Floristic structure and phytodiversity along an elevational gradient in Peepalkoti-Joshimath area of Garhwal Himalaya, India

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Abstract: The present study was conducted in temperate Himalayan forests of Joshimath area in Chamoli district of Uttarakhand to understand the effect of altitudinal variation on structure and composition of the vegetation and to record the floristic diversity and economic utilities of the plants in the study area. Three altitudinal zones viz., upper zone (U) = 2000-2200m asl, middle zone (M) = 1800-2000m asl and lower zone (L) = 1600-1800m asl were selected for the study. In the present floristic survey the total of 74 families (72 Angiospermous and 2 Gymnospermous), 149 Genera (145 Angiospermous and 4 Gymnospermous) and 177 species (173 Angiospermous and 4 Gymnospermous) were recorded in the study area. Out of these 177 species identified in the study area 100, 47, 20 and 10 were herbs, shrubs, trees and climbers respectively. Rosaceae was the dominant family recorded with 16 species in the study area followed by the Asteraceae (15), Lamiaceae (11), Fabaceae (11) and Caryophyllaceae (5). In Ethnobotanical survey very useful information was recorded about the economic utility of the plants species present in the study area. Uses recorded were medicinal, fuel, fodder, edible and timber. Tree Species richness (SR) decreased from lower altitude to higher altitude. Species diversity (richness) and dominance (Simpson index) were found to be inversely related to each other. Tree density decreased from lower altitude to upper altitude, whereas TBC showed reverse trend.

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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). The biodiversity which few years ago was considered unimportant by ecosystem ecologists, has now been shown to be significantly important for many aspects of ecosystem functioning. Diversity at all organizational levels, ranging from genetic diversity within populations to the diversity of ecosystems in landscapes, contributes to global biodiversity. The biodiversity has long been a source of amazement and scientific curiosity and increasingly a source of concern. 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). 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 temperate Himalayan forests of Bajoli-Holi area of Chamba district in Himachal Pradesh, 1) to record plant species present in the study area along with their economic uses and 2) to understand the effect of altitude on the structure and composition of the vegetation of natural forests.

Material and Methods

The present study was conducted in temperate Himalayan forests of Joshimath area in Chamoli district of Uttarakhand in year 2008. After the reconnaissance survey three altitudinal zones viz., upper zone (U) = 2200-2000m asl, middle zone (M) = 2000-1800m asl and lower zone (L) = 1800-1600m asl were identified to study the effect of altitudinal variation on structure and composition of the vegetation. The climate of the study area is typical temperate type. The year is represented by three main seasons; the cool and relatively dry winter (December to March); the warm and dry summer (mid-April to June); and a warm and wet period (July to mid-September) called as the monsoon or rainy season. The rainy season accounts for about three-quarters of the annual rainfall. Apart from these main seasons, the transitional periods interconnecting rainy and winter, and winter and summer are referred to as autumn (October to November) and spring (February to March). The mean annual rainfall was recorded as 1500mm and mean annual temperature between 5°C to 28°C.

The composition of the forest along the altitudinal gradient was analysed by using nested quadrate 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 X 10m each were sampled. Trees (≥10cm dbh) were analyzed by 10m x 10m sized quadrats, whereas shrubs by 5m x 5m sized quadrats. Further, quadrats of 1x1m size were randomly laid out with in each 10x10m sized quadrat at each site, to study plants in the herb 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/cover is the sum of basal area/cover of all species present in the forest. The data were quantitatively analyzed for density, frequency and abundance following Curtis and McIntosh (1950). Species Richness was simply taken as a count of number of species present in that forest type. Basal area (m^2/ha) was used to determine the relative dominance of a tree species. Importance Value Index (IVI) was the sum of relative frequency, relative density and relative dominance (Phillips, 1959). The diversity (H') was determined by using Shannon-Wiener information index (Shannon and Weaver, 1963) as: $H' = - \sum n_i /n \log_2 n_i /n$; where, n_i was the IVI value of a species and n was the sum of total IVI values of all species in that forest type. The Simpson's concentration of dominance (Simpson, 1949) was measured as: $Cd= \sum Pi^2$, where, $\sum Pi = \sum n_i /n$, where, ni 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. Species heterogeneity was calculated as under root of concentration of dominance (Cd).

To study the phytodiversity in the study area, regular field trips were undertaken in different seasons i.e., rainy, winter and summer, to collect the specimens of higher plants (Gymnosperms and Angiosperms). Identification of the specimens was done with the help of the existing Herbariums of Botany Department HNB Garhwal University (GUH), Forest Research Institute (DD) and Botanical Survey of India, Northern Circle (BSD). After identification, the enumeration of plants was done according to Bentham and Hooker's system of classification (1862-1883). The plants were divided into categories of common and uncommon according to their occurrence in the study area. An Ethnobotanical survey was also conducted in the villages nearby the study area to know the economic utility of various plant species encountered.

