called as the monsoon or rainy season. Apart from these main seasons, the transitional periods interconnecting rainy and winter, and winter and summer seasons are referred to as autumn (October to November) and spring (February to March). Geologically, the rocks were complex mixture of mainly sedimentary, low grade metamorphosed with sequence capped by crystalline nappe (Valdiya, 1980).

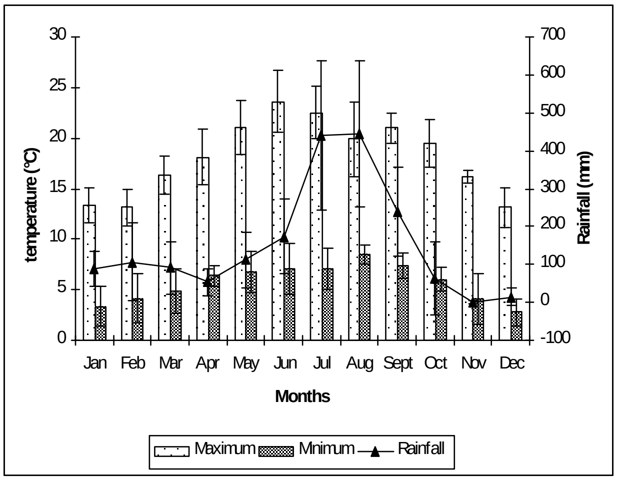

Figure 2. Climatic details of the study area (1998-2007).

2.2. Data Analysis

The study was conducted during the years 2006-2007. After the reconnaissance survey, ten forest cover types having different species compositions, altitudes, slopes and aspects were identified (table 1). Each forest type was named according to the composition of dominant tree species as per Ram Prakash (1986), viz., ≥ 75% as pure; 50-75% as mainly; 25-50% as mixed and < 25% miscellaneous. Physiographic factors i.e., altitude (m asl), slope steepness (Degree), direction of the slope, slope position (Upper, Middle, and Lower) across different cover types were measured by GPS (Garmin, Rino-130). A total of 120 plots (twenty plots in each forest type) measuring 10m X 10m each, were sampled at the study area. Plots were laid out by stratified random approach; stratification allowed equal repetition. The trees were identified with the help of Flora of the District Garhwal North West Himalaya (Gaur, 1999) and others. Trees were considered to be individuals ≥ 10 cm dbh (diameter at breast height i.e., 1.37m) (Knight, 1963). Trees were analyzed by 10m X 10m sized quadrats respectively. Total Species Richness was simply taken as a count of number of species present in that forest type. Species richness (number of species per unit area) was calculated as: SR = S-1/ln (N); where, SR = Margalef (1958) index of species richness, S = Number of species and N = total number of individuals. 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. The ratio of abundance to frequency (A/F) for different species was determined for eliciting the distribution pattern. This ratio has indicated regular (<0.025), random (0.025-0.05) and contagious (>0.05) distribution patterns (Whitford, 1949). The diversity (H') was determined by using Shannon-Wiener information index (Shannon and Weaver, 1963) as: $H' = - \sum n_i /n \log_2 n_i /n$; where, n_i was the IVI value of a species and n was the sum of total IVI values of all species in that forest type. Simpson's diversity index (Simpson, 1949) was calculated as: D = 1-Cd, where, D = Simpson's diversity and Cd = Simpson's concentration of dominance = $(\sum n_i /n)^2$.

