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Forest Structure and Composition in the Vicinity of Srinagar Hydroelectric Power Project in Alaknanda Valley, Garhwal Himalaya, India

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Abstract

We studied forest structure and composition in the vicinity of Srinagar Hydroelectric Power Project in Alaknanda Valley, Garhwal Himalaya, India to provide baseline data for the management of forests. Eight sites were selected in the vicinity of power project based on elevation and species composition. Density varied from 650 to 340 ind ha^{-1} for trees and from 4,360 to 6,480 ind ha^{-1} for shrubs. TBC ranged from 35.02 to 54.02 m^2 ha^{-1} for trees and from 0.875 to 2.628 m^2 ha^{-1} for shrubs. On the basis of density and IVI, *Pinus roxburghii* was found dominant tree species in most of the sites, whereas among the shrubs, *Carissa opaca* was dominant. Dominance of *Pinus roxburghii* in most of the sites is an indication towards possible threat to associated species in the area. The dominance-diversity curve of trees showed a geometric distribution, whereas the shrubs displayed log-normal curves. The forest has rich and diverse species composition however; habitat degradation caused by the construction of Power Project might lead to reduction of plant species from the area. The information obtained from this study will be helpful in predicting possible changes in the forest ecosystem properties in near future after completion of the power project.

Key Words: diversity, forest composition, himalaya, hydroelectric power project, management implications

Introduction

Understanding of forest structure and composition is a pre-requisite to describe various ecological processes and also to model the functioning and dynamics of forests (Elourard et al. 1997). Thus, the structure and composition of the vegetation reflect the ecosystem properties and ecological condition of an area that form the basis for further scientific study and management of an area (Lindenmayer and Franklin 1997). This emphasizes the need for structural analysis of vegetation in forest stands (Pandey 2003). Variations in species richness and diversity at a local scale are affected by a number of complex and interacting variables, including both natural environmental factors and human-made changes to the local environment (Larpkrern et al. 2009).

Various changes in the Garhwal Himalayan forests are appearing in their structure, density and composition due to global warming (Gaur 1982) and anthropogenic pressures such as uncontrolled lopping and felling of trees for fuel wood, fodder, grazing, etc. (Bargali et al. 1998; Kumar et al. 2004; Tiwari et al. 2010; Ballabha 2011; Ballabha et al. 2013a, 2013b). These biotic pressures play an important role in forest community dynamics and each form of biotic

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pressures has different effect on the subsequent development of vegetation (Loucks et al. 1981; Pandey and Singh, 1985).

Major ecological degradation such as deforestation is accelerated due to hill road construction and execution of large river valley projects, which collectively create several environmental problems in the Himalayan region. Construction and operation of the Srinagar Hydroelectric Power Project is one of the infrastructure projects that being threatened forests in Alaknanda Valley, Garhwal Himalaya (Ballabha et al. 2014).

Hydroelectric Power Projects create environmental issues originating from submergence of large forest area (Samant et al. 2007). Submergence of forests by the hydroelectric projects can cause a great threat to biodiversity of any region (Nair and Balasubramanyam 1985; Mohanty and Mathew 1987). It is felt by environmentalists that the environmental problems have started to multiply with the ever-increasing number of these projects particularly during constructions within a small geographical area (Kuniyal and Sharma 2002). Moreover, the catchment area of rivers supports a large number of plant species of human use and scientific interest, including highly potential medicinal plants; these require special attention for conservation (Gaur et al. 1993).

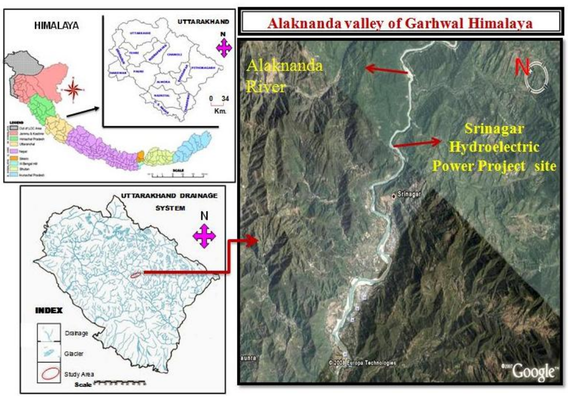

Fig. 1. Map showing the study area (Source: Ballabha et al. 2014).

Thus, conservation of forests requires an understanding of the composition of the particular forest, the effect of past disturbances, and the present impact of neighboring land use on the forest (Geldenhuys and Murthy 1993). Keeping in view these facts as stated, an attempt has been made to study the forest structure and composition in the vicinity of Srinagar Hydroelectric Power Project in Alaknanda Valley of Garhwal Himalaya, India.

