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Quantitative analysis of sub-alpine grasslands in trans-Himalayan region of Manang, central Nepal

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Abstract

Species composition and richness of grassland vegetation were studied in trans-Himalayan region of Manang. Two south-facing sites, both at the similar altitude (3800-4200 m asl), were selected and a total of 40 plots (10 x 10 m) with 200 quadrates (1 m x 1 m) were sampled. Altogether, 97 plant species were recorded. The similarity index between two sites was 12.37%. There was significant negative correlation between species richness and altitude in site I. Species richness did not show significant relationship with altitude in site II. Various physical and biological factors interact differently in different sites to create habitat heterogeneity which determine the distribution pattern of plant species and influence variations in species composition and diversity.

Key-words: alpine region, quantitative analysis, species diversity, vegetation.

Introduction

Nepal, a small mountaneous landlocked country, has diverse type of vegetation and is rich in plant species. About 118 types of ecosystems have been identified in different physiographic zones of Nepal, with 52 and 33 ecosystems in the mid hills and highlands respectively (BPP 1995). The vegetation of different parts of the country, including high altitude region has been studied by various workers (Banerji 1963; Stainton 1972; Kanai *et al*. 1975; Dobremez 1976). Altogether, 75 vegetation types have been identified in Nepal (Dobremez 1976). High altitude vegetations are found above 3100 m. asl in northern part covering outer and inner Himalayas (Dobremz 1976). Here, climate is cold, dry and windy. Major forests at this level (3100-4100 m asl) comprise of conifers, such as fir (*Abies spectabilis*) at lower elevations and birch-rhododendron (*Betula utilis – Rhododendron campanulatum*) at upper elevations (Dobremz 1976).

In Nepal, grasslands cover 13% of total land (HMG/N 1992). There are four types of grasslands in Nepal (Tuschida 1983), they are tropical, temperate, sub-alpine and alpine. Natural grasslands in Nepal are rich in terms of biodiversity and sources of forage for wild ungulates and domestic livestock (Richard *et al*. 2000). The alpine zone is characterized by moist alpine scrub and dry alpine scrub at an altitude above the timberline. This zone consists of several species of important medicinal plant. However, the dominant species are the grasses. Subalpine and alpine grassland species are disappearing at alarming rates worldwide, reducing annually by 1–4% of their current area (Laurence 1999). The dominant species in these areas are therefore also declining (Ferraz *et al*. 2004). It has been speculated that a large proportion of these are likely to become extinct in the next few decades, leading to a large scale loss of genetic diversity (Wilson 1992).

Quantitative studies have been used in recent years to characterize forest vegetation (Phillips *et al* 2003). Most studies regarding the quantitative analysis of grassland vegetation are concentrated in tropical to temperate region of the country but studies pertaining to high altitude grassland are very meager. At high altitude areas of Nepal, most of the works are confined to the botanical expeditions and plant identifications (e.g., Kihara 1955; Yoda 1968; Kanai *et al*. 1975). Only few studies on species diversity in trans-Himalayan region have been carried out (e.g., Grytnes and Vetaas 2002). In this study, an account of quantitative analysis of grassland vegetation has been carried out in south-facing slopes in a trans-Himalayan valley of Manang district to assess the effect of altitude and other environmental factors in vegetation composition and species diversity.

Materials and Methods

STUDY AREA

Present study was conducted in trans-Himalayan region of Manang district of central Nepal in June/September 2005. The study was focused on south facing slopes between 3800 m asl to 4200 m asl (from Manang Gaun to Yak Kharka). Climate of the study area varies from subtropical to temperate, xerophilous and alpine formations (Pohle 1990). Two sites (site I at Ice Lake and site II at Yak Kharka) were selected for the study.

METHODS

An imaginary transect was made in north-south direction. Transect starts from 3800 m asl and ends at 4200 m asl. In each transect, 10 x 10 m plot was laid down at each 100 m elevation interval. Each plot was divided into 4 sub-plots from the center. In each sub-plot, 5 quadrats of 1 m x 1 m were laid down. In each quadrat, number of individuals of each species was counted and percent ground cover of each species was estimated by visual assumption method. Most of the plant species were identified in the field; while unidentified species were later confirmed with the help of herbarium housed at Tribhuvan University Central Herbarium (TUCH) and using standard references. However, some specimens still remained unidentified. Quantitative parameters, like frequency, density, relative frequency, relative density, relative coverage and importance value index (IVI) were analyzed following Zobel *et al*. (1987). Species richness (ά-diversity) was calculated as number of species per quadrat. In addition, Simpson's dominance index (C) was also calculated. Similarity index was analyzed by applying Sorenson's index (IS). One-way ANOVA was used to compare species richness and physical variables (soil pH and moisture) between two sites. Relationships between species richness and different physical variables (elevation, soil pH and moisture) were analyzed separately for two sites by fitting linear regression models. For pairs of characters having significant relations the regression lines were shown. All statistical analyses were done with the help of SPSS computer program.

Results

SPECIES COMPOSITION

In the present study, altogether 59 herbaceous species were recorded from site I; and 50 species from site II (Appendix 1, 2; Table 1). Among them, only 12 species were common to both sites. In site I, *Androsace muscoidea* had the highest IVI (24.02), followed by *Potentilla fructicosa* (17.52), *Euphorbia stracheyi* (16.02), *Gerbera nivea* (11.75), and *Bistorta affinis* (10.13). Similarly, in site II, *Androsace strigillosa* had the highest IVI (33), followed by unidentified herb-4 (25.12), unidentified herb-5