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SPECIES RICHNESS AND DIVERSITY OF TREE SPECIES ALONG AN ALTITUDINAL GRADIENT IN DHANAULTI REGION OF GARHWAL HIMALAYA, INDIA

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Abstract

Garhwal Himalaya is considered as a hot spot of biodiversity in India and support a large number of plant species. It's wide altitudinal range and variations in other factors like soil texture, climate, rainfall etc., influence the diversity of plant species of this region, which also supports the life and livelihood of local people in many ways. The present study was carried out in Dhanaulti forest of Garhwal Himalaya to reveal the impact of altitude gradient on the species richness, species diversity and dispersion behaviour of different tree species along the altitudinal gradient for proper management, sustainable utilization and conservation of the forest resources. We have observed that the values of all the growth indices *i.e.,* Margalef's index (MI) (3.54 to 11.57), Menheink's index (MeI) (0.32 to 0.80), Species diversity (H') (1.81 to 2.93) and Simpson's diversity index (SDI) (3.49 to 11.85) were maximum at the lower altitudes (1600-1200m asl), medium at mid-altitudes (2400-1800m asl) and lowest at the higher altitudes (2800-2600m asl). A moderate negative correlation between density, species richness, MI, MeI, H' and SDI with altitude and slope was recorded. The present study suggests that species richness and diversity of different tree species are regulated by the altitude and various climatic factors. Additionally, the growth of different tree species on selected forest types also indicates the presence of high anthropogenic pressure. Hence, appropriate conservation strategy should be implemented to save economically important forests as well as the inhabiting species.

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

Introduction

Indian subcontinent is rich in biodiversity and constitutes one of the 12 mega-diversity countries in the world. Garhwal Himalaya is one of the hot spots of biodiversity situated in the western part of Central Himalaya. It shows wide altitudinal range, rapid change in altitudinal gradient even at small distances (Singh and Singh, 1992; Zobel and Singh, 1997; Chandra *et al.*, 2010). In Himalayan region, elevation and climatic factors are important factors for regional differences in species composition (Lee and Chun 2016; Sharma *et al.,* 2016). The vegetation diversity of forest ecosystems of Himalaya is influenced by many factors such as topography, soil, climate and geographical location (Chandra *et al.,* 2010). There is a great diversity in the floristic pattern due to altitudinal variation and rainfall (Arora, 1995). Ellu and Obua (2005) have reported the influence of different altitudes and slopes over species richness and dispersion behavior of tree species. Hussain *et al.*, 2008 have also reported that distribution of tree communities in Kumaon Himalaya was governed mainly by altitudinal gradient, slope and canopy cover. Moreover, altitude itself is a complex of various climatic variables closely related to many other environmental properties like soil texture, nutrients, substrate stability etc. (Ramsay and Oxley, 1997).

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The Himalayan forest supports the life and livelihood of local people in different ways (Patnaik, 1986; Dhyani *et al.*, 2011). Collection of fuelwood and fodder from forest turns the cycle of economy and livelihood of the rurals inhabiting in Himalaya (Patnaik, 1986 and Dhyani *et al.*, 2011). Many tree species provide many ecosystem services and have considerable conservation significance in this region (Saxena and Singh, 1982; Upreti *et al.*, 1985). Many plant species are associated not only with agro-ecosystems but also with the life support systems of the inhabitants of the hills in the Himalaya. For instance, oak forests are source of fuel wood, timber and can be correlated with natural springs and wildlife (Singh *et al.*, 1981). Likewise, *Rhododendron arboreum* is considered as an ecological keystone species (Paine 1969). But over the past few decades, the Himalaya has experienced unprecedented land use changes due to rapid population growth and human activities (Pandit *et al.*, 2007). Moreover, limited employment opportunities and poverty have increased the dependency of local people for fuel wood, fodder, building material and non-timber forest products on adjacent forests. Most Himalayan forest has become less productive due to this extra pressure (Saxena *et al.*, 2005).

