

Forest community structure and composition along an elevational gradient of Parshuram Kund area in Lohit District of Arunachal Pradesh, India.

C.S. Rana and Sumeet Gairola

Department of Botany, HNB Garhwal University, Srinagar Garhwal- 246 174, Uttarakhand, India
dracsir@gmail.com, sumeetgairola@gmail.com

Abstract: The present study was conducted in natural Himalayan forests of Parsuram Kund area in Lohit district of Arunachal Pradesh to understand the effect of altitudinal variation on structure and composition of the vegetation. Three altitudinal zones viz., upper zone (U) = 550-850 m asl, middle zone (M) = 500-700 m asl and lower zone (L) = 350-450 m asl were selected for the study. Tree Species richness (SR) was recorded to be highest (26) on the middle altitude followed by lower (21) and upper altitude (13). Species diversity (richness) and dominance (Simpson Concentration of dominance index) were found to be inversely related to each other. Shrub and herb species richness were also recorded to be higher on middle altitude followed by lower and upper altitudes. [Nature and Science 2010;8(2):27-35]. (ISSN: 1545-0740).

Key words: Phytosociology, species richness, diversity indices, altitude.

1. Introduction

The Indian Himalayan region occupies a special place in the mountain ecosystems of the world. These geodynamically young mountains are not only important from the stand point of climate and as a provider of life, giving water to a large part of the Indian subcontinent, but they also harbor a rich variety of flora, fauna, human communities and cultural diversity (Singh, 2006). Understanding of forest structure is a pre-requisite to describe various ecological processes and also to model the functioning and dynamics of forests (Elourard et al., 1997). Species diversity has functional consequences, because the number and kinds of species present in any area determine the organismal traits, which influence ecosystem processes. The components of species diversity that determine the expression of traits include the number of species present (species richness), their relative abundance (species evenness), presence of the particular species (species composition), the interactions among species (non-additive effects), and the temporal and spatial variation in these properties. In addition to its effects on current functioning of ecosystems, species diversity influences the resilience and resistance of ecosystems to environmental changes (Chapin et al., 2000).

The altitude and aspect play a key role in determining the temperature regime and atmospheric pressure of any site. Within one altitude the cofactors

like topography, aspect, inclination of slope and soil type affect the forest composition (Shank and Noorie, 1950). Ellu and Obua (2005) have suggested that different altitudes and slopes influence the species richness and dispersion behavior of tree species. Moreover, Kharkwal et al. (2005) have pointed out that altitude and climatic variables like temperature and rainfall are the determinants of species richness. The distribution and species richness pattern of different species are largely regulated by altitude and physiographic factors (Sharma et al., 2009a, 2009b). The micro-environment of different aspects of hill slopes is influenced by the intensity and duration of available sunlight (Yadav and Gupta, 2006). This type of ecological knowledge is fundamental for conservation and sustainable utilization, and may provide important information for the policy makers for drafting management plans of fragile mountain ecosystems. Under the backdrop of the aforesaid facts, the present study was undertaken in natural Himalayan forests of Parsuram Kund area of Lohit district in Arunachal Pradesh to understand the effect of altitude on the structure and composition of the vegetation of natural forests.

2. Material and methods

The study was conducted in the natural Himalayan forest of Parsuram Kund area of Lohit district in Arunachal Pradesh. The Lohit district is one

of the districts of the state of Arunachal Pradesh in India. The Lohit District is located at the north-eastern edge of the state. The district stretches from 97° 24' E longitude to 95° 15' E longitude and 29° 22' N latitude to 27° 33' N latitude. The main ethnic groups that inhabit the place are Tai Khamti, Mishmi and Singpho. This river originates from the eastern part of Tibet and becomes a part of India at a place called Kibithoo. The district headquarters are located at Tezu. According to Indian census of 2001, it has a total area of 11402 Km²

and a population of 143,478. The district is named after one of the important river of the state, Lohit River, from the Sanskrit Louhitya, reddish- or rust-coloured, and consists of the river valley and hills/mountains to the North and South. The area is highly inaccessible, and it is only in 2004 that a permanent bridge has been made operational across the Lohit at the holy site of Parashuram Kund, giving round-the-year connection to Tezu.

