SPECIES COMPOSITION AND DIVERSITY OF HERBACEOUS VEGETATION IN TWO MAJOR OAK FORESTS OF CENTRAL HIMALAYA: AN EFFECT OF ASPECT AND SLOPE

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Abstract. Vegetation in mountain area in affected by several factors of which altitude, aspect, slope is predominant as they modify regimes of moisture and exposure to sun. The study site was located between 29º19′ and 29º24′ lat. N and 79º19′ and 79º26′ long. E along an elevational transect of 1200-2000 m in Central Himalaya. The study revealed that difference between hill base sites and other slope positions was greater than between two aspects. Aspects play a significant role in determining vegetation, and often even growth forms differ from one aspect to another. The study shows that the hill base and mesic aspect supports more species than higher slope positions and xeric aspect, respectively. Across the forests, species diversity ranged from 2.51 to 2.98. Species richness and diversity were generally higher in banj-oak forest, compared to kharsu-oak forest.

Keywords. **mesic aspect, species composition, species diversity, species richness, xeric aspect**

I. Introduction

The most striking feature of Earth is the existence of life, and the most striking feature of life is its diversity (Tilman, 2000). Biodiversity is at the heart of ecological research. Himalaya is one of the "hot spots" of biodiversity. The unusually wide altitudinal range (over 3000 m), rapid change in altitude and high endemism (Singh and Singh1992, Zobel and Singh, 1997), make it interesting area for studies on diversity. Central Himalaya harbours rich biodiversity because of its unique and diverse climate.

In Himalaya, an elevation transect includes vegetation from tropical monsoon forest to alpine meadows and scrub, constituting an unusually extensive elevational and vegetation gradient (Singh and Singh1992). Extensive oak and conifer forest characterize the Himalaya moist temperate forest extending from 1500-3000 m in Western and Central Himalaya (Saxena, 1978).

Vegetation in mountain area in affected by several factors of which altitude, aspect, slope, soil depth are predominant as they modify regimes of moisture and exposure to sun. Bormann *et al.* (1970) revealed that along an altitudinal gradient, the total basal area per tree, deciduousness and productivity decreased with increasing elevation, while density evergreenness and species diversity increased. Aspect was found to play a significant role in determining plant distribution (Ebermayer, 1976).

We undertook this study to understand the spatial pattern of the forest and the factors, which determine that. The present study, therefore taken up to understand the floristic composition, pattern of distribution and diversity in two major forest types (Kharsu- oak and banj-oak) of Central Himalaya.

II. Material and Methods

The study site was located between 29º19′ and 29º24′ lat. N and 79º19′ and 79º26′ long. E. along an elevational transect of 1200-2000 m in Central Himalaya. This altitudinal range encompasses major forests of Central Himalaya. These forests are well defined by Singh and Singh (1987, 1992) and Singh *et al.* (1994).

This study took place over a two years period from 2003- 2005; using two forest types (Kharsu and banj oak forest). The soil at both sites was sandy loam. The soil pH ranged from 5.8 to 6.4, being slightly acidic. The study was carried out at two contrasting North and South aspects. For detailed study each site was divided into three elevational slopes (i.e. hill base 1200 and 1400m and 1700 and 1800m; mid-slope: 1400 and 1600m and 1800 and 1900m; hill top: 1600 and 1700m and 1900 and 2000m for kharsu-oak and banj-oak site, respectively) each on north and south aspect to find out the effect of drought and light on vegetation.

The climate of the study area sites is monsoon pattern. The annual rainfall of the study period was 1831 mm. The monthly rainfall ranges from 4.5 mm in November to 526 in July. The mean annual temperature was 15.7 ºC, the mean minimum temperature was -1 ºC in January and the mean maximum temperature was 30.5º C in April.

Vegetation types and species composition

Stands were selected in relatively undisturbed areas after repeated surveys of the elevational belt of 1200-2000m. Three stands one each on hill base, mid-slope and hill top were sampled on both the aspects.

The phytosociological analysis of each stand was carried out by using 10, 10 x 10 m quadrats placed randomly for tree layer (circumference, at breast height, cbh, that is 1.37 m from ground; trees with cbh ≥ 31.5 cm were considered (Saxena and Singh, 1982).

