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An ordination of the forest communities in Nainital catchment of Kumaun Himalaya

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Abstract: *Evergreen forest communities distributed within 1580-2600 m above sea level (asl) in Kumaun Himalaya were studied. Quercus leucotrichophora A. Campus, Q. floribunda Lindl. ex Rehder, Q. semecarpifolia J.E. Smith and Pinus roxburghii Sarg. are the dominant tree species in banj-oak, tilonj-oak, kharsu-oak and chir-pine forests, respectively. Total density for tree, shrub and herb layer varied from 3.7 to 10.5 (individual 100 m^{-2}), 2.0 to 38.8 (individual 100 m^{-2}) and 5.5 to 44.0 (individual m^{-2}), respectively. A total of five forests types (27 stands) were identified in the field on the basis of species richness and species diversity by applying polar ordination method. The diversity value for tree, shrub and herb layer ranged from 0 to 3.62, 0.36 to 3.85 and 1.23 to 4.21, respectively. Present study indicates the spatial patterns of vegetation in different forest communities at different altitudes.*

Key words: *Species composition, Density, Diversity, Ordination, Central Himalayan forest*
PDF of full length paper is available online

Introduction

The forests of Kumaun Himalaya are represented mostly by pine forests, pine mixed forests, evergreen broad leaf species (Champion and Seth, 1968). Concerning ecological structure and composition in oak forests especially the banj-oak and tilonj-oak forests were less complex than kharsu oak forest (Kharkwal *et al.*, 2005). Throughout the Central Himalaya, evergreen forests are preponderant, except in some forest stands where winter deciduous species exist. The geography influences the distribution of rain precipitation, temperature and air moisture, draughts and snow layers accumulation as well as the kind of growing vegetation under which the northern and eastern exposure of an area indicates greater moisture than southern and western due to the difference in temperature and evaporation. This explains the variation in plant species that lies in different directions (Mountousis *et al.*, 2006).

According to Boyce and Ellison (2001), ordination is a technique that is used by community ecologists, to quantify and study spatial patterns in plant communities. It consists of a set of multivariate techniques which reduce the multiple variables in a community to a few dimensions which reflect the most important patterns in the data set (Digby and Kempton, 1987). Bray-curtis ordination is a polar ordination technique that determines how similar or dissimilar vegetation plots are based on the relative abundance of each species within each plot. Data were transformed in this manner because the ordination technique used recognizes species with larger numbers as a relatively more abundant component of the plant community and the most abundant species in a plot is typically several times more abundant than the least abundant species. The main aim of ordination is to arrange the vegetation within a multidimensional hyper space so as to gain a better understanding of spatial pattern of vegetation. In the present study, the ordination method was applied following Bray and Curtis (1957) to check the vegetation pattern by using species composition and diversity parameter data of tree, shrub and herb species.

Materials and Methods

Study area: The study sites are located between 29°21'-29°24' N latitude and 79°25'-79°29' E longitude in Nainital catchment in Kumaun region of central Himalaya. Details of the study sites are given in Table 1. The climate of the area is monsoon type, and the average annual rainfall is 2668 mm yr^{-1}. The year is divisible into three seasons, rainy (mid-June to mid-September), winter (November to February) and summer (April to mid-June). Spring (March) and autumn (October) are the transition periods. Snowfall is being frequent during winter months. The average maximum temperature ranged from 13.0 and 23.7°C and minimum temperature varied from 4.9 to 16.6°C (Source, U.P Aries State Observatory, Nainital). The year of study was in 1999-2000.

The soil moisture (0-30cm) varied from 42 to 57% in the rainy season. Soil pH was in the range of 5 to 6 indicating the acidic nature of the soil. The percentage of sand, silt and clay varied from 50-65, 17-30 and 11-28%, respectively. Organic matter and water holding capacity ranged from 3 to 5% and 55 to 80%, respectively. The rocks of Nainital belong to Krol series. Krol formation consists predominantly of carbonate, limestone, marl and slates in the lower part and dolomites in the upper part (Valdia, 1983).