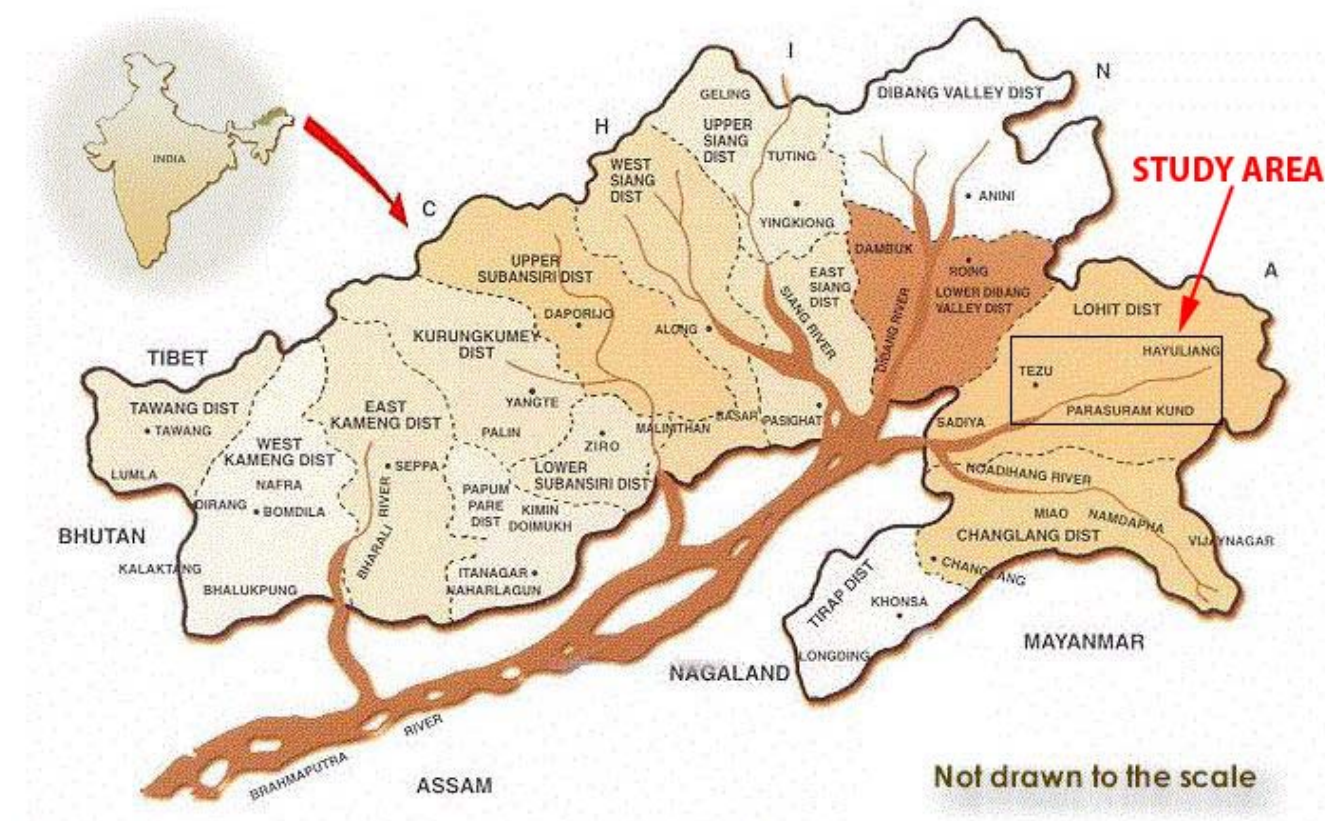


Figure 1: Map of the study area.

The climate of this place is mainly of two types. The high-altitude places are slightly cold, while the low-altitude places as well as the valleys are quite humid and hot. The period between the later part of November to the early part of March is winter time. The rainy season is experienced by the place between June and October. The climate is hot and highly humid in the lower elevations and in the Valleys and mildly cold in the higher elevations. The winter prevails during the months from late November to early March. The period from March to May is the pre-monsoon season. It is

followed by monsoon from June to October. After the reconnaissance survey three altitudinal zones viz., upper zone (U) = 550-850 m asl, middle zone (M) = 500-700 m asl and lower zone (L) = 350-450 m asl were identified to study the effect of altitudinal variation on structure and composition of the vegetation.

The composition of the forest along the altitudinal gradient was analysed by using nested quadrat method or centre point quadrat method for trees, shrubs and herbs species as per Kent and Coker (1992). Three vegetation layers, (i.e., trees, shrubs and

herbs) were analyzed for species richness, density and diversity. A total of 60 plots (twenty plots in each forest type) measuring 10m × 10m each were sampled. Trees (≥10cm dbh) were analyzed by 10m × 10m sized quadrats, whereas shrubs by 5m × 5m sized quadrats. Further, quadrats of 1m × 1m size were randomly laid out with in each 10m × 10m sized quadrat at each site, to study plants in the herbaceous layer. Circumference at breast height (cbh= 1.37m) was taken for the determination of tree basal area and was calculated as πr^2 , where r is the radius. Total basal area is the sum of basal area of all species present in the forest. Species Richness was simply taken as a count of number of species present in that forest type. Basal area (m²/ha) was used to determine the relative dominance of a tree species. The diversity (\bar{H}) was determined by using Shannon-Wiener information index (Shannon and Weaver, 1963) as: $\bar{H} = - \sum n_i / n \log_2 n_i / n$; where, n_i was the density of a species and n was the sum of total density of all species in that forest type. The Simpson's concentration of dominance (Simpson, 1949) was measured as: $Cd = \sum P_i^2$, where, $\sum P_i = \sum n_i / n$, where, n_i and n are same as in Shannon-Wiener diversity index. Simpson's diversity index (Simpson, 1949) was

calculated as: $D = 1/Cd$, where, D = Simpson's diversity and Cd = Simpson's concentration of dominance.