Results

Forest community structure and composition: Results of forest community structure and composition are given in tables 1 to 3.

Trees: At upper altitude *Cedrus deodara* was the dominant tree species with highest density (170 Ind/ha), TBC (98.82 m^2/ha) and IVI (155.96). At middle altitude *Pinus wallichiana* was the dominant tree species with highest density (180 Ind/ha), TBC (84.41 m^2/ha) and IVI (120.59). At lower altitude *Alnus nepalensis* was the dominant tree species with highest density (340 Ind/ha) and IVI (85.90), whereas highest TBC (3.78 m^2/ha) at this altitude was recorded for *Quercus semecarpifolia*. Tree Species richness (SR) decreased from lower altitude to higher altitude with highest SR at lower (19) altitude followed by middle (8) and upper (3) altitude. Highest (800 Ind/ha) tree density was recorded at lower zone followed by middle (600 Ind/ha) and lower (330 Ind/ha) altitudinal zone, where as highest (181.5 m^2/ha) TBC was recorded at upper altitude followed by middle (143.05 m^2/ha) and lower (9.63 m^2/ha) altitudes. Tree density decreased from lower altitude to upper altitude, whereas TBC showed reverse trend. Cd was found to be highest (0.4328) on upper altitude followed by middle (0.2561) and lower (0.1958) altitude whereas Simpson's diversity index showed reverse trend with highest (6.80)

value at lower altitude followed by middle (6.74) and upper (2.57) altitude. Value H' was found to be highest (0.67) at upper altitude followed by middle (0.28) and lower (0.15) altitude.

Shrubs: At upper altitude *Rabdosia rugosa* was the dominant shrub species with highest density (520 Ind/ha) and TBC (0.3600 m^2/ha), whereas highest IVI (82.38 m^2/ha) at this altitude was recorded for *Corairia nepalensis.* At middle altitude *Rabdosia rugosa* was the dominant shrub species with highest density (680 Ind/ha), TBC (0.4310 m^2/ha) and IVI (89.98). At lower altitude *Desmodium elegans* was the dominant shrub species with highest density (440 Ind/ha), TBC (0.1300 m^2/ha) and IVI (70.27). Shrub Species richness (SR) decreased from lower altitude to higher altitude with highest SR at lower (22) altitude followed by middle (10) and upper (7) altitude. Highest (2420 Ind/ha) density was recorded at middle altitude followed by lower (2020 Ind/ha) and upper (1620 Ind/ha) altitudinal zone, where as highest TBC (1.21 m^2/ha) was recorded at middle altitude followed by upper (0.75 m^2/ha) and lower (0.39 m^2/ha) altitudes. Cd was found to be highest (0.1996) on middle altitude followed by upper (0.1896) and lower (0.1138) altitude, whereas H' was found to be highest (0.17) at middle altitude followed by upper (0.14) and lower (0.06) altitude. Simpson's diversity index varied between 15.89 (lower altitude) to 7.81 (upper altitude).

Herbs: At upper altitude *Galium* sp. was the dominant herb species with highest density (15000 Ind/ha), TBC (0.0183 m^2/ha) and IVI (54.36). At middle altitude *Geranium* sp. was the dominant herb species with highest density (28750 Ind/ha), TBC (0.0760 m^2/ha) and IVI (70.52). At lower altitude *Pilea umbrosa* was the dominant herb species with highest density (16250 Ind/ha), TBC (0.0191 m^2/ha) and IVI (44.31). Herb Species richness (SR) decreased from lower altitude to higher altitude with highest SR at lower (19) altitude followed by middle (16) and upper (7) altitude. Highest (174375 Ind/ha) density was recorded at middle altitude followed by lower (136250 Ind/ha) and upper (112500 Ind/ha) altitudinal zone, where as highest TBC (0.17 m^2/ha) was recorded at middle altitude followed by lower (0.08 m^2/ha) and upper (0.06 m^2/ha) altitudes. Cd was found to be highest (0.0961) on middle altitude followed by upper (0.0777) and lower (0.0711) altitude, whereas H' was found to be highest (0.05) at middle altitude followed by upper (0.03) and lower (0.02) altitude. Simpson's diversity index varied between 21.90 (middle altitude) to 18.93 (lower altitude).

