Species Diversity and Community Structure of a Temperate Mixed *Rhododendron* Forest along an Altitudinal Gradient in West Siang District of Arunachal Pradesh, India

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Abstract: Species diversity and community structure of a *Rhododendron* forest along an altitudinal gradient was studied through quadrat method and all important community parameters were worked out using standard procedures. A total of 72 species representing 58 genera belonging to 35 families were recorded from the three study stands at different altitudes. The species richness index of tree and shrub species was highest in Hanuman Camp (mid altitude) while, for herb it was highest in Shegong (lower altitude). The richness index of tree species shows a positive relation while, the shrub and herb species have a negative relation with the altitudinal gradient. Hanuman Camp has highest tree species richness, tree density (individual ha^{-1}) and basal area (m^2 ha^{-1}) with *Rhododendron grande* as the dominant tree species. *Rhododendron kenderickii* and *Rhododendron* sp. (seems to be a new species and nomenclature process is under process) dominates Shegong and Yarlung (Upper altitude) respectively. The α diversity of shrub and herb species was found to be much higher in Shegong compared to the other two study stands. The Shannon-Weiner diversity index of tree and shrub species shows a positive relation with increasing altitude while, herb species have a negative relation with altitude. The Simpson's dominance index for tree was recorded highest in Shegong (0.08) while, it is similar (0.07) in both Hanuman Camp and Yarlung. On the other hand, dominance index of shrub species have negative and the herb species have positive relation with the increasing altitude. The high similarity was found between Shegong and Hanuman Camp. Further, it was found that most of the species exhibits clump or contagious distribution in all study stands. The present study suggested that the variation in species diversity and community structure of the *Rhododendron* forest in the three study stand is mainly regulated by the altitude which may be due to the difference in microclimate and edaphic factors.
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Key words: altitude; diversity; species richness; microclimate; edaphic factors; Himalaya.

1. Introduction

The nature of ecological communities is a fundamental issue in ecology. Many have considered communities as integrated, possibly discrete entities with emergent structure and function shaped by species interactions and co-evolution (Drake, 1990). The study of species diversity is helpful to understanding community composition, structure, change and development (Li & Zhou, 2002). Moreover, species diversity is affected by multi-environmental factors (Gaston, 2000, Li & Zhou, 2002, Lan, 2003 and Tang, 2004) especially by the altitudinal gradient. The altitudinal gradient is an important factor affecting species composition and structure (Whittaker, 1972). The change of abiotic condition (e.g. climate, soil and temperature) along with the altitudinal gradient affects species composition and distribution. The relationship between vegetation and altitude has been studied since the early 19th century (Kala & Mathur, 2002). Climatic and soil factors are deemed to be primary determinants of change in species composition and community structure in mountains (Whittaker, 1975).

Forest structure and composition are strongly correlated with the environmental factors, such as climate and topography (Schall & Pinaka, 1978, Wright, 1983 and Currie, 1991) while, vegetation within a forest is greatly affected by differences in the microclimate, aspect and altitude (Chaudhary, 1999 and Pande et al., 2002). Structural and functional analysis of natural plant communities provide a valuable sources of information for understanding relationship between plant form, vegetation structure and environment (Parsons, 1976).

Species diversity has functional consequences, because the number and kinds of species present in any area determine the organismal traits, which influence ecosystem processes. Species diversity reflects species richness and evenness and expresses differences of community structure, community composition and community habitat conditions (Lan, 2003). Understanding of forest structure is a pre-requisite to describe various ecological processes and also dynamics of forests (Elourard et al., 1997).

The present study deals with the floristic composition, and quantitative analysis of the vegetation of three Rhododendron forest stands along an altitudinal gradient in Mechuka area of West Siang District, Arunachal Pradesh. Further, the present study aims to analyze (i) Is elevation has any impact on species richness/diversity? (ii) Whether there is any variation in community structure with change in altitude.

2. Materials and methods

2.1. Study site

The study was carried out in a *Rhododendron* forest at Mechuka under the sub division Mechuka in West Siang district of Arunachal Pradesh, northeast India (**Figure 1**). The West Siang district lies between 27° 32´ to 28° 59´ N latitude and 93°58´ to 94° 58´ E longitude. The district is spread over 7,813 sq. km and constitutes 9.33% of the total geographical area of the state. The total forest cover of the district is 6,719 sq. km (86 % of the total geographical area), out of which very dense forest comprises of 2,478 sq. km, moderately dense forest 2,741 sq. km and open forest covers about 1,501 sq. km (FSI, 2009). The climate of the area has a markedly continental character with average annual rainfall of 3000 mm. Temperature ranges from a minimum of 5°C in winter to a maximum of 38° C in summer at the foothills and plains, whereas it varies from below freezing point to 25° C at higher reaches. Various ecological zones, viz. tropical, subtropical, temperate, subalpine and alpine are present in the district.

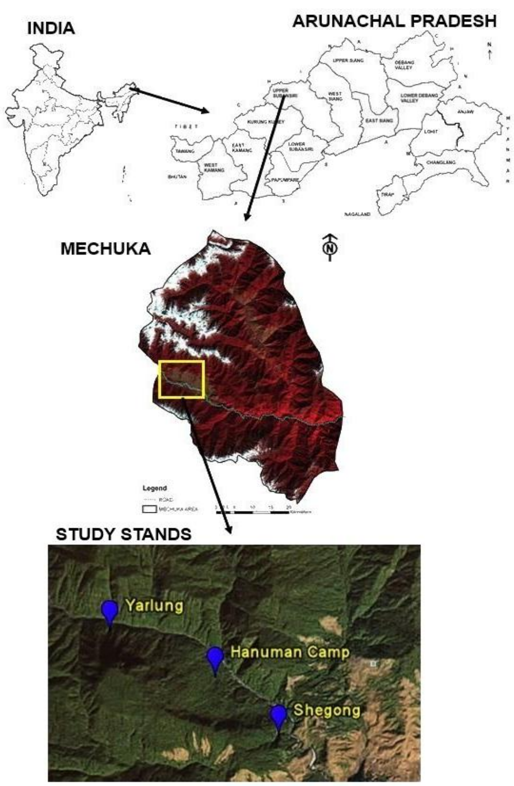


Figure 1: Map showing location of the study stands in Mechuka of West Siang district in Arunachal Pradesh, India.

Mechuka falls under the Himalayan range and is characterised by rough topography with mountains, deeply incised valleys, escarpments and plateaus. Mechuka is bordered by Upper Siang district in the northeast, Upper Subansiri district in southwest, whereas, the northwestern side is bordered by China. For the present, study the *Rhododendron* forest at Mechuka was divided into three study stands along the altitudinal gradient viz, Shegong (1900–2100m), Hanuman camp (2100–2300m) and Yarlung (>2300m). The forest is in climax stage and very old aged. The precise age of the forest is not known due to non availability of the forest history with the local forest department. Thick spongy humus layer covers the forest floor. The soil is coarse textured with sandy to loamy in nature and the pH ranged from 4.08 to 4.71. The organic carbon content ranged from 4.87% – 6.89% while the total nitrogen, available phosphorus and potassium content ranged from 0.15% to 0.25%, 0.007% to 0.01% and 0.37% to 0.43% respectively.