The present study was carried out to reveal the impact of altitude on common occurring tree species in various forest types of temperate region of Garhwal Himalaya for assessment and analysis of change in the dispersion pattern along the altitudinal gradient for sustainable utilization, proper management and conservation of the forest resources.

Materials and Methods

Study Area

The present study was carried out on the forest tree species along an altitudinal gradient in Dhanaulti region of Garhwal Himalaya of Uttarakhand), covering about 328ha area (Fig. 1; Location map of study area). It is

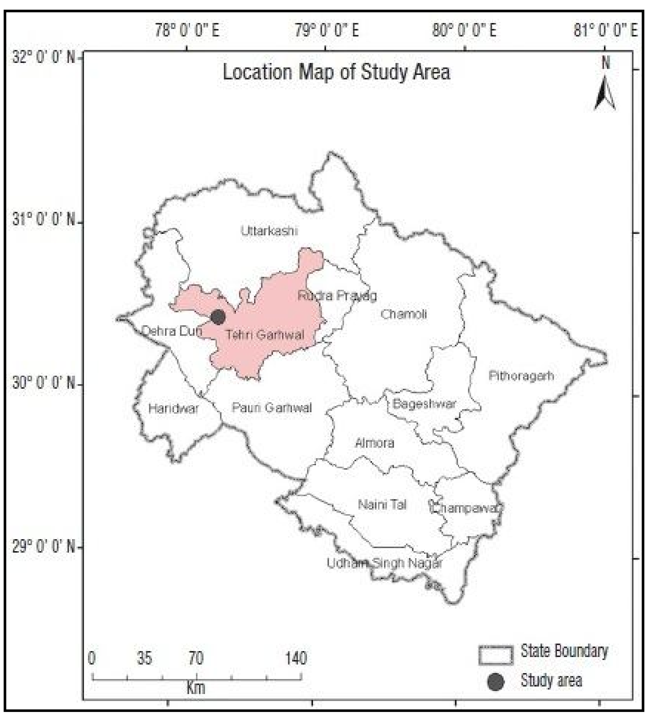

Fig. 1: Location map of the study area in Uttarakhand.

located in Garhwal Hills between 30° 27' 0" N78° 15' 0" E in western part of Uttarakhand state. The place is about 24 Km. from Mussoorie '*Queen of Hills'* and is situated at an altitude of 2286 m. above sea level (asl). Topography of this region is mountainous with loamy-clay soil. Geologically, the rocks of the study area are mainly of Precambrian to early Cambarian in age with recent and sub-recent river terraces. The soils of this region change according to aspect, altitude and climate; belong to mollisols and of Satengal to inceptisols. The soils are generally acidic in nature with pH increasing with depth and support different types of vegetation in the natural forests (Saha *et al.,* 2016). The climatic data of the study area are given in Fig. 2. Dhanaulti has an excellent climate round the year. The study area experiences typical moist temperate climate with mean maximum and minimum temperatures. The temperature in this region is cool throughout the year. The summer months are cool and winters are not very freezing but provide a misty view of distant mountains. The summer temperatures range from 25°C to 16°C while the winter temperature ranges from 13°C to 2.8°C.

Details of the forest types and data analysis:

The present study was carried out in ten different forest types of Dhanaulti region along elevation range between 1200 to 2800 meters above sea level (m asl) (Fig. 1 Google map). Ten forest types of the study area were selected on the basis of altitude, slope aspect and species composition. Each forest type was named on the basis of 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 table 1. A total of 120 plots (twenty plots in each forest type) measuring 10m × 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 Dhanaulti Garhwal Himalaya (Gaur, 1999) and others. Trees were considered to be individuals ≥ 10 cm dbh (diameter at

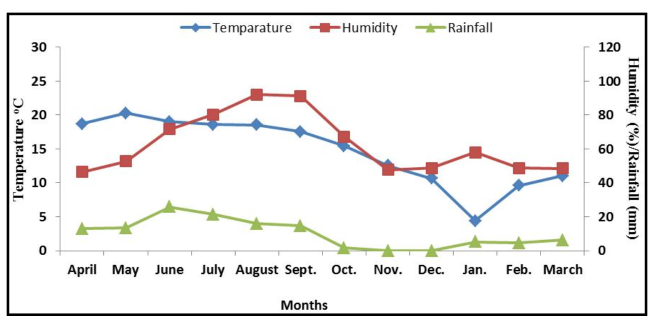

Fig. 2: Climatic details of the study area (Source: Forest Department, Dhanaulti, Uttarakhand).