3. Results

3.1. Species richness and diversity parameters

In the present study, the total species richness and Margalef's index were recorded from 2 to 9 and 0.17 to 1.14, across 1850-2800m asl altitudinal gradient. At the highest elevation (2800-2700m asl), the minimum species richness (2 species) and Margalef's index (0.17) were recorded, while maximum values (9 species and 1.14) of these parameters were encountered at lower elevation (2250-1850 m asl). A peak level of species richness (7 to 9 species) was recorded at a range between 2600-1850 m asl; However, species richness (constant 6 species) and Margalef's index (0.88 to 0.98) did not vary sharply between 2700-2500m asl elevation. Above 2600m asl, the both respective parameters (species richness & Margalef's index) decreased from 5 to 2 species and 0.68 to 0.17 exponentially with increase in elevation and subsequently dropped to a minimum at the highest (2800m asl) elevation (Table 2 and Figure 3). Menheink's index was recorded between 0.272 to 1.039, the minimum value was observed at the highest elevation 2800-2700m asl, whereas the maximum value was recorded at mid-elevation 2600-2500m asl. Interestingly, second highest value (0.849) was also recorded at upper elevation 2700-2600m asl which declined (0.272) at middle elevation (Table 2 and Figure 3).

Table 2. Total species richness and diversity parameters of tree species along altitudinal gradient.

Altitude (m asl)	SR	MI	MeI	H'	D
2800-2700	2	0.174	0.272	0.992	1.494
2800-2650	3	0.358	0.433	1.003	2.426
2700-2600	5	0.683	0.657	1.923	4.709
2700-2600	6	0.886	0.849	2.094	5.715
2600-2500	6	0.988	1.039	2.137	5.732
2600-2500	5	0.748	0.784	1.852	4.674
2600-2450	6	0.798	0.684	2.089	5.708
2600-2400	7	0.955	0.793	2.379	6.775
2400-2250	7	0.881	0.661	2.313	6.766
2250-1850	9	1.148	0.805	2.349	8.736

Abbreviations: SR= Species Richness; MI= Marglef's Index; MeI= Menheink's Index; H= Shannon Wiener Diversity Index; D= Simpson's Diversity Index.

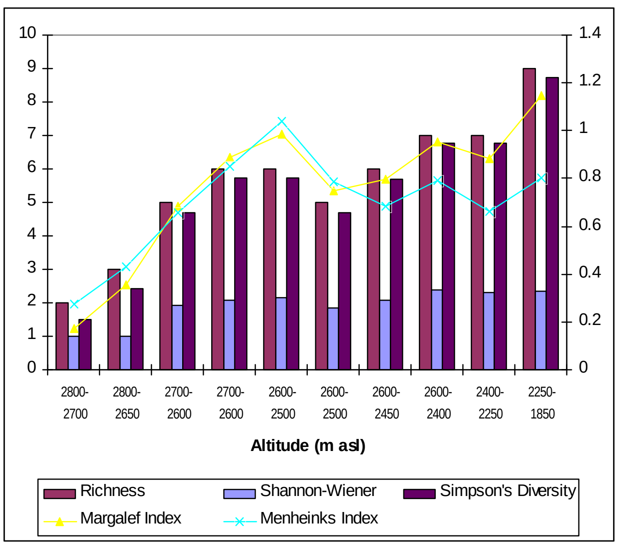

Figure 3. Species richness and diversity parameters along altitudinal gradient.

