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Phytosociological Analysis of Woody Species in Kedarnath Wildlife Sanctuary and Its Adjoining Areas in Western Himalaya, India

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Abstract

The aim of the present study was to assess the variation in species composition and diversity of woody species at different altitudes (900 to 2600 m asl) in Kedarnath Wildlife Sanctuary (KWLS) and its adjoining areas in Garhwal Himalaya, India. A total of 94 woody plant species (including 44 tree and 50 shrub species) belonging to 72 genera and 44 families were reported. Density varied from 235±9 to 505±21 trees ha^{-1} and 4,730±474 to 9,530±700 shrubs ha^{-1}. Total basal cover varied from 10.49±0.66 to 42.92±2.57 m^2 ha^{-1} (trees) and 0.36±0.024 to 0.62±0.047 m^2 ha^{-1} (shrubs). Shannon-Wiener Index fluctuated between 2.30 to 3.53 (trees) and 2.74 to 3.78 (shrubs). Analysis of variance (ANOVA) indicated that altitude and aspect had significant effect on the distribution of woody species. Taxonomically, Rosaceae with 15 species emerged as the dominant family. Low value of maturity index and contiguous distribution of species denoted the early successional status of the studied forests. The conservation assessment based on altitudinal regimes and the information on species structure and function can provide baseline information for monitoring and sustaining the biodiversity.

Key Words: Himalaya, Altitude, Vegetation, Diversity, Woody species

Introduction

Biodiversity is essential for human survival and economic well being and for the ecosystem function and stability (Singh 2002). Biodiversity, as a part of our daily life, constitutes the resource base upon which our fate of future generations depend (Pushpangadan et al. 1997). Maintenance and periodic assessment of diverse ecosystems and a whole of biological diversity therein are, therefore, crucial for long term survival of human beings (Malik 2014; Malik et al. 2014a). Plant species diversity is affected by several topographic gradients and climatic variations. The factors which affect plant species richness and diversity are of crucial importance in ecology and conservation biology. The number of species in a particular forest varies markedly along the altitudinal range of its growth, which depends on the complex suit of factors that characterize the habitat of individual species (Gairola et al. 2011). The physiographic factors are widely known to show a major impact on plant microhabitats, especially in hill-slope form (Sharma et al. 2010). The physiographic features such as elevation and aspect have a profound influence on the distribution, growth, form and structure of tree species, as a result of which the individual tree species has different values for density and

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basal cover at various altitudes and aspects (Wikum and Wali 1974). 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). Thus it is necessary to understand the dynamics and relationship between various factors which affect richness and diversity of the forests. Understanding of forest structure is pre-requisite to describe various ecological processes and also to model the functioning and dynamics of forest (Elouard et al. 1997). The sound management of Himalayan ecosystem and the knowledge of plant community, diversity, population, distribution, regeneration, utilization, environmental impact assessment, etc. are essential to support the conservation and restoration of the environment (Gairola et al. 2011).

Mountains, the most vulnerable and hazardous environments, harbour rich repositories of biodiversity. The Indian Himalayan region (IHR) occupies a special place in the mountain ecosystems of the world. It is considered as the repository of biological and cultural diversity and supports about 18,440 species of plant, including 1,748 species of medicinal plants and 675 species of wild edibles (Negi and Gaur 1994). Kedarnath Wildlife Sanctuary (KWLS) is a highly diverse site of the Indian Himalayan Region (IHR), located in Western Himalaya. Unfortunately during the last decade the vegetation of this area has been degraded largely because of human disturbances, though the occurrence of natural hazards during the last few years has also exacerbated the degradation (Malik and Bhatt 2015). It has been realized that for the sound management of Himalayan ecosystem, the knowledge of plant community, diversity, population, distribution, regeneration, utilization, environmental impact assessment, etc are essential to support the conservation and restoration of the environment (Gairola et al. 2011; Malik 2014). Therefore, assessment of vegetation composition and understanding species richness and diversity patterns is fundamental for conservation of these natural areas; these patterns have frequently been the focus of ecological studies (Zhang et al. 2013). Hence the present study was carried out to assess the variation in species composition and diversity of woody species (i.e. trees and shrubs) at different altitudes in KWLS and its adjoining areas. Quantitative information on the distribution and abundance of woody species is of key significance to understand the form and structure of a community and for planning and implementation of conservation strategy of the community. This type of ecological knowledge is fundamental for conservation and sustainable utilization, and may provide important information to the policy makers for drafting management plans of fragile mountain ecosystems.

Materials and Methods

Study Area

The study area lies in the sub-montane, montane and subalpine zones of Garhwal Himalaya, India. The

Table 1. Details of studied forests at different altitudes*

Sub-Sites	Geo-coordinates	Aspect	Slope
Site 1 (Kund, 900-1200 m asl), Adjoining area of KWLS			
Barmadi Forest (BR) (900-1,100 m asl)	(30°30’02.91N, 079°05’22.12E)	NWW	30°±10°
Pathali Forest (PT) (1,000-1,150 m asl)	(30°30’00.30N, 079°05’25.73E)	SE	23°±8°
Site 2 (Phata, 1,650-2,000 m asl), Fringe area of KWLS			
Kukrani Band Forest (KB) (1,650-1,750 m asl)	(30°34’ 51.36 N, 079°02’11.29 E)	SW	15°±8°
Jamu Forest (JM) (1,850-1,950 m asl)	(30°34’57 N, 079°01’ 49 E)	S	16°±9°
Site 3 (Triyuginarayan, 2,250-2,600 m asl), Core zone of KWLS			
Triyuginarayan Forest 1 (TN1) (2,300-2,600 m asl)	(30°38’04.02N, 078°58’49.90E)	SSW	33°±6°
Triyuginarayan Forest 2 (TN2) (2,250-2,400 m asl)	(30°38’47.11N, 078°58’4.75E)	WWS	30°±5°

*Adopted from Malik and Bhatt, 2015.

Kedarnath Wildlife Sanctuary (KWLS) is one of the largest protected areas comprising 975 km^2 of the districts Chamoli (25 km^2) and Rudraprayag (72 km^2) of Uttarakhand between the coordinates 30°25'- 30°41' N, 78°55'-79°22' E in the Garhwal region of Greater Himalaya (Malik et al. 2014b). It falls under the IUCN management category IV (Managed Nature Reserve). KWLS lies in the upper catchment of the Alaknanda and Mandakini Rivers, two major tributaries of the Ganges (Malik et al. 2014b).