Materials and Methods

The study area lies between 30°12′40′′-30°16′52.2′′ N and 78°45′17′′-78°56′08′′ E, with elevation ranging from 530-1,500 meter above sea level. Physiographically, the area consists of hill slopes and valleys of Pauri Garhwal, Tehri Garhwal and Rudraprayag districts of Uttarakhand state with subtropical forests. A total of eight sites, differing in elevations, aspects and species compositions, were randomly selected for our present investigation in the vicinity of Srinagar Hydroelectric Power Project in Alaknanda Valley of Garhwal Himalaya (Fig. 1). These sites are referred to as (i) Site A1, (ii) Site A2, (iii) Site B1, (iv) Site B2, (v) Site C1, (vi) Site C2, (vii) Site D1 and (viii) Site D2. Sites A1, B1, C1 and D1 were located on the right flank of the Alaknanda river and sites A2, B2, C2 and D2

Table 1. General characteristic features of the study sites

Study site	Elevation (m a.s.l.)	Slope	Latitude (N)	Longitude (E)	Dominant tree species
A_1	530-990	South-east	30°13′09″-30°13′47″	78°45′47″-8°45′17″	*Pinus roxburghii*
A_2	540-1,070	North	30°12′59″-0°12′40″	78°45′54″-8°46′50″	*Pinus roxburghii*
B_1	630-1,250	South	30°14′15″-0°15′01″	78°50′28″-8°50′17″	*Pinus roxburghii*
B_2	620-1,130	North	30°14′04″-0°13′28″	78°50′25″-8°50′47″	*Pinus roxburghii*
C_1	660-1,210	South-east	30°14′49″-0° 15′41″	78°51′45″-8°51′45″	*Anogeissus latifolius*
C_2	625-1,230	North	30°14′35″-0°14′08″	78°51′50″-8°52′17″	*Pinus roxburghii*
D_1	615-1,450	South-east	30°15′28″-0°16′52″	78°55′42″-8°54′40″	*Anogeissus latifolius*
D_2	680-1,500	North	30°15′29″-0°14′34″	78°55′50″-8°56′08″	*Pinus roxburghii*

on the left flank. The general characteristics of the study sites are presented in Table 1.

We used a method consisting of quadrats to assess the species composition at all selected sites during 2009-2010. Trees were measured in ten randomly selected 10 m×10 m quadrats, while shrubs were counted in 20 quadrats 5 m×5 m in size at each study site, as proposed by Curtis and McIntosh (1950) and Phillips (1959). The frequency, density and abundance values for tree and shrub layers were calculated following Curtis and McIntosh (1950). The ratio of abundance to frequency (A/F) was calculated by species to describe the distribution pattern (Whitford 1949). Importance Value Index (IVI) was calculated by summing relative density, relative frequency and relative dominance (Phillips 1959). Species richness was the total number of species in a particular study site.

Shannon-Wiener Diversity Index ($\overline{H}$) was calculated as per Shannon and Weaver (1963), employing following formula:

$$\overline{H} = -\sum_{i=1}^{s}\left(\frac{N_i}{N}\right)\log_2\left(\frac{N_i}{N}\right)$$

Where, $\overline{H}$=Shannon-Wiener Diversity Index; N_i= Importance Value Index of a species; N=Total Importance Value Index of all the species.

The Concentration of dominance (Cd) was calculated by using following formula given by Simpson (1949):

$$C_d = \sum_{i=1}^{s} P_i^2 = \sum \frac{N_i}{N}$$

Where, N_i and N are same as in Shannon-Wiener Diversity Index.

Simpson's diversity index (I_{SD}) was calculated by using following formula (Simpson 1949):

$$I_{SD} = 1 - C_d$$

Where, I_{SD} is Simpson's diversity index, and C_d is Simpson's Concentration of dominance.

Equitability (E_p) was calculated as per Pielou (1966), by using following formula:

$$E_p = \frac{\overline{H}}{\overline{H}_{max}}$$

Table 2. Tree density value at different study sites

Species	Density ind ha^{-1}/sites							
	A1	A2	B1	B2	C1	C2	D1	D2
Acacia catechu	50	-	40	-	30	-	20	-
Aegle marmelos	-	-	20	-	10	-	-	-
Anogeissus latifolius	120	-	260	-	280	10	260	250
Bauhinia variegata	-	-	-	-	-	-	20	40
Bombax ceiba	-	10	-	-	-	-	-	-
Cassia fistula	20	-	-	-	-	-	-	-
Dalbergia sissoo	-	50	-	20	-	-	-	-
Engelhardtia spicata	-	30	-	40	20	40	-	30
Erythrina variegata	-	-	-	-	-	10	-	-
Haldinia cordifolia	10	-	10	-	-	-	-	-
Lannea coromandelica	10	-	70	-	60	20	60	50
Mallotus philippensis	-	50	20	30	-	-	10	10
Mangifera indica	-	-		10	-	-	-	-
Ougeinia oojeinensis	-	-		-	10	30	30	30
Phyllanthus emblica	10	-	10			10		-
Pinus roxburghii	200	280	140	220	100	300	110	220
Syzygium cumini	-	-	-	20		20	-	-
Terminalia alata	-	-	-	-	10	30	20	20
Toona hexandra	-	20	-	-	-	-	-	-
Total	420	440	570	340	520	470	530	650

Where, $\overline{\mathrm{H}}$ is Shannon-Wiener Diversity Index, and $\overline{H}_{max}$ is natural log of number of species.