2.2. Methods

The vegetation sampling was done by quadrat method. The trees (>10 cm GBH) were measured and recorded by randomly sampling with forty quadrats of 10 m x 10 m size in each study stand. The shrubs were also recorded within the same 10 m x 10 m quadrat, while herbs were recorded by placing two 1 m x 1 m quadrat within each 10 m x 10 quadrats. Specimens of all species were collected and herbariums were prepared following Jain & Rao (1977) and identification was done following flora references like, Materials for the flora of Arunachal Pradesh, Flowers of Himalaya, and Flora of Assam etc.

Important community parameters such as frequency, density, abundance, basal area and importance value index (IVI) of all the plant species were worked out by following Misra (1968) and Muller–Dombois & Ellenberg (1974). The IVI for tree species calculated by summing up the relative values of frequency, density and basal area while, the IVI for shrubs and herbs were obtained by summing the relative values of frequency and density. The species richness 'S' was obtained by listing all the plant species occurring in the respective study stands following Whittaker (1972). The species richness index 'd' was calculated for each altitudinal zone using the formula d = S/√N given by Menhinick (1964); where, 'S' is the total number of species occurred and 'N' is the total number of individuals of all species. Alpha and beta diversity were estimated following Whittaker (1960) as α = S/log N; where, 'S' is the total number of species present in each stand and 'N' is the total number of individuals of all the species present in each stand and β = (S/α)-1; where, 'S' is the total number of species recorded in the two sites considering each species only once and 'α' is the mean species richness of the two sites. The species diversity index (H') was determined by using the method given by Shannon & Wiener (1963):

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

Where, H' = Shannon -Weiner diversity index, p_i is the proportion of individuals in the *i*th species i.e (n_i/N); n_i = importance value index of the species; and N = importance value index of all the species. The dominance index was calculated by Simpson's index (1949):

$$D = \sum_{i=1}^{s} (p_i)^2$$

Where, p_i is same as for the Shannon-Weiner diversity. The similarity index was worked out by following the formula SI = (2C/A+B) x 100 (Sorensen 1948); where, A is the total number of species in site A; B is the total number of species in site B; and C is the total number of common species in both the site A and B. The evenness index (E) was calculated as E = H'/ ln S following Pielou (1966); where, E is Pielou's evenness index, H' is Shannon-Weiner diversity index and S is total number of species. The spatial distribution patterns of various species in different altitudinal zone were studied using the ratio of abundance to frequency (A/F); the value <0.025 indicates regular distribution, 0.025 – 0.050 indicates random distribution, >0.050 indicates contagious or clump distribution (Whitford 1949).

3. Results

3.1. Floristic diversity of the study stands

A total of 72 species representing 58 genera belonging to 35 families were recorded from the three study stands. Of these, 30 were tree species (≥ 10cm gbh) representing 23 genera belonging to 14 families. 16 species were shrubs belonging to 9 families and 11 genera, 26 species were herbs representing 18 families and 26 genera. The families, genera and species of the three study stands are given in **table 1**.

3.2. Species richness

The species richness was found to be highest in Shegong with 52 species representing 46 genera under 35 families. Out of the 52 species 15 were tree species belonging to 18 genera under 10 families, 13 were shrub species from 9 genera under 8 families and 24 were herbs belonging to 24 genera under 17 families. The species richness in Hanuman Camp is represented by 51 species with 42 genera belonging to 31 families. Out of these total 51 species, 21 tree species belonging to 17 genera under 12 families, 12 were shrubs from 7 genera under 5 families while, herbs are represented by 18 species from 18 genera under 14 families. Yarlung have the least species richness with 45 species made up of tree, shrub and herb with 37 genera under 27 families. The tree contribute 19 species from 15 genera belonging to 10 families, 11 shrub species under 7 genera from 5 families and the herbs were represented by 15 species under 15 genera belonging to 12 families (**Table 2**). One *Rhododendron* tree species was seems to be a new one and the process of identification and nomenclature is under progress.

3.3. Density

The total density of all tree, shrub and herb was highest in Shegong followed by Yarlung and lowest in Hanuman Camp. However, tree density was recorded highest in Hanuman Camp (963 individual ha^{-1}), followed by Yarlung (823 individual ha^{-1}) and Shegong (707 individual ha^{-1}) (**Table 2**). Tree species like *Rhododendron kenderickii*, *R. grande*, *Illicium griffithii*, *Litsea sericea* etc. contribute maximum density in Shegong while, *Rhododendron kenderickii*, *R. grande*, *Illicium griffithii*, *Castanopsis tribuloides* shows maximum density in Hanuman Camp. In Yarlung, trees like *Illicium ghiffithii*, *Rhododendron* sp., *Rhododendron kenderickii*, *R. grande* have maximum density (**Annexure I**). In case of shrubs, maximum density 2617 individual ha^{-1} was recorded in Shegong followed by Yarlung (2157 individual ha^{-1}) and lowest 1387 individual ha^{-1} in Hanuman Camp (**Table 2**). Herbs also shows maximum density (38000 individual ha^{-1}) in Shegong followed by Yarlung (28667 individual ha^{-1}) and minimum (28333 individual ha^{-1}) in Hanuman Camp (**Table 2**).

3.4. Basal area

The total basal area of tree species was recorded highest in Hanuman Camp (74.6 m^2 ha^{-1}) followed by Yarlung (63.2 m^2 ha^{-1}) and minimum (54.2 m^2 ha^{-1}) in Shegong (**Table 2**). Due to the presence of large trees with high density, Hanuman Camp has the highest basal area (**Figure 2**). Tree species like *Rhododendron grande*, *Pinus wallichiana*, *Taxus wallichiana*, *Abies densa* share maximum basal area in Shegong. In Hanuman Camp, species like *Abies densa*, *R. grande*, *Taxus wallichiana*, unidentified sp. 1, *Castanopsis tribuloides* contribute major basal area to the study stand. While, in Yarlung major basal area was shared by species like *Abies densa*, *Illicium griffithii*, *Pinus wallichiana*, *Quercus lamellosa*, *R. grande*, *Rhododendron* sp., *Taxus wallichiana* (**Annexure I**).

3.5. Dominance

Dominance of species was assigned based on the calculated IVI values. It was found that in Shegong *R. kenderickii* was the dominant species with highest IVI (39.79) followed by species like *R. grande* (35.33), *Abies densa* (30.08), *Taxus wallichiana* (28.86), *Illicium griffhithii* (25.45), *Pinus wallichiana* (24.25) etc. The shrub layer is dominated by Bamboo sp. with highest IVI (81.30). *R. grande* (IVI=48.61) dominates the tree layer in Hanuman Camp while, the species in the shrub layer share almost equal IVI. The *Rhododendron* sp. was the dominant tree species in Yarlung with highest IVI (44.7) while, *Dephne papyracea* is the dominant shrub (IVI=37.45). *Dryopteris* sp. dominates the ground vegetation with highest IVI in all the study stands (**Annexure I**).

The dominance-diversity curve (**Figure 3**) for trees, shrubs and herbs shows that in all the three study stands relatively few species had a high IVI value. These curves illustrate resource partitioning among the various species (Verma et al., 2001).

Table 1. Family, genera and species enumerated in the three study stands.