The low elevation appeared likely to be drier although precipitation varied inconsistently with elevation (Singh et al., 1994). At the highest elevation (2800-2700m asl) the maximum species diversity (0.52) and Simpson's diversity (0.80) was recorded for *Quercus semecarpifolia*, while minimum species diversity (0.47) and Simpson's diversity (0.69) for *Abies pindrow*. Just beneath this, at 2800-2650m asl elevation the highest species diversity (0.51) and Simpson's diversity (0.99) was recorded for *Q. semecarpifolia* and *Symplocos paniculata* whereas, the lowest values (0.15 and 0.49) of these parameters were observed for *A. pindrow*. At the 2700-2600m asl elevation the maximum species diversity (0.53) and Simpson's diversity (1.00) was recorded for *A. pindrow* and *Buxus wallichiana*. At middle elevation (2700-2600m asl), the highest species diversity (0.52) and Simpson's diversity (1.00) were recorded for *Q. semecarpifolia* and *Lyonia ovalifolia*, while the lowest values (0.10 and 0.80) were recorded for *L. ovalifolia* and *Q. semecarpifolia*. Between 2600-2500m asl, the maximum species diversity (0.53) and Simpson's diversity (0.99) were recorded for *A. pindrow* and *Acer acuminatum* while, minimum values of both the respective parameters (0.15 and 0.84) were recorded for *A. acuminatum* and *A. pindrow*. At 2600-2500m asl, maximum species diversity (0.52) was recorded for *Q. semecarpifolia* and minimum(0.15) for *Persea duthiei*. Between2600-2450m asl the highest species diversity (0.52) and Simpson's diversity (0.99) were recorded for *A. pindrow* and *L. ovalifolia*, while the lowest values (0.21 and 0.79) were recorded for *L. ovalifolia* and *A. pindrow*. Between 2600-2400m asl, the maximum species diversity (0.53) was recorded for *Q. floribunda* and minimum (0.09) for *A. spectabilis*. At 2400-2250m asl the highest species diversity (0.52) and Simpson's diversity (1.00) were recorded for *Q. floribunda* and *A. pindrow*, while the lowest values (0.09 and 0.90) were recorded for *A. pindrow* and *Q. floribunda*. At lowest elevation (2250-1850m asl) the maximum values of species diversity (0.53) was recorded for *Pinus roxburghii* and minimum (0.08) for *Myrica esculenta*. The overall maximum species diversity (Shannon-Wiener index) (2.37) was recorded at comparatively lower elevation (2600-2400m asl). However, second maximum species diversity (2.34) and the maximum Simpson's diversity (8.73) were recorded at the lowest elevation (2250-1850m asl), whereas, minimum species diversity (Shannon-Wiener index) (0.99) and Simpson's diversity (1.49) were observed at the highest elevation (2800-2700m asl) respectively (Table 2, 3 and Figure 3).

Table 3. Species diversity and Simpson's diversity of tree species along altitudinal gradient.

Tree Species	Altitude (m asl)																			
	2800-2700		2800-2650		2700-2600		2700-2600		2600-2500		2600-2500		2600-2450		2600-2400		2400-2250		2250-1850	
	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D
Abies pindrow	0.47	0.695	0.35	0.495	0.53	0.866	0.29	0.993	0.53	0.847	0.41	0.978	0.52	0.794	0.27	0.995	0.09	1.000	-	-
A. spectabilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.09	1.000	-	-	-	-
Acer acuminatum	-	-	-	-	-	-	-	-	0.15	0.999	-	-	-	-	-	-	-	-	-	-
Alnus nepalensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.000	0.19	0.998
Betula alnoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.14	0.999
Buxus wallichiana	-	-	-	-	0.12	1.000	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carpinus vominea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.19	0.998	-	-	-	-
Lyonia ovalifolia	-	-	-	-	0.26	0.995	0.10	1.000	0.27	0.995	0.26	0.996	0.21	0.998	0.40	0.980	0.27	0.995	0.50	0.935
Myrica esculenta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08	1.000
Persea dutheii	-	-	-	-	-	-	0.48	0.949	0.47	0.958	0.15	0.999	0.45	0.966	0.41	0.978	0.16	0.999	-	-
Pinus roxburghii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.53	0.825
Pyrus pashia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.28	0.995	0.13	0.999
Quercus floribunda	-	-	-	-	-	-	-	-	-	-	-	-	0.47	0.955	0.53	0.882	0.52	0.909	0.12	0.999
Q. leucotrichophora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.52	0.914	0.30	0.993
Q. semecarpifolia	0.52	0.800	0.51	0.932	0.52	0.903	0.52	0.806	0.50	0.935	0.52	0.790	0.22	0.997	-	-	-	-	-	-
Rhododendron arboreum	-	-	-	-	0.49	0.945	0.43	0.973	-	-	0.52	0.912	0.22	0.997	0.49	0.942	0.48	0.954	0.35	0.987
Symplocos paniculata	-	-	0.15	0.999	-	-	0.27	0.995	-	-	-	-	-	-	-	-	-	-	-	-
Taxus baccata	-	-	-	-	-	-	-	-	0.21	0.998	-	-	-	-	-	-	-	-	-	-