Margalef Index (I_M) Margalef index of species richness (Margalef 1958) was calculated by the following formula:

$$I_M = \frac{S-1}{\mathrm{In}N}$$

Where, I_M is Margalef index of species richness (number of species per unit area), and N=total number of individuals.

Sorenson Similarity Index (I_S) was calculated using following formula given by Sorenson (1948):

$$I_s = \frac{2C}{A+B}$$

Where, I_S=Sorenson Index of Similarity, C is species com-

Table 3. Shrub density value at different study sites

Species	Density ind ha^{-1}/sites							
	A1	A2	B1	B2	C1	C2	D1	D2
Adhatoda zeylanica	320	-	280	-	600	-	-	-
Aechmanthera gossypina	-	-	-	160	-	320	-	720
Agave americana	-	160	160	-	280	-	-	-
Artemisia roxburghiana	-	280	-	-	-	-	240	-
Asparagus adscendense	-	160	-	-	-	200	-	-
Asparagus filicinus	-	-	-	-	-	160	-	-
Berberis asiatica	-	120	-	80	-	-	-	-
Boehmeria platyphylla	-	-	-	-	-	200	280	280
Callicarpa macrophylla	-	-	-	120	-	200	160	-
Campylotropis stenocarpa	160	160	-	-	-	-	-	-
Carissa opaca	1,080	880	1200	1,000	1,120	760	680	520
Cassia occidentalis	160	-	240	-	-	-	-	-
Catunaregam spinosa	280	-	-	-	200	-	-	160
Colebrookia oppositifolia	360	280	120	200	-	280	360	240
Cotinus coggygria	-	-	-	-	-	80	-	-
Eupatorium adenophorum	-	680	-	560	-	-	-	-
Euphorbia royleana	160	160	200	-	240	-	200	-
Indigofera astragalina	280	320	-	160	200	-	400	520
Indigofera cassioides	-	-	120	-	-	-	280	160
Indigofera hirsuta	520	-	-	-	-	-	-	-
Inula cappa	-	440	-	320		400	-	-
Lantana camara	880	560	920	-	720	800	-	400
Murraya koenigii	240	-	560	320	280	-	520	-
Nyctanthes arbor-tristis	440	-	600	-	640	280	840	600
Pavatta tomentosa	-	-	-	160	-	-	-	-
Reinwardtia indica	-	-	-	-	-	-	-	440
Rhus parviflora	560	1,120	840	840	600	680	960	600
Ricinus communis	-	160	-	-	-	-	-	-
Roylea cinerea	-	-	-	-	-	-	-	400
Rubus ellipticus		240				320		240
Solanum erianthum	-	-	-	80	-	80	-	-
Spermadictyon suaveolens	200	-	-	160	-	-	-	280
Vitex negundo	-	-	-	-	-	200	-	200
Woodfordia fruticosa	360	520	400	200	280	240	320	320
Zanthoxylum armatum	-	-	-	-	-	80	-	-
Ziziphus mauritiana	280	240	240	-	-	-	280	-
Total	6,280	6,480	5,880	4,360	5,160	5,280	5,520	6,080

mon at both the forest cover types, *A* is the total number of species in forest cover type A, and B is the total number of species in forest cover type B.

We drew dominance-diversity curves (d-d curves) to represent resource apportionment by species in tree and shrub layers. The relative importance value is an expressive measure of niche of species, thus treated as an expression of the relative niche size. Carl-Pearson Correlation coefficient was calculated between various quantitative parameters for all study sites using SPSS Software.

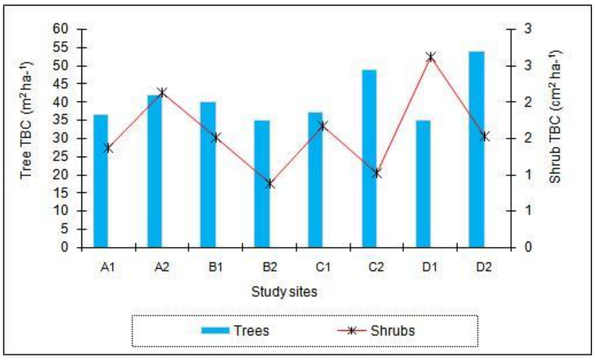

Fig. 2. Total basal cover values for tree and shrub layers.