Phytodiversity: In the present floristic survey the total of 74 families (72 Angiospermous and 2 Gymnospermous), 149 Genera (145 Angiospermous and 4 Gymnospermous) and 177 species (173 Angiospermous and 4 Gymnospermous) were recorded in the study area (table 4). Out of these 177 species identified in the study area 100, 47, 20 and 10 were herbs, shrubs, trees and climbers respectively. Rosaceae was the dominant family recorded with 16 species in the study area followed by the Asteraceae (15), Lamiaceae (11), Fabaceae (11) and Caryophyllaceae (5). Families with only one species were Agavaceae, Anacardiaceae, Aquifoliaceae, Araliaceae, Asclepidaceae, Berberidaceae, Betulaceae, Buxaceae, Cannabinaceae, Chenopodiaceae, Coriariaceae, Crassulaceae, Cucurbitaceae, Cuperasaceae, Cuscutaceae, Dioscoreaceae, Dipsacaceae, Elaeagnaceae, Ericaceae, Euphorbiaceae, Fabaceae, Gentianaceae, Geraniaceae, Hippocastanaceae, Hydrangeaceae, Juglandaceae, Lythraceae, Malvaceae, Meliaceae, Mimosaceae, Nictaginaceae, Orchidaceae, Oxalidaceae, Philadelphaceae, Phytolaccaceae, Plantaginaceae, Polygalaceae, Primulaceae, Rhamnaceae, Rutaceae, Saxifragaceae, Smilacaceae and Vitaceae. Families with two species were Boraginaceae, Brassicaceae, Campanulaceae, Caprifoliaceae, Onagraceae, Salicaceae, Thymelaeaceae, Ulmaceae, Urticaceae and Violaceae. Families with three species were Acanthaceae, Amaranthaceae, Araceae, Balsaminaceae, Cyperaceae, Moraceae, Oleaceae, Pinaceae, Rubiaceae, Scrophulariaceae and Solanaceae. Families with four species were Apiaceae, Hypericaceae, Poaceae, Polygonaceae and Ranunculaceae. In Ethnobotanical survey of the plant species present in the study area, very useful information was recorded about the economic utility of the plants. Uses recorded were medicinal, fuel, fodder, edible and timber and results are shown in the table 4.

Table 1: Analytical characters for different forest types.

	Density (Ind/ha)			TBC (m^2/ha)			IVI		
Trees	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**
Aesculus indica	-	40	-	-	3.41	-	-	19.58	-
Alnus nepalensis	30	120	340	0.28	3.76	0.96	25.91	33.15	85.80
Cedrus deodara	170	140	-	98.82	49.32	-	155.96	78.86	-
Celtis australis	-	-	30	-	-	0.35	-	-	15.72
Lyonia ovalifolia	-	40	50	-	1.20	1.26	-	18.03	27.67
Pinus wallichiana	130	180	-	82.40	84.41	-	118.13	120.59	-