Table 1: Forest types selected in the study site (on the basis of slope aspect, altitude and species composition).

FT	Forest Type	Slope Aspect	Altitude (m asl)	Dominant species/IVI
FT-1	Pure broad leaved Forest Type	NW facing	1200	*Quercus floribunda* (76),*Rhododendron arboreum* (49.5),*Cupressus torulosa* (37)
FT-2	Pure *Pinus roxbunshi* Forest Type	N facing	1400	*Quercus floribunda* (92.43),*Pinus roxburghii* (78.62),*Cupressus torulosa* (35.71)
FT-3	Mixed *Pinus roxburghii* Forest Type	NE facing	1600	*Quercus floribunda* (90.34),*Pinus roxburghii* (74.55),*Rhododendron arboreum* (45.1)
FT-4	Mixed *Coniferous* Forest Type	S facing	1800	*Pinus roxburghii* (82.75),*Quercus floribunda* (75.8),*Pyrus pashia* (52.97)
FT-5	Pure broad leaved Forest Type	NE facing	2000	*Quercus floribunda* (91.84),*Cupressus torulosa* (49.72),*Populus sps.* (48.74)
FT-6	Mixed broad leaved Forest Type	SW facing	2200	*Pyrus pashia* (75.04),*Quercus floribunda* (73.16),*Rhododendron arboreum* (71.72)
FT-7	Mixed *Quercus floribunda* Forest Type	W facing	2400	*Cupressus torulosa* (102.4),*Quercus floribunda* (84.31),*Rhododendron arboreum* (70.04)
FT-8	Pure *Quercus semecarpifolia* Forest Type	SW facing	2600	*Betula alnoides* (216.30),*Quercus floribunda* (65.56),*Rhododendron arboreum* (63.50)
FT-9	Mixed *Cupressus torulosa* Forest Type	NW facing	2700	*Cupressus torulosa* (140.2)*Quercus floribunda* (65.84),*Rhododendron arboreum* (47.84)
FT-10	Pure *Cupressus torulosa* Forest Type	N facing	2800	*Quercus floribunda* (86.07),*Cupressus torulosa* (83.67),*Pyrus pashia* (45)

Abbreviations: FT = Forest types; NW = North West facing; N = North facing; NE = North East facing; S = South facing; W = West facing; IVI= Importance Value Index.

breast height *i.e.,* 1.37m) (Knight, 1963). Total Species Richness in any forest was simply taken as a count of number of species present in that forest type.

Species richness (SR):

Species richness (number of species per unit area) was calculated as:

SR = S-1/ln (N)

where, SR = Margalef index of species richness (1958), S = Number of species and N = total number of individuals.

Menheink Index (MeI):

Menheink Index of species richness was calculated with the help of following formula (Whittaker, 1977)

$$MeI = \frac{S}{\sqrt{N}}$$

Where, S= number of species; N=Total number of individuals of all the species.

Margalef Index (MI):

Margalef Index of species richness (number of species per unit area); N= Total number of individuals,

$$MI = \frac{S-1}{In(N)}$$

Where, MI= Margalef's Index of species richness (Number of species per unit area); N=Total no. of individuals.

Shannon-Wiener Diversity Index (H'):

Shannon-Wiener Diversity Index was calculated as per Shannon and Wiener (1963) by employing the following formula:

$$H' = \sum_{i=1}^{n} \left(\frac{N_1}{N}\right) \log_2 \left(\frac{N_1}{N}\right)$$

Where, H'= Shannon – Wiener Diversity Index; Ni = Importance Value Index of a species; N = Total Importance Value Index of all the species.