Abbreviations: H'= Shannon-Wiener index; D = Simpson's Diversity index

The overall pattern of species richness, Margalef's index, Menheink's index, Shannon-Wiener index (species diversity) and Simpson's diversity index showed a sharp decline at the highest altitude (2800-2700m asl). A similar pattern of tree species richness in timberline area was reported by Rawal et al. (1991). Tree species richness increases with increasing moisture in the Indian Central Himalaya (Rikhari et al.1989). In this study, a negative relationship was found between species richness, Margalef's index, Menheink's index, species diversity and Simpson's diversity index vs elevation (Table 2, 3 and Figure 3, 4). Sagar et al. (2008) have suggested that species richness decreases with an increase in species dominance.

3.2. Distribution pattern (A/F) ratio

Hubbell et al. (1999) reported that the dispersal limitation is an important ecological factor for controlling species distribution pattern and a connection between biotic and abiotic ecological factors. A number of tree species found in the Himalaya showed varying patterns of distribution. The extension of climate gradient enabled several species to realize their fullest range of elevational adaptability. An analysis of dispersion pattern (Table 4) indicated that maximum species had random distribution at the altitude between 2800-1850m asl. At the higher altitude (2800-2600m asl) maximum tree species were distributed in random pattern, interestingly same tendency was observed for the species at lower altitude (2600-1850m asl), while at middle altitudinal range (2600-2450m asl) most of the species were distributed in contiguous pattern and rarely in regular pattern also. The *Abies pindrow* and *Rhododendron arboreum* changed their dispersion pattern from contiguous (2400-2250m asl) to random (2600-2450m asl) followed by again contiguous (2700-2600m asl) to finally random at the higher altitude (2800-2650m asl). *Quercus* species was found distributed in random pattern from lower (2250-1850m asl) to the higher (2800-2700m asl) altitudes. *Persea duthiei* showed contiguous to random distribution patterns while *Lyonia ovalifolia* showed regular and random and finally contiguous patterns along lower, middle and higher altitudinal ranges. The species-aggregation relationship predicts that spatial aggregation of individuals within species results in lower species richness Sagar et al. (2008).