The phytosociological analysis of herbs was done by Nested Plot Technique following Muller-Dombois and Ellenberg (1974). For the study of herbaceous vegetation, 10 quadrats (1m x 1 m) were placed on the area selected by Nested Plot Technique in each of the forest stands (hill base, hill slope and hill top).

Vegetational data were analysed for abundance (A), density (D) and frequency (F) following Curtis and McIntosh (1950), A/F ratio following Muller- Dombois and Ellenberg (1974), Distribution pattern, relative values of density (RD), dominance(R Dom) and frequency (RF) following Curtis and Cottam (1956). According to Curtis and Cottam (1956), the A/F ratio below 0.025 indicates regular distribution, between 0.025 and 0.05 indicates random distribution and >0.05 indicates contagious distribution.

For each forest stand species diversity was calculated by using Shannon–Wiener information Index (1963):

$$\text{Species diversity (H')} = -\sum_{i=1}^{s}\left(\frac{N_i}{N}\right)\times\left(\ln\frac{N_i}{N}\right) \qquad \text{(Eq.1)}$$

Where Ni is the total number of species i and N is the number of individuals of all species in that site. Concentration of dominance was calculated following Simpson (1949). Evenness or Equitability and beta diversity was calculated following Whittaker (1972, 1975).

III. Results

Vegetation analysis

Banj-oak Forest

Table 2 shows that the total number of herb species was more on north aspect (36) than that of southeast aspect (28), and across the slopes ranged from 18 at hill top to 31 at hill base at north aspect whereas at southeast aspect it ranged from 22 at hill base to 15 at hill top. On the north aspect total herb density was maximum at hill base (25.7 ind. m^{-2}) followed by mid-slope (19.6 ind m^{-2}) and hill top (14.2 ind m^{-2}). On the southeast aspect total herb density was maximum at hill base (23.6 ind. m^{-2}) followed by mid-slope (18.4 ind m^{-2}) and hill top (13.0 ind m^{-2}). Each aspect and each slope was generally dominated by different herb species.

Kharsu-oak forest

Table 2 shows that across the aspects the total number of herb species was more at northwest aspect (38) than that of southeast aspect (29). Across the slopes, species richness remained more or less similar at both the aspects (16-23 at northwest and 15-22 at southeast aspect).

At northeast aspect herb density tend to decrease from hill base to hill top and it ranged from 13.9 (hill top) to 19.6 ind. m^{-2} (hill base), whereas at east aspect herb density was maximum at hill top (12.3 ind. m^{-2}) and minimum at mid-slope (6.3 ind. m^{-2})

Species Diversity

Banj-oak forest

Table 3 shows that across the aspects, the herb species richness ranged between 15 and 31 (Herb diversity was more at north aspect and tend to decrease from hill base to hill top). The concentration of dominance for herbs ranged between 0.08 (hill slope and 0.11 at the hill top of north aspect. The value of equitability for herbs ranged between 0.83 and 0.94, the maximum being at the hill slope of north aspect and minimum at the hill base of southeast aspect. The value of beta diversity at north and southeast aspect was 2.25 and 1.39, respectively.

Kharsu-oak forest

Herb diversity ranged between 2.47 and 2.85, the maximum being at the hill base of southeast aspect and minimum at the hill top of northwest aspect. The concentration of dominance for herbs ranged between 0.07 at the hill base of northwest aspect and 0.10 at the hill top of southeast aspect. The value of equitability for herbs ranged between 0.88 and 0.94, the maximum being at the hill slope of northwest aspect and minimum at the hill base of southeast aspect. The value of beta diversity at northwest and south- eastern aspect was 3.27 and 2.84, respectively (*Table 3*).

IV. Discussion

With respect to slope and aspect, the herb density was maximum at the hill base of north aspect of banj-oak forest (25.7 ind. m^{-2}) and the minimum at the mid-slope of southeast aspect of kharsu –oak forest (6.3 ind. m^{-2}). This indicates that hill base and north aspect of banj-oak forest provides favourable conditions for the growth of herbs in comparison to that of kharsu-oak forest. Similar pattern were reported by Ram *et al.* (2001) and Khera *et al.* (2001).