The present study was carried out at three different altitudes of KWLS in Rudraprayag district. After reconnaissance survey, three sites at different altitudes *i.e.* lower (Kund, 900-1,200 m asl), middle (Phata, 1,650-2,000 m asl) and higher (Triyuginarayan, 2,250-2,600 m asl) were selected and from each of these sites, two forests, differing in aspect and slope were selected (Table 1). Compass and clinometers were used to determine the aspect and slope respectively of the selected forests. Hence a total of six forests, two from each altitudinal range, were investigated for species composition, diversity, concentration of dominance and other phytosociological attributes of woody (trees and shrub) species. Forests of higher altitude (Triyuginarayan) form the core zone of KWLS; those of middle altitude (Phata) form its fringe areas, while those at lower altitude (Kund) come under the adjoining areas of KWLS (Table 1 and Fig. 1).

The studied forests have been named after the respective adjacent villages like *Barmadi*, *Pathali*, *Jamu*, etc. The study area is characterized by gentle slopes varying from 15°±8° to 33°±6°. The soil types found in the study area are dark brown and black soils that are podzolic in nature. Large boulders are common in forest soils of lower altitude; otherwise the soils are generally gravelly in the whole study area (Malik 2014). Forests of this region are mainly dominated by different oak species *viz*., *Quercus glauca* (Harinj), *Quercus leucotrichophora* (Banj), *Quercus floribunda* (Moru) and *Quercus semecarpifolia* (Kharsu) which form the climax vegetation at different climatic zones and are found associated with *Albizia chinensis*, *Bauhinia variegata*, *Cinnamomum tamala*, *Mallotus phillipensis*, *Neolitsea cuipala and Toona hexendra* at lower altitude; *Alnus nepalensis*, *Betula alnoides*, *Pyrus pashia*, *Lyonia ovalifolia*, *Myrica esculenta*, *Rhododendron arboreum*, *Buxus wallichiana*, *Euonymus pendulus*, *Ilex dipyrena*, *Juglans regia*, *Lindera pulcherrima*, *Litsea elongata*,

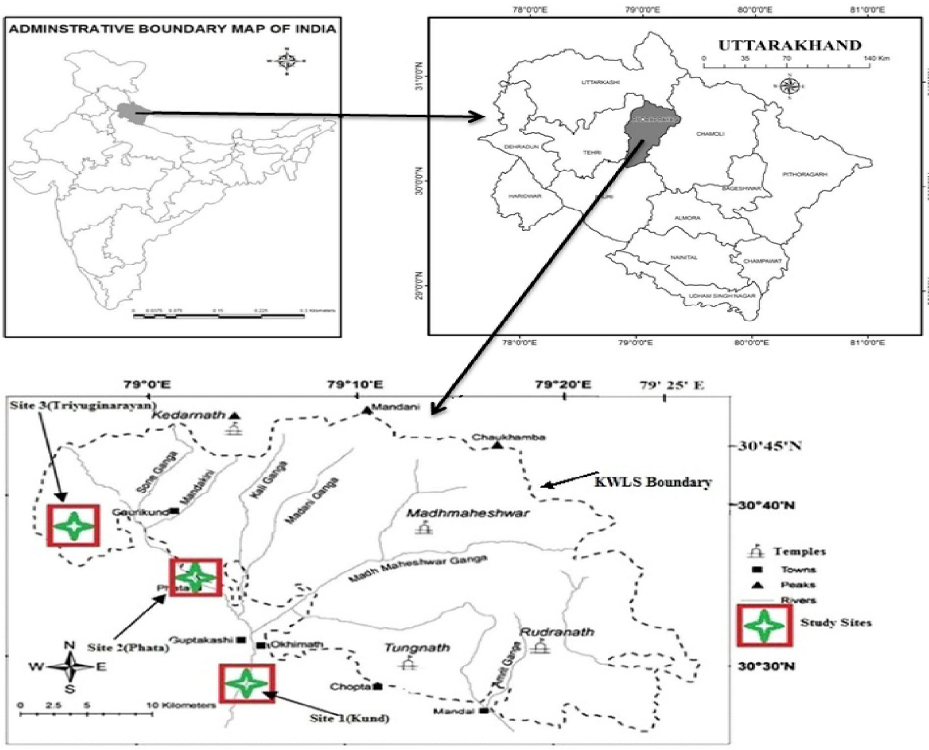

Fig. 1. Map of study area showing the location of study sites.

etc., at middle and higher altitudes of this region. *Q. leucotrichophora* grows in north aspect mainly cooler region below 2,000 m and is found either pure or mixed with other broadleaved and conifer species. *Q. semecarpifolia* occurs in the sub alpine region of the study area in association with *Abies sp*, *Betula utilis*, *Rhododendron campanulatum*, *etc*. *Q. glauca* occurs mainly in lower altitudes, although it has a wide range of occurrence in the study area (Malik 2014). The climate in the study areas is divisible into four distinct seasons, viz., summer (May-July), rainy (mid July-September), winter (October-January) and spring (February-April). The rainfall pattern in the region is largely governed by the monsoon rains (July-September), which account for about 60-80% of the total annual rainfall. However, at higher altitudes, precipitation is almost a daily routine (Malik et al. 2014c). During the study period, mean annual maximum temperature ranged from $19.00\pm5.2^{o}C$ to $31.50\pm7.18^{o}C$, whereas mean annual minimum temperature fluctuated between $2.50\pm0.53^{o}C$ to $10.73\pm1.40^{o}C$. Mean annual maximum relative humidity was recorded from $65.70\pm7.87\%$ to $90.43\pm5.66\%$, while its mean annual minimum value was recorded between $35.42\pm6.86\%$ to $55.00\pm4.79\%$. Mean annual maximum rainfall fluctuated between 365.00 ± 80.41 mm to 640.00 ± 110.43 mm, while its minimum mean value ranged from 15.00 ± 5.17 mm to 125.00 ± 20.43 mm (Malik 2014).