Simpson's diversity index (D):

Simpson's diversity index (D) was calculated by using following formula (Simpson, 1949):

SDI=1-Cd

Where, SDI= Simpson's Diversity Index; Cd=Simpson's Concentration of Dominance

A/F Ratio:

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).

Results

Species richness and diversity parameters

In the present study, the total species richness was recorded from 4 to 12 and Margalef's index was recorded from 3.54 to 11.57, across 1200-2800m asl. altitudinal gradient. At high elevation (2700m asl.), the minimum species richness (4 species) and Margalef's index (3.54) were recorded, while maximum values (12 species and 11.57) of these parameters were encountered at lower elevation (1200m asl.). Moreover, the species richness (constant 6 species) and Margalef's index (5.58 to 5.56) did not vary between 1400-2200m asl. elevation. At 2700 m asl. elevation both parameters- species richness and Margalef's index decreased to minimum (4 species and 3.54, respectively). Menheink's index was recorded between 0.32 to 0.80, the minimum value was observed at the high elevation 2700 m asl., whereas the maximum value was recorded at lowest elevation. Interestingly, value of Menheink's index remained constant (0.40) between 1400 to 2200 m asl.. Maximum species diversity (Shannon-Wiener index) (2.93) and Simpson's diversity index (11.85) were recorded at lowest elevation (1200 m asl.). Interestingly, second maximum species diversity (2.44) was observed at 2600 m asl., while minimum species diversity (1.81) and Simpson's diversity index (3.49) were recorded at comparatively higher elevation (2700 m asl.) table 2, Fig. 3.

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

Forest Type	Altitude (m asl)	SR	MI	Mel	H'	D
FT-1	1200	12	11.57	0.80	2.93	11.85
FT-2	1400	6	5.58	0.40	2.39	5.71
FT-3	1600	6	5.58	0.39	2.39	5.82
FT-4	1800	6	5.58	0.40	2.39	5.80
FT-5	2000	6	5.58	0.40	2.43	5.81
FT-6	2200	6	5.57	0.40	2.38	5.80
FT-7	2400	5	4.57	0.35	2.04	4.75
FT-8	2600	6	5.58	0.39	2.44	5.82
FT-9	2700	4	3.54	0.32	1.81	3.49
FT-10	2800	6	5.56	0.45	2.34	5.79

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

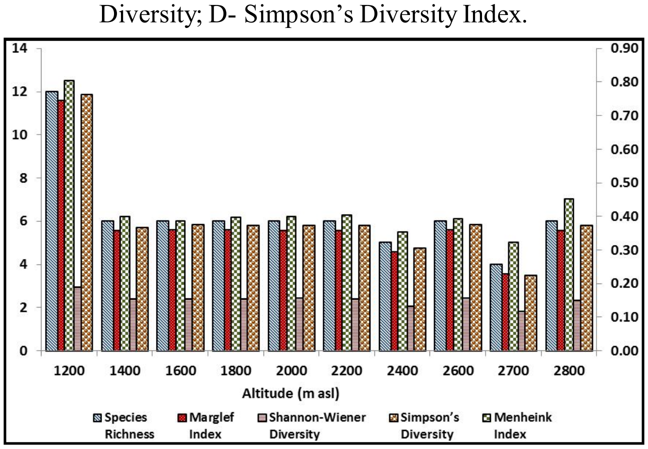

Fig. 3: Species richness and diversity parameters along altitudinal gradient.

Overall, pattern of species richness, Margalef's index, Menheink's index, Shannon-Wiener index (species diversity) and Simpson's diversity index showed a decline at higher altitude (2700 m asl), indicating negative relationship between these parameters and elevation.