Family	No. of genera	No. of species
Aceraceae	1	1
Asteraceae	3	3
Begoniaceae	1	1
Berberidaceae	1	1
Betulaceae	1	1
Caprafoliaceae	1	1
Caryophyllaceae	1	1
Circaeasteraceae	1	1
Compositae	1	1
Cornaceae	2	2
Dryopteridaceae	2	2
Ericaceae	4	13
Fabaceae	1	1
Fagaceae	2	4
Gentianaceae	2	2
Illiciaceae	1	1
Lauraceae	3	5
Lycopodiaceae	1	1
Magnoliaceae	1	1
Malvaceae	1	1
Pinaceae	3	3
Plantaginaceae	1	1
Poaceae	4	4
Polygonaceae	2	2
Ranunculaceae	1	1
Rosaceae	5	5
Rutaceae	1	1
Scrophulariaceae	1	1
Taxaceae	1	1
Theaceae	1	2
Thelypteridaceae	1	1
Thymelaeaceae	1	1
Trilliaceae	1	1
Urticaceae	2	2
Vitaceae	1	1
Unidentified	1	1

Table 2. Various phyto–sociological characteristics of tree, shrub and herb of the three study stands.

Parameters	Shegong			Hanuman camp			Yarlung		
	Tree	Shrub	Herb	Tree	Shrub	Herb	Tree	Shrub	Herb
Species richness (S)	15	13	24	21	12	18	19	11	15
No. of genera	13	9	24	17	7	18	15	7	15
No. of Family	10	8	17	12	5	14	10	5	12
Menhinick's Species Richness Index (d)	1.03	0.46	2.25	1.24	0.59	1.95	1.21	0.43	1.62
α diversity	2.80	1.95	5.07	3.71	1.99	4.05	3.45	1.70	3.38
Shannon and Wiener diversity index (H')	2.59	2.13	3.01	2.80	2.46	2.67	2.78	2.32	2.49
Simpson's index (D)	0.08	0.20	0.06	0.07	0.09	0.09	0.07	0.11	0.10
Species evenness index (E)	0.96	0.83	0.95	0.92	0.99	0.92	0.94	0.97	0.92
Density (Individual ha^{-1})	707	2617	38000	963	1387	28333	823	2157	28667
Basal area (m^2 ha^{-1})	54.2	–	–	74.6	–	–	63.2	–	–

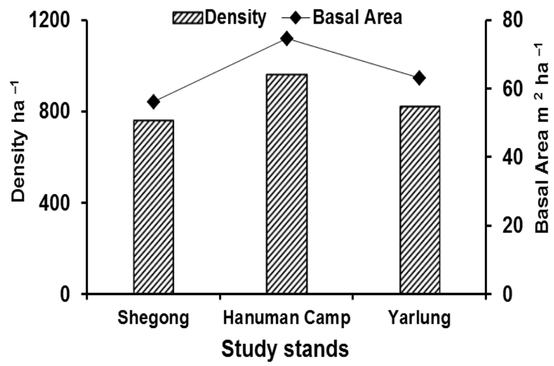


Figure 2. Stand density (ha $^{-1}$) and basal area (m^2 ha^{-1}) of tree species in the three study stands.

3.6. Species richness index, α diversity, β diversity, Shannon–Weiner Index, Simpson's index

The species richness index was found to be fluctuating from stand to stand as well as among the tree, shrub and herb. Hanuman Camp had the highest tree species richness index 1.24 followed by Yarlung and Shegong with 1.21 and 1.03 respectively. The shrub shows the highest richness index (0.59) in Hanuman camp followed by Shegong (0.46) and Yarlung (0.43). On the other hand, the herb has the highest richness index 2.25 in Shegong followed by Hanuman Camp and Yarlung with 1.95 and 1.62 respectively (**Table 2**). The *α* diversity of tree was highest in Hanuman camp (3.71) followed by Yarlung (3.45) and lowest in Shegong (2.80). While, α diversity for shrub was recorded maximum in Shegong (1.95) followed by Hanuman Camp (1.99) and minimum at Yarlung (1.70). The herb also showed the same trend as the shrub having maximum α diversity in Shegong (5.07) followed by Hanuman Camp (4.05) and minimum (3.38) in Yarlung (**Table 2**). The β diversity was recorded highest between Hanuman camp and Yarlung (0.33) followed by Shegong and Yarlung (0.31) while, minimum between Shegong and Hanuman Camp (0.28) (**Table 3**).

The Shannon-Weiner diversity index for the tree was recorded highest in Hanuman Camp (2.80) followed by Yarlung (2.78) and lowest in Shegong (2.59). The diversity index of shrub was maximum in Hanuman Camp (2.46) followed by Yarlung (2.32) and minimum in Shegong (2.13). While, the herb shows highest diversity index (3.01) in Shegong followed by Hanuman Camp (2.67) and minimum (2.49) in Yarlung (**Table 2**).

The Simpson's dominance index for tree was found highest in Shegong (0.08) while, it is similar (0.07) in both Hanuman Camp and Yarlung. For shrub, the index was highest (0.20) in Shegong followed by Yarlung (0.11) and lowest in Hanuman Camp (0.09). For herb, the value is found maximum in Yarlung (0.10) followed by Hanuman Camp (0.09) and minimum (0.06) in Shegong (**Table 2**).

Table 3. β diversity among the three study stands.

Study stands	Hanuman Camp	Yarlung
Shegong	0.28	0.31
Hanuman Camp	–	0.33

3.7. Similarity index

The overall species similarity was highest (71.84%) between Shegong and Hanuman Camp. The trees have 61.11 %, shrubs 72% and herbs 80.95% similarity between these two study stands. On the other hand, Hanuman Camp and Yarlung have least (66.67%) similarity in all species. Trees have 60.00%, shrub 78.26% and herb 66.67% similarity between these two study stands. Shegong and Yarlung have 64.58% similarity in all species while, trees, shrubs and herbs between these two study stand shows similarity of 58.82%, 75.00% and 66.67% respectively (**Table 4**).

3.8. Species evenness index

The evenness index (**Table 2**) of tree species was found highest in Shegong (0.96) followed by Yarlung (0.94) and minimum in Hanuman Camp (0.92). The shrub species show highest evenness in Hanuman Camp (0.99) followed by Yarlung (0.97) and lowest in Shegong (0.83). The herb species show maximum evenness in Shegong (0.95) while, Hanuman Camp and Yarlung have similar evenness index (0.92). **Figure 4** shows the co-relation between altitude and various indices of tree, shrub and herb species.

3.9. Distribution pattern

Table 5 shows the distribution pattern for all the species from the three study stands. About 75 % of the total species recorded from Shegong exhibits clumped distribution, 23 % have random distribution while, only 2 % exhibits regular distribution. In Hanuman Camp 82 % species have clumped distribution and 18 % exhibits random distribution. None of the species from Hanuman Camp exhibits regular distribution. In Yarlung also 76 % of the total recorded species shows clumped distribution, 20% exhibits random distribution whereas, only 4 % shows regular distribution (**Figure 5**).

3.10. Density girth distribution, basal area and species richness

The highest stand density and species richness of the tree species in the three study stands were recorded in the girth class 40–70 cm. Stand density and species richness consistently decreased with increase in girth. In Shegong and Hanuman Camp, it was found that the basal area increases upto the girth class 70-100 cm and beyond it the basal area was unevenly distributed. However, the girth class >250 cm recorded highest basal area with low density and species diversity. While, in Yarlung it was found that beyond girth class 40-70 cm there is an irregular distribution of basal area and like the other two stands the girth class >250 cm recorded highest basal area (**Figure 6**). In Shegong, the girth class 160-190 cm shows minimum basal area (1.5 m^2ha^{-1}), while the girth class >250 cm shows highest basal area (18.6 m^2ha^{-1}). In Hanuman Camp, the minimum basal area (2.9 m^2ha^{-1}) is recorded in girth class 10-30 cm and highest (19.9 m^2ha^{-1}) in girth class >250 cm. From Yarlung minimum basal area (2.0 m^2ha^{-1}) was recorded in girth class 10-30 cm, while maximum (12.8 m^2ha^{-1}) in girth class >250cm.