Methods: The size of the quadrat was determined by 'species area curve' following Braun-Blanquet (1932) and Misra (1968). At

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three positions in each locality, *viz.,* hill-base, hill-slope and hilltop, quadrats were examined. The phytosociological analysis of each forest site was carried out by using 10 number, 10 m x 10 m quadrats placed randomly for tree layer (circumference at breast height, cbh, *i.e.*, 1.37 m from ground; trees with cbh ≥ 31.5 cm were considered). The cbh of all tree species were measured individually in each quadrat. Shrubs were sampled by using 10, 5m x 5m quadrats randomly. Species area curve was developed for herb layer (Kharkwal, 2002) and it was sampled randomly by using 10, 1×1 m size quadrats in each forest stand and each shoot of herb was considered as an individual plant (Singh and Yadava, 1974). Vegetational data were analyzed for density following Curtis and McIntosh (1950). Species richness was calculated by the number of species per unit area (Whittaker, 1960) and species diversity of different forest stands was computed by using Shannon and Wiener (1963) information function.

A total of 27 forest stands were subjected to gradient analysis. The species richness and diversity value of each species was double standardized before computing percent similarity. Similarity index (IS) was calculated (Mueller-Dombois and Ellenberg, 1974) as: IS = 2C x 100/ (A + B), where A, B and C represents the number of species in stand A, B and both. The percent similarity (PS) between the stands was simplified to PS = ∑ minimum (X, Y), in which minimum (X, Y) is the smaller of two values for a given species in a samples X and Y, and lower values for each species were summed to determine similarity values between the stands. The percent difference (dissimilarity) is calculated as: PD = 100 – PS', where PS' = percent similarity and PD = percentage difference. For the construction of the first ordination axis (x-axis) two most dissimilar samples (stands) were chosen at the end points (reference stands). The x value for different samples (stands) was calculated following Bray and Curtis (1957):

$$X = [\ L^2 + (D_1^{\ 2} - D_2^{\ 2})\ ]\ 2\ l^{-1}$$

where, L is the distance between two end points and D_1 and D_2 are the distance of the samples located from the first and second points, respectively. For the construction of second ordination axis (y-axis) first of all ex^2 was calculated from each stand by the formula.

$$ex^2 = D_2^{\ 2} - x^2$$

The x-axis fit for each stand is indicated by ex and first reference stand on the y-axis was a stand, that was particularly fitted to the x-axis. $D_2^{\ 2}$ stands for dissimilarties.

Table - 1: General characteristics of the study sites

Sites No.	Stand No.	Location	Elevation (meters)	Forest type	Aspect	Dominant tree species
S1	1-6	Pines	1580-1700	Chir-pine	E, SW	*Pinus roxburghii*
S2	7-9	Baldiakhan	1700-1800	Chir-pine	N E	*P. roxburghii*
S3	10-15	Kailakhan	1800-1950	Banj-oak	E, W	*Quercus leucotrichophora*
S4	16-21	Tiffon- top	2000-2300	Tilonj-oak	E, SW	*Q. floribunda*
S5	22-27	China-peak	2300-2600	Kharsu-oak	NE, NW	*Q. semecarpifolia*

E = East, SW = South west, NE = North east, NW = North west

Results and Discussion

Based on the density value the dominant tree species on S1 and S2 site was *Pinus roxburghii.* The S3, S4 and S5 sites were *Quercus leucotrichophora, Quercus floribunda* and *Quercus semecarpifolia*, respectively. *Boenninghausenia albiflora* was the dominant shrub species on most of the stands. The dominant herb species at S1 site was *Ageratum haoustonianum* and co-dominant