At the highest elevation (2800 m asl.) the maximum species diversity (0.51) and minimum Simpson's diversity (0.92) was recorded for *Cupressus torulosa* and *Quercus floribunda,* while minimum species diversity (0.81) was observed for *Lyonia ovalifolia* and maximum Simpson's diversity (0.99) was recorded for *Lyonia ovalifolia* and *Rhododendron arboreum.* Just beneath it, at 2700 m asl. elevation the highest species diversity (0.51) and Simpson's diversity (0.95) was recorded for *Cupressus torulosa* and *Quercus floribunda*, respectively, whereas, the lowest value 0.41 and 0.70 of these parameters were observed for *Leucaena leucocephala* and *Rhododendron arboreum*, respectively. At the 2600 m asl. elevation the maximum species diversity (0.49) and minimum Simpson's diversity (0.94) was recorded for *Betula alnoides* whereas, minimum species diversity (0.25) and maximum Simpson's diversity (0.99) was observed for *Pyrus pashia*. At middle elevation (2400 m asl.), the highest species diversity (0.52) and minimum Simpson's diversity (0.89) were recorded for *Cupressus torulosa* while, minimum species diversity (0.23) was recorded for *Betula alnoides* and maximum Simpson's diversity (0.99) was exhibited by *Betula alnoides* and *Pinus roxburghii*. At 2200 m asl. maximum species diversity (0.49) and minimum Simpson's diversity (0.94) were recorded for *Pyrus pashia, Quercus floribunda* and *Rhododendron arboreum* while, minimum species diversity (0.22) was recorded for *Lyonia ovalifolia* and maximum Simpson's diversity (0.99) was exhibited by *Lyonia ovalifolia, Cupressus torulosa* and *Populus species*. At 2000 m asl., maximum species diversity (0.52) and minimum Simpson's diversity (0.91) were recorded for *Q. floribunda*. The minimum species diversity (0.30) was recorded for *Thuja occidentalis* and maximum Simpson's diversity (0.99) was observed for

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

Tree species	Altitude (m asl)																			
	1200		1400		1600		1800		2000		2200		2400		2600		2700		2800	
	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D	H'	D
Azadirachta indica	0.17	0.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bauhinia variegata	0.13	0.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Betula alnoides	-	-	-	-	-	-	-	-	-	-	-	-	0.23	0.99	0.49	0.94	0.41	0.77	0.40	0.98
Callistemon citrinus	0.10	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cupressus torulosa	0.39	0.98	0.36	0.89	0.38	0.99	0.30	0.99	0.42	0.97	0.35	0.99	0.52	0.89	0.37	0.98	0.51	0.79	0.51	0.92
Ficus sps.	0.13	0.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gravillea robusta	0.11	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leucaena leucocephala	0.11	1.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.41	0.77	-	-
Lyonia ovalifolia	-	-	-	-	0.33	0.99	0.24	0.99	-	-	0.22	0.99	-	-	-	-	-	-	0.18	0.99
Pinus roxburghii	0.38	0.98	0.5	0.94	0.49	0.94	0.51	0.93	-	-	-	-	0.30	0.99	0.41	0.98	-	-	-	-
Populus sps.	-	-	-	-	-	-	-	-	0.42	0.97	0.34	0.99	-	-	-	-	-	-	0.41	0.98
Pyrus pashia	0.31	0.99	0.35	0.99	-	-	0.44	0.97	0.43	0.97	0.49	0.94	-	-	0.25	0.99	-	-	-	-
Quercus floribunda	0.51	0.92	0.52	0.91	0.52	0.92	0.50	0.94	0.52	0.91	0.49	0.94	0.51	0.92	0.47	0.95	0.47	0.95	0.51	0.92
Rhododendron arboreum	0.44	0.97	0.34	0.99	0.4	0.98	0.40	0.98	0.34	0.99	0.49	0.94	0.48	0.95	0.45	0.97	0.42	0.70	0.32	0.99
Thuja occidentalis	-	-	0.32	0.99	0.27	0.99	-	-	0.30	0.99	-	-	-	-	-	-	-	-	-	-
Toona ciliata	0.15	0.99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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