Results and Discussion

Forest structure and composition

The highest density value (650 ind・ha^{-1}) for tree layer was recorded at site D2 and lowest (340 ind ha^{-1}) at site B2 (Table 2). These values were within the range of earlier reported (130 to 830 ind・ha^{-1}) from the forests of the Garhwal Himalaya (Baduni and Sharma 1996; Ghildiyal et al. 1998; Sharma et al. 2001; Srivastava et al. 2005). Singh et al. (1984) obtained a range of tree density value 280 to 1,630 ind・ha^{-1} in different forest types and Khera et al. (2001) reported the value from 480 to 640 ind・ha^{-1} in mid elevational forests of Central Himalaya.

Shrub density (Table 3) ranged from 4,360 ind・ha^{-1} (site B2) to 6480 ind・ha^{-1}(site A2), which was within the range of earlier reported values (3,720 to 7,200 ind・ha^{-1}) from the mid elevational forests of Central Himalaya (Khera et al. 2001). Bankoti et al. (1992) reported shrub density value in 650-1,150 ind・ha^{-1} for the forests of Central Himalaya, whereas Dhar et al. (1997) obtained this value of 2,260-18,540 ind・ha^{-1} in Askot Wildlife Sanctury in Kumaun Himalaya.

There is a great variation in the range of total basal cover

Table 4. Important value index (IVI) for trees at different study sites

Species	A1	A2	B1	B2	C1	C2	D1	D2
Acacia catechu	37.4	-	21.23	-	21.88	-	13.97	-
Aegle marmelos	-	-	11.96	-	6.89	-	-	-
Anogeissus latifolius	65.7	-	101.34	-	129.33	6.86	129.16	86.62
Bauhinia variegata	-	-	-	-	-	-	15.56	27.17
Bombax ceiba	-	8.82	-	-	-	-	-	-
Cassia fistula	17.01	-	-	-	-	-	-	-
Dalbergia sissoo	-	30.16	-	20.82	-	-	-	-
Engelhardtia spicata	-	20.53	-	34.49	15.19	23.13	-	17.35
Erythrina variegata	-	-	-	-	-	7.17	-	-
Haldinia cordifolia	8.95	-	6.68	-	-	-	-	-
Lannea coromandelica	8.14	-	37.18	-	32.64	14.77	38.98	22.58
Mallotus philippensis	-	34.49	11.89	27.96	-	-	6.72	5.48
Mangifera indica	-	-	-	17.17	-	-	-	-
Ougeinia oojeinensis	-	-	-	-	6.81	15.89	14.99	17.07
Phyllanthus emblica	8.11	-	6.03	-	-	6.68	-	-
Pinus roxburghii	154.69	184.62	103.68	178.92	79.21	189.79	64.33	110.86
Syzygium cumini	-	-	-	20.65	-	14.94	-	-
Terminalia alata	-	-	-	-	8.06	20.79	16.3	12.87
Toona hexandra	-	21.37	-	-	-	-	-	-

(TBC) of tree species at different sites. The value of TBC varied from 35.02 $m^2 \cdot ha^{-1}$ (site D1) to 54.02 $m^2 \cdot ha^{-1}$ (site D2) in tree layer (Fig. 2). Similar findings have been reported for various forest types in Kumaun and Garhwal Himalaya by Saxena and Singh (1982), Singh and Singh (1987), Dani et al. (1991), Dhar et al. (1997) and Bhandari et al. (2000). The trees with higher basal area indicate the best performance of the species and lower basal area either demarcated the chance occurrence of the species or the biotic disturbance in the past were the causative factors (Saxena et al. 1978). In shrub layer, TBC value ranged between 0.875 $m^2 \cdot ha^{-1}$ (site B2) and 2.628$m^2 \cdot ha^{-1}$ (site D1), which is similar to the value of shrub TBC recorded by Tripathi et al. (2003) for sub-tropical pine forest of Meghalaya in Northeastern Himalaya.

Analysis of Importance Value Index (IVI) of a species can be used to recognize the pattern of association of dominant species in a community (Parthasarathy and Karthikeyan