Phytosociological analysis

Field expeditions were made to the selected forests during 2012-13. The analysis of woody species was carried out by placing random sampling plots (quadrats) as per Mishra (1968). The collected plants were identified with the help of taxonomists, available literature and regional floras (Naithani 1984-1985; Gaur 1999). Trees ($\geq$30 cm dbh) were analyzed by placing twenty 10x10 m sized quadrats and nested within each such quadrat; two plots of 5x5 m each were used to enumerate shrubs. Density and basal cover were calculated for each species. Frequency, density and abundance were calculated following Curtis and McIntosh (1950). Species richness (SR) was simply taken as a count of total number of species in that particular forest. The A/F ratio indicated the distribution pattern (Curtis and Cottam 1956). Importance value index (IVI) was calculated as sum of the values of relative frequency, relative density and relative dominance (Phillips 1959). The Maturity Index was calculated following Pichi-Sermolli (1948).

The Shannon-Wiener diversity index (Shannon and Weaver 1963), Simpson concentration of dominance (Simpson 1949), Pielou equitability (Pielou 1966), Margalef (Margalef 1958) and Menheink (Menheik 1964) indices of species richness, beta diversity (Whittaker 1972) and Sorenson index of similarity (Sorenson 1948) were calculated with the following formulae:

$$\overline{H} = -\sum(ni/N)^2\log_2(ni/N) \quad \cdots(1)$$
$$Cd = \sum Pi^2 \quad \cdots(2)$$
$$E = \overline{H}/\text{In } S \quad \cdots(3)$$
$$MI = S - 1/\text{In } S \quad \cdots(4)$$
$$MeI = S/\sqrt{N} \quad \cdots(5)$$
$$\beta - \text{diversity} = Sc/Sa \quad \cdots(6)$$
$$IS = (2C/A + B)x100 \quad \cdots(7)$$

where, $\overline{H}$ is the Shannon-Wiener diversity index, Cd is Simpson concentration of dominance, E is Pielou equitability, lnS is natural log of S, MI and MeI are Margalef and Menheink indices of species richness respectively, n is total IVI values of all species, N is total number of individuals, ni is the IVI value of a species, S is total number of species in forest, Sc is the total number of species occurring in a set of samples counting each species only once whether or not it occur more than once and Sa is the average number of species per individual sample, C is the common number of species in two comparable sites while A and B are the total number of species in site A and B respectively.

Statistical analysis

Carl-Pearson correlation coefficient was calculated between various phytosociological parameters using Microsoft Excel-2007. Analysis of variance (ANOVA) was carried out to find out the relationship of phytosociological variables with each other and with the environmental factors like altitude and aspect.

Results

A total of 94 woody plant species (including 44 tree and 50 shrub species) belonging to 72 genera and 44 families were reported from different altitudes in the study area. Total values of phytosociological and diversity indices of trees and shrubs in different forest are placed in Table 2a and 2b respectively.

Lower Altitude (Site 1, Kund; 900-1,200 m asl)

The two sub-sites of lower altitude *i.e.* Barmadi (BR) and Pathali (PT) forests differ in aspect and slope and are separated by the River Mandakini that originates from glaciers of Kedarnath peak. Tree diversity was slightly higher in BR ($\overline{H}$ =2.67) than PT (2.30). In BR, 12 tree species belonging to 12 genera and 10 families and 18 shrub species, belonging to 17 genera and 15 families were recorded. *Quercus glauca* (IVI 51.09) was dominant tree species followed by *Neolitsea cuipala* (49.38) and others (Table 3). Among shrub species, *Rhamnus purureus* was dominant (61.12), followed by *Colebrookia oppositifolia* (32.08) and others (Table 4).

Table 2a. Total values of phytosociological and diversity indices of trees in KWLS

Description	Altitudinal range of Studied Forests					
	900-1,200 m asl		1,650-2,000 m asl		2,250-2,600 m asl	
	BR	PT	KB	JM	TN1	TN2
Number of species/genera/families	12/12/10	11/11/10	15/15/9	18/18/12	22/19/16	20/16/13
Number of monogeneric families	8	7	4	7	9	9
Density (Ind/ha)	280±12	235±9	410±20	465±18	465±13	505±21
Total Basal Area (m^2/ha)	13.67±0.94	10.49±0.66	20.40±1.24	26.79±1.10	31.51±1.86	42.92±2.57
β-Diversity	6.48	6.28	4.83	5.90	6.37	6.45
Shannon-Wiener Index (H')	2.67	2.30	3.02	3.21	3.53	3.34
Margalef Index (SR)	2.73	2.59	3.17	3.75	4.63	4.11
Menheink Index	1.60	1.60	1.65	1.86	2.28	1.99
Equitability	1.07	0.95	1.11	1.11	1.14	1.11
Concentration of dominance	0.1	0.1	0.09	0.07	0.06	0.08
Simpson Index	0.89	0.89	0.90	0.92	0.94	0.91
Maturity Index	15.41	15.90	20.66	16.94	15.68	15.5

Table 2b. Total values of phytosociological and diversity indices of shrub species in KWLS

Description	Altitudinal range of Studied Forests					
	900-1200 m asl		1650-2000 m asl		2250-2600 m asl	
	BR	PT	KB	JM	TN1	TN2
Number of species/genera/families	18/17/15	16/15/13	16/13/11	12/10/9	22/15/9	14/11/8
Number of monogeneric families	13	11	9	8	5	4
Density (ind/ha)	5,060±221	6,460±277	5,660±368	4,730±474	9,530±700	5,840±400
Totab Basal Area (m^2/ha)	0.62±0.047	0.54±0.028	0.36±0.024	0.39±0.046	0.57±0.045	0.6±0.047
β-Diversity	5.76	4.38	6.15	6.95	6.61	6.22
Shannon-Wiener Index (H')	3.78	3.7	3.43	2.74	3.48	3.19
Margelef Index (SR)	2.73	2.31	2.36	1.78	3.06	2.04
Menheink Index	0.8	0.62	0.67	0.55	0.71	0.57
Equitability	1.3	1.33	1.23	1.1	1.13	1.22
Concentration of dominance	0.08	0.09	0.12	0.19	0.15	0.13
Simpson Index	0.91	0.9	0.88	0.8	0.84	0.87
Maturity Index	17.36	22.81	16.25	14.37	15	16.07

*Studied Forests/Sub-sites: BR, Barmadi; PT, Pathali; KB, Kukraniband; JM, Jamu; TN1 & TN2, Two Triyuginarayan Forests.