4. Discussion

All together 72 plant species were recorded from the three study stands belonging to 58 genera under 35 families. The result of the present study is much less than that of 113 species from temperate forest between 1800-2200 m altitude of Subansiri district of Arunachal Pradesh and 122 species from temperate forest of rhododendrons of western Arunachal Pradesh reported by Behera & Kushwaha (2007) and Paul (2008) respectively, as well as from other temperate forest (Kukshal et al., 2009; Semwal, 2010; Chandra et al., 2010; Panthi et al., 2007 and Zegeye et al., 2011). However, the plant species richness in this study is much greater than that of 19 species from Southern Manang Valley, Nepal (Ghimire et al., 2008), 40 species from temperate/subalpine coniferous forest of Subansiri District of Arunachal Pradesh (Behera et al., 2002), 45 species from temperate old growth evergreen broad leaved forest in Japan (Manabe et al., 2000). Out of the total species recorded from the three study stands, 31 were tree species, 15 were shrubs and 26 herb species. However, Paul (2008) has reported 26 tree, 40 shrub and 56 herb species from temperate forest of western Arunachal Pradesh. The species richness of the vegetation in the present study followed the trend as tree layer>herb layer>shrub layer which is similar to that reported by Negi (2008) from temperate forest of Garhwal Himalaya in Chamoli district. On contrary, Paul (2008) have reported the species richness in temperate broadleaved *Rhododendron* forest from western Arunachal Pradesh following the trend as herb>shrub>tree. Ericaceae is most dominant family in the study site followed by Poaceae and Rosaceae. In addition, Lauraceae, Asteraceae and Pinaceae were the other co-dominant families. Behera et al. (2002) and Paul (2008) have also reported similar dominant families (Asteraceae, Ericaceae and Rosaceae) from temperate/subalpine forest of Arunachal Himalaya.

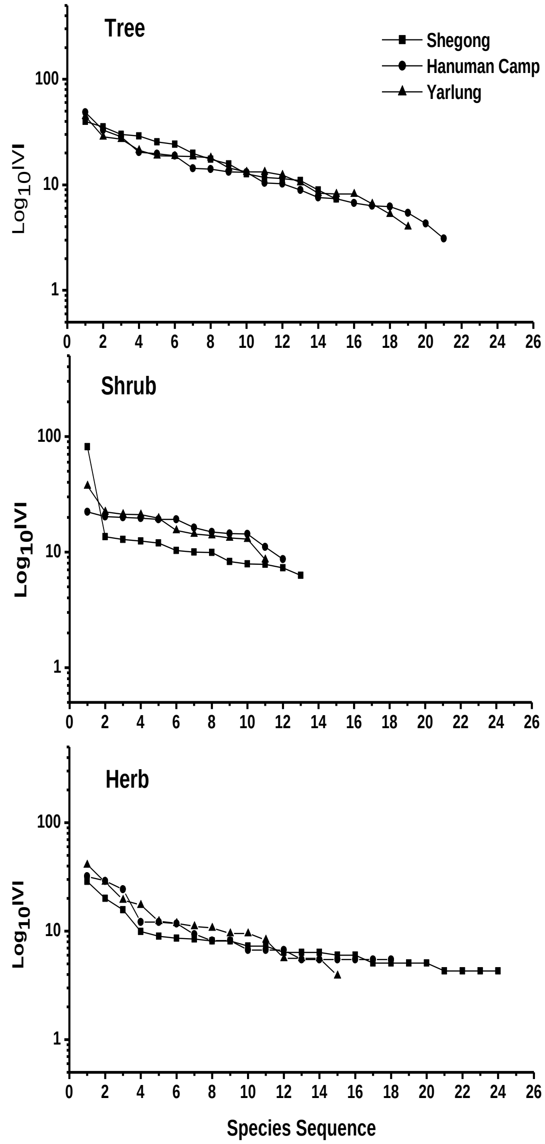


Figure 3. Dominance-diversity curve of tree, shrub and herb species in the three study stands.

The species richness of the three study stands vary from each other where, Shegong have the highest richness with 52 species, followed by Hanuman camp with 51 species while, Yarlung have least richness with 45 species. However, the tree species richness is highest in Hanuman Camp followed by Yarlung and lowest in Shegong. This variation in tree species among the study stands may be attributed to the microclimate and edaphic characteristics.

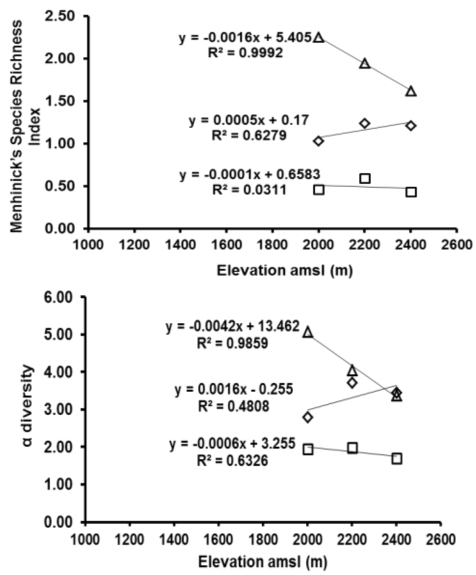
Table 4. Similarity Index (%) of tree, shrub and herb species between different study stands.

Study stands		Hanuman Camp				Yarlung			
		A	T	S	H	A	T	S	H
Shegong	A	71.84	–	–	–	64.58	–	–	–
	T		61.11	–	–	–	58.82	–	–
	S			72.00	–	–	–	75.00	–
	H				80.95	–	–	–	66.67
Hanuman Camp	A					66.67	–	–	–
	T						60.00	–	–
	S							78.26	–
	H								66.67

A – All species, T – Trees, S – Shrubs, H – Herbs.

The overall pattern of species richness shows inverse relationship with increasing altitude. Kharkwal et al., (2005) and Goirala et al., (2008) also shows a similar pattern of decreasing species richness along altitudinal gradient in temperate and alpine zone of central Himalaya and Western Himalaya respectively. Several other workers also reported similar patterns of decreasing species richness along altitudinal gradient (Kitayama, 1992, Odland & Birks, 1999, Wang et al., 2007 and Ghimire et al., 2008). Further, this decrease in diversity and species richness along the altitude could be due to ecophysiological constraints, such as reduced growing season, low temperature and low productivity (Korner, 1998). Ellu & Obua (2005) have also suggested that different altitudes and slopes influence the species richness. Moreover, Sharma et al., (2009) reported that the distribution and species richness pattern of different species are largely regulated by the altitude and climatic factors.