Table 5. Important value index (IVI) for shrubs at different study sites

Species	A1	A2	B1	B2	C1	C2	D1	D2
Adhatoda zeylanica	13.31	-	13.59	-	26.21	-	-	-
Aechmanthera gossypina	-	-	-	14.39	-	21.44	-	31.36
Agave americana	-	10.55	8.45	-	24.8	-	-	-
Artemisia roxburghiana	-	8.69	-	-	-	-	9.89	-
Asparagus adscendense	-	6.46	-	-	-	10.42	-	-
Asparagus filicinus	-	-	-	-	-	8.07	-	-
Berberis asiatica	-	5.78	-	6.95	-	-	-	-
Boehmeria platyphylla	-	-	-	-	-	15.17	16.65	16.32
Callicarpa macrophylla	-	-	-	9.13	-	14.05	9.74	-
Campylotropis stenocarpa	8.2	6.53	-	-	-	-	-	-
Carissa opaca	48.9	31.31	52.68	69.58	40.89	43.77	26.77	24.35
Cassia occidentalis	8.2	-	10.23	-	-	-	-	-
Catunaregam spinosa	14.31	-	-	-	18.5	-	-	11.7
Colebrookia oppositifolia	15.54	14.75	8.29	14.15	-	17.14	19.63	15.55
Cotinus coggygria	-	-	-	-	-	5.46	-	-
Eupatorium adenophorum	-	19.86	-	26.15	-	-	-	-
Euphorbia royleana	33.57	63.6	35.84	-	51.8	-	74.71	-
Indigofera astragalina	14.53	14.99	-	12.78	14.26	-	22.52	25.86
Indigofera cassioides	-	-	6.9	-	-	-	13.76	8.83
Indigofera hirsuta	19.39	-	-	-	-	-	-	-
Inula cappa	-	14.38	-	19.29	-	15.18	-	-
Lantana camara	35.61	20.68	34.95	-	36.36	40.35	-	19.95
Murraya koenigii	11.26	-	22.24	19.06	13.06		18.87	-
Nyctanthes arbor-tristis	19.53	-	43.85	-	30.19	13.97	30.52	28.79
Pavatta tomentosa	-	-	-	18.48	-	-	-	-
Reinwardtia indica	-	-	-	-	-	-	-	26.5
Rhus parviflora	21.28	32.61	31.08	54.57	29.78	30.44	32.55	25.31
Ricinus communis	-	12.95	-	-	-	-	-	-
Roylea cinerea	-	-	-	-	-	-	-	15.2
Rubus ellipticus	-	8.1	-	-	-	15.48	-	11.03
Solanum erianthum	-	-	-	10.75	-	8.22	-	-
Spermadictyon suaveolens	7.82	-	-	10.92	-	-	-	11.49
Vitex negundo	-	-	-	-	-	18.58	-	12.57
Woodfordia fruticosa	16.09	16.32	19.91	13.79	14.14	16.58	13.77	15.19
Zanthoxylum armatum	-	-	-	-	-	5.69	-	-
Ziziphus mauritiana	12.47	12.43	11.99	-	-	-	10.62	-

1997). The high IVI of a species indicated its dominance and ecological success, its good power of regeneration and greater ecological amplitude. Among the trees, *Pinus roxburghii* was dominant species at most of the sites (site A1, A2, B1, B2, C2 and D2), while as *Anogeissus latifolius* was the dominant species at site C1 and D1. *Anogeissus latifolius* (site A1, B1 & D2), *Mallotus philippensis* (site A2), *Engelhardtia spicata* (site B2 & C2) and *Pinus roxburghii* (site C1 & D1) were the co-dominant species (Table 4).

Among the shrubs, *Carissa opaca* was dominant species at most of the sites (site A1, B1, B2 & C2), *Euphorbia royleana* was the dominant species at A2, C1 and D1 sites, while *Aechmanthera gossypina* was the dominant species at site D2. *Lantana camara* (sites B1 & D2), *Rhus parviflora* (site A2, B2 & D1), *Nyctanthes arbor-tristis* (site B2 & C2) and *Carissa opaca* (site C1) were the co-dominant (Table 5).

On the basis of density, basal cover and Importance Value Index (IVI), *Pinus roxburghii* was found to be the most important and dominant tree species in most of the sites, whereas among the shrubs, *Carissa opaca* was dominant species at most of the sites. The dominance of *Pinus roxburghii* in most of the sites is an indication towards possible threat to the associated species. Degradation of the forest through high anthropogenic pressure will provide appropriate conditions for the *Pinus roxburghii* to invade, thereby posing a serious threat to the ecological balance of this region (Singh et al. 1984).

Distribution pattern of species

The dispersal limitation is an important ecological factor for controlling species distribution pattern and a connection between biotic and abiotic ecological factors (Hubbell et al. 1999). In the present study, the plant species showed varying patterns of distribution (Fig. 3). Both trees and shrubs were showed random and contagious distribution pattern. Regular and random distribution is indicative of uniform environment (Pande et al. 2001), while contagious distribution is common in nature (Odum 1971). Connell (1978) suggested that the uniform dispersion pattern of species in tropical forests largely enable the maintenance of high levels of diversity. The changes in the distribution patterns may reflect the reactions of species to disturbance as well as to changes in the habitat conditions (Sagar et al. 2003).

Diversity and related measurements

Diversity is a combination of two factors, the number of species present, referred to as species richness and the distribution of individuals among the species, referred to as evenness or equitability. In the present study, species richness (α-diversity) for trees ranged from 6 (sites A2 and B2) to 9 (site C2), which is similar to earlier reported values from the mid elevational forests and mixed oak-conifer forests of central Himalaya (Khera et al. 2001; Pandey 2003), and higher than the value reported by Mishra et al. (2003) from sub-montane forests of Garhwal Himalaya. Whereas in shrub layer the maximum species richness (18) was recorded at sites C2 and minimum (11) at site C1. The species richness was very high in shrub layer than any other broad leaved forests of Garhwal Himalaya (Bhandari and Tiwari 1997; Bhandari et al. 1998). High species richness in shrub layer may be due to relatively less developed canopy in these young forests which permit sufficient sunlight to reach the ground resulting in the luxuriant growth of shrub species.