Rhododendron arboreum and *Thuja occidentalis*. Likewise, at 1800 m asl., maximum species diversity (0.51) and minimum Simpson's diversity (0.93) were recorded for *Pinus roxburghii*. The minimum species diversity (0.24) was recorded for *Lyonia ovalifolia* and maximum Simpson's diversity (0.99) was exhibited by *Lyonia ovalifolia, Cupressus torulosa*. At 1600 m asl., maximum species diversity (0.52) and minimum Simpson's diversity (0.92) were recorded for *Quercus floribunda*. The minimum species diversity (0.27) was recorded for *Thuja occidentalis* and maximum Simpson's diversity (0.99) was exhibited by *Thuja occidentalis* with *Lyonia ovalifolia, Cupressus torulosa*. At 1400 m asl., the maximum (0.52) and minimum species diversity (0.32) was recorded for *Quercus floribunda* and *Thuja occidentalis*, respectively. The maximum Simpson's diversity (0.99) was recorded for *Thuja occidentalis*, *Pyrus pashia* and *Rhododendron arboreum* and minimum Simpson's diversity (0.89) was found for *Cupressus torulosa*. At lowest elevation (1200 m asl.), maximum species diversity (0.51) and minimum Simpson's diversity (0.92) were recorded for *Quercus floribunda*. The minimum species diversity (0.10) was recorded for *Callistemon citrinus,* while maximum Simpson's diversity (0.99) was shown by *Callistemon citrinus, Leucaena leucocephala* and *Gravillea robusta* table 3.

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 large number of tree species existing in the Himalaya represents varying patterns of distribution. The present study has indicated that maximum tree species had contiguous distribution at the altitude between 2800-1200m asl. However, a few species showed random distribution pattern at upper altitude (2700-2800 m asl). *Betula alnoides* changed the distribution pattern from contagious (at 2400-2600 m asl) to random (at 2700-2800 m asl). Likewise, *Cupressus torulosa* and *Quercus floribunda* exhibited contagious distribution pattern between 1200-2600 m asl, which changed to random at 2700 m asl. Moreover, the distribution pattern of *Cupressus torulosa* changed to regular and *Quercus floribunda* changed to contagious at 2800 m asl. *Rhododendron* *arboreum* also showed contagious distribution pattern between 1200-2800 m asl, except at 2400 m asl, where it was random. Interestingly, all growing tree species at 2700 m asl exhibited random distribution pattern except, *Rhododendron arboreum* which showed contagious pattern of distribution table 4. Overall, most of the tree species in this study showed contagious distribution pattern.

Discussion

Species richness

Assesment of biodiversity and their drivers along environmental gradient is one of the important topics in ecology (Lee and Chun, 2016). Vaiations in different quantitative parameters, species composition and forest composition among all studied forests sites may be due to difference in climatic, physiographic and edaphic factors (Sharma *et al.*, 2017) along altitudes. Quantitative analysis of diversity of tree species recorded in this study may provide baseline information for formulating conservation and management strategies for the natural forests. The present study revealed that tree species richness was greatest at lower altitude (1200 m asl.; Pure broad leaved Forest Type) as compared to higher altitude. Contrary to it, Rathore (1993) and Singh *et al.*, (1994) were noticed high species richness and diversity of tree species at low altitudinal *Pinus roxburghii*-mixed broad-leaved forests. Common useful species for local people such as *Azadirachta indica, Ficus species, Gravillea robusta*, *Azadirachta indica*, *Bauhinia variegata, Leucaena leucocephala* and *Toona ciliata* were only seen at lower altiutude at 1200 m asl. and completely absent above it. It indicates the impact of human in the form of open spaces left after selective tree felling. These spaces may favoured the existence of shade–intolerant species and enhanced the regeneration of mixed pine-broadleaved forest (Wangda and Ohsawa, 2006). Almost constant figures of species richness as recorded in other forest types was also in contrary to the another study done in mixed forest of pine and oak which suggests higher plant diversity in the mixed forests as compared to the pioneering pine or late successional oak forests (Singh and Singh 1992; Upreti *et al.*, 1985). Moreover, presence of *Quercus floribunda, Rhododendron arboreum* and *Cupressus torulosa* communities almost on all the sites along altitudinal gradient suggests their tolerance to biotic pressure and wider ecological amplitude. Oak forests are most extensively distributed between the altitudes 1000 m asl. to timberline and represent the climax stage, throughout the Central Himalaya (Champion and Seth, 1968; Upreti *et al.*, 1985). Furthermore, in the present study, species richness of tree strata ranged from 4 species at upper altitude and 6 species at middle altitude, whereas, 12 species at lower altitude. Higher species richness is reported at lower elevation, while high elevation forests had the lowest. The overall pattern of species richness showed a decline as the altitude increased. Sharma *et al.,* (2009) also reported negative relation of tree species richness index with increasing altitude. Similarly, Rawal *et al.,* (1991)