Populus ciliata	-	-	40	-	-	0.84	-	-	22.06
Pyrus pashia	-	30	80	-	0.25	1.49	-	10.44	37.97
Quercus semecarpifolia	-	-	190	-	-	3.78	-	-	79.67
Salix alba	-	50	70	-	0.70	0.95	-	19.35	31.12
	330	600	800	181.50	143.05	9.63	300.00	300.00	300.00
Shrubs	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**
Berberis sp	-	120	60	-	0.0040	0.0040	-	10.55	8.26
Buddleja paniculata	-	-	80	-	-	0.0100	-	-	10.80
Corairia nepalensis	340	440	-	0.3300	0.3100	-	82.38	59.61	-
Cotoneaster baccilaris	-	60	-	-	0.0020	-	-	5.28	-
Cotoneaster microphyllus	40	-	60	0.0004	-	0.0100	8.40	-	9.81
Daphne retusa	-	-	80	-	-	0.0050	-	-	11.64
Dapnae sp.	100	140	-	0.0020	0.0050	-	35.85	14.09	-
Desmodium elegans	360	520	440	0.3600	0.4300	0.1300	75.82	72.84	70.27
Deutzia compacta	-	-	160	-	-	0.0200	-	-	23.73
Elaeagnus conferta	-	-	140	-	-	0.0600	-	-	28.82
Lonicera quinquelocularis	-	-	40	-	-	0.0030	-	-	4.88
Princepia utilis	-	60	100	-	0.0020	0.0200	-	7.91	16.50
Rabdosia rugosa	520	680	320	0.0500	0.4310	0.0500	47.55	89.98	39.40
Rhamnus persica	-	-	60	-	-	0.0040	-	-	8.26
Rhamnus sp.	40	60	-	0.0010	0.0040	-	20.25	8.07	-
Rhamnus virgatus	-	-	40	-	-	0.0020	-	-	4.62
Rubus foliolosus	-	-	40	-	-	0.0030	-	-	4.88
Rubus niveus	-	-	80	-	-	0.0050	-	-	11.64
Sorbaria tomentosa	120	200	240	0.0100	0.0200	0.0600	20.50	20.45	35.90
Wikstroemia canescens	100	140	80	0.0010	0.0020	0.0010	9.25	11.21	10.60
	1620	2420	2020	0.7544	1.2090	0.3870	300.00	300.00	300.00
Herbs	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**
Ajuga paviflora	-	-	5000	-	-	0.0008	-	-	9.25
Arisaema sp.	2500	1875	-	0.0004	0.0002	-	5.49	3.44	-
Artemisia capillaris	-	-	2500	-	-	0.0004	-	-	5.40
Bidens pilosa	-	-	5000	-	-	0.0018	-	-	8.93
Chenopodium album	3750	-	-	0.0006	-	-	9.33	-	-
Chenopodium sp.	-	5000	2500	-	0.0016	0.0004	-	9.19	5.40
Circium sp.	-	3750	-	-	0.0011	-	-	6.09	-
Circium verutum	2500	-	-	0.0004	-	-	5.49	-	-
Clinopodium sp.	6250	5000	4375	0.0030	0.0016	0.0008	15.63	8.15	7.26
Conyza japonica	-	-	4375	-	-	0.0011	-	-	7.62
Cynoglossum glochidium	3750	7500	8750	0.0006	0.0046	0.0062	8.14	12.41	20.09
Elsholtzia sp.	5000	8750	-	0.0018	0.0062	-	12.48	12.01	-
Eriophorum comosum	-	-	6250	-	-	0.0029	-	-	11.18
Fragarea sp.	5000	-	-	0.0016	-	-	12.14	-	-
Fragaria nubicola	-	5625	-	-	0.0011	-	-	8.21	-
Galium sp.	15000	17500	10000	0.0183	0.0183	0.0046	54.36	27.54	20.61
Geranium sp.	11250	28750	-	0.0058	0.0760	-	27.42	70.52	-
Hypericum elodeoides	-	3750	-	-	0.0008	-	-	4.88	-
Impatiens sp.	6250	8750	7500	0.0029	0.0062	0.0050	16.65	14.08	17.72
Lactuca sp.	2500	2500	-	0.0004	0.0004	-	5.49	3.92	-
Malva verticilata	-	-	5000	-	-	0.0018	-	-	8.93
Micromeria biflora	-	-	6250	-	-	0.0023	-	-	11.99

Origanum vulgare	8750	11250	9375	0.0050	0.0103	0.0072	23.84	19.18	21.76
Oxalis acetocella	7500	23125	10000	0.0030	0.0220	0.0062	16.74	31.76	22.55
Phytolacca acinosa	5000	5000	-	0.0050	0.0026	-	17.91	9.77	-
Pilea umbrosa	-	-	16250	-	-	0.0191	-	-	44.31
Pimpinella sp.	3750	11250	8750	0.0006	0.0080	0.0046	9.33	17.80	18.15
Plantago sp.	-	2500	-	-	0.0002	-	-	3.80	-
Polygonum sp.	-	-	11250	-	-	0.0109	-	-	29.16
Prunella vulgare	7500	5000	5625	0.0050	0.0018	0.0018	21.33	8.27	12.46
Salvia moocroftiana	-	-	7500	-	-	0.0046	-	-	17.23
Salvia sp.	3750	3750	-	0.0006	0.0006	-	9.33	6.83	-
Stellarea sp.	5000	7500	-	0.0016	0.0029	-	13.34	11.40	-
Thalictrum sp.	-	2500	-	-	0.0002	-	-	3.80	-
Viola sp.	7500	3750	-	0.0023	0.0008	-	15.55	6.95	-
	112500	174375	136250	0.0589	0.1675	0.0825	300.00	300.00	300.00

Abbreviations: U= Upper altitude; M= Middle altitude; L= Lower altitude; TBC= Total Basal Cover; IVI= Importance Value Index.

Table 2: Diversity Indices of different forest types.