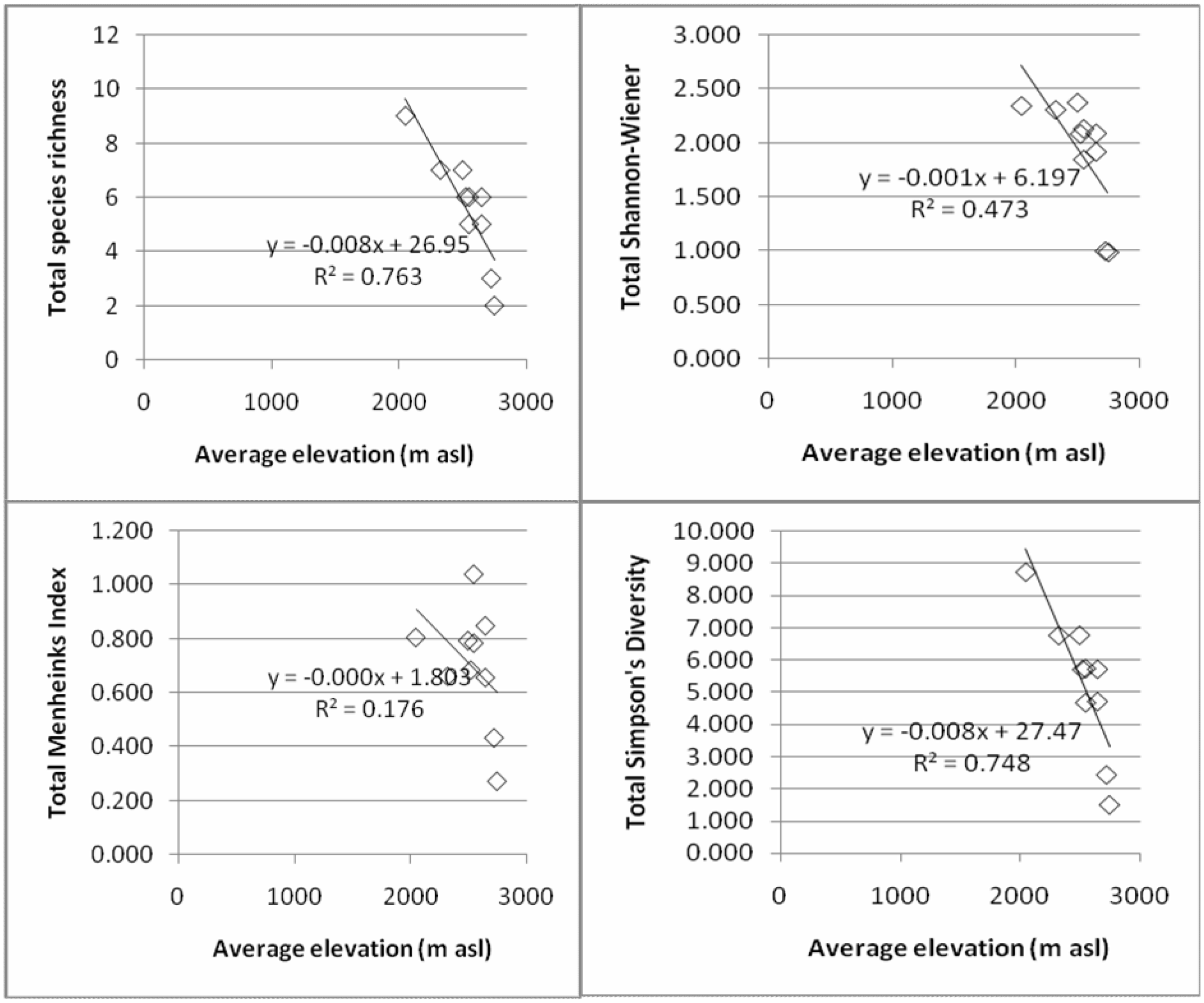

Figure 4. Species richness and diversity parameters of tree species along increasing elevation.

According to Odum (1971), the clumped distribution is common in nature, while random distribution is found only in uniform environments. The clumping of individuals of a species may be due to insufficient mode of seed dispersal (Richards, 1996) or when death of trees creates a large gap encouraging recruitment and growth of numerous saplings (Armesto et al., 1986). Connell (1978) suggested that the uniform dispersion pattern of species in tropical forests largely enable the maintenance of high levels of diversity. The changes in the dispersion patterns may reflect the reactions of species to disturbance as well as to changes in the habitat conditions (Sagar et al., 2003).

4. Discussion

A number of tree species found in the Himalaya exhibit varying patterns of distribution. The extension of climatic gradient enabled several species to realize their fullest range of elevational adaptability. Distributional ranges of several species were segregated along the widened altitudinal ranges (Kharakwal et al., 2005). He & Legendre (2002) reported species-area relation, which predicts that species richness increases with increasing area. Pausas & Austin (2001) also suggested that over any large region the distribution of species richness is likely to be governed by two or more environmental factors and not by a single factor. Pangtey et al. (1991) argued that the effect of monsoon is not substantially weakened at higher altitudes and also the amount of rainfall is not much different from that of the lower altitudinal range of Central Himalaya. This has also been used to explain the patterns of decrease in species richness with altitude (Rahbek, 1997). In the temperate

Table 4. Dispersion behaviour of tree species along altitudinal gradient.