The tree density in the present study ranged between 707 to 963 individual ha^{-1} which is within the ranged values 192 to 1852 individual ha^{-1} reported by Paul (2008) from Arunachal Himalaya, 420 to 1640 individual ha^{-1} from temperate forests of Kumaon Himalaya (Saxena & Singh, 1982), 652 to 1028 individual ha^{-1} from Garhwal Himalaya (Kumar et al., 2009). However, many other workers have reported much higher density from Himalayan temperate forest, 1570–1785 individual ha^{-1} in the montane forests of Garhwal Himalaya (Bhandari & Tiwari, 1997), 2090 to 2100 individual ha^{-1} from Dolpa district of mid-west Nepal (Kunwar & Sharma, 2004). The density of shrub is within the range value of 504 to 3576 individual ha^{-1} reported by Paul (2008) from temperate forest of western Arunachal Pradesh. However, it is much lower than that reported by Koirala (2004) from Tinjure-Milke region, Nepal. The herb species also show similar pattern as the shrub and has the density of 28,333 to 38,000 individual ha^{-1} and is within the range value (14380 to 45000 individual ha^{-1}) that reported by Paul (2008) from Arunachal Himalaya. However, the total density of herb in the present study is much lower compared to the reported values by other workers from Himalayan forest (Kumar & Ram, 2005, Uniyal, 2010 and Kharkwal & Rawat, 2010). Highest density and species richness of herbs and shrubs in Shegong may be because of open canopy. The altitude, environmental factors, habitat and soil characteristics may be the main factors which eventually lead to the variations in species diversity and density in the three study stands.



The basal area recorded is ranged between 54.2 to 74.6 m^2 ha^{-1} which is within the range value 9.38 to 137.45 m^2 ha^{-1} reported by Paul (2008) from Arunachal Himalaya as well as 17.9 to 180.1 m^2 ha^{-1} reported from other part of temperate forest of Himalaya (Baduni, 1996, Ghildiyal et al., 1998, Sharma & Baduni, 2000 and Ram et al., 2004). Highest basal area was recorded from Hanuman Camp while, minimum from Shegong. The less basal area in Shegong could be due to less density and sparse distribution of tree species. Moreover, Shegong is the transition zone between the forested area and open bare land of Mechuka valley.

The higher basal area in Hanuman Camp may be due to higher density, diversity of trees and more favorable micro climatic as well as edaphic condition for growth. Moreover, the variation in basal area of all the study stands may be due to presence or absence of higher number of individuals having larger girth which contributes to the greater basal area.

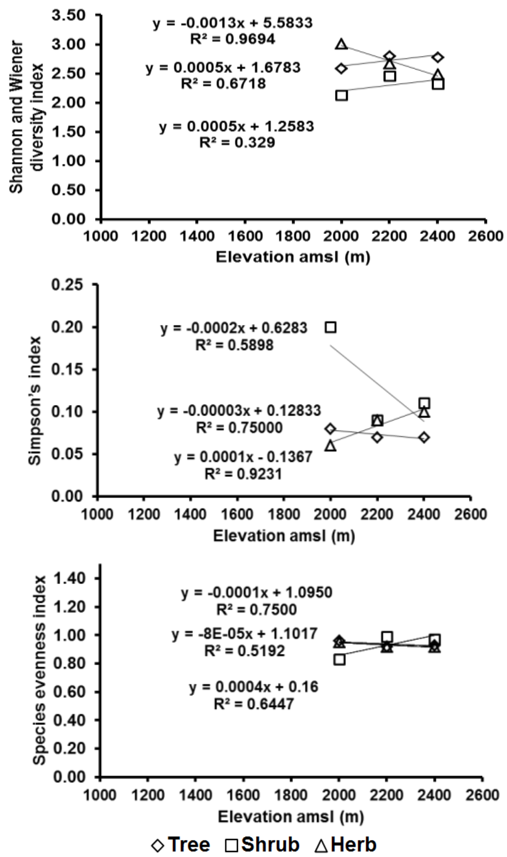


Figure 4. Scatter plot showing relation between altitude and various species richness and diversity parameters.

In Shegong *R. kenderickii* have maximum IVI (39.79) with density of 143 individuals ha^{-1} followed by *R. grande* (35.33) with 93 individuals ha^{-1}. While, bamboo is dominated shrub in Shegong with highest IVI (81.3) and density of 1723 individuals ha^{-1}. On the other hand, all the herb species share more or less equal IVI. In Hanuman Camp *R. grande* was the dominant tree species with IVI (48.6) and density 223 individuals ha^{-1} while, the shrub and herb species share almost similar IVI. Yarlung is dominated by *Rhododendron* sp. with highest IVI (44.7) and density 127 individuals ha^{-1}. However, the IVI of the dominant species of the three study stands are lower than that reported by Majila & Kala (2010) from temperate forest of Uttarakhand Himalaya. He studied the four geographical aspects in the forest viz., east, west, north and south and found the IVI of the dominant species as 94.73, 65.64, 111.14 and 107.09 respectively.

The species richness index of the three study stands were in the order of herb>tree>shrub. However, there is variation in richness indices within herb, shrub and tree species at different altitudes. The species richness index of tree and shrub species was highest in Hanuman Camp while, for herb it was highest in Shegong. The richness index of tree species shows a positive relation with increasing altitude while, the shrub and herb species have a negative relation with the altitudinal gradient. However, Sharma et al. (2009) have reported a negative relation of tree species richness index with increasing altitude. Menhinick's index of species richness presupposed that a kind of functional relationship existed between the number of species and individuals present in the community. The richness index for tree species is more than that reported by Sharma et al. (2009) from temperate forest of Garhwal Himalaya, while, it is much lower than that reported by Behera et al. (2002), from temperate forest of Arunachal Himalaya. On the other hand, the richness index of tree and herb species from the present study is more and the richness index of shrub is less than that reported by Paul (2008) from western Arunachal Himalaya.

Table 5. Distribution pattern of tree, shrub and herb species at the three study stands.

Species	Family	Study stands		
TREE		Shegong	Hanuman Camp	Yarlung
Abies densa Griff.	Pinaceae	0.094 (C)	0.100 (C)	0.075 (C)
Acer caesium Wall. ex Brandis	Aceraceae	–	0.075 (C)	–
Alnus nepalensis D.Don.	Betulaceae	0.015 (Re)	–	–
Castanopsis armata Roxb.	Fagaceae	–	–	0.043 (R)
Castanopsis tribuloides (Smith) A. DC.	Fagaceae	0.047 (R)	0.028 (R)	–
Castanopsis indica Roxb.	Fagaceae	0.067 (C)	0.025 (R)	–
Cinnamomum glaucescens Nees.	Lauraceae	–	–	0.055 (C)
Cornus capitata Wallich	Cornaceae	–	0.108 (C)	–