3. Results

Results of forest community structure and composition are given in tables 1 to 4.

Trees: At upper altitude *Albizia lucida* was the dominant tree species with highest density (240 ind/ha) and TBC (8.19 m²/ha). At middle altitude *Artocarpus chaplasha* had highest density (120 ind/ha) and TBC was highest in *Terminalia myriocarpa* (28.12 m²/ha). At lower altitude *Albizia lucida* had highest density (120 ind/ha) and *Dubanga grandiflora* had highest TBC (9.62 m²/ha). Tree Species richness (SR) was recorded to be highest at middle altitude (26) followed by lower (21) and upper (13) altitudes. Highest tree density was recorded at middle zone (860 ind/ha) followed by upper (600 ind/ha) and lower (550 ind/ha) altitudinal zone. Cd was found to be highest (0.2078) on upper altitude followed by lower (0.1094) and middle (0.0719) altitude. Value \bar{H} was found to be highest (4.171) at middle altitude followed by lower (3.740) and upper (2.893) altitude.

Table 1: Phytosociology and diversity of tree strata.

Species	Density (ind/ha)			Basal Area (m ² /ha)			Cd			Shannon-Wiener (\bar{H})		
	U	M	L	U	M	L	U	M	L	U	M	L
<i>Actinodaphne obovata</i>	-	20	-	-	0.07	-	-	0.0005	-	-	0.126	-
<i>Ailanthus excelsa</i>	-	10	-	-	2.58	-	-	0.0001	-	-	0.075	-
<i>Alangium begoniaefolia</i>	50	20	-	0.78	0.09	-	0.0069	0.0005	-	0.299	0.126	-
<i>Albizia lucida</i>	240	-	120	8.19	-	7.21	0.1600	0.0000	0.0476	0.529	-	0.479
<i>Albizia sp.</i>	-	80	-	-	3.03	-	-	0.0087	-	-	0.319	-
<i>Artocarpus chaplasha</i>	-	120	20	-	1.15	0.01	-	0.0195	0.0013	-	0.396	0.174
<i>Bombax ceiba</i>	-	-	10	-	-	8.60	-	0.0000	0.0003	-	-	0.105
<i>Brassiopsis glomerulata</i>	10	10	-	0.1	0.05	-	0.0003	0.0001	-	0.098	0.075	-
<i>Callicarpa arborea</i>	-	-	10	-	-	1.08	-	-	0.0003	-	-	0.105
<i>Cinnamomum sp.</i>	-	-	10	-	-	0.01	-	-	0.0003	-	-	0.105
<i>Cyanometra polyandra</i>	-	-	10	-	-	4.03	-	-	0.0003	-	-	0.105
<i>Dalbergia sisso</i>	80	20	50	6.8	3.2	5.60	0.0178	0.0005	0.0083	0.387	0.126	0.314
<i>Dalbergia sp.</i>	10	-	-	0.39	-	-	0.0003	-	-	0.098	-	-
<i>Dendrocalamus hamiltonii</i>	-	80	-	-	0.56	-	-	0.0087	-	-	0.319	-
<i>Dilenia indica</i>	-	-	10	-	-	3.20	-	0.0000	0.0003	-	-	0.105
<i>Duabanga grandiflora</i>	70	20	100	3.45	1.94	9.62	0.0136	0.0005	0.0331	0.362	0.126	0.447
<i>Dysoxylon hamiltonii</i>	-	20	-	-	1.26	-	-	0.0005	-	-	0.126	-
<i>Engelhardtia spicata</i>	-	-	50	-	-	6.80	-	-	0.0083	-	-	0.314
<i>Ficus cunia</i>	-	10	-	-	0.16	-	-	0.0001	-	-	0.075	-
<i>Ficus roxburghii</i>	-	10	-	-	0.39	-	-	0.0001	-	-	0.075	-