Tree Species	Family	Altitude (m asl)									
		2800-2700	2800-2650	2700-2600	2700-2600	2600-2500	2600-2500	2600-2450	2600-2400	2400-2250	2250-1850
Abies pindrow	Pinaceae	0.04(R)	0.05(R)	0.02(Re)	0.07(C)	0.02(Re)	0.04(R)	0.03(R)	0.06(C)	0.10(C)	-
A. spectabilis	Pinaceae	-	-	-	-	-	-	-	0.10(C)	-	-
Acer acuminatum	Aceraceae	-	-	-	-	0.30(C)	-	-	-	-	-
Alnus nepalensis	Betulaceae	-	-	-	-	-	-	-	-	-	0.10(C)
Betula alnoides	Betulaceae	-	-	-	-	-	-	-	-	-	0.08(C)
Buxus wallichiana	Buxaceae	-	-	0.10(C)	-	-	-	-	-	-	-
Carpinus vaminea	Corylaceae	-	-	-	-	-	-	-	0.08(C)	-	-
Lyonia ovalifolia	Eriaceae	-	-	0.04(R)	0.15(C)	0.07(C)	0.19(C)	0.03(R)	0.03(R)	0.02(Re)	0.04(R)
Myrica esculenta	Myricaceae	-	-	-	-	-	-	-	-	-	0.10(C)
Persea dutheii	Lauraceae	-	-	-	0.10(C)	0.04(R)	0.30(C)	0.04(R)	0.03(R)	0.08(C)	-
Pinus roxburghii	Pinaceae	-	-	-	-	-	-	-	-	-	0.05(R)
Pyrus pashia	Rosaceae	-	-	-	-	-	-	-	-	0.05(R)	0.05(R)
Quercus floribunda	Fagaceae	-	-	-	-	-	-	0.04(R)	0.04(R)	0.04(R)	0.05(R)
Q. leucotrichophora	Fagaceae	-	-	-	-	-	-	-	-	0.04(R)	0.03(R)
Q. semecarpifolia	Fagaceae	0.03(R)	0.02(Re)	0.03(R)	0.06(R)	0.03(R)	0.03(R)	0.05(R)	-	-	-
Rhododendron arboreum	Ericaceae	-	-	0.05(C)	0.04(R)	-	0.08(C)	0.04(R)	0.02(Re)	0.03(R)	0.07(C)
Symplocos paniculata	Symlocaceae	-	0.10(C)	-	0.04(R)	-	-	-	-	-	-
Taxus baccata	Taxaceae	-	-	-	-	0.08(C)	-	-	-	-	-

Abbreviations: R = Random; Re = Regular; C = Contiguous

Table 5: Carl Pearson correlation coefficient between different parameters:

	Altitude	Slope	Density	TBC	SR	MI	MEI	H'	Cd	D
Altitude	1.000									
Slope	0.719*	1.000								
Density	-0.848**	-0.635*	1.000							
TBC	-0.207	0.196	0.461	1.000						
SR	-0.874**	-0.817**	0.684*	-0.175	1.000					
MI	-0.750*	-0.750*	0.457	-0.392	0.960**	1.000				
MEI	-0.420	-0.499	0.001	-0.669*	0.723*	0.887**	1.000			
H	-0.688*	-0.804**	0.501	-0.464	0.932**	0.952**	0.807**	1.000		
Cd	0.590	0.732*	-0.413	0.559	-0.851**	-0.889**	-0.784*	-0.978**	1.000	
D	-0.865**	-0.819**	0.674*	-0.198	1.000**	0.964**	0.732*	0.942**	-0.866**	1.000

**. Correlation is significant at the 0.01 level; *. Correlation is significant at the 0.05 level.

forests mean tree species richness was maximum in mixed broad-leaved forest which decreased from highly to least disturbed forests (Kumar & Ram, 2005). Consequently, our study revealed the maximum species richness of tree species at lower elevation, compared to higher elevational forests as suggested by Kumar & Ram (2005). Rathore (1993) has noticed high species richness and diversity in the *Pinus roxburghii*-mixed broad-leaved forests. In another study Singh et al. (1994) reported that *P. roxburghii*-mixed broad-leaved forests had the highest species richness, while high elevation forests had the lowest. Burns (1995) and Austin et al. (1996) have found that the total species richness was greatest at lower elevation and warmer sites. The overall pattern of species richness showed a sharp decline as the altitude increased beyond 3000m asl. A similar pattern of tree species richness (deciduous) in timberline area was reported by Rawal et al. (1991).