Eurya accuminata DC.	Theaceae	–	–	0.060 (C)
Eurya sp.	Theaceae	0.067 (C)	0.055 (C)	–
Grewia sp	Malvaceae	–	–	0.058 (C)
Illicium griffithii Hook.f. & Thomson	Illiciaceae	0.037 (R)	0.050 (C)	0.056 (C)
Leea sp.	Vitaceae	0.042 (R)	0.094 (C)	0.049 (R)
Litsea sericea (Nees) Hook. f.	Lauraceae	0.081 (C)	0.047 (R)	0.033 (R)
Litsea glutinousa (Lour.) Robinson	Lauraceae	–	0.044 (R)	0.052 (C)
Litsea sp.	Lauraceae	–	–	0.075 (C)
Lyonia ovalifolia (Wall.) Drude	Ericaceae	0.042 (R)	–	–
Magnolia hodgsonii Hook.f. & Thomson	Magnoliaceae	0.037 (R)	0.052 (C)	0.056 (C)
Persea sp.	Lauraceae	–	0.100 (C)	
Pinus wallichiana A.B. Jacks.	Pinaceae	0.050 (R)	–	0.075 (C)
Prunus cerasoides D.Don.	Rosaceae	–	0.096 (C)	–
Quercus lamellosa Sm.	Fagaceae	0.047 (R)	–	0.150 (C)
Rhododendron arizelum I. B. Balfour & Forrest	Ericaceae	–	0.072 (C)	0.019 (Re)
R. grande Wight	Ericaceae	0.050 (C)	0.042 (R)	0.098 (C)
R. kenderickii Nutt.	Ericaceae	0.040 (R)	0.044 (R)	0.057 (C)
Rhododendron sp. *	Ericaceae	–	0.045 (R)	0.018 (Re)
Taxus wallichiana Zuccarni.	Taxaceae	0.042 (R)	0.083 (C)	0.036 (R)
Tsuga sp.	Pinaceae	–	0.075 (C)	–
Unidentified 1	Rosaceae	–	0.075 (C)	0.133 (C)
Unidentified 2	–	–	0.167 (C)	–
SHRUB				
Aconogonum molle D.Don.	Polygonaceae	0.058 (C)	–	0.083 (C)
Bamboo sp.	Poaceae	0.352 (C)	0.375 (C)	–
Berberis wallichiana DC.	Berberidaceae	–	0.220 (C)	0.230 (C)
Daphne papyracea Wall. ex. Steud	Thymelaeaceae	0.092 (C)	0.096 (C)	0.175 (C)
Gaultheria trichophylla Royle	Ericaceae	0.075 (C)	0.122 (C)	0.079 (C)
G. fragrantissima Wall.	Ericaceae	0.104 (C)	0.097 (C)	0.047 (R)
Gaultheria sp.	Ericaceae	–	0.061 (C)	0.063 (C)
Helwingia himalaica J. D. Hooker & Thomson ex C. B. Clarke	Cornaceae	0.063 (C)	0.102 (C)	–
Lonicera sp.	Caprafoliaceae	0.125 (C)	–	0.094 (C)
Rhododendron bothii Nutt.	Ericaceae	0.070 (C)	0.129 (C)	0.052 (C)
R. vaccinoides Hook. f.	Ericaceae	0.060 (C)	0.097 (C)	0.097 (C)
R. edgeworthii Hook. f.	Ericaceae	0.052 (C)	0.083 (C)	0.049 (R)
Rhododendron sp.	Ericaceae	0.057 (C)	0.079 (C)	0.096 (C)
Spiraea canescens D. Don	Rosaceae	0.069 (C)	–	–
Vaccinium nummularia Hook. f. and Thomson ex C. B. Clarke	Ericaceae	–	0.141 (C)	–
Zanthoxylum sp.	Rutaceae	0.089 (C)	–	–
HERB				
Anaphalis busua Buch.-Ham. ex D. Don.	Asteraceae	0.133 (C)	0.094 (C)	–
Artemisia nilagirica Clarke	Asteraceae	0.225 (C)	–	0.094 (C)
Begonia sp.	Begoniaceae	0.300 (C)	0.094 (C)	0.150 (C)
Bidens pilosa Linn.	Asteraceae	0.150 (C)	0.100 (C)	–
Circaeaster agrestis Maxim	Circaeasteraceae	0.100 (C)	0.150 (C)	–
Crawfurdia speciosa Wallich	Gentianaceae	0.525 (C)	0.150 (C)	0.133 (C)
Cyclosorus appendiculatus C. Presl	Thelypteridaceae	0.049 (R)	0.066 (C)	0.043 (R)
Desmodium triflorum DC.	Fabaceae	0.150 (C)	–	–
Diplazium caudatum J.Smith	Dryopteridaceae	0.037 (R)	0.047 (R)	0.044 (R)
Drymaria diandra Blume	Caryophyllaceae	0.225 (C)	–	–
Dryopteris sp.	Dryopteridaceae	0.042 (R)	0.042 (R)	0.050 (R)
Elatostema sessile J.R.Forst. & G.Forst	Urticaceae	0.100 (C)	0.200 (C)	0.150 (C)
Fragaria vesca L.	Rosaceae	0.133 (C)	0.225 (C)	0.167 (C)
Halenia elliptica D.Don	Gentianaceae	0.167 (C)	0.150 (C)	–

Hypochaeris radicata Linn.	Compositae	0.225 (C)	0.133 (C)	0.150 (C)
Lycopodium clavatum Linn.	Lycopodiaceae	0.167 (C)	0.100 (C)	–
Panicum sp.	Poaceae	0.150 (C)	0.225 (C)	0.075 (C)
Paris polyphylla Sm.	Trilliaceae	0.150 (C)	–	–
Paspalum sp.	Poaceae	0.233 (C)	–	–
Persicaria capitata Buch.-Ham. ex D. Don	Polygonaceae	0.075 (C)	0.225 (C)	0.200 (C)
Pilea umbrosa Blume	Urticaceae	0.100 (C)	–	0.133 (C)
Plantago major Linn.	Plantaginaceae	0.225 (C)	0.150 (C)	–
Poa annua Linn.	Poaceae	0.300 (C)	0.150 (C)	–
Potentilla microphylla D. Don	Rosaceae	–	–	0.600 (C)
Ranunculus sp.	Ranunculaceae	0.200 (C)	–	0.096 (C)
Wulfenia amherstiana Benth.	Scrophulariaceae	–	0.150 (C)	0.100 (C)

Re= Regular, R= Random, C= Clumped.

(*Seems to be a new *Rhododendron* tree species and the process of identification and nomenclature is under progress)

Alpha diversity of shrub and herb species was found to be much highest in Shegong compared to the other two study stands. This may be due to sparse canopy of the tree layer which provides suitable light condition and favours the growth of herbs (Bhatnagar 1966). On the other hand, α diversity of tree is much higher in Hanuman Camp. This may be due to favourable growth conditions for tree species. The α diversity of trees and herbs in the present study is more while, it is less for shrubs compared to that reported by Paul (2008) from western Arunachal Himalaya. The calculated β diversity values elucidate that the extent of changes of species in the tree layer was highest between Hanuman Camp and Yarlung. Different topography, microclimate, edaphic factors may have contributed to the different species composition between these stands. The variation in β diversity value of the three stands shows that species composition varies through the altitudinal gradient. Mehta et al. (1997) also reported high β diversity between the four sites in temperate forest of Garhwal Himalayas. Pande et al. (1996) argued that the altitude and different aspects, significantly affect the turnover of species. The range of diversity index values recorded in the present study falls within the lower limit of the values recorded for temperate forests of Himalaya and other parts of the world (Ralhan et al., 1982, Upreti et al., 1985, Bahera et al., 2002 and Paul, 2008). The low Shannon-Wiener diversity value of the forest stands indicats that the ecological structure is less complex (Odum, 1971). However, the diversity index of tree species is more than that reported by Kunwar & Sharma (2004) and Sharma et al. (2009) from temperate forest of Nepal Himalaya and Garhwal Himalaya respectively. Moreover, there is variation in diversity index of tree, shrub and herb species along the altitude. Diversity index of tree and shrub species shows a positive relation with increasing altitude while, herb species have a negative relation with altitude. The variation of Shannon–Weiner index along the altitudinal gradient suggests an unimodal relationship between the species richness and the environmental condition with regards to altitudinal factors (Jiang et al., 2007). The diversity of vegetation patterns and the spatial variation of Shannon–Weiner index of plant communities might be the simple but effective indicators for predicting the species richness level (Jiang et al., 2007).