	Cd			SDI			H'			Heterogeneity		
Trees	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**
Aesculus indica	-	0.0043	-	-	0.9957	-	-	0.00	-	-	0.07	-
Alnus nepalensis	0.0075	0.0122	0.0818	0.9925	0.9878	0.9182	0.0021	0.00	0.08	0.09	0.11	0.29
Cedrus deodara	0.2703	0.0691	-	0.7297	0.9309	-	0.4666	0.06	-	0.52	0.26	-
Celtis australis	-	-	0.0027	-	-	0.9973	-	-	0.00	-	-	0.05
Lyonia ovalifolia	-	0.0036	0.0085	-	0.9964	0.9915	-	0.00	0.00	-	0.06	0.09
Pinus wallichiana	0.1550	0.1616	-	0.8450	0.8384	-	0.2027	0.22	-	0.39	0.40	-
Populus ciliata	-	-	0.0054	-	-	0.9946	-	-	0.00	-	-	0.07
Pyrus pashia	-	0.0012	0.0160	-	0.9988	0.9840	-	0.00	0.01	-	0.03	0.13
Quercus semecarpifolia	-	-	0.0705	-	-	0.9295	-	-	0.06	-	-	0.27
Salix alba	-	0.0042	0.0108	-	0.9958	0.9892	-	0.00	0.00	-	0.06	0.10
	0.4328	0.2561	0.1958	2.5672	6.7439	6.8042	0.6715	0.28	0.15	1.00	1.00	1.00
Shrubs	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**
Berberis sp	-	0.0012	0.0008	-	0.9988	0.9992	-	0.00	0.00	-	0.04	0.03
Buddleja paniculata	-	-	0.0013	-	-	0.9987	-	-	0.00	-	-	0.04
Corairia nepalensis	0.0754	0.0395	-	0.9246	0.9605	-	0.0688	0.03	-	0.27	0.20	-
Cotoneaster baccilaris	-	0.0003	-	-	0.9997	-	-	0.00	-	-	0.02	-
Cotoneaster microphyllus	0.0008	-	0.0011	0.9992	-	0.9989	0.0001	-	0.00	0.03	-	0.03
Daphne retusa	-	-	0.0015	-	-	0.9985	-	-	0.00	-	-	0.04
Dapnae sp.	0.0143	0.0022	-	0.9857	0.9978	-	0.0057	0.00	-	0.12	0.05	-
Desmodium elegans	0.0639	0.0590	0.0549	0.9361	0.9410	0.9451	0.0536	0.05	0.04	0.25	0.24	0.23
Deutzia compacta	-	-	0.0063	-	-	0.9937	-	-	0.00	-	-	0.08
Elaeagnus conferta	-	-	0.0092	-	-	0.9908	-	-	0.00	-	-	0.10
Lonicera quinquelocularis	-	-	0.0003	-	-	0.9997	-	-	0.00	-	-	0.02
Princepia utilis	-	0.0007	0.0030	-	0.9993	0.9970	-	0.00	0.00	-	0.03	0.06
Rabdosia rugosa	0.0251	0.0900	0.0172	0.9749	0.9100	0.9828	0.0132	0.09	0.01	0.16	0.30	0.13
Rhamnus persica	-	-	0.0008	-	-	0.9992	-	-	0.00	-	-	0.03
Rhamnus sp.	0.0046	0.0007	-	0.9954	0.9993	-	0.0010	0.00	-	0.07	0.03	-
Rhamnus virgatus	-	-	0.0002	-	-	0.9998	-	-	0.00	-	-	0.02
Rubus foliolosus	-	-	0.0003	-	-	0.9997	-	-	0.00	-	-	0.02
Rubus niveus	-	-	0.0015	-	-	0.9985	-	-	0.00	-	-	0.04
Sorbaria tomentosa	0.0047	0.0046	0.0143	0.9953	0.9954	0.9857	0.0011	0.00	0.01	0.07	0.07	0.12