Table 3. Density, TBC and IVI of tree species at lower altitude

Site 1 (Kund, 900-1,200 m asl)							
BR (900-1,100 m asl)				PT (1,000-1,150 m asl)			
Tree Species	D/ha	TBC (m^2/ha)	IVI	Tree Species	D/ha	TBC (m^2/ha)	IVI
Alnus nepalensis	15	0.642	15.46	*Albizia chinensis*	15	0.585	20.52
Bauhinia variegata	20	0.503	18.93	*Cinnamomum tamala*	25	0.815	26.97
Cinnamomum tamala	30	1.97	33.23	*Engelhardtia spicata*	15	0.454	19.28
Engelhardtia spicata	15	0.714	15.98	*Ficus auriculata*	20	0.195	18.94
Ficus semicardifolia	15	0.224	15.1	*Lyonia ovalifolia*	15	0.53	17.15
Mallotus philippensis	35	1.421	33.71	*Mallotus philippensis*	20	1.019	26.78
Neolitsea cuipala	45	2.337	49.38	*Neolitsea cuipala*	45	2.105	59.2
Olea glandulifera	15	0.764	16.35	*Pinus roxburghii*	20	1.191	28.43
Ougeinia oogeinensis	20	0.322	14.9	*Quercus leucotrichophora*	20	0.78	24.51
Quercus glauca	40	3.184	51.09	*Rhododendron arboreum*	15	0.585	17.67
Sapium insinge	15	0.429	13.9	*Toona hexandra*	25	2.236	40.51
Toona hexandra	15	1.154	21.91				
Total	280±12	13.67±0.94			235±9	10.49±0.66	

Table 4. Density, TBC and IVI of shrub species of lower altitude

Site 1 (Kund, 900-1,200 m asl)							
BR (900-1,100 m asl)				PT (1,000-1,150 m asl)			
Shrub Species	D/ha	TBC (m^2/ha)	IVI	Shrub Species	D/ha	TBC (m^2/ha)	IVI
Asparagus adscendens	100	0.0038	4.99	*Agave americana*	20	0.0358	7.51
Berberis asiatica	270	0.0569	21.71	*Artemesia nilagirica*	250	0.0118	10.13
Boehmeria platyphylla	250	0.0048	11.32	*A. adscendens*	430	0.0095	13.88
Carissa opaca	200	0.0212	12.16	*B. asiatica*	550	0.0638	28.35
Cocculus laurifolius	200	0.1006	25.75	*C. opaca*	460	0.0506	24.55
Colebrookia oppositifolia	800	0.0315	32.08	*Catunaregam spinosa*	310	0.0251	15.54
Cyathula tomentosa	270	0.0117	14.42	*C. laurifolius*	130	0.0896	22.44
Eupatorium adenophorum	380	0.004	16.16	*C. oppositifolia*	1,210	0.0315	40.22
Euphorbia royleana	30	0.0424	9.03	*Debregeasia salicifolia*	310	0.0503	18.75
Pavetta indica	270	0.0109	12.7	*E. adenophorum*	460	0.0056	13.62
Pavetta tomentosa	180	0.0081	8.87	*E. riparium*	430	0.004	12.88
Rhamnus purpureus	780	0.1994	61.12	*R. purpureus*	490	0.0786	28.75
Rubus ellipticus	180	0.0276	11.2	*R. ellipticus*	190	0.0092	9.42
Solanum hispidium	130	0.0102	7.42	*S. hispidium*	320	0.005	11.35
Spermadictyon sauveolens	110	0.0035	5.93	*U. dioica*	180	0.0101	8.06
Woodfordia fruticosa	490	0.0453	23.38	*W. fruticosa*	720	0.068	34.48
Urtica dioica	390	0.0256	18.23				
Zanthoxylum armatum	30	0.0128	3.46				
Total	5,060±221	0.62± 0.04			6,460±277	0.54±0.028	

In PT, 11 tree species belonging to 11 genera and 10 families and 16 shrub species belonging to 15 genera and 13 families were recorded. *Neolitsea cuipala* (IVI 59.2) was dominant tree species followed by *Toona hexandra* (40.51; Table 3). Among shrubs, the dominant species was *Colebrookia oppositifolia* (40.22) followed by *Woodfordia frui-*

Table 5. Density, TBC and IVI of tree species of middle altitude

Site 2 (Phata, 1650-2000 m asl)							
KB (1650-1750 m asl)				JM (1850-1950 m asl)			
Species	D/ha	TBC (m^2/ha)	IVI	Species	D/ha	TBC (m^2/ha)	IVI
Alnus nepalensis	60	5.084	50.84	*Aesculus indica*	15	1.445	11.89
Betula alnoides	20	1.362	18	*Alnus nepalensis*	20	2.105	17.07
Cinnamomum tamala	10	0.541	8.32	*Betula alnoides*	35	2.668	25.68
Fraxinus micrantha	10	0.311	7.18	*Daphniphyllum himalense*	70	3.298	40.47
Juglanus regia	20	0.808	12.06	*Fraxinus micrantha*	20	1.84	16.08
Lindera pulcherrima	40	0.95	24.09	*Ilex dipyrena*	25	0.624	12.62
Litsea elongate	70	1.888	42.45	*Juglanus regia*	20	2.796	19.65
Lyonia ovalifolia	45	1.851	31.34	*Lindera pulcherrima*	25	0.58	12.46
Myrica esculenta	20	0.683	13.06	*Litsea elongata*	50	1.279	25.36
Pinus roxburghii	15	2.869	20.94	*Lyonia ovalifolia*	40	2.473	26.02
Prunus cerasoides	5	0.78	6.65	*Persea odoratissima*	10	0.161	4.39
Pyrus pashia	20	0.418	11.76	*Prunus venosa*	5	0.206	3.48
Quercus glauca	15	0.361	8.65	*Pyrus pashia*	25	0.716	12.96
Q. leucotrichophora	35	1.461	25.37	*Quercus floribunda*	15	2.23	14.82
Rhododendron arboreum	25	1.031	19.21	*Q. leucotrichophora*	40	2.438	27.53
				Rhamnus virgatus	10	0.127	5.9
				Rhododendron arboreum	35	1.658	20.27
				Swida macrophylla	5	0.143	3.24
Total	410±20	20.40±1.24			465±18	26.79±1.10	