The Simpson's dominance index of tree species in the study stands were less than that reported by Behera (2002) and Paul (2008) from Arunachal Himalaya. The shrub species showed the negative while, the herb species have positive relation with the increasing altitude. Kunwar & Sharma (2004) and Koirala (2004) also reported very low value of dominance index from Nepal Himalaya. Low value of Simpson's index of dominance indicates that the stands are more stabilized and more active (Odum, 1971). Moreover, high diversity and low dominance index may be due to the different microclimatic influence in the study stands. In general, species diversity and dominance index showed inverse relationship (Murthy & Pathak, 1972 and Joshi & Behera, 1991) and Simpson's index is heavily weighed towards the most abundant species in the sample and is less sensitive to species having only a few individuals (Magurran, 1988).

High similarity in species composition was found between Shegong and Hanuman Camp while, it was less between Hanuman Camp and Yarlung. The high similarity could be attributed to the presence of some species which have wide geographical range. Moreover, there is high similarity between herbs of these two study stands and it is a known fact that the herbs have a very wide geographical range in distribution. Further, there is a gradual change in altitude between these two study stands. There is a very low similarity between trees of Hanuman Camp and Yarlung and as a result the similarity value of all species between these two stands drops. This could be due to the reason that there is an abrupt change in altitude between Hanuman Camp and Yarlung and as a result a rapid turn over of tree species occurs. Murphy & Logo (1986) suggested that the differences in the species composition and physiognomy of vegetation might be due to soil characteristics. The variation in other habitat conditions may also alter the species composition. The evenness index of tree, shrub and herb in the present study are very high. Uniyal et al. (2010) also reported high value of evenness index from undisturbed mixed forest in Dewalgarh watershed of Garhwal Himalaya. The higher values of evenness index indicate an even distribution of individuals within the various species. In fact, a high value of the evenness index reflects that much of the value of diversity is attributed to the species that are relatively rare (Pandey & Shukla, 2003).

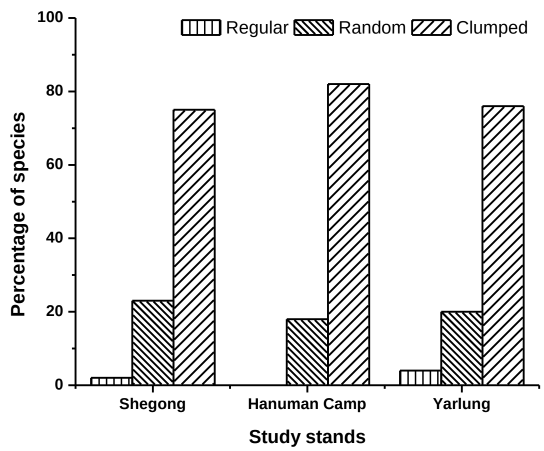


Figure 5. Species distribution pattern in three study stands.

In all the three study stands most of the species exhibits clump or contagious distribution while, only few species shows regular and random distribution. None of the species in Hanuman Camp shows regular distribution. Paul (2008) also reported clump distribution of plant species from temperate broad leaved *Rhododendron* forest of western Arunachal Pradesh. Moreover, contagious distribution has been reported by many other workers (Mehta et al., 1997, Kumar & Bhatt, 2006 and Singh et al., 2009) from temperate forest of Garhwal Himalayas. However, Semwal (2010) have reported that although few species exhibits regular distribution but random distribution is common in temperate forest of Kedarnath Wildlife Sanctuary, Central Himalaya. Odum (1971) have emphasized that contagious distribution is the commonest pattern in nature, which is due to small but significant variations in the environment. The random distribution is found only in very uniform environmental conditions whereas, the regular distribution occurs where severe competition between the individuals exists (Panchal & Pandey, 2004).

Highest species richness and density is represented by the girth class 40–70 cm in all the study stands. However, there is decrease in richness as well as in density with increasing girth class which is in conformity with the finding of Newbery et al. (1992) from Dipterocarp forest at Danum valley in Malaysia, Hara et al. (1997) in evergreen broad-leaved forests from Japan, Kadavul & Parthasaeathy (1999) in semi-evergreen forest in the Shervarayan hills of Eastern Ghats, India. The basal area also increases initially upto certain level with increasing girth class. Highest basal area was recorded in higher girth class (>250 cm) in all the three study stands could be attributed to the presence of large trees (*Taxus walliciana*, *Abies densa*, *Pinus wallichiana* etc.) having large bole.

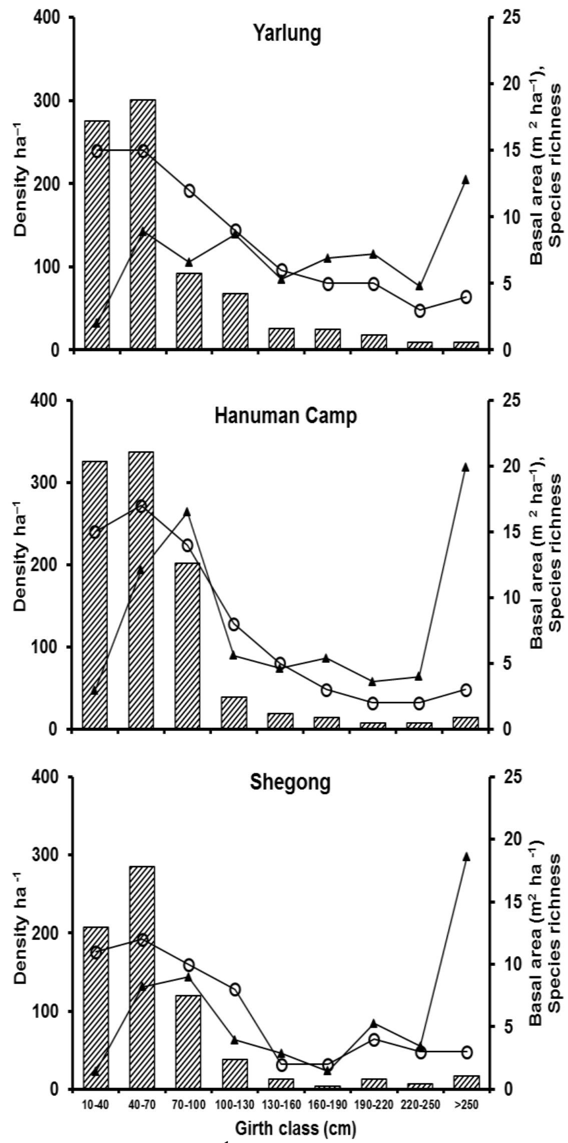


Figure 6. Density ha^{-1} (▨), species richness (-o-) and Basal area (m^{2}ha^{-1}) (-▲-) of woody species in different girth classes (cm) in the three study stands.

5. Conclusion

From the present study, it can be concluded that there is a variation in species richness/diversity in the three study stands along the altitudinal gradient. Moreover, it was found that there is considerable difference between the study stands in species composition and community structure. The lower altitude has more species richness and decreases with the increase in altitude. The change in species composition along the altitudinal gradient may be due to variation in microclimate and edaphic factors. The species richness of trees, shrubs and herbs is one of the major considerations in recognizing of an area for conservation. According to Whittaker (1972) the altitudinal gradient is an important factor affecting species composition and structure and climatic and soil factors changed in a regular way along altitudinal gradient.