<i>Ficus semecordata</i>	-	40	10	-	15.81	3.56	-	0.0022	0.0003	-	0.206	0.105
<i>Garuga gamblei</i>	-	-	20	-	-	9.60	-	-	0.0013	-	0.126	0.174
<i>Gynocardia odorata</i>	10	20	10	0.29	1.3	2.20	0.0003	0.0005	0.0003	0.098	-	0.105
<i>Knema angustifolia</i>	-	10	-	-	0.07	-	-	0.0001	-	-	0.075	-
<i>Kydia calycina</i>	-	10	20	-	0.96	4.38	-	0.0001	0.0013	-	0.075	0.174
<i>Laportea sp.</i>	-	-	10	-	-	2.13	-	-	0.0003	-	-	0.105
<i>Leea sp.</i>	-	10	-	-	0.15	-	-	0.0001	-	-	0.075	-
<i>Macaranga denticulata</i>	20	90	20	0.9	3.39	2.00	0.0011	0.0110	0.0013	0.164	0.341	0.174
<i>Macropanax dispermus</i>	-	10	10	-	0.07	0.72	-	0.0001	0.0003	-	0.075	0.105
<i>Mallotus tetracoccus</i>	20	-	-	0.3	-	-	0.0011	-	-	0.164	-	-
<i>Ostodes paniculata</i>	-	20	-	-	0.26	-	-	0.0005	-	-	0.126	-
<i>Pandanus odoratissima</i>	30	40	-	0.19	0.39	-	0.0025	0.0022	-	0.216	0.206	-
<i>Pterospermum acerifolium</i>	20	60	10	1.36	8.84	2.30	0.0011	0.0049	0.0003	0.164	0.268	0.105
<i>Sapindus rarak</i>	-	-	30	-	-	4.50	-	-	0.0030	-	-	0.229
<i>Sarcosperma griffithii</i>	-	30	-	-	0.51	-	-	0.0012	-	-	0.169	-
<i>Saurauria nepalensis</i>	-	10	-	-	0.05	-	-	0.0001	-	-	0.075	-
<i>Stercularia villosa</i>	30	-	-	0.31	-	-	0.0025	-	-	0.216	-	-
<i>Talauma hodgsonii</i>	-	-	10	-	-	0.78	-	-	0.0003	-	-	0.105
<i>Terminalia myriocarpa</i>	10	80	-	1.15	25.12	-	0.0003	0.0087	-	0.098	0.319	-
<i>Toona ciliata</i>	-	10	-	-	3.51	-	-	0.0001	-	-	0.075	-
<i>Trema orientalis</i>	-	-	10	-	-	0.01	-	-	0.0003	-	-	0.105
	600	860	550	19.61	74.91	78.32	0.2078	0.0719	0.1094	2.893	4.171	3.740

Shrubs: At upper altitude *Musa nagensium* was the dominant shrub species with highest density (680 ind/ha) and TBC (16.24 m²/ha). At middle altitude also *Musa nagensium* was the dominant shrub species with highest density (560 ind/ha) and TBC (4.24 m²/ha). At lower altitude *Piper peepuloides* was the dominant shrub species with highest density (540 ind/ha) and highest TBC was recorded for *Grewia disperma* (1.45 m²/ha). Shrub Species richness (SR) decreased from upper altitude to lower altitude with highest SR at upper (12) altitude followed by middle (10) and lower (10) altitude.

Highest (3180 ind/ha) density was recorded at upper altitude followed by lower (2640 ind/ha) and middle (2380 ind/ha) altitudinal zone, where as highest TBC (17.45 m²/ha) was recorded at upper altitude followed by middle (9.31 m²/ha) and lower (1.93 m²/ha) altitudes. Cd was found to be highest (0.143) on middle altitude followed by upper (0.120) and lower (0.118) altitude, whereas H was found to be highest (3.27) at upper altitude followed by lower (3.21) and middle (2.99) altitude.

Table 2: Phytosociology and diversity of shrub strata.

Species	Density (ind/ha)			Basal Area (m ² /ha)			Cd			Shannon-Wiener (H)		
	U	M	L	U	M	L	U	M	L	U	M	L
<i>Acacia pinnata</i>	40	280	-	0.03	0.02	-	0.0002	0.0138	-	0.079	0.363	-
<i>Artemisia nelagirca</i>	160	-	200	0.01	-	0.02	0.0025	-	0.0057	0.217	-	0.282
<i>Bambusa pallida</i>	-	60	-	-	2.17	-	-	0.0006	-	-	0.134	-
<i>Boehmeria longifolia</i>	360	-	220	0.04	-	0.02	0.0128	-	0.0069	0.356	-	0.299
<i>Boehmeria macrophylla</i>	240	-	-	0.4	-	-	0.0057	-	-	0.281	-	-
<i>Calamus leptospadix</i>	440	-	-	0.38	-	-	0.0191	-	-	0.395	-	-
<i>C. floribundus</i>	120	-	340	0.02	-	0.09	0.0014	-	0.0166	0.178	-	0.381
<i>Debregeasia longifolia</i>	160	240	120	0.19	0.62	0.12	0.0025	0.0102	0.0021	0.217	0.334	0.203
<i>Dendrocalamus giganteus</i>	-	40	-	-	0.35	-	-	0.0003	-	-	0.099	-
<i>Ficus urophylla</i>	-	100	-	-	0.22	-	-	0.0018	-	-	0.192	-