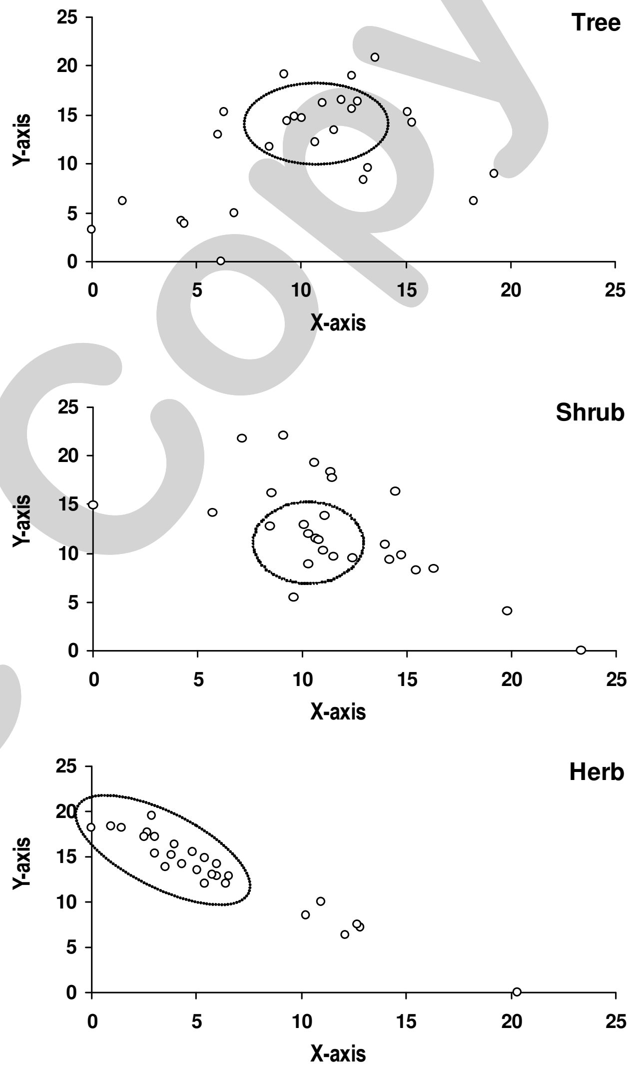

Fig. 1.: Polar ordination for tree, shrub and herb species composition showing species richness and diversity in different forest stands (circle marked with dotted line shows cluster of high values)

Table - 2: Total density of plant species in different forest communities

Site	Aspect	Species	Position	Tree (individual 100 m^{-2})	Shrub (individual 100 m^{-2})	Herb (individual m^{-2})
S1	E	*P. roxburghii*	HB	6.9	9.6	18.9
			HS	7.1	10.0	31.2
			HT	7.2	13.6	19.7
S1	SW	*P. roxburghii*	HB	8.2	6.8	13.9
			HS	8.5	4.8	24.2
			HT	6.6	2.8	17.7
S2	NE	*P. roxburghii*	HB	7.8	2.8	35.2
			HS	7.0	2.0	24.4
			HT	4.7	2.4	44.0
S3	E	*Q. leucotrichophora*	HB	11.4	9.2	22.9
			HS	10.5	10.0	22.3
			HT	6.7	8.0	15.8
S3	W	*Q. leucotrichophora*	HB	9.8	4.8	42.9
			HS	10.6	4.8	40.9
			HT	7.2	4.0	20.2
S4	E	*Q. floribunda*	HB	6.7	9.2	22.1
			HS	6.6	12.0	23.9
			HT	5.9	6.0	9.02
S4	SW	*Q. floribunda*	HB	6.1	7.6	12.8
			HS	5.8	6.8	24.6
			HT	5.0	4.8	26.4
S5	NE	*Q. semecarpifolia*	HB	5.5	2.8	10.0
			HS	3.7	38.8	9.9
			HT	5.8	20.0	9.1
S5	NW	*Q. semecarpifolia*	HB	4.0	11.8	10.3
			HS	6.5	13.6	5.5
			HT	6.4	9.2	12.3