Wikstroemia canescens	0.0009	0.0014	0.0012	0.9991	0.9986	0.9988	0.0001	0.00	0.00	0.03	0.04	0.04
	0.1896	0.1996	0.1138	7.8104	9.8004	15.8862	0.1435	0.17	0.06	1.00	1.00	1.00
Herbs	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**	**U**	**M**	**L**
Ajuga paviflora	-	-	0.0010	-	-	0.9990	-	-	0.00	-	-	0.03
Arisaema sp.	0.0003	0.0001	-	0.9997	0.9999	-	0.0000	0.00	-	0.02	0.01	-
Artemisia capillaris	-	-	0.0003	-	-	0.9997	-	-	0.00	-	-	0.02
Bidens pilosa	-	-	0.0009	-	-	0.9991	-	-	0.00	-	-	0.03
Chenopodium album	0.0010	-	-	0.9990	-	-	0.0001	-	-	0.03	-	-
Chenopodium sp.	-	0.0009	0.0003	-	0.9991	0.9997	-	0.00	0.00	-	0.03	0.02
Circium sp.	-	0.0004	-	-	0.9996	-	-	0.00	-	-	0.02	-
Circium verutum	0.0003	-	-	0.9997	-	-	0.0000	-	-	0.02	-	-
Clinopodium sp.	0.0027	0.0007	0.0006	0.9973	0.9993	0.9994	0.0005	0.00	0.00	0.05	0.03	0.02
Conyza japonica	-	-	0.0006	-	-	0.9994	-	-	0.00	-	-	0.03
Cynoglossum glochidium	0.0007	0.0017	0.0045	0.9993	0.9983	0.9955	0.0001	0.00	0.00	0.03	0.04	0.07
Elsholtzia sp.	0.0017	0.0016	-	0.9983	0.9984	-	0.0002	0.00	-	0.04	0.04	-
Eriophorum comosum	-	-	0.0014	-	-	0.9986	-	-	0.00	-	-	0.04
Fragarea sp.	0.0016	-	-	0.9984	-	-	0.0002	-	-	0.04	-	-
Fragaria nubicola	-	0.0007	-	-	0.9993	-	-	0.00	-	-	0.03	-
Galium sp.	0.0328	0.0084	0.0047	0.9672	0.9916	0.9953	0.0198	0.00	0.00	0.18	0.09	0.07
Geranium sp.	0.0084	0.0553	-	0.9916	0.9447	-	0.0025	0.04	-	0.09	0.24	-
Hypericum elodeoides	-	0.0003	-	-	0.9997	-	-	0.00	-	-	0.02	-
Impatiens sp.	0.0031	0.0022	0.0035	0.9969	0.9978	0.9965	0.0006	0.00	0.00	0.06	0.05	0.06
Lactuca sp.	0.0003	0.0002	-	0.9997	0.9998	-	0.0000	0.00		0.02	0.01	-
Malva verticilata	-	-	0.0009	-	-	0.9991	-	-	0.00	-	-	0.03
Micromeria biflora	-	-	0.0016	-	-	0.9984	-	-	0.00	-	-	0.04
Origanum vulgare	0.0063	0.0041	0.0053	0.9937	0.9959	0.9947	0.0017	0.00	0.00	0.08	0.06	0.07
Oxalis acetocella	0.0031	0.0112	0.0056	0.9969	0.9888	0.9944	0.0006	0.00	0.00	0.06	0.11	0.08
Phytolacca acinosa	0.0036	0.0011	-	0.9964	0.9989	-	0.0007	0.00	-	0.06	0.03	-
Pilea umbrosa	-	-	0.0218	-	-	0.9782	-		0.01	-	-	0.15
Pimpinella sp.	0.0010	0.0035	0.0037	0.9990	0.9965	0.9963	0.0001	0.00	0.00	0.03	0.06	0.06
Plantago sp.	-	0.0002	-	-	0.9998	-	-	0.00	-	-	0.01	-
Polygonum sp.	-	-	0.0094	-	-	0.9906	-	-	0.00	-	-	0.10
Prunella vulgare	0.0051	0.0008	0.0017	0.9949	0.9992	0.9983	0.0012	0.00	0.00	0.07	0.03	0.04
Salvia moocroftiana	-	-	0.0033	-	-	0.9967	-	-	0.00	-	-	0.06
Salvia sp.	0.0010	0.0005	-	0.9990	0.9995	-	0.0001	0.00	-	0.03	0.02	-
Stellarea sp.	0.0020	0.0014	-	0.9980	0.9986	-	0.0003	0.00	-	0.04	0.04	-
Thalictrum sp.	-	0.0002	-	-	0.9998	-	-	0.00	-	-	0.01	-
Viola sp.	0.0027	0.0005	-	0.9973	0.9995	-	0.0005	0.00	-	0.05	0.02	-
	0.0777	0.0961	0.0711	18.9223	21.9039	18.9289	0.0291	0.05	0.02	1.00	0.80	0.00

Abbreviations: U= Upper altitude; M= Middle altitude; L= Lower altitude; Cd= Simpson's Concentration of Dominance; SDI= Simpson's Diversity Index; H'= Shannon-Wiener Diversity Index.

Table 3: Total Diversity Indices of different forest types.

		Density (Ind/ha)	TBC (m^2/ha)	Cd	SWDI	H'	SR
Trees	**Upper**	330	181.50	0.4328	2.57	0.67	3
	Middle	600	143.05	0.2561	6.74	0.28	8
	Lower	800	9.63	0.1958	6.80	0.15	19
Shrubs	**Upper**	1620	0.75	0.1896	7.81	0.14	7
	Middle	2420	1.21	0.1996	9.80	0.17	10
	Lower	2020	0.39	0.1138	15.89	0.06	22
Herbs	**Upper**	112500	0.06	0.0777	18.92	0.03	7
	Middle	174375	0.17	0.0961	21.90	0.05	16
	Lower	136250	0.08	0.0711	18.93	0.02	19

Table 4: Details and uses of the plant species recorded in the Chamoli-Joshimath study area.