<i>Girardinia diversifolia</i>	180	-	280	0.02	-	0.06	0.0032	-	0.0112	0.234	-	0.343
<i>Grewia disperma</i>	-	-	240	-	-	1.45	-	-	0.0083	-	-	0.314
<i>Jasminium sp.</i>	300	-	-	0.03	-	-	0.0089	-	-	0.321	-	-
<i>Mesea indica</i>	420	-	-	0.05	-	-	0.0174	-	-	0.386	-	-
<i>Murraya paniculata</i>	-	120	-	-	0.17	-	-	0.0025	-	-	0.217	-
<i>Musa nagensium</i>	680	560	-	16.24	4.24	-	0.0457	0.0554	-	0.476	0.491	-
<i>Piper peepuloides</i>	-	-	540	-	-	0.12	-	-	0.0418	-	-	0.468
<i>P. griffithii</i>	-	340	240	-	1.44	0.01	-	0.0204	0.0083	-	0.401	0.314
<i>Rubus ellipticus</i>	-	400	-	-	0.06	-	-	0.0282	-	-	0.432	-
<i>Sida rhombifolia</i>	-	-	160	-	-	0.01	-	-	0.0037	-	-	0.245
<i>Trevesia palmata</i>	80	-	-	0.04	-	-	0.0006	-	-	0.134	-	-
<i>Triumfetta bartramia</i>	-	240	-	-	0.02	-	-	0.0102	-	-	0.334	-
<i>Zanthoxylum nepalensis</i>	-	-	300	-	-	0.03	-	-	0.0129	-	-	0.356
	3180	2380	2640	17.45	9.31	1.93	0.1202	0.1434	0.1175	3.274	2.997	3.206

Monsoon Herbs: At upper altitude *Imperata cylindrica* was the dominant herb species with highest density (3300 ind/ha) followed by *Equisetum sp.* (2100 ind/ha) and *Saccharum spontaneum* (1400 ind/ha). At lower altitude *Bidens pilosa* was the dominant herb species with highest density (4000 ind/ha) followed by *Elatostemma sp.* (1800 ind/ha) and *Imperata cylindrical* (1600 ind/ha). At middle altitude *Elatostemma sp.* was the dominant herb species with highest density (1900 ind/ha) followed by *Pilea sp.* (1800 ind/ha) and *Phyrrinum pubinerve* (1600 ind/ha). Herb Species

richness (SR) was found to be higher at middle altitude (29) followed by upper and lower altitude with 21 species each. Highest (14200 ind/ha) density was recorded at upper altitude followed by middle (13100 ind/ha) and lower (13800 ind/ha) altitudinal zone. Cd was found to be highest (0.133) on lower altitude followed by upper (0.105) and lower (0.077) altitude, whereas H was found to be highest (4.21) at middle altitude followed by upper (3.78) and lower (3.55) altitude.

Table 3: Phytosociology and diversity of herb strata in monsoon and post monsoon seasons.

Species	Density (ind/ha)			Cd			Shannon-Wiener (H)		
	U	M	L	U	M	L	U	M	L
Monsoon Season Herbs									
<i>Begonia sp.</i>	400	100	100	0.0008	0.0001	0.0001	0.145	0.054	0.051
<i>Bidens pilosa</i>	-	-	4000	-	-	0.0840	-	-	0.518
<i>Colocossia sp.</i>	-	300	-	-	0.0005	-	-	0.125	-
<i>Commelina bengalensis</i>	-	200	-	-	0.0002	-	-	0.092	-
<i>Cyanotis vaga</i>	-	200	400	-	0.0002	0.0008	-	0.092	0.148
<i>Cyperus sp.</i>	-	200	200	-	0.0002	0.0002	-	0.092	0.089
<i>Elatostemma sp.</i>	1100	1900	1800	0.0060	0.0210	0.0170	0.286	0.404	0.383
<i>Equisetum sp.</i>	2100	400	-	0.0219	0.0009	-	0.408	0.154	-
<i>Eupatorium adenophorum</i>	-	-	1000	-	-	0.0053	-	-	0.274
<i>Eupatorium odoratum</i>	200	200	-	0.0002	0.0002	-	0.087	0.092	-
<i>Forrestica sp.</i>	-	200	-	-	0.0002	-	-	0.092	-
<i>Imperata cylindrica</i>	3300	500	1600	0.0540	0.0015	0.0134	0.489	0.180	0.360
<i>Lygodium flexuosum</i>	300	100	-	0.0004	0.0001	-	0.118	0.054	-
<i>Mastersia sp.</i>	-	200	-	-	0.0002	-	-	0.092	-
<i>Mikania micrantha</i>	600	300	100	0.0018	0.0005	0.0001	0.193	0.125	0.051
<i>Molinera cucurboides</i>	100	200	200	-	0.0002	0.0002	0.050	0.092	0.089
<i>Nephrolepis cordifolia</i>	400	200	300	0.0008	0.0002	0.0005	0.145	0.092	0.120
<i>Ophiopogon intermedius</i>	200	300	300	0.0002	0.0005	0.0005	0.087	0.125	0.120
<i>Paederia foetida</i>	500	100	500	0.0012	0.0001	0.0013	0.170	0.054	0.173