In the present study, contagious distribution was most common. This may be due to the fact that the majority of herb species reproduce vegetatively. However, the vegetative reproduction may not be the only reason for this, the contagious distribution in vegetation may be due to multitude factors (Kershaw, 1973).

Species diversity is one of the most important components of ecosystems and it has been related to succession, stability and various other aspects. Species richness has been regarded as index of diversity right from the beginning and despite the development of several expressions for diversity; authors like Whittaker (1977) consider it most purposeful measure of diversity.

Across the forests, species diversity ranged from 2.51 to 2.98. Species richness and diversity were generally higher in banj-oak forest, compared to kharsu-oak forest. Similar findings were reported by Kumar (2000) and Kharkwal *et al.* (2005) for Central Himalayan forest areas. Our results indicate that for each growth form at the mesic aspects (N, NW) had more species than the xeric aspect (SE).

The herb species richness across the forest types was higher in kharsu-oak forest (45 species) than banj-oak forest (37 species). Across the slopes in different forest types (values averaged across the aspects) the average species richness and diversity were the highest at the hill base of banj-oak forest (26.5 and 2.89, respectively) and the lowest at the mid-slope of kharsu-oak forest (15.5 and 2.48). Across the aspects (values averaged across the slopes), the species richness and diversity were the highest at the north aspect of banj-oak forest (24.3 and 2.75, respectively) whereas lowest at southeast aspect of kharsu oak forest (17.3 and 2.49). Across the slopes and aspects in different forest types, species richness and diversity were highest at the hill base of north aspect of banj-oak forest (31 and 2.98, respectively) and the lowest at the hill top of southwest aspect of Kharsu- oak forest (15 and 2.47, respectively).

Herb diversities were clearly lower in kharsu-oak forest than banj-oak forest. Across the forest types, the species richness and the diversity were higher at the mesic aspect than that of xeric aspect. However, even in the kharsu-oak forest the mesic aspect supported a sizeable diversity. Across the location, the species richness and diversity were generally higher at the hill base followed by mid-slope and hill top. Favourable effect of moisture on species was reflected in its higher value in the mesic aspects and at the hill base. Across the forest types, the species diversity was low and comparable with temperate forests. The low diversity in temperate vegetation could be due to lower rate of evolution and diversification of communities (Fisher, 1960; Simpson, 1964) and severity in the environment (Connell and Orias, 1964). In temperate forests highest values for diversity index were recorded between 2 and 3 (Monk, 1967, Risser and Rice, 1971). Braun (1950) reported tree diversity between 1.7 and 3.4 in an eastern forest of North America. In certain forests of the Kumaun Himalaya the values are reported to range from 0.8 to 2.3 (Saxena and Singh 1982; Ralhan *et al*. 1982; Upreti, 1982; Adhikari *et al*. 1991; Srivastava, 2002). For tropical rain forests, higher diversity (5.40) was reported by Knight (1975). Braun (1950) reported 1.69–3.40 tree diversity in certain temperate forests. Low tree species diversity regardless to altitude in the central Himalayan forest stands appears to be a common feature. Although these forests resemble tropical forests in several ecosystem characters like nutrient turnover, they are closer to temperate forests in terms of species diversity. The dominant species of all the forests (kharsu-oak and oaks) are ectomycorrhizal, which are known to effectively out-compete other species possibly through their strong access to resources.

Across all the studied forests, beta diversity ranged from 1.39 to 2.25. The values are more and less similar to the values reported by Kharkwal et al. (2005). The beta diversity for trees was the maximum on southeast aspect of banj-oak forest and the minimum on the northeast aspect of kharsu-oak forest.