Diversity is a combination of two factors, the number of species present, referred to as species richness and the distribution of individuals among the species, referred to as evenness or equitability. Single species populations are defined as having a diversity of zero, regardless of the index used. Species diversity, therefore, refers to the variations that exist among the different forms. Shannon-Wiener's index ($\overline{H}$) of diversity is one of the most popular measures of general diversity. Tree species diversity varies greatly from place to place mainly due to variation in biogeography, hab-

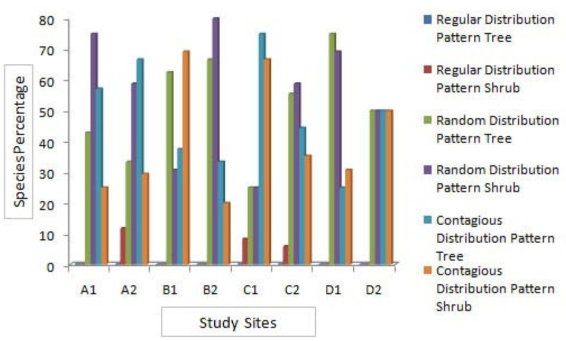

Fig. 3. Distribution pattern of trees and shrubs in the study area.

itat and intensity of disturbance (Hubbell et al. 1999; Sagar et al. 2003), which are important factors for structuring the forest communities. The highest tree diversity (2.25) was recorded for site D2 and lowest (1.71) for site B2 (Table 6), which was within the range of early reported values for trees from Central Himalayan forests (Khera et al. 2001), sub-montane forests of Garhwal Himalaya (Mishra et al. 2003), oak dominant conifer mixed forests of Garhwal Himalaya (Srivastava et al. 2005), moist temperate Himalayan forests (Pande et al. 2001), Kumaun Himalaya (Dhar et al. 1997) and sub-tropical Pine forests of Meghalaya, Northeast India (Tripathi et al. 2004). Whereas, these reported values were more than the earlier observed values from Garhwal (Baduni and Sharma 2001; Mishra et al. 2002) and Kumaun Himalaya (Saxena and Singh 1982; Singh and Singh 1987; Adhikari et al. 1991). Putman (1994) stated that diversity tends to increase as the environment becomes more favorable and more predictable.

In shrub layer, Shannon-Wiener's diversity ($\overline{H}$) value (Table 7) ranged from 3.22 (site C1) to 3.86 (site D2). These values were similar to the values reported from Central Himalayan forests (Khera et al. 2001) and sub-tropical pine forests of Northeast India (Tripathi et al. 2004), but higher than the values as reported by Bhandari et al. (2000) from montane forest of Garhwal Himalaya.

Concentration of dominance (Cd) for trees was ranged from 0.28 (site D2) to 0.45 (site B2). The values of Cd in our study were similar to the earlier reported values for Central Himalayan forests (Khera et al. 2001; Pandey 2003), moist temperate Himalayan forests (Pande et al. 2001), and oak dominant conifer mixed forests of Garhwal Himalaya (Srivastava et al. 2005) and sub-montane forests of Garhwal Himalaya (Mishra et al. 2003). The Cd value for shrub layer ranged between 0.0746 (site D2) and 0.1280 (site B2), and was comparable to reported values for moist temperate Himalayan forests (Pande et al. 2001) and Central Himalayan forests (Khera et al. 2001; Pandey 2003).

Table 6. Diversity and related measurements for tree layer in the study area

Sites	Species richness	Shannon-Wiener diversity index ($\overline{H}$)	Concentration of dominance (Cd)	Simpson diversity index (SDI)	Pielou equitability (Eq)	Margalef index of species richness (MI)
A1	7	1.99	0.33	6.67	1.02	1.61
A2	6	1.72	0.44	5.56	0.96	1.32
B1	8	2.20	0.29	7.71	1.06	1.73
B2	6	1.71	0.45	5.55	0.95	1.42
C1	8	2.04	0.35	7.65	0.98	1.77
C2	9	1.96	0.43	8.57	0.89	2.08
D1	8	2.21	0.30	7.70	1.06	1.76
D2	8	2.25	0.28	7.72	1.08	1.68

Table 7. Diversity and related measurements for shrub layer in the study area

Sites	Species richness	Shannon-Wiener diversity index ($\overline{H}$)	Concentration of dominance (Cd)	Simpson diversity index (SDI)	Pielou equitability (Eq)	Margalef index of species richness (MI)
A1	16	3.75	0.0885	15.912	1.925	2.97
A2	17	3.76	0.0902	16.910	1.930	3.14
B1	13	3.33	0.1190	12.881	1.713	2.40
B2	14	3.34	0.1280	13.872	1.717	2.77
C1	11	3.22	0.1230	10.877	1.657	2.06
C2	18	3.76	0.0884	16.912	1.934	3.48
D1	13	3.49	0.1021	12.898	1.792	2.44
D2	16	3.86	0.0746	15.925	1.984	2.99