<i>Paspalam sp.</i>	600	300	300	0.0018	0.0005	0.0005	0.193	0.125	0.120
<i>Photos scandens</i>	700	200	200	0.0024	0.0002	0.0002	0.214	0.092	0.089
<i>Phrynium pubinerve</i>	500	1600	-	0.0012	0.0149	-	0.170	0.370	-
<i>Pilea sp.</i>	-	1800	-	-	0.0189	-	-	0.393	-
<i>Polygonum capitatum</i>	-	-	200	-	-	0.0002	-	-	0.089
<i>Polypodium sp.</i>	400	300	200	0.0008	0.0005	0.0002	0.145	0.125	0.089
<i>Pteris sp.</i>	300	700	300	0.0004	0.0029	0.0005	0.118	0.226	0.120
<i>Saccharum spontaneum</i>	1400	1200	1000	0.0097	0.0084	0.0053	0.329	0.316	0.274
<i>Senecio cappa</i>	200	200	-	0.0002	0.0002	-	0.087	0.092	-
<i>Sonchus oleraceus</i>	300	200	200	0.0004	0.0002	0.0002	0.118	0.092	0.089
<i>Thladiantha calcarata</i>	300	100	-	0.0004	0.0001	-	0.118	0.054	-
<i>Thysanolaena maxima</i>	300	200	200	0.0004	0.0002	0.0002	0.118	0.092	0.089
<i>Urtica dioica</i>	-	700	700	-	0.0029	0.0026	-	0.226	0.218
	14200	13100	13800	0.1053	0.0770	0.1332	3.784	4.212	3.552
Post-monsoon Season Herbs	U	M	L	U	M	L	U	M	L
<i>Begonia sp.</i>	100	100	200	0.0001	0.0001	0.0002	0.052	0.055	0.089
<i>Bidens pilosa</i>	-	-	3800	-	-	0.0781	-	-	0.514
<i>Colocossia sp.</i>	-	100	-	-	0.0001	-	-	0.055	-
<i>Commelina bengalensis</i>	-	200	-	-	0.0002	-	-	0.094	-
<i>Cyanotis cappa</i>	200	-	-	0.0002	-	-	0.089	-	-
<i>Cyanotis vaga</i>	-	200	300	-	0.0002	0.0005	-	0.094	0.121
<i>Elatostemma sp.</i>	1200	2100	1600	0.0078	0.0269	0.0138	0.309	0.428	0.363
<i>Equisetum sp.</i>	2200	700	-	0.0262	0.0030	-	0.425	0.229	-
<i>Eupatorium adenophorum</i>	-	-	800	-	-	0.0035	-	-	0.240
<i>Eupatorium odoratum</i>	400	200	-	0.0009	0.0002	-	0.150	0.094	-
<i>Forrestica sp.</i>	-	200	-	-	0.0002	-	-	0.094	-
<i>Imperata cylindrica</i>	2900	700	1400	0.0455	0.0030	0.0106	0.475	0.229	0.338
<i>Lygodium flexuosum.</i>	200	100	-	0.0002	0.0001	-	0.089	0.055	-
<i>Mastersia sp.</i>	-	200	-	-	0.0002	-	-	0.094	-
<i>Mikania micrantha</i>	500	300	300	0.0014	0.0005	0.0005	0.175	0.127	0.121
<i>Molinera cucurboides</i>	-	100	200	-	0.0001	0.0002	-	0.055	0.089
<i>Nephrolepis cordifolia</i>	400	200	200	0.0009	0.0002	0.0002	0.150	0.094	0.089
<i>Ophiopogon intermedius</i>	300	300	500	0.0005	0.0005	0.0014	0.121	0.127	0.175
<i>Paederia foetida</i>	400	200	600	0.0009	0.0002	0.0019	0.150	0.094	0.199
<i>Paspalam sp.</i>	800	400	200	0.0035	0.0010	0.0002	0.240	0.156	0.089
<i>Photos scandens</i>	500	200	800	0.0014	0.0002	0.0035	0.175	0.094	0.240
<i>Phrynium pubinerve</i>	800	1000	-	0.0035	0.0061	-	0.240	0.287	-
<i>Pilea sp.</i>	-	1900	-	-	0.0220	-	-	0.408	-
<i>Pogonetum sp.</i>	-	200	100	-	0.0002	0.0001	-	0.094	0.052
<i>Polygonum capitatum</i>	-	-	100	-	-	0.0001	-	-	0.052
<i>Polypodium sp.</i>	200	0	100	0.0002	-	0.0001	0.089	-	0.052
<i>Pteris sp.</i>	500	800	400	0.0014	0.0039	0.0005	0.175	0.250	0.121
<i>Saccharum spontaneum</i>	1000	1000	1000	0.0054	0.0061	0.0054	0.277	0.287	0.277
<i>Senecio cappa</i>	300	100	-	0.0005	0.0001	-	0.121	0.055	-
<i>Sonchus oleraceus</i>	100	300	200	0.0001	0.0005	0.0002	0.052	0.127	0.089
<i>Thladiantha calcarata</i>	200	100	-	0.0002	0.0001	-	0.089	0.055	-
<i>Thysanolaena maxima</i>	400	200	300	0.0009	0.0002	0.0005	0.150	0.094	0.121
<i>Urtica dioica</i>	-	700	600	-	0.0030	0.0019	-	0.229	0.199
	13600	12800	13700	0.1012	0.0795	0.1233	3.795	4.150	3.634

Post-monsoon Herbs: At upper altitude *Imperata cylindrica* was the dominant herb species with highest density (2900 ind/ha) followed by *Equisetum* sp. (2200 ind/ha) and *Saccharum spontaneum* (1000 ind/ha). At middle altitude *Elatostemma* sp. was the dominant herb species with highest density (2100 ind/ha) followed by *Pilea* sp. (1900 ind/ha). At lower altitude *Bidens pilosa* was the dominant herb species with highest density (3800 ind/ha) followed by *Elatostemma* sp. (1600 ind/ha) and *Saccharum spontaneum* (1000 ind/ha).