Equitability, that is, species per log cycle index is another aspect of diversity. Several authors have used Shannon-Wiener information index (1963) in order to express the combined effect of species richness and equitability, i.e. evenness among the importance values of the species and it has often been termed as synthetic index. However, equitability showed stronger correlation with species richness than diversity did with species richness. It appears that Shannon-Wiener information index is simply another measure of equitability and fails to incorporate the component of species richness (Whittaker, 1977, Tewari, 1982). In this study transect the equitability values ranged from 0.82 to 0.96 for herbs. A low value of the concentration of dominance (0.07 to 0.13 for herbs) indicates that in these forests, the dominance is shared by many species. These values were similar to the values (0.21 to 0.29) reported by Srivastava (2002). For a tropical forest, Knight (1975) reported an average value of 0.06. Chandra (1991) also reported the low values of concentration of dominance (0.21 to 0.40).

Table 1. Composition of herb layer in banj-oak forest.

	Abundance	Density	Frequency	A/f
North aspect		**Hill base**		
Achyranthes bidentata	5.86	4.10	70	0.08
Agrimonia pilosa	2.25	0.90	40	0.06
Ainsliaea latifolia	3.00	0.60	20	0.15
Anaphalis cinnamonea	2.00	0.20	10	0.20
Athyrium foliolosum	4.00	0.40	10	0.40
Bidens biternata	2.50	0.50	20	0.13
Carex cruciata	1.00	0.10	10	0.10
Circaea lutea	2.50	0.50	20	0.13
Clinopodium umbrosum	3.50	0.70	20	0.18
Commelina benghalensis	3.86	2.70	70	0.06
Desmodium multiflorus	1.50	0.30	20	0.08
Dicliptera bupleuroides	3.00	0.60	20	0.15
Erigeron karvinskianus	2.33	0.70	30	0.08
Fragaria indica	3.00	0.30	10	0.30
Galinsonga ciliata	3.67	1.10	30	0.12
Galium rotundifolium	4.00	0.40	10	0.40
Geranium nepalense	3.00	0.30	10	0.30
Geranium wallichianum	3.00	0.60	20	0.15
Hedychium spicatum	1.50	0.30	20	0.08
Justicia simplex	1.00	0.10	10	0.10
Oxalis corniculata	4.00	2.40	60	0.07
Paris polyphylla	5.00	2.00	40	0.13
Pilea umbrosa	3.71	2.60	70	0.05
Plectranthus striatus	2.50	0.50	20	0.13
Pouzolzia hirta	2.00	0.20	10	0.20
Roscoea purpurea	2.67	0.80	30	0.09
Sanicula elata	1.00	0.10	10	0.10
Seigesbeckia orientalis	1.67	0.50	30	0.06
Thalictrum foliolosum	2.00	0.40	20	0.10
Torilis japonicus	2.00	0.40	20	0.10
Viola canescens	4.00	0.40	10	0.40
		25.70	**790**	**4.63**
		Mid-slope		
Achyranthes bidentata	4.83	2.90	60	0.08
Agrimonia pilosa	4.25	1.70	40	0.11
Ainsliaea latifolia	5.75	2.30	40	0.14
Athyrium foliolosum	2.00	0.20	10	0.20
Carex cruciata	2.00	0.20	10	0.20
Commelina benghalensis	1.67	0.50	30	0.06
Desmodium multiflorus	3.00	0.30	10	0.30
Dicliptera bupleuroides	1.00	0.10	10	0.10
Epilobium royleanum	2.50	0.50	20	0.13
Fragaria indica	2.67	0.80	30	0.09
Galinsonga ciliata	3.33	1.00	30	0.11
Galium rotundifolium	2.33	0.70	30	0.08
Geranium nepalense	1.00	0.10	10	0.10
Geranium wallichianum	1.00	0.20	20	0.05
Hedychium spicatum	2.00	0.60	30	0.07
Nervelia crispata	1.00	0.10	10	0.10
	Abundance	**Density**	**Frequency**	**A/f**
Oxalis corniculata	4.00	0.80	20	0.20
Oxalis latifolia	6.00	0.60	10	0.60
Paris polyphylla	2.67	0.80	30	0.09
Pilea umbrosa	2.00	0.20	10	0.20
Plectranthus striatus	2.00	0.20	10	0.20
Polygonum nepalensis	3.00	1.20	40	0.08
Pouzolzia hirta	3.00	0.90	30	0.10