HB = Hill base, HS = Hill slope, HT = Hill top

herb species on this site were *Micromeria biflora*, *Urena lobata* and *Ajuga parviflora*. *Neanotis calycina* was the dominant species and co-dominant species were *Carex nubigena* and *Commelina benghalensis* at S2 site. Dominant species at S3 site was *Pilea umbrosa* and co-dominant species were *Agrimonia pilosa*, *Pouzolzia hirta*, *Carex cruciata*, *Achyranthes bidentata* and *Nervilea crispate*. S4 site was dominated by *Achyranthes bidentata* and co-dominant species were *Arthraxon prionodes* and *Oryzopsis aequiglumis*. The S5 site was dominated by *Athyrium rupicola* and co-dominant species on this site were *Polygonum amplexicaule*, *Synotis rufinervis*, *Micromeria biflora*, *Sanicula elata* and *Plectranthus striatus*.

The value of density, richness and diversity for tree, shrub and herb layer are depicted in Table 2 and 3. The tree density ranged from 3.7 to 11.4 individual 100 m^{-2}. It was maximum in *Q. leucotrichophora* and minimum in *Q semecarpifolia* forest. Shrub density varied from 2.0 to 38.8 individual 100m^{-2}. It was maximum in *Q. semecarpifolia* and minimum in *P. roxburghii* forest. Herb density ranged from 5.5 to 44.0 individual m^{-2} and it was maximum in *P. roxburghii* and minimum in *Q. semecarpifolia* forest. The variation in density along with slope was significant for trees ($p<0.05$), shrubs ($p<0.01$) and herbs ($p<0.01$). Along the stands, tree, shrub and herb density varied significantly ($p<0.01$). These values are comparable with the values generally reported for temperate forests (Monk, 1967; Singh and Singh, 1987; Garkoti, 1992; Singh *et al*., 1994; Tyagi, 2007; Sah, 2007).

Species richness value for tree, shrub and herb layer varied from 1.0 to 2.2, 0.5 to 5.9 and 4.3 to 10 per m^2, respectively. Tree and shrub richness was highest at S5 site (NE aspect) as compared to other forests sites, while herb richness was maximum on S2 site (NE aspect). The variation in tree, shrub and herb richness along with altitude was found to be significant ($p<0.05$). Similarly, species diversity ranged from 0 to 6.2 for tree layer, 0.4 to 7.8 for shrub layer and 1.2 to 4.4 for herb layer. Tree and shrub diversity was maximum on S3 (W aspect) and S2 (NE aspect) sites. However, herb diversity was found to be maximum on S1 site (E aspect). Variation in diversity of trees, shrubs and herbs along altitude and was found to be significant ($p<0.05$). Similar findings were reported by Saxena and Singh (1982), Garkoti (1992),, Ram *et al.* (2004)

Table - 3: Species richness (per m^2) and diversity of different plant communities