Table 4: Dispersion behavior of tree species along altitudinal gradient.

Species	Family	1200 m asl	1400 m asl	1600 m asl	1800 m asl	2000 m asl	2200 m asl	2400 m asl	2600 m asl	2700 m asl	2800 m asl
Azadirachta indica	Meliaceae	0.48 C	-	-	-	-	-	-	-	-	-
Bauhinia variegata	Fabaceae	0.48 C	-	-	-	-	-	-	-	-	-
Betula alnoides	Betulaceae	-	-	-	-	-	-	0.42 C	0.06 C	0.04 R	0.05 R
Callistemon citrinus	Myrtaceae	0.48 C	-	-	-	-	-	-	-	-	-
Cupressus torulosa	Cupressaceae	0.08 C	0.15 C	0.15 C	0.12 C	0.07 C	0.21 C	0.07 C	0.24 C	0.05 R	0.02 Re
Ficus sps.	Moraceae	0.60 C	-	-	-	-	-	-	-	-	-
Gravillea robusta	Proteaceae	0.48 C	-	-	-	-	-	-	-	-	-
Leucaena leucocephala	Fabaceae	0.60 C	-	-	-	-	-	-	-	-	-
Lyonia ovalifolia	Eriaceae	-	-	0.17 C	0.18 C	-	0.17 C	-	-	-	0.96 C
Pinus roxburghii	Pinaceae	0.25 C	0.10 C	0.12 C	0.09 C	-	-	0.32 C	0.16 C	-	-
Populus sps.	Salicaceae	-	-	-	-	0.20 C	0.12 C	-	-	-	-
Pyrus pashia	Rosaceae	0.15 C	0.16 C	-	0.07 C	0.20 C	0.11 C	-	0.21 C	-	0.46 C
Quercus floribunda	Fagaceae	0.15 C	0.07 C	0.07 C	0.09 C	0.08 C	0.07 C	0.07 C	0.10 C	0.03 R	0.14 C
Rhododendron arboreum	Ericaceae	0.07 C	0.18 C	0.16 C	0.11 C	0.15 C	0.07 C	0.05 R	0.07 C	0.06 C	0.11 C
Thuja occidentalis	Cupressaceae	-	0.15 C	0.21 C	-	0.29 C	-	-	-	-	-
Toona ciliate	Meliaceae	0.24 C	-	-	-	-	-	-	-	-	-

Abbreviations: Re = Regular; R = Random; C = Contagious.

and Kharkwal *et al.,* (2005) reported that the total numbers of species, including all growth forms were higher near low altitude to mid altitude but with further increase in altitude it is decreased consistently due to decrease in atmospheric temperature with increase in altitude.