Table 6. Density, TBC and IVI of shrub species of middle altitude

Site 2 (Phata, 1650-2000 m asl)							
KB (1650-1750 m asl)				JM (1850-1950 m asl)			
Species	D/ha	TBC (m^2/ha)	IVI	Species	D/ha	TBC (m^2/ha)	IVI
Asparagus capitatus	220	0.002	11.2	*Asparagus capitatus*	130	0.002	8.93
Berberis lycium	160	0.018	12.6	*Berberis asiatica*	570	0.139	61.3
Berberis asiatica	310	0.089	39.6	*Daphne papyracea*	1,420	0.022	55.9
Caesalpinia decaptala	140	0.071	25	*Debregeasia salicifolia*	170	0.02	11.6
Daphne papyracea	900	0.026	33.7	*Duetzia staminea*	30	0.002	2.5
Debregeasia salicifolia	570	0.025	27.7	*Rubus ellipticus*	230	0.016	17.6
Elsholtzia fruticosa	140	0.005	6.76	*Rubus paniculatus*	210	0.021	16.9
Eupatorium adenophorum	470	0.0008	15.3	*Rubus nivens*	50	0.003	4.63
Prinsepia utilis	360	0.011	16.1	*Rosa brunoii*	460	0.033	29.7
Pyracanthus crenulata	330	0.035	24	*Sarcococca saligna*	1,270	0.014	46.2
Sarcococca saligna	1,460	0.014	42.1	*Solanum hispidium*	160	0.005	9.1
Rubus ellipticus	70	0.013	7.74	*Viburnum mullaha*	30	0.122	35.8
Rubus nivens	70	0.012	7.32				
Rubus paniculatus	190	0.01	11.9				
Sinarudinaria falcata	210	0.0004	7.68				
Zanthoxylum armatum	60	0.031	11.4				
Total	5,660±68	0.36±0.024			4,730±474	0.39±0.046	

ticosa (34.48, Table 4).

Mid-Altitude (Site 2, Phata; 1,650-2,000 m asl)

Among two sub-sites of mid-altitude, tree diversity was slightly higher (3.21) in Jamu (JM) than Kukraniband (KB) forest (3.02). In JM, 18 tree species belonging to 18 genera and 12 families and 12 shrub species, belonging to 10 genera and 9 families were recorded. *Daphniphyllum himalense* (IVI 40.47) was found to be dominant tree species followed by *Quercus leucotrichophora* (27.53) and other associates (Table 5). Among shrub species, *Berberis asiatica* (IVI 61.3) was dominant, followed by *Daphne papyracea* (55.87) and others (Table 6).

In KB, 15 tree species of 15 genera and 9 families and 16 shrub species of 13 genera and 11 families were registered. *Alnus nepalensis* (IVI 50.84) was dominant tree species followed by *Litsea elongata* (42.45) as understorey species (Table 5). Among shrubs, the dominant species was *Sarcococca saligna* (42.09) followed by *Berberis asiatica* (39.55) and others (Table 6).

Higher Altitude (Site 3, Triyuginarayan; 2,250-2,600 m asl)

Among the two sub-sites of higher altitude, tree diversity was higher ($\overline{H}$ =3.53) in Triyuginarayan Forest 1 (TN1) than Triyuginarayan Forest 2 (TN2, $\overline{H}$ =3.34). In TN1, 22 tree species belonging to 19 genera and 16 families and 22 shrub species of 15 genera and 9 families were recorded. *Quercus floribunda* (IVI 45.60) was dominant tree species followed by *Quercus semecarpifolia* (32.53) and others (Table 7). Among shrub species, *Sarcococca saligna* (IVI 47.91) was dominant, followed by *Cotoneaster bacillaris* (37.27, Table 8).

In TN2, 20 tree species belonging to 16 genera and 13 families and 14 shrub species of 11 genera and 8 families

Table 7. Density, TBC and IVI of tree species of higher altitude

Site 3 (Triyuginarayan, 2250-2600 m asl)							
TN1 (2300-2600 m asl)				TN2 (2250-2400 m asl)			
Species	D/ha	TBC (m^2/ha)	IVI	Species	D/ha	TBC (m^2/ha)	IVI
Acer caesium	15	0.53	9.25	*A. caesium*	15	0.40	7.14
Acer cappadocicum	10	0.28	5.95	*A. cappadocicum*	10	0.57	6.54
Aesculus indica	15	2.68	16.09	*A. indica*	20	4.01	19.76
Betula utilis	5	0.19	3.14	*B. wallichiana*	20	0.20	9.28
Buxus wallichiana	30	0.76	13.23	*E. pendulus*	15	0.29	6.89
Euonymous pendulus	20	0.32	9.67	*F. micrantha*	10	1.14	7.87
Ilex dipyrena	30	1.34	16.51	*I. dipyrena*	30	1.04	14.82
Juglanus regia	10	1.34	9.31	*J. regia*	15	2.28	13.13
Lindera pulcherrima	30	0.59	14.14	*L. pulcherrima*	25	0.35	10.6
Litsea elongate	40	1.19	19.63	*L. elogata*	20	0.57	11.74
Lyonia ovalifolia	30	1.34	16.51	*L. ovalifolia*	45	4.64	27.8
Persea odoratissima	10	0.39	6.28	*P. odoratissima*	10	0.31	4.31
Picea smithiana	10	0.50	6.66	*P. pashia*	15	0.24	6.75
Pyrus pashia	25	0.47	12.68	*Q. glauca*	10	1.09	6.15
Quercus floribunda	55	6.99	45.6	*Q. floribunda*	35	4.40	23.64
Q.leucotrichophora	30	2.80	21.14	*Q. leucotrichophora*	50	4.10	27.52
Quercus semicarpifolia	35	6.51	32.53	*Q. semicarpifolia*	30	7.81	30.59
Rhamnus virgatus	5	0.12	2.9	*R. arboreum*	100	8.52	50.9
Rhododendron arboreum	15	0.70	9.8	*S. ramosissima*	15	0.33	6.98
R.campanulatum	5	0.10	2.866	*T. baccata*	15	0.55	7.49
Symplocos ramosissima	15	0.53	9.25				
Taxus baccata	25	1.75	16.75				
Total	465±13	31.51±1.86			505±21	42.92±2.57	

were recorded. *Rhododendron arboreum* (IVI 50.90) was dominant tree species followed by *Quercus semecarpifolia* (30.59) and associate species (Table 7). Among shrubs, the dominant species was *Pyracantha crenulata* (58.99) followed by co-dominant *Caesalpinia decaptala* (29.55) and others (Table 8).