Table 4: Total diversity indices of different forest strata at different altitudes.

Variable	Site	Trees	Shrubs	Herbs	
				Monsoon	Post-monsoon
Density (Ind/ha)	Upper	600	3180	14200	13600
	Middle	860	2380	13100	12800
	Lower	550	2640	13800	13700
Cd	Upper	0.208	0.12	0.105	0.101
	Middle	0.072	0.1434	0.077	0.079
	Lower	0.109	0.118	0.133	0.123
\bar{H}	Upper	2.89	3.27	3.78	3.79
	Middle	4.17	2.99	4.21	4.15
	Lower	3.74	3.21	3.55	3.63
SR	Upper	13	12	21	21
	Middle	26	10	29	28
	Lower	21	10	21	21

4. Discussion

The diversity of trees is fundamental to total forest biodiversity, because trees provide resources and habitat for almost all other forest species (Huang et al., 2003). At large scales, species diversity generally was found related to climate and productivity (Rahbek, 2005). Franklin et al. (1989) proposed that long-term productivity of natural forest ecosystems with high tree species diversity may be greater than that of forests with low diversity as a result of increased ecosystem resilience to disturbance. Slobodkin and Sanders (1969) opined that species richness of any community is a function of severity, variability and predictability of the environment in which it develops. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable (Putman, 1994). Tree species diversity varied greatly from place to place mainly due to variation in biogeography, habitat and disturbance (Sagar et al., 2003), which have also been considered as the important factors for structuring the

Post-monsoon Herb Species richness (SR) was found to higher on middle altitude (28) followed by lower and upper altitude both with 21 species each. Highest (13700 ind/ha) density was recorded at lower altitude followed by upper (13600 ind/ha) and middle (12800 ind/ha) altitudinal zone. Cd was found to be highest (0.123) on lower altitude followed by upper (0.101) and middle (0.079) altitude, whereas \bar{H} was found to be highest (4.15) at middle altitude followed by upper (3.79) and lower (3.63) altitude.

forest communities (Burslem and Whitmore, 1999). Srivastava et al. (2005) reported that the community characters differ among aspect, slope and altitude even in the same vegetation type. In our study we found that tree diversity decreased from lower altitude to higher altitude which means in our study area the environment at lower altitude was favourable for increasing tree diversity as compared to higher altitude.

In many other studies, the mean \bar{H} values for the other forests of temperate Himalaya varied from 0.4 to 2.8 (Singh et al., 1994), 0.08 to 1.29 (Shivnath et al., 1993) and 1.55 to 1.97 (Mishra et al., 2000), whereas in our study values reported by us are bit higher. Whittaker (1965) and Risser and Rice (1971) have reported the range of values of Cd for certain temperate vegetation from 0.19 to 0.99. The values of concentration of dominance (Cd) of the present study were more or less similar to the earlier reported values for temperate forests. Mean Cd values of 0.31 to 0.42 (Mishra et al., 2000) and 0.07 to 0.25 (Shivnath et al., 1993) were reported earlier from other parts of Indian Himalaya. The higher value of Cd in the forest growing on upper altitude was due to lower species richness. According to Baduni and Sharma (1997) the Cd or Simpson's index was strongly affected by the IVI of the first three relatively important species in a community. Species diversity (richness) and dominance (Simpson index) are inversely related to each other (Zobel et al., 1976). The Himalayan region is bestowed with a variety of natural resources which have been exploited by mankind since time immemorial. The link between forest management and the well-being of communities in forested areas has traditionally been defined by forest sector employment opportunities (Sharma and Gairola, 2007). The reported values of diversity and density in these forests can be utilized for management purposes and in the future for technological advancement,

economic prosperity and providing employment opportunity to the local people.

Correspondence to:

Dr. C.S. Rana
Department of Botany
HNB Garhwal University
Srinagar Garhwal – 246 174
Uttarakhand India
Cellular phone: 09456308319
Emails: dracsir@gmail.com