Diversity

In the present study, Shannon diversity values were recorded between 1.81 to 2.93 for higher altitudinal (FT-9) and lower altitudinal (FT-1), respectively. These values were found close to the reported range of 1.10 to 3.40 for the Himalayan range (Pandey, 2001, Kumar and Sharma, 2004; Pandey *et al.*, 2016). Likewise, Rawat and Chandhok (2009) have reported species diversity from 1.9 to 2.24. Sharma *et al.*, 2017 have also reported higher diversity on the forest types of lower altitudes and lower diversity on the forest types of higher altitudes. Although, Gairola *et al.*, (2008) did not find any specific change in species diversity with altitude, but slight decreasing trend in it along altitude was recorded in present investigation. He explained the variation in species diversity (H') with reference to climate, productivity, biotic interaction, habitat heterogeneity and history (Willig *et al.,* 2003; Qian and Ricklefs, 2004).

In general, a moderate negative correlation was recorded between density, species richness, MI, MeI, H and SDI with altitude and slope. The correlation between various parameters is shown in table 5.

Distribution pattern

According to Odum (1971), the contagious distribution (clumping) is common in nature, while random distribution is found only in uniform environments, and regular distribution occurs under severe competition between individuals. In the present study the distribution pattern of different tree species was contagious upto 2600 m asl. Many researchers (Greig-Smith, 1957; Kershaw, 1973; Singh and Yadav, 1974; Kumar and Bhatt, 2006) have also observed contagious distribution in natural forest of Garhwal Himalaya. 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). At higher altitude (2700 m asl.) 3 species (out of four species) exhibited random distribution which indicates the uniform environmental conditions at this elevation. Sagar *et al.,* 2003 suggested that the changes in the dispersion patterns may reflect the reactions of species to disturbance as well as to changes in the habitat conditions. Hence, increase in total number of species with more contagious distribution at 2800 m asl. was probably due to improvement in natural conditions at this elevation.

In the present study on the basis IVI records, *Quercus floribunda* was found to be dominant species from 1200 m asl. to 2600 m asl. which was co-dominated with *Pinus roxburghii* upto 1800 m asl. At higher altitude *Cupressus torulosa* was dominant species followed by *Quercus floribunda* table 1. Additionally, from 1200 m asl. to 1800 m asl. and 2400 m asl. to 2600 m asl., growth of *Quercus floribunda, Rhododendron arboreum* and *Lyonia ovalifolia* was seen with *Pinus roxburghii*. Forest types on such elevation are facing heavy biotic pressure because studies revealed that a dense oak forest with a closed canopy harbours rich undergrowth of late-successional species including tree species like *Rhododendron arboreum* and *Lyonia ovalifolia* etc. (Dhaila *et al.*, 1995). The anthropogenic disturbances cause them to convert into open oak forests with light reaching on the forest floor, resulting the reestablishment of pine and other associated light-demanding species (Gupta, 1978).

Conclusion

The present study suggests that species richness and diversity of different tree species in selected forest types are regulated by the altitude and different climatic factors. At lower altitudinal forest types the species richness and related parameters of diversity are high as compared to the forest types at higher altitude. Moreover, a mixure of early succeccional and climax community in the form of oak-pine forest with dominance of oak was seen in most of the selected forest types. Dominance of conifers like *Pinus roxburghii* at 1800 m asl. and *Cupressus torulosa* beyond 2200 m asl. indicate the reduce water table; perhaps

Table 5: Carl Pearson correlation coefficient between different parameters.

	Altitude	Density	TBC	SR	MI	Mel	H	Cd	SDI
Altitude	1.000								
Density	-0.578	1.000							
TBC	-0.352	0.830	1.000						
SR	-0.638	0.312	0.022	1.000					
MI	-0.640	0.316	0.026	1.000	1.000				
Mel	-0.546	0.153	-0.106	0.985	0.984	1.000			
H	-0.664	0.608	0.245	0.889	0.891	0.821	1.000		
Cd	0.377	-0.733	-0.338	-0.537	-0.540	-0.440	-0.783	1.000	
SDI	-0.639	0.338	0.038	0.999	0.999	0.980	0.903	-0.570	1.000

Correlation is significant at the 0.05 level.

due to more anthropogenic pressure in such forest types. Hence, such forest types are unstable and therefore, appropriate conservation strategy should be implemented to save economically important forests as well as inhabiting species.

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