It is evident from above tables that *Quercus* spp, *Lyonia ovalifolia* and *Rhododendron arboreum* were distributed throughout the study area but showed varied values for phytosociological and diversity indices at different altitudes. These species acted as dominant or associate tree species at various altitudes. The reason for this distribution is that these species were well adapted to various altitudes and aspects, which helped them to flourish throughout the study area.

Distribution Pattern (A/F Ratio)

An analysis of dispersion pattern indicated that in case of trees, maximum species (%) had contagious distribution (91.66% in BR, 90.9% in PT, 53.33% in KB, 77.77% in JM, 95.45% in TN1 and 90% in TN2) although there are a few species (%) that showed random distribution (8.37% in BR, 9.09% in PT, 46.66% in KB, 22.22% in JM, 4.54% in TN1 and 10% in TN2). None of the reported species was found with regular distribution. In case of shrubs, 100% of species showed contagious distribution.

Dominant families

The woody vegetation in the study area is represented by a total of 94 species belonging to 72 genera and 44 families. The number of species in each family varied from 1 to 15. Nearly 45% (*i.e.* 20 families) were represented by single species (monotypic). Taxonomically, Rosaceae, with 15 species, emerged as dominant family. Taking both trees and shrub species into consideration, Buxaceae (with 7,330

Table 8. Density, TBC and IVI of shrub species of higher altitude

Site 3 (Triyuginarayan, 2250-2699 m asl)							
TN1 (2300-2600 m asl)				TN2 (2250-2400 m asl)			
Species	D/ha	TBC (m^2/ha)	IVI	Species	D/ha	TBC (m^2/ha)	IVI
Berberis aristata	810	0.036	28.41	*B. aristata*	200	0.022	15.01
Berberis chitria	490	0.01	17.5	*B. chitria*	90	0.001	4.09
Berberis petiolaris	250	0.009	8.84	*Caesalpinia decaptala*	210	0.109	29.55
Cotoneaster acuminatus	290	0.02	9.67	*C. bacillaris*	260	0.033	15.5
Cotoneaster bacillaris	30	0.20	37.27	*F. oxyphylla*	20	0.099	19.08
Cotoneaster integrifolius	320	0.008	10.21	*P. crenulata*	890	0.143	58.99
Daphne papyracea	440	0.004	12.29	*R. brunonii*	320	0.031	20.65
Elsholtzia fruticosa	200	0.002	4.74	*R. macrophylla*	200	0.023	14
Fagara oxyphylla	280	0.026	10.5	*S. saligna*	1,170	0.001	29.21
Princepia utilis	240	0.014	8.87	*S. falcata*	850	0.000	20.12
Pyracanthus crenulata	210	0.014	9.27	*T. spathiflora*	1,070	0.004	25.77
Rosa brunonii	140	0.012	5.15	*V. cotinifolium*	330	0.02	16.89
Rosa macrophylla	180	0.025	8.57	*U. dioca*	200	0.014	11.35
Rosa sericea	120	0.015	7.04	*V. mullaha*	30	0.095	19.7
Rubus foliolosus	180	0.006	6.78				
Salix denticulata	70	0.002	2.69				
Sarcococca saligna	3,380	0.005	47.91				
Sinarudinaria falcata	820	0.000	13.19				
Spiraea canescens	110	0.004	3.39				
Thamnocalamus spathiflora	760	0.000	11.91				
Viburnum cotinifolium	180	0.05	15.18				
Viburnum mullaha	30	0.10	20.7				
Total	9,530±700	0.57±0.04			5,840±400	0.60±0.047	

ind/ha) was the dominant family on the basis of density followed by Rosaceae (5,815 ind/ha), Berberidaceae (3,700 ind/ha) *etc.* Lowest density was recorded for family Cornaceae (5 ind/ha).

At lower altitude, maximum number of species was reported for Euphorbiaceae, Rosaceae and Asteraceae (3 each) while on the basis of density, Lamiaceae was found to be the dominant family at this altitude with the highest density of 800-1,210 ind/ha. Rosaceae with 7 species was the dominant family at mid altitude followed by Lauraceae with 3 species. At higher altitude, taxonomically Rosaceae with 11 species was dominant followed by Berberidaceae with 5 species. On the basis of density, Buxaceae was the dominant family at both mid and higher altitudes with the highest density of 1,270-1,460 and 1,190-3,410 ind/ha respectively.

Similarity Indices

Similarity index between any two forests varied from one altitude to another. Minimum similarity was shown by the two forests of lower altitude, followed by mid altitudinal forests, while its maximum value was recorded between the two forests of higher altitudes. It means similarity increased with increase in the altitude. In case of tree stratum, the highest value of similarity index, 85.71%, was reported for TN1 and TN2, followed by 68.42% (JM and TN2), 65% (JM and TN2), 60.6% (JM and KB), 51.42% (KB and TN2), 43.47% (BR and PT), 37.83% (KB and TN1), 30.76% (PT and KB), 22.22% (KB and BR), 20.68% (JM and PT), 19.35% (PT and TN2), 18.18% (TN1 and PT), 6.6% (JM and BR), 6.25% (TN2 and BR) and 0% (TN1 and BR). In case of shrub stratum, the highest value of similarity index, 66.66% was reported for TN1 and TN2 followed by 58.82% (BR and PT), 57.14% (KB and JM), 31.57% (KB and TN1), 28.57% (JM and PT), 26.66% (KB and TN2), 25% (PT and KB), 23.52% (JM and TN1), 23.07% (JM and TN2), 20% (BR and JM), 11.76% (BR and KB), 6.66% (PT and TN2), 6.25% (BR and TN2) and 0% (TN1 and BR, TN1 and PT).