Viola canescens	6.75	2.70	40	0.17
		19.60	**580**	**3.54**
		Hill top		
Achyranthes bidentata	3.75	1.50	40	0.09
Carex cruciata	1.00	0.10	10	0.10
Circaea lutea	4.00	0.40	10	0.40
Commelina benghalensis	2.33	0.70	30	0.08
Dicliptera bupleuroides	5.00	1.50	30	0.17
Epilobium royleanum	7.75	3.10	40	0.19
Fragaria indica	6.00	0.60	10	0.60
Galinsonga ciliata	1.00	0.10	10	0.10
Galium rotundifolium	2.00	0.40	20	0.10
Geranium nepalense	1.00	0.10	10	0.10
Hedychium spicatum	2.33	0.70	30	0.08
Oxalis latifolia	5.00	1.00	20	0.25
Pilea scripta	1.00	0.20	20	0.05
Pilea umbrosa	1.00	0.20	20	0.05
Plectranthus striatus	7.00	0.70	10	0.70
Polygonum nepalensis	3.00	0.90	30	0.10
Pouzolzia hirta	2.13	1.70	80	0.03
Viola canescens	3.00	0.30	10	0.30
		14.20	**430**	**3.49**
Southeast aspect		**Hill base**		
Achyranthes bidentata	7.50	4.50	60	0.13
Ainsliea latifolia	2.00	0.40	20	0.10
Carex cruciata	4.00	2.00	50	0.08
Circaea lutea	2.50	0.50	20	0.13
Clinopodium umbrosum	2.50	1.00	40	0.06
Commelina benghalensis	3.00	0.90	30	0.10
Dicliptera bupleuroides	4.00	1.20	30	0.13
Erigeron karvinskianus	5.00	1.50	30	0.17
Fragaria indica	4.00	0.80	20	0.20
Galinsonga ciliata	2.00	0.40	20	0.10
Justicia simplex	2.33	0.70	30	0.08
Oxalis corniculata	2.00	1.20	60	0.03
Oxalis latifolia	6.00	2.40	40	0.15
Paris polyphylla	2.25	0.90	40	0.06
Pilea scripta	2.25	0.90	40	0.06
Pilea umbrosa	5.00	1.50	30	0.17
Plectranthus striatus	1.20	0.60	50	0.02
Pouzolzia hirta	2.00	0.60	30	0.07
Roscoea purpurea	2.50	0.50	20	0.13
Swertia tetragona	3.00	0.90	30	0.10
Torilis japonicus	1.00	0.10	10	0.10
Viola canescens	1.00	0.10	10	0.10
		23.60	**710**	**2.25**
	Abundance	**Density**	**Frequency**	**A/f**
		Mid-slope		
Achyranthes bidentata	3.71	2.60	70	0.05
Agrimonia pilosa	1.67	0.50	30	0.06
Carex cruciata	2.67	0.80	30	0.09
Circaea lutea	4.00	0.80	20	0.20
Commelina benghalensis	2.67	0.80	30	0.09
Dicliptera bupleuroides	3.50	1.40	40	0.09
Fragaria indica	4.00	0.80	20	0.20
Galinsonga ciliata	1.50	0.30	20	0.08
Galium rotundifolium	2.33	0.70	30	0.08
Geranium nepalense	3.25	1.30	40	0.08
Hedychium spicatum	2.50	0.50	20	0.13
Oxalis latifolia	4.25	1.70	40	0.11
Paris polyphylla	4.75	1.90	40	0.12
Pilea umbrosa	3.00	0.90	30	0.10

Polygonum nepalensis	3.25	1.30	40	0.08
Pouzolzia hirta	2.67	0.80	30	0.09
Torilis japonicus	1.75	0.70	40	0.04
Viola canescens	3.00	0.60	20	0.15
		18.40	**590**	**1.82**
		Hill top		
Achyranthes bidentata	2.00	0.80	40	0.05
Clinopodium umbrosum	3.25	1.30	40	0.08
Commelina benghalensis	3.00	0.90	30	0.10
Erigeron karvinskianus	4.00	2.40	60	0.07
Fragaria indica	3.33	1.00	30	0.11
Galium rotundifolium	2.00	0.80	40	0.05
Geranium nepalense	3.00	0.30	10	0.30
Hedychium spicatum	3.00	0.90	30	0.10
Nervelia crispata	1.75	0.70	40	0.04
Oxalis latifolia	3.67	1.10	30	0.12
Paris polyphylla	2.67	0.80	30	0.09
Pilea umbrosa	2.25	0.90	40	0.06
Pouzolzia hirta	3.00	0.30	10	0.30
Roscoea purpurea	4.00	0.40	10	0.40
Torilis japonicus	2.00	0.40	20	0.10
		13.00	**460**	**1.97**