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Annexure I. Structure and composition of trees, shrubs and herbs in the three studied stands (Density in ha^{-1} and basal area in m^2 ha^{-1}).

Name of Species	Shegong			Hanuman Camp			Yarlung		
	Density	BA	IVI	Density	BA	IVI	Density	BA	IVI
TREES									
Abies densa Griff.	17	13.4	30.08	10	11.98	18.88	13	5.8	13.2
Acer caesium Wall. ex Brandis	–	–	–	30	1.69	8.95	–	–	–
Alnus nepalensis D.Don.	27	0.27	7.29	–	–	–	–	–	–
Castanopsis armata Roxb.	–	–	–	–	–	–	23	2.2	10.5
Castanopsis tribuloides (Smith) A. DC.	37	1.61	15.73	53	5.34	20.43	–	–	–
Castanopsis indica Roxb.	27	1.43	10.95	47	1.14	14.12	–	–	–
Cinnamomum glaucescens Nees.	–	–	–	–	–	–	30	0.2	8.2
Cornus capitata Wallich	–	–	–	30	0.12	6.25	–	–	–
Eurya accuminata DC.	–	–	–	–	–	–	17	0.2	5.3
Eurya sp.	27	0.33	8.93	30	0.07	7.38	–	–	–
Grewia sp	–	–	–	–	–	–	23	0.1	6.6
Illicium griffithii Hook.f. & Thomson	70	3.09	25.45	80	3.2	19.75	90	2.0	21.3
Leea sp.	30	0.83	11.83	17	0.12	4.27	27	0.5	8.2
Litsea sericea (Nees) Hook. f.	73	1.43	19.82	40	0.48	10.16	43	3.6	18.7
Litsea glutinousa (Lour.) Robinson	–	–	–	33	1.59	10.35	47	2.2	14.5
Litsea sp.	–	–	–	–	–	–	30	0.7	8.3
Lyonia ovalifolia (Wall.) Drude	30	0.66	11.52	–	–	–	–	–	–
Magnolia hodgsonii Hook.f. & Thomson	50	1.07	17.38	47	2.23	13.2	40	2.2	13.5
Persea sp.	–	–	–	10	0.18	3.06	–	–	–
Pinus wallichiana A.B. Jacks.	20	9.14	24.25	–	–	–	13	5.3	12.4
Prunus cerasoides D.Don.	–	–	–	27	0.72	6.72	–	–	–
Quercus lamellosa Sm.	33	1.06	12.72	–	–	–	7	10.1	18.0
Rhododendron arizelum I. B. Balfour & Forrest	–	–	–	20	0.29	5.44	60	0.7	18.6
R. grande Wight	93	6.65	35.33	223	9.19	48.61	70	3.5	18.8
R. kenderickii Nutt.	143	3.18	39.79	140	2.77	28.39	110	3.4	27.1
Rhododendron sp.	–	–	–	50	1.46	13.09	127	9.0	44.7
Taxus wallichiana Zuccarni.	30	10.06	28.86	33	19.26	32.86	40	11.1	28.4
Tsuga sp.	–	–	–	13	1.88	6.28	–	–	–
Unidentified 1	–	–	–	13	7.87	14.31	13	0.4	4.0
Unidentified 2	–	–	–	17	3.02	7.56	–	–	–

		Density	IVI		Density	IVI		Density	IVI
SHRUBS									
Aconogonum molle D.Don.	–	93	12.39	–	–	–	–	207	19.58
Bamboo sp.	–	1723	81.30	–	150	16.18	–	–	–
Berberis wallichiana DC.	–	–	–	–	120	14.90	–	163	12.91
Daphne papyracea Wall. ex. Steud	–	123	12.80	–	87	14.29	–	563	37.45
Gaultheria trichophylla Royle	–	53	7.92	–	67	11.06	–	127	13.87
G. fragrantissima Wall.	–	–	–	–	33	8.66	–	57	8.63
Gaultheria sp.	–	57	7.31	–	130	19.2	–	117	15.41
Helwingia himalaica J. D. Hooker & Thomson ex C. B. Clarke	–	70	10.03	–	137	19.68	–	–	–
Lonicera sp.	–	50	6.32	–	–	–	–	127	13.21
Rhododendron bothii Nutt.	–	50	7.79	–	173	22.33	–	207	22.25
R. vaccinoides Hook. f.	–	66	9.90	–	130	19.20	–	243	21.28
R. edgeworthii Hook. f.	–	83	12.01	–	133	20.34	–	107	14.28
Rhododendron sp.	–	107	13.64	–	127	19.86	–	240	21.13

Spiraea canescens D. Don	–	77	10.28	–	–	–	–	–	–
Vaccinium nummularia Hook. f. and Thomson ex C. B. Clarke	–	–	–	–	100	14.36	–	–	–
Zanthoxylum sp.	–	63	8.30	–	–	–	–	–	–

		Density	IVI		Density	IVI		Density	IVI
HERBS									
Anaphalis busua Buch.-Ham. ex D. Don.	–	1333	7.3	–	1667	12.1	–	–	–
Artemisia nilagirica Clarke	–	1000	5.1	–	–	–	–	1667	12.3
Begonia sp.	–	1333	6.0	–	1667	12.1	–	667	5.6
Bidens pilosa Linn.	–	667	4.3	–	1000	8.2	–	–	–
Circaeaster agrestis Maxim	–	1000	6.4	–	667	5.5	–	–	–
Crawfurdia speciosa Wallich	–	2333	8.6	–	667	5.5	–	1333	9.5
Cyclosorus appendiculatus C. Presl	–	2667	15.8	–	4667	29.0	–	2333	19.4
Desmodium triflorum DC.	–	667	4.3	–	–	–	–	–	–
Diplazium caudatum J.Smith	–	3333	20.0	–	3333	24.3	–	4000	28.5
Drymaria diandra Blume	–	1000	5.1	–	–	–	–	–	–
Dryopteris sp.	–	5667	28.7	–	4667	32.1	–	6667	41.0
Elatostema sessile J.R.Forst. & G.Forst	–	1000	6.4	–	2000	11.7	–	667	5.6
Fragaria vesca L.	–	1333	7.3	–	1000	6.7	–	1667	10.7
Halenia elliptica D.Don	–	1667	8.1	–	667	5.5	–	–	–
Hypochaeris radicata Linn.	–	1000	5.1	–	1333	9.4	–	667	5.6
Lycopodium clavatum Linn.	–	1667	8.1	–	1000	8.2	–	–	–
Panicum sp.	–	667	4.3	–	1000	6.7	–	1333	11.1
Paris polyphylla Sm.	–	667	4.3	–	–	–	–	–	–
Paspalum sp.	–	2333	9.9	–	–	–	–	–	–
Persicaria capitata Buch.-Ham. ex D. Don	–	1333	8.5	–	1000	6.7	–	2000	11.8
Pilea umbrosa Blume	–	1000	6.4	–	–	–	–	1333	9.5
Plantago major Linn.	–	1000	5.1	–	667	5.5	–	–	–
Poa annua Linn.	–	1333	6.0	–	667	5.5	–	–	–
Potentilla microphylla D. Don	–	–	–	–	–	–	–	667	3.9
Ranunculus sp.	–	2000	9.0	–	–	–	–	2667	17.4
Wulfenia amherstiana Benth.	–	–	–	–	667	5.5	–	1000	8.3

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