Botanical Name	Family	Occurrence	Economic Utility	LF
Abelia triflora	Caprifoliaceae	UC	Fu	S
Abies pindrow	Pinaceae	C	Tm, Me	T
Achyranthes bidentata	Amaranthaceae	UC	-	H
Adenocaulon himalaicum	Asteraceae	C	Me	H
Aesculus indica	Hippocastanaceae	UC	Fo, Me	T
Agave americana	Agavaceae	C	Me	S
Agrimonia pilosa	Rosaceae	C	Me	H
Albizia julibrissin	Mimosaceae	UC	Me	T
Alnus nitida	Betulaceae	C	Fu	T
Alpinia mutica	Poaceae	C	Me	H
Amaranthes viridis	Amaranthaceae	C	Me	H
Ammi majus	Asteraceae	UC	Me	H
Anaphalis contrata	Asteraceae	C	Me	H
A. triplinervis	Asteraceae	C	Me	H
Andropogon controtus	Poaceae	C	Me	H
Androsace sp.	Primulaceae	UC	-	H
Anemone sp.	Rosaceae	UC	Me	H
A. vitifolia	Rosaceae	UC	Me	H
Aquilegia pubiflora	Aquifoliaceae	UC	Me	H
Arghis sp.	Brassicaceae	C	Me	H
Arctium lappa	Asteraceae	C	Me	H
Arenaria sp.	Caryophyllaceae	C	Me	H
Arisaema sp.	Araceae	C	-	H
A. concinnum	Araceae	UC	Me	H
Artemisia capillaris	Asteraceae	C	-	H
A. roxburghiana	Asteraceae	UC	Me	H
Astragalus chlorostachys	Fabaceae	C	Me	S
Barleria cristata	Acanthaceae	UC	Me	S
Berberis angulosa	Berberidaceae	C	-	S
Bergenia ciliata	Saxifragaceae	C	Me	H
Boerhavia diffusa	Nictaginaceae	C	Me	H
Buddleja paniculata	Scrophulariaceae	C	Fu	S
Bupleurum falcatum	Apiaceae	UC	Me	H
Campanula sp.	Campanulaceae	UC	-	H
Canabis sativa	Cannabinaceae	C	Me	S
Carex sp.	Cyperaceae	C	-	H
Cedrus deodara	Pinaceae	UC	Tm, Me	T
Celtis australis	Ulmaceae	C	Ed, Fu	T
Cerastrium sp.	Caryophyllaceae	C	Fo	H
Chenopodium album	Chenopodiaceae	C	Ed	H
Cichorium intybus	Asteraceae	C	-	H
Circium verutum	Asteraceae	UC	Me	H
Clematis connata	Ranunculaceae	C	Me	C
Clinopodium sp.	Lamiaceae	C	Me	H
Corarla nepalensis	Corlariaceae	C	Fu	S
Cotoneaster baccilaris	Rosaceae	C	Fu	S
C. microphyllus	Rosaceae	C	Fu	S
Cupressus torulosa	Cuperasaceae	UC	Tm, Me	T
Cuscuta reflexa	Cuscutaceae	C	Me	H
Cyathula tomentosa	Amaranthaceae	C	Me	H
Cynodon dactylon	Poaceae	C	Me	H
Cynoglossum glochidiatum	Boraginaceae	C	Me	H
C. lanceolatum	Boraginaceae	UC	Me	H
Daphne retusa	Thymelaeaceae	UC	-	S
Datura sp.	Solanaceae	UC	Me	H
Delphinium danudatum	Ranunculaceae	UC	Me	H
Desmodium elegans	Fabaceae	C	Me, Fu	H
D. multiflorum	Fabaceae	C	Fu	H
Deutzia compacta	Hydrangeaceae	C	Fu	S
Dioscorea deltoidea	Dioscoreaceae	C	Me	H
Dipsacus mitis	Dipsacaceae	UC	-	H
Elaeagnus conferta	Elaeagnaceae	C	Ed	S
Elsholtzia sp.	Lamiaceae	C	-	H
E. fruticosa	Lamiaceae	C	Fu	S
E. flava	Lamiaceae	C	Me	S
Epilobium sp.	Onagraceae	UC	Me	H
Erigeron sp.	Asteraceae	UC	-	H
Eriophorum comosum	Cyperaceae	C	Fo	H
Erysimum hieraciifolium	Brassicaceae	UC	Me	H
Euphorbia sp.	Euphorbiaceae	C	Fu	S
Euphrasia himaliana	Scrophulariaceae	C	Me	H
Fagopyrum dibotryis	Polygonaceae	C	Ed	H
F. pallida	Campanulaceae	UC	-	H
Fallopia pterocarpa	Polygonaceae	UC	-	H