Table 2. Composition of herb layer in kharsu-oak forest.

	Abundance	Density	Frequency	A/f
Northwest aspect		**Hill base**		
Achyranthes bidentata	5.50	1.10	20	0.275
Anthraxon prionoides	4.00	0.80	20	0.200
Aster asperculus	4.75	1.90	40	0.119
Athyrium rupicola	1.33	0.40	30	0.044
Campanula colorata	3.00	0.30	10	0.300
Conyza japonica	1.67	0.50	30	0.056
Cynoglossum glochidiatum	1.00	0.20	20	0.050
Dipsacus mites	2.00	0.20	10	0.200
Galium aparina	1.00	0.10	10	0.100
Hedychium spicatum	3.25	1.30	40	0.081
Micromeria biflora	2.33	0.70	30	0.078
Oplimensis compositus	3.00	0.60	20	0.150
Plectranthus japonicus	3.17	1.90	60	0.053
Plectranthus striatus	3.89	3.50	90	0.043
Polygonum amplexicaule	3.43	2.40	70	0.049
Polygonum nepalensis	2.00	0.40	20	0.100
Stachys sericea	2.00	0.20	10	0.200
Swertia pulchella	4.00	1.20	30	0.133
Swertia tetragona	1.00	0.20	20	0.050
Thalictrum foliolosum	1.00	0.10	10	0.100
Torilis japonicus	2.00	0.20	10	0.200
Viola pilosa	3.50	0.70	20	0.175
Wulfenia amherstiana	3.50	0.70	20	0.175
		19.60	**640**	**2.93**
		Mid-slope		
Athyrium rupicola	3.29	2.30	70	0.047
Commelina benghalensis	1.25	0.50	40	0.031
Conyza japonica	1.50	0.60	40	0.038
Dipsacus mites	3.00	0.60	20	0.150
Geranium wallichianum	1.00	0.20	20	0.050
Lychnis fimbricata	3.40	1.70	50	0.068
Oplimensis compositus	2.67	0.80	30	0.089
Polycarpaea corymbosa	1.00	0.20	20	0.050
Polygonum amplexicaule	3.00	2.10	70	0.043
Pouzolzia hirta	2.00	0.80	40	0.050
Pteris cretica	1.25	0.50	40	0.031
Roscoea purpurea	2.80	1.40	50	0.056
Setaria foliolosum	2.00	0.60	30	0.067
Setaria homonyma	3.25	1.30	40	0.081
Swertia tetragona	1.00	0.10	10	0.100
Synotis rufinervis	3.17	1.90	60	0.053
		15.60	**630**	**1.00**
		Hill top		
Anaphalis busua	1.75	0.70	40	0.044
Anthraxon prionoides	1.00	0.40	40	0.025
Athyrium rupicola	2.00	1.00	50	0.040
Bupleurum tenue	3.00	2.10	70	0.043
Conyza japonica	1.00	0.20	20	0.050
	Abundance	**Density**	**Frequency**	**A/f**
Dipsacus mites	1.00	0.20	20	0.050
Geranium wallichianum	2.75	1.10	40	0.069
Micromeria biflora	2.00	0.20	10	0.200
Oxalis latifolia	1.50	0.30	20	0.075
Plectranthus striatus	3.00	1.50	50	0.060
Polygonum amplexicaule	2.60	1.30	50	0.052
Pteris cretica	1.00	0.20	20	0.050