In the present study, the values of Concentration of dominance (Cd) showed reverse trend as compared to species diversity in the two vegetational layers viz., trees (Table 6) and shrubs (Table 7). Species diversity ($\overline{H}$) and dominance (Cd) were inversely related with each other in the established forests (Zobel et al. 1976). The lower diversity and consequently greater Cd in temperate vegetation could be due to lower rate of evolution and diversification of communities (Fischer 1960; Simpson 1964). The maximum Simpson Diversity Index (8.57) was recorded for site C2 and minimum (5.55) for site B2 (Table 6) in tree layer, whereas in shrub layer (Table 7), its value ranged from 10.877 (site C1) to 16.912 (site C2). These values were higher than the values recorded by Tripathi et al. (2004) for sub-tropical pine forests of Northeast India and indicating lower stability of these forest types (Kharkwal et al. 2005).

The Equitability value for tree layer (Fig. 4) oscillated between 0.89 (site C2) and 1.08 (site D2). These values were less than the values reported by Kumar and Ram (2005) and Srivastava et al. (2005) for tree layer from Kumaun and Garhwal Himalayan forests respectively. In shrub layer, the equitability values ranged from 1.657 (site C1) to 1.984 (site D2) and were similar to values recorded by Kumar and Ram (2005) for Kumaun Himalaya.

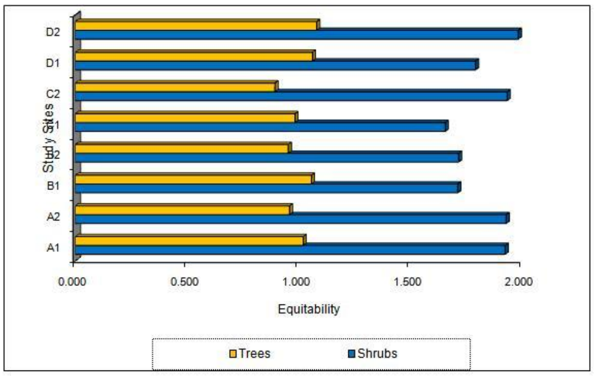

Fig. 4. Variation in equitability at tree and shrub layers.

Highest value of Margalef Index (2.08) was observed at site C2 and lowest (1.32) was recorded at site A2 among the tree layer (Table 6), whereas among the shrub layer (Table 7), its value oscillated between 2.06 (site C1) and 3.48 (site C2). The values for trees and shrubs were similar to the values recorded by Tripathi et al. (2004) for sub-tropical pine forests of Northeast India.

Similarity coefficient of communities

The similarity index was calculated to understand the extent of similarity between the sites. Similarity between different communities did not follow any specific pattern at all the study sites. In the vegetation layers, *viz.*, tree and shrub, communities showed affinity with each other. Most of the communities showed high similarity index (>50%) indicating frequent dispersal of the species between all the sites. Among the tree layer, maximum similarity was recorded between study sites D1 and D2 followed by sites A1 and site B1, while minimum similarity was recorded between sites A1 and A2 and sites A1 and B2 (Table 8). The highest similarity for shrub layer was shown by site A1 with site B1 followed by sites B1 and C1, while lowest similarity was reported between sites C1 and C2 (Table 9).

Dominance-diversity curve

The dominance diversity (d-d) curves are frequently used to interpret the community organization in terms of resource sharing and niche space (Whittaker 1975). Minor differences in d-d curves reveal the importance of each spe-

Table 8. Similarity Indices between tree layer at different sites

	A1	A2	B1	B2	C1	C2	D1	D2
A1	1.00	0.15	0.80	0.15	0.53	0.50	0.53	0.40
A2	-	1.00	0.29	0.67	0.29	0.27	0.29	0.43
B1	-	-	1.00	0.29	0.63	0.47	0.63	0.50
B2	-	-	-	1.00	0.29	0.40	0.29	0.43
C1	-	-	-	-	1.00	0.71	0.75	0.75
C2	-	-	-	-	-	1.00	0.59	0.71
D1	-	-	-	-	-	-	1.00	0.88
D2	-	-	-	-	-	-	-	1.00

Table 9. Similarity Indices between shrub layer at different sites

	A1	A2	B1	B2	C1	C2	D1	D2
A1	1.00	0.55	0.76	0.47	0.74	0.41	0.62	0.56
A2	-	1.00	0.53	0.52	0.50	0.51	0.53	0.42
B1	-	-	1.00	0.37	0.75	0.45	0.69	0.48
B2	-	-	-	1.00	0.40	0.50	0.52	0.47
C1	-	-	-	-	1.00	0.34	0.58	0.52
C2	-	-	-	-	-	1.00	0.45	0.53
D1	-	-	-	-	-	-	1.00	0.55
D2	-	-	-	-	-	-	-	1.00