Philadelphus tomentosus	Philadelphaceae	UC	Ed, Fu	T
Phyllanthus acinosa	Phyllanthaceae	C	Ed, Me	C
Pimpinella sp.	Apiaceae	UC	Ed	H
Pinus wallichiana	Pinaceae	UC	Tm, Me	T
Plantago himalaica	Plantaginaceae	C	Me	H
Polygala sp.	Polygalaceae	UC	-	H
Populus ciliata	Salicaceae	UC	Fo, Me	T
Potentilla sp.	Rosaceae	UC	Me	H
Princepia utilis	Rosaceae	C	Me, Fu	S
Pteracanthus alatus	Acanthaceae	C	-	H
Pyrus pashia	Rosaceae	C	Ed, Fu	T
Quercus semecarpifolia	Fagaceae	C	Fo, Me	T
Rabdosia rugosa	Lamiaceae	C	Fu	H
Ranunculus sp.	Ranunculaceae	UC	Me	H
Rhamnus persica	Rhamnaceae	UC	-	H
R. virgatus	Rhamnaceae	UC	Fu	H
Rhus javanica	Anacardiaceae	UC	Fo, Me	T
Rosa brunonii	Rosaceae	C	-	S
Rosularia sp.	Crassulaceae	UC	-	H
Rubia cordifolia	Rubiaceae	UC	Me	C
Rubus ellipticus	Rosaceae	C	Ed	S
R. foliolosus	Rosaceae	C	Ed	S
R. prostrata	Rosaceae	C	-	H
Rumex hastatus	Polygonaceae	C	Ed, Me	H
R. nepalensis	Polygonaceae	C	Me	H
Salix alba	Salicaceae	C	Fo	T
Salvia sp.	Lamiaceae	UC	Fu	H
S. mocrotianna	Lamiaceae	C	-	H
Sarcococca saligna	Buxaceae	C	-	S
Saussurea albscens	Asteraceae	C	-	H
Sedum multicaule	Crassulaceae	UC	-	H
Selinum vaginatum	Apiaceae	UC	Me	H
Senecio chrysanthamoides	Asteraceae	UC	-	H
Silene sp.	Caryophyllaceae	C	Fo	H
S. edgeworthii	Caryophyllaceae	C	-	H
Smilax aspra	Smilacaceae	UC	Me	H
Solanum sp.	Solanaceae	C	-	H
S. nigrum	Solanaceae	UC	Me	H
Solena heterophylla	Cucurbitaceae	UC	Ed, Fo	H
Peristrophe paniculata	Acanthaceae	UC	-	H

Sorbaria tomentosa	Rosaceae	C	Fu	S
Spiraea canascens	Rosaceae	C	Fu	S
Spiranthes sinensis	Orchidaceae	UC	Me	H
Stellaria media	Caryophyllaceae	C	-	H
Swertia angustifolia	Gentianaceae	UC	Me	H
Tagetus minuta	Asteraceae	C	-	H
Thalictrum sp.	Ranunculaceae	UC	Me	H
Thymus linearis	Lamiaceae	UC	Me	H
Toona serrata	Meliaceae	UC	Me	T
Trifoleum repens	Fabaceae	C	-	H
Trigonella corniculata	Fabaceae	UC	Me, Ed	H
Typhonium diversifolium	Araceae	UC	-	H
Ulmus villosa	Ulmaceae	UC	Tm, Me	T
Urtica dioica	Urticaceae	C	Me	S
Verbascum thapsus	Scrophulariaceae	UC	Me	H
Vigna sp.	Fabaceae	UC	Fo	C
Vincetoxicum hirundinaria	Asclepidaceae	UC	Me	H
Viola betonicifolia	Violaceae	C	Me	H
V. pilosa	Violaceae	UC	Me	H
Vitis sp.	Vitaceae	C	-	C
Wikstroemia canescens	Thymelaeaceae	UC	-	S
Woodfordia fruticosa	Lythraceae	UC	Me	S
Youngia sp.	Asteraceae	UC	-	H
Zanthoxylum armatum	Rutaceae	UC	Me	S

Abbreviations: C= Climber; C= Common; Ed= Edible; Fo= Fodder; Fu= Fuel; H= Herb; LF= Life Form; Me= Medicinal; S= Shrub; T= Tree; Tm= Timber; UC= Uncommon.

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 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 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 it varied between 0.67 to 0.15. 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). Ethnobotanical studies typically focus on recording the knowledge of traditional societies in remote places (Hodges and Bennett, 2006).Indigenous people have a vast knowledge of, and capacity for, developing innovative practices and products from their environment. Indigenous knowledge grows from close interdependence between knowledge, land, environment and other aspects of culture in indigenous societies, and the oral transmission of knowledge in accordance with well understood cultural principles and rules regarding secrecy and sacredness that govern the management of knowledge (Tripathi *et al*., 2000). In the present study the traditional uses of various plant species by indigenous people have been recorded, which can be utilized in the future for technological advancement, economic prosperity and providing employment opportunity to the local people.

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