Sanicula elata	2.33	0.70	30	0.078
Stachys sericea	1.67	0.50	30	0.056
Synotis rufinervis	2.78	2.50	90	0.031
Themeda anthera	1.50	0.60	40	0.038
Viola pilosa	2.00	0.40	20	0.100
		13.90	**640**	**1.059**
Southeast aspect		**Hill base**		
Aster asperculus	2.00	0.20	10	0.200
Athyrium rupicola	3.33	1.00	30	0.111
Circaea alpine	1.00	0.10	10	0.100
Conyza japonica	3.83	2.30	60	0.064
Dipsacus mites	1.50	0.30	20	0.075
Epilobium royleanum	3.00	0.30	10	0.300
Erigeron karvinskianus	4.00	2.00	50	0.080
Galinsonga ciliata	1.50	0.30	20	0.075
Galium aparina	1.00	0.10	10	0.100
Geranium wallichianum	1.00	0.30	30	0.033
Melissa flava	2.00	0.40	20	0.100
Micromeria M biflora	4.40	2.20	50	0.088
Paris polyphylla	1.50	0.30	20	0.075
Plectranthus striatus	3.43	2.40	70	0.049
Polygonum nepalensis	1.00	0.10	10	0.100
Roscoea purpurea	1.67	0.50	30	0.056
Swertia pulchella	1.00	0.10	10	0.100
Synotis rufinervis	1.00	0.20	20	0.050
Thalictrum foliolosum	1.00	0.10	10	0.100
Viola canescens	3.00	1.20	40	0.075
Viola pilosa	1.00	0.30	30	0.033
Wulfenia amherstiana	4.40	2.20	50	0.088
		16.90	**610**	**2.05**
		Mid-slope		
Anaphalis busua	1.75	0.70	40	0.044
Athyrium rupicola	2.25	0.90	40	0.056
Bupleurum tenue	2.50	0.50	20	0.125
Circaea alpine	4.50	0.90	20	0.225
Conyza japonica	2.00	0.40	20	0.100
Galium aparina	2.00	0.20	10	0.200
Geranium wallichianum	3.75	1.50	40	0.094
Plectranthus striatus	3.67	2.20	60	0.061
Polygonum amplexicaule	3.40	1.70	50	0.068
Polygonum nepalensis	2.00	0.20	10	0.200
Sanicula elata	1.00	0.10	10	0.100
Stachys sericea	4.00	0.80	20	0.200
	Abundance	**Density**	**Frequency**	**A/f**
Synotis rufinervis	2.00	0.20	10	0.200
Themeda anthera	2.80	1.40	50	0.056
Viola pilosa	2.33	0.70	30	0.078
		12.40	**430**	**1.81**
		Hill top		
Anaphalis busua	2.00	0.20	10	0.200
Anthraxon prionoides	2.00	0.80	40	0.050
Circaea alpine	1.50	0.30	20	0.075
Conyza japonica	1.33	0.40	30	0.044
Dipsacus mites	2.20	1.10	50	0.044
Galium aparina	1.00	0.20	20	0.050
Geranium wallichianum	2.00	1.20	60	0.033
Melissa flava	2.50	1.50	60	0.042
Plectranthus striatus	2.00	0.80	40	0.050

Polygonum nepalensis	2.25	0.90	40	0.056
Sanicula elata	2.25	1.80	80	0.028
Stachys sericea	2.00	0.20	10	0.200
Synotis rufinervis	2.71	1.90	70	0.039
Themeda anthera	2.33	0.70	30	0.078
Viola pilosa	1.00	0.30	30	0.033
		12.30	**590**	**1.02**

Table 3. Pattern of species richness and diversity in kharsu-oak and banj-oak forest in relation to aspect and position along the hill slope.

Forest types	**Mesic aspect**				**Xeric aspect**			
	Hill base	**Mid-slope**	**Hill top**	**Total**	**Hill base**	**Mid-slope**	**Hill top**	**Total**
Richness								
Herb layer								
Banj-oak	31	24	18	36	22	18	15	28
Kharsu-oak	23	16	17	38	22	15	15	29
Species diversity								
Herb layer								
Banj-oak	2.98	2.77	2.51		2.80	2.75	2.56	
Kharsu-oak	2.71	2.51	2.47		2.85	2.61	2.59	

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