Statistical Analysis

Carl-Pearson correlation test (Table 9) showed that tree density was significantly and positively correlated to tree species richness (0.92), tree Shannon-Wiener Index (0.95), and shrub β-diversity (0.85) while it was significantly and negatively correlated with tree concentration of dominance (-0.82). Tree total basal cover (TTBC) was significantly and positively correlated with tree Shannon-Wiener index of diversity (0.86) and tree species richness (0.89). Tree diversity was significantly and positively correlated with tree species richness (0.96) and shrub β-diversity (0.88) whereas it was negatively and significantly (-0.89) correlated with tree concentration of dominance. Tree β-diversity was significantly and positively related to shrub total basal cover (0.87).

Analysis of variance (ANOVA) showed that altitude (F=2.788, p=0.001), and site/aspect (F=2.569, p=0.003) had a significant effect on the shrub diversity (Table 10). In case of trees, ANOVA showed that tree density is sig-

Table 9. Carl-Pearson Correlation coefficients between various phytosociological parameters of trees and shrubs

	TD	TTBC	T$\overline{H}$	TSR	TBD	TCd	SD	STBC	SBD
TD	1	0.91*	0.95*	0.92*	-0.13	-0.82**	0.17	-0.22	0.85**
TTBC	-	1	0.86**	0.89**	0.16	-0.7	0.23	0.12	0.65
T$\overline{H}$	-	-	1	0.96*	-0.03	-0.89**	0.23	-0.09	0.88**
TSR	-	-	-	1	0.11	-0.93*	0.5	0.01	0.77
TBD	-	-	-	-	1	-0.08	0.24	0.87**	-0.17
TCd	-	-	-	-	-	1	-0.53	0.13	-0.78
SD	-	-	-	-	-	-	1	0.31	0.04
STBC	-	-	-	-	-	-	-	1	-0.31
SBD	-	-	-	-	-	-	-	-	1

*Correlation is significant at 0.01 significance level; ** Correlation is significant at 0.05 significance level.
Abbreviations: TD, Tree Density; TTBC, Tree TBC; TH, Tree Shannon-Wiener Diversity Index; TSR, Tree Species Richness; TBD, Tree β-Diversity; TCd, Tree concentration of dominance; SD, Shrub Density; STBC, Shrub TBC; SBD, Shrub β-Diversity.

Table 10. Summary of ANOVA, showing the relationship between phytosociological variables and environmental factors

Observation	Factors	df	Fcal	Ftab	p
Tree Density	Altitude	7,112	12.44	2.09	0.000*
	Shannon Wiener Index	7,112	1.001	2.09	0.434
	IVI	7,112	0.948	2.09	0.473
	TBC	7,112	0.856	2.09	0.544
	Cd	7,112	1.318	2.09	0.248
	Site/Aspect	7,112	11.34	2.09	0.000*
TBC	Altitude	86,33	1.515	1.66	0.091
	Shannon Wiener Index	86,33	0.628	1.66	0.955
	IVI	86,33	0.89	1.66	0.673
	Cd	86,33	1.038	1.66	0.466
	Tree Density	86,33	1.346	1.66	0.171
	Site	86,33	1.115	1.66	0.371
Shannon Wiener Index	Altitude	40,79	7.18	1.54	0.000*
	IVI	40,79	1.11	1.54	0.337
	Cd	40,79	0.49	1.54	0.993
	Tree Density	40,79	2.41	1.54	0.000*
	TBC	40,79	3.32	1.54	0.000*
	Site/Aspect	40,79	4.81	1.54	0.000*
Shrub density	Altitude	43,196	1.242	1.44	0.164
	Site/Aspect	43,196	1.323	1.44	0.104
	Diversity Index	43,196	0.778	1.44	0.834
Shrub Diversity	Altitude	12,227	2.788	1.79	0.001*
	Site/Aspect	12,227	2.569	1.79	0.003*
	Shrub Density	12,227	0.661	1.79	0.787

df[1], degrees of freedom; Fcal[2], F-calculated; Ftab[3], F-tabulated; cd, Concentration of dominance.
*significant at 0.05 level of significance.

nificantly different in different sites/aspects (F=11.34, p=0.000) and at different altitudes (F=12.44, p=0.000). It clearly indicates that both altitude as well as sites/aspects had some effect on the distribution of trees, while other phytosociological parameters like Cd, TBC, IVI did not show significant effect on the tree density in the study area (Table 10). Altitude (F=7.18, p=0.000), tree density (F=2.41, p=0.000), TBC (F=3.32, p=0.000) and site (F=4.81, p=0.000) has a significant effect on the diversity of trees, $\overline{H}$ (Table 10). Thus the physiographic features such as elevation and aspect have a profound influence on the distribution, growth, form and structure of tree species, as a result of which the individual tree species has different values for density and basal cover at various altitudes and aspects.

Discussion

The values of various phytosociological and diversity indices reported in the present study are best fitted within those reported earlier from different parts of Western Himalaya like Kumaon, Garhwal, Himachal Pradesh, Nepal and Pakistan.

In present investigation, the tree density ranged from 235±9 trees/ha (lower altitude) to 505±21 trees/ha (higher altitude). These values of density are within the earlier values reported by various authors like Pant and Samant (2007); Semwal et al. (2010), Gairola et al. (2011); Raturi (2012) and Bhat (2012). Shrub density varied from 4,730±474 to 9,530±700 ind/ha. Pant and Samant (2007) reported shrub density ranging from 704 to 11,056/ha. Gairola et al. (2011) reported shrub density ranging from 6639-24853/ha from different moist temperate forests of

Garhwal Himalaya.