References

- [1] Singh J.S. Sustainable development of the Indian Himalayan region: Linking ecological and economic concerns. *Current Science* 2006;90(6):784-788.
- [2] Elourard C., Pascal J.P., Pelissier R., Ramesh B.R., Houllier F., Durand M, Aravajy S, Moravie M.A., Gimaret-Carpentier C. Monitoring the structure and dynamics of a dense moist evergreen forest in the Western Ghats (Kodagu District, Karnataka, India). *Tropical Ecology* 1997;38: 193-214.
- [3] Chapin III, Erika F.S., Zavaleta S., Eviner V.T., Naylor R.L., Vitousek P.M., Reynolds H.L., Hooper D.U., Lavorel S., Sala O.E., Hobbie S.E., Mack M.C., Diaz S. Consequences of changing biodiversity. *Nature* 2000;405: 234-242.
- [4] Shank R.E., Noorie E.N. Microclimate vegetation in a small valley in eastern Tennessee. *Ecology* 1950;11: 531-539.
- [5] Ellu G, Obua J. Tree condition and natural regeneration in disturbed sites of Bwindi Impenetrable forest national park, southwestern Uganda. *Tropical Ecology* 2005;46(1):99-111.
- [6] Kharkwal G, Mehrotra P, Rawat YS, Pangtey YPS. Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. *Current Science* 2005;89(5):873-878.
- [7] Sharma C.M., Suyal S., Gairola S., Ghildiyal S.K. Species richness and diversity along an altitudinal gradient in moist temperate forest of Garhwal Himalaya. *The Journal of American Science* 2009a;5(5):119-128.
- [8] Sharma C.M., Suyal S., Ghildiyal S.K., Gairola S. Role of Physiographic factors in distribution of *Abies pindrow* (Silver Fir) along an altitudinal gradient in Himalayan temperate Forests. *The Environmentalist* 2009b;DOI 10.1007/s 10669-009-9245-1.
- [9] Yadav A.S., Gupta S.K. Effect of micro-environment and human disturbance on the diversity of woody species in the Sariska Tiger Project in India. *Forest Ecology and Management* 2006;225:178-189.
- [10] Kent M., Coker P. *Vegetation description and Analysis*, Belhaven Press, London. 1992.
- [11] Shannon C.E., Weaver W. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, Illinois, USA. 1963; 117.
- [12] Simpson E.H. Measurement of diversity. *Nature* 1949;163:688.
- [13] Huang W., Pohjonen V., Johansson S., Nashanda M., Katigula, Luvkkanen O. Forest structure, Species composition and diversity of Tanzanian rain forest. *Forest Ecology and Management* 2003;173:11-24.
- [14] Rahbek C. The role of spatial scale and the perception of large-scale species-richness patterns. *Ecology Letter* 2005;8:224-239.
- [15] Franklin J.F., Perry D.A., Schowaltr M.E., Harmon M.E., Mckee A., Spies T.A. Importance of ecological diversity in maintaining long-term site productivity. In: *Maintaining the long-term productivity of Pacific Northwest forest ecosystems*, Perry, D.A., Meurisse, R., Thomas, B., Miller, R., Boyle, J., Means, J., Perry, C.R., Powers, R.F. (Eds.). Timber Press, Portland OR, 1989;82-97.
- [16] Slobodkin L.B., Sanders H.L. On the contribution of environmental predictability to species diversity. *Brookhaven Symposium on Biology* 1969;22:82-95.
- [17] Putman R.J. *Community Ecology*. Chapman & Hall, London. 1994.
- [18] Sagar R., Ragubanshi A.S., Singh J.S. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management* 2003;186:61-71.
- [19] Burslem D.F., Whitmore T.C. Species diversity susceptibility to disturbance and tree population dynamics in tropical rain forest. *Journal of Vegetation Science* 1999;10:767-776.
- [20] Srivastava R.K., Khanduri V.P., Sharma C.M., Kumar P. Structure, diversity and regeneration

- potential of Oak dominant conifer mixed forest along an altitudinal gradient of Garhwal Himalaya. *Indian Forester* 2005;131(12):1537-1553.
- [21] Singh S.P., Adhikari B.S., Zobel D.B. Biomass productivity, leaf longevity and forest structure in the central Himalaya. *Ecological Monograph* 1994;64:401-421.
- [22] Shivnath S., Gupta K., Rajwar G.S. Analysis of forest vegetation in a part of Garhwal Himalaya. *Recent Research in Ecology and Environmental Pollution* 1993;6:47-58.
- [23] Mishra A., Sharma C.M., Sharma S.D., Baduni N.P. Effect of aspect on the structure of vegetation community of moist bhabar and tarai *Shorea robusta* forest in Central Himalaya. *Indian Forester* 2000;126(6):634-642.
- [24] Whittaker R.H. Dominance and diversity in land plant communities. *Science* 1965;147:250-260.
- [25] Risser P.G., Rice E.L. Diversity in tree species in Oklahoma upland forest. *Ecology* 1971;52:876-880.
- [26] Baduni N.P., Sharma C.M. Flexibility fitness compromise in some moist temperate forests of Garhwal Himalaya. *Annals of Forestry* 1997;5:126-135.
- [27] Zobel D.B., Mckee A., Hawk G.M., Dyrness C.T. Relationship of environment to the composition, structure and diversity of forest communities of the central western cascades of Oregon. *Ecological Monograph* 1976;46:135-156.
- [28] Sharma C.M., Gairola S. Prospects of Carbon Management in Uttarakhand: An Overview. *Samaj Vigyan Shodh Patrika, Special Issue (Uttarakhand-1)*, 23-34;2007.

12/5/2009