Between 2450-2600 and 2600-2500 m asl, species richness fluctuated due to change in the climatic conditions (Table 2 and Figure 3). More than 60%

(Maximum) plant species were either present at 1850m asl, where the temperature cover a range from 10°C to 24°C (Champion & Seth, 1968). The low elevational sites were relatively densely populated probably because human interference in these areas facilitates the introduction and establishment of non-native species (Rawal & Pangtey, 1994). The human impact at lower altitudes was evident in the form of open spaces left after selective tree felling. These spaces may exacerbate the establishment of shade–intolerant species and enhance the regeneration of mixed pine-broadleaved forest (Wangda & Ohsawa, 2006). As a result of which the maximum tree species were encountered at lower elevation (Pine-mixed broad-leaved forest) compared to higher elevational sites. In this study the richness of non-native species like *Pinus roxburghii, Pyrus pashia*, *Lyonia ovalifolia*, *Betula alnoides* and *Alnus nepalensis* was more prevalent in early successional/ pioneer communities, because the species richness is believed to be more in pioneer communities (Rajmanek, 1989). Occurrence of *Abies pindrow*, *Quercus semecarpifolia*, *Q. leucotrichophora* and *Rhododendron arboretum* community (Table 4) almost on all the sites along the altitudinal gradient suggests their tolerance to biotic pressures and wider ecological amplitude. *Pinus roxburghii* is an early successional species and Oak a climatic climax, while the successional stage of *Abies pindrow* forest is considered to be climax for west-Himalaya (Champion & Seth, 1968). The expected compositional changes in *Q. leucotrichophora* forests are associated with biomass destruction. All *Quercus spp*. are repeatedly lopped for their fuel wood and fodder values. This activity reduces vigour and seed production (Saxena & Singh, 1984) in this species. Large scale extraction of selected species also causes structural change in plant communities (Spurr & Barnes 1980). Heavy browsing by animals at seedling and sapling stages is also responsible for poor representation in recruitment classes of *Q. leucotrichophora*, *Q. floribunda and Q. semecarpifolia* (Dhar et al. 1997). Accompanying frequent reproduction and expanding populations of two co-dominant native species, *Rhododendron arboreum* and *Lyonia ovalifolia*, result in structural/compositional changes, because they are unpalatable and less preferred for fuel wood. Poor recruitment of dominant *A. pindrow* and *Q. semecarpifolia* and other species in high elevation forests indicates possible decline in their populations. The prevention of recruitment of dominant natives is considered to be a causal process resulting in changes in structural and functional aspects of reserve's ecosystem (Macdonald et al., 1989). For analysis of variability in dispersion, about half of the analyzed species in this study showed no effect of disturbance on dispersal behaviour and were characterized by clumped distribution. Clumping in these species may be due to patchy distribution of microhabitats suitable for plant growth in forest soils. The correlation between various parameters is shown in Table 4.

5. Conclusions

The present study highlights a very poor status of total species richness in the entire forest area along with regulation of tree species at various altitudes. Our findings revealed that lower elevational cover-types had comparatively higher number of species than lower number of species at higher elevational cover-types which implies that higher elevational forest types should be conserved with necessary implementations. Lower altitudinal forest types preferred optimum species richness, diversity and related parameters including soil status. At the higher altitudinal forest types species richness and diversity were found lesser prevalent because of high dependency of the people on fuel wood, extraction of NTFPs from the forest for generation of income. Significantly negative correlation of density and species richness with altitude and slope was recorded. The study suggests that the distribution and species richness pattern of different tree species are largely regulated by the altitude and climatic factors.

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