The TBC (total basal cover) ranged from 10.49±0.66 m^2/ha (lower altitude) to 42.92±2.57 m^2/ha (higher altitude). The possible reason for higher value of TBC at higher altitude could be that these forests constitute the buffer zone of KWLS and hence are protected and mature, which seems to have reached their higher limit of productivity while the forests of lower altitude come under adjoining areas of KWLS that are not protected from anthropogenic disturbances. According to Saxena et al. (1978) the trees with higher TBC indicate the best performance of the species in a particular set of environmental conditions and lower TBC either demarcate the chance occurrence of the species or presence of the biotic disturbances in the past. These values of TBC (m^2/ha) are within the earlier values reported by various authors like Pant and Samant 2007 (19-234); Gairola et al. 2011 (35-84); Raturi 2012 (3-44) and Bhat 2012 (3-38).

Shannon-Wiener diversity index ranged between 2.67 (lower altitude) and 3.53 (higher altitude). The higher diversity at higher altitude may be due to interaction of different species on these sites. Higher number of species with generally overlapping niches may coexist and it may be concluded that higher diversity always give higher stability (Kharkwal 2009). These values of diversity index are well within those reported earlier by various workers in different parts of Western Himalaya in general and Uttarakhand Himalaya in particular like Gairola et al. 2011 (2.43-3.33), Khan et al. 2012 (3.33-4.0), Raturi 2012 (0.78-3.45) and Singh 2013 (0.95-3.30).

The values of Cd ranged from 0.06 (higher altitude) to 0.1 (lower altitude) in tree layer and 0.08 (lower altitude) to 0.19 (Mid altitude) in shrub layer. The value of Cd depends on the specie richness and its lower values are associated with high species richness. According to Baduni and Sharma (1997) the Cd is strongly affected by the IVI of the first three relatively important species in a community. $\overline{H}$ and Cd were inversely related with each other in the study area, which is generally the case in established forests (Zobel et al. 1976).

The values of Pielou equitability ranged from 0.95 to 1.14 in tree layer, 1.1 to 1.33 in shrub layer. Uniyal et al. (2010) reported equitability ranging from 0.47 to 0.83 for trees and 0.69-0.87 for shrubs from Garhwal Himalaya. Gairola et al. (2011) reported equitability between 0.73 and 0.89 for trees and 0.83-0.90 for shrubs from moist temperate forests of Garhwal. Kharakwal (2009) reported equitability values between 3.1 and 3.8 from Kumoan Himalaya.

Inter community or inter-habitat diversity is termed as β-Diversity. It is also defined as extent of species replacement or species turnover along an environmental gradient (Whittaker 1972). The values of β-Diversity varied from 4.83 to 6.48 for tree layer, 4.38 to 6.95 for shrub layer. Gairola et al. (2011) reported that the values of β-Diversity varied from 1.74 to 3.63 for tree layer, 1.65 to 4.48 for shrub layer. Bhat (2012) reported β-Diversity ranging from 2.97 to 6.11 for trees and 4.95 to 8.62 for shrubs. All of the studied forests showed high values of β-Diversity (>4.0). These high values of β-Diversity show high level of inter-habitat diversity along the topographic gradient.

Communities under different environmental conditions differ in the number of species they contain. Margalef's index of species richness ranged from 2.37 to 4.63 for trees and 1.78 to 3.06 for shrubs. The values are similar to those reported from different parts of Uttarakhand Himalaya by Uniyal et al. 2010 (2.21-7.00 for trees and 3.74-5.93 for shrubs), Gairola et al. 2011 (1.36-2.17 for trees and 0.63-1.69 for shrubs). Along the altitude, the geographic and climatic conditions change sharply (Kharkwal et al. 2005). The maximum species richness at higher altitude may be due to presence of favourable conditions like high moisture, humidity, rain fall etc. The upper limit of species richness remains high up to a considerable altitudinal level and tree richness increases with increasing moisture in the Indian Central Himalaya (Rikhari et al. 1989). According to Champion and Seth (1968) more than 60% plant species are generally present at middle altitudes, where the temperature covers a range from 10°C to 24°C.

Dispersal limitation is an important ecological factor for controlling species distribution patterns and a connection between biotic and abiotic ecological factors (Hubbell et al. 1999). The extension of climate gradient enabled several species to realize their fullest range of elevational adaptability. The species-aggregation relationship predicts that spatial aggregation of individuals within species results in lower species richness (Sagar et al. 2003).

In the present study, all the shrub species and most of the tree species (78-95%) showed contagious distribution.

According to Odum (1971) contagious distribution is the most common pattern in nature. The clumping of individuals of a species may be due to insufficient mode of seed dispersal (Richards 1996) or when death of trees creates a large gap encouraging recruitment and growth of numerous saplings (Armesto et al. 1986). Clumping in these species may be due to patchy distribution of microhabitats suitable for plant growth in forest soils. The changes in the dispersion patterns may reflect the reactions of species to disturbance as well as to changes in the habitat conditions (Sagar et al. 2003).

The maturity index is an important tool for representation of quantitative and qualitative characteristics of a community and in evaluating the biodiversity and conservation of intact habitat and plant life in specific area (Malik et al. 2014b). In the present study, maturity index varied from 15.41 (lower altitude) to 20.66 (mid altitude) for trees and 14.37 (mid altitude) to 22.81 (lower altitude) for shrubs. Shaheen et al. (2012) reported values of maturity index between 38 and 53 from Western Himalayan moist temperate forests of Pakistan. The reason for the low values for maturity index in the present study may be different forms of natural (landslides, cloud burst) and anthropogenic disturbances (lopping, grazing and fuelwood collection by local people) in these forests. Mature communities are composed of few well established and uniformly distributed species occupying maximum space and out-competing the sporadic flora. Species in a mature community manage to establish them to local conditions achieving a balanced state with other members (Nautiyal and Kaechele 2007). Low maturity index values indicate the heterogeneity within communities due to a lesser adaptation to the ecological conditions of area. The high intensity of anthropogenic disturbances regularly disturbs the natural balance of forest communities, thus preventing them to reach a climax stage of community maturity (Saxena and Singh 1984). Moreover, most of the tree species and all shrub species showed contagious distribution (Table 9) in the study area and according to Whitford (1949), in pioneer communities plants tend to be aggregated but as the community progresses towards climax, their distribution become more random or even regular. The low maturity value and contiguous distribution of species denote the early successional status of the studied forests.

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