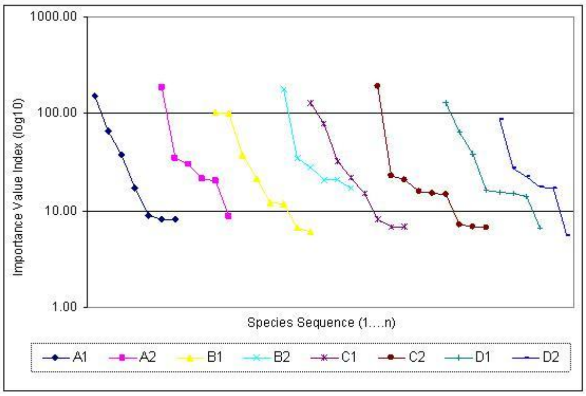

Fig. 5. Dominance-diversity curves for tree layer at different sites.

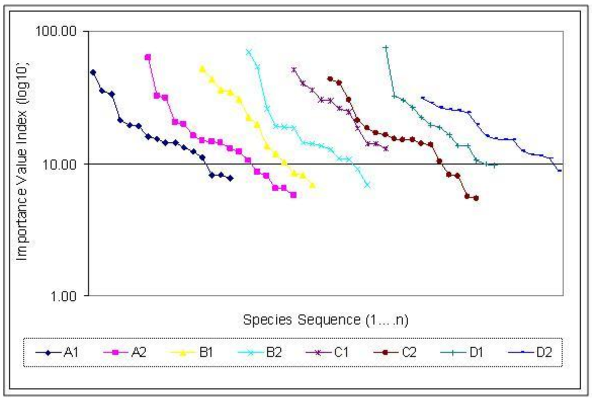

Fig. 6. Dominance-diversity curves for shrub layer at different sites.

cies is community. The dominance diversity (d-d) curves approach a geometric distribution for tree layer (Fig. 5). Mostly these curves follow the geometric series in conformity with niche pre-emption hypothesis (Motomura 1932). The geometric form is often shown by vascular plants having lower density (Whittaker 1975). It is indicative of low competition among the species, because IVI values of species are proportional to the amount of the resource they utilize. Hence, the most dominant species always utilize the maximum niche space and resources within the communities.

The shrub layer showed the log-normal curve (Fig. 6). Log-normal series represent high diversity condition. The log-normal series in most cases of tree and shrubs is indicative of the highly mixed nature of vegetation (Whittaker 1975; Saxena and Singh 1982). The log-normal series describes the partitioning of realized niche space among various species and it is the consequence of the evolution of diversity in the species along the niche parameters that they exploit (Whittaker 1965).

Statistical analysis

Carl-Pearson Correlation test was analyzed between various quantitative features of shrub and tree layers (Table 10). Tree density showed positive and significant correlation with tree species diversity (0.877). Tree total basal cover (TBC) was positively correlated with shrub diversity index (0.678), whereas tree species richness showed positive and significant relationship with tree diversity index (0.737) and shrub species richness revealed positive and significant relationship with shrub diversity index (0.896).

Conclusion and management implications

We provided comprehensive information on forest structure and composition in the vicinity of Srinagar Hydroelectric Power Project in Alaknanda Valley of Garhwal Himalaya, India. Based on the results, it can be concluded that the area has good vegetation composition. However, this forest area

Table 10. Carl-pearson correlation coefficients between various quantitative parameters of tree and shrub layers

	TD	SD	TTBC	STBC	TSR	SSR	TSDI	SSDI
TD	1							
SD	0.391	1						
TTBC	0.564	0.319	1					
STBC	0.353	0.443	-0.221	1				
TSR	0.639	-0.031	0.434	0.003	1			
SSR	-0.172	0.400	0.601	-0.259	-0.056	1		
TSDI	0.877**	0.245	0.279	0.322	0.737*	-0.319	1	
SSDI	0.139	0.619	0.678*	0.002	0.044	0.896**	-0.005	1

*Correlation is significant at 0.05 level. ** Correlation is significant at 0.01 level.
TD, tree density; SD, shrub density; TTBC, tree TBC; STBC, shrub TBC; TSR, tree species richness; SSR, shrub species richness; TSDI, tree Shannon-Wiener diversity index; SSDI, shrub Shannon-Wiener diversity index.

is being disturbed by the construction of Srinagar hydroelectric power project, operation of roads and movement of vehicles particularly on unsealed roads which is affecting the vegetation composition and further deteriorates the site quality of already degraded habitat by increasing the potential of soil erosion. Habitat degradation by the construction of power project and unplanned use of the resources may lead to reduction of the plant species from the area. The scientific information obtained from the present study will strengthen the data base, and will be helpful in predicting possible change in the ecosystem properties and forest composition in near future after completion of the power project. Therefore, the impact of anthropogenic and natural disturbances on the forest composition should be monitored temporally by assessing changes in vegetation composition and diversity in future, so that sustainable utilization of these species could be ensured.

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