Site	Aspect	Forest	Stand	Specie richness			Diversity		
				Tree	Shrub	Herb	Tree	Shrub	Herb
S1	E	*P. roxburghii*	HB	1.3	1.6	6.0	0.3	2.8	4.5
			HS	1.3	1.4	5.8	0.3	2.2	2.4
			HT	1.0	1.2	5.3	0	1.5	3.2
S1	SW	*P. roxburghii*	HB	1.3	1.3	5.3	0.3	1.6	3.6
			HS	1.3	1.0	6.3	0.3	5.2	3.6
			HT	1.0	0.5	6.0	0	0.5	3.3
S2	NE	*P. roxburghii*	HB	1.0	1.3	10.5	0	1.0	4.4
			HS	1.3	1.0	6.5	0.3	1.0	4.0
			HT	1.0	0.5	4.7	0	7.8	3.4
S3	E	*Q. leucotrichophora*	HB	1.5	1.6	5.0	0.4	2.3	3.5
			HS	1.6	1.8	6.0	0.4	2.8	4.2
			HT	1.2	1.5	6.9	0.2	1.8	4.2
S3	W	*Q. leucotrichophora*	HB	1.4	1.1	6.5	6.2	2.1	3.9
			HS	1.3	1.3	5.5	0.4	2.4	3.2
			HT	1.4	1.3	4.7	0.4	2.0	3.0
S4	E	*Q. floribunda*	HB	2.2	1.8	6.8	0.6	2.6	4.2
			HS	1.9	1.4	7.5	0.8	1.8	4.2
			HT	1.3	1.4	4.3	0.3	2.0	3.7
S4	SW	*Q. floribunda*	HB	1.4	1.8	6.5	0.5	2.3	1.2
			HS	1.7	1.5	7.0	0.5	1.8	3.3
			HT	1.4	1.0	6.3	0.4	1.5	3.0
S5	NE	*Q. semecarpifolia*	HB	2.9	4.9	5.8	2.0	3.7	4.0
			HS	2.3	5.9	5.9	1.6	3.8	3.8
			HT	2.1	3.3	6.5	3.6	2.9	4.2
S5	NW	Q. *semecarpifolia*	HB	1.9	2.2	6.2	1.2	2.4	4.2
			HS	1.9	3.0	4.5	0.9	2.8	3.7
			HT	1.0	1.8	6.1	0	0.4	4.1

and Sah (2007) for central Himalayan forest ecosystems and by Ramzan *et al.* (2008) in the black sea region forests. The diversity value zero in the present study represents that only one plant species was present at a particular site. Knight (1975) calculated high tree diversity (5.40) in tropical rain forest and for temperate forest the range was 1.7 to 3.4 (Braun, 1950). Thus, our values of diversity fall in the range of temperate forests.

Significant negative correlation ($p<0.01$) was found between clayey soil and tree and shrub species richness across all stands in the present study. Soil moisture was significantly correlated with tree and shrub species richness ($p<0.05$) across all stands. The herb density indicated a positive relation with tree density ($p<0.01$) whilst there was a negative relationship between tree and shrub density ($p<0.01$) and shrub and herb density ($p<0.01$). Similar findings were reported by Sah (2007) for central Himalayan oak forest ecosystems.

It is interesting to note that species richness and species diversity for the shrub layer was found to be higher in comparison to the tree layer. Similar values were reported by Saxena and Singh (1982), Garkoti (1992), Tyagi (2006) and Sah (2007) for Central Himalayan forest ecosystems. The higher species richness and diversity in shrub layer than in tree layer may be due to formation of forest gaps, which provide opportunity for the invasion of more shrubs. Whittaker (1972) also suggested that the dominance of one stratum might affect the diversity of another stratum. The influence of diversity of trees to shrubs ($p<0.05$) and herbs ($p<0.01$) was significant, while no relationship was found between shrub and herb diversity.

In the present study area the gradient analysis was examined by using polar ordination technique of Bray and Curtis (1957) which made several patterns apparent with regard to community characteristics and species distributions. Ordination technique for all forest stands was made in the present study in which boundaries of ecosystems are artificially imposed for the sake of classification and accounting. The values of tree, shrub and herb species richness and diversity are plotted in the ordination graphs (Fig. 1). The main reason for species forming clusters of stands in ordination graphs is that the mesic hill-base stands showed reasonably similar species composition. Hill-slope and hill-top stands indicated relatively higher species diversity and species richness (marked with dotted lines in the given figures).

Whittaker (1975) assumed that diversity indicates the luxuriance growth of vegetation in different forest stands. On the basis of the present study we can suggest that in Central Himalaya, vegetation does not decline (in terms of species richness) up to 2600 m asl elevations. However, temperature becomes less favorable for plant growth with increasing elevation due the mesic condition and evapo-transpiration. These mid-altitude forest stands also resemble the low altitude forest of Central Himalaya in tree, shrub and herb species diversity. Using the polar ordination method it is suggested that with increasing elevation up to 2500 m asl, community characters, forest vegetation and variation in species composition does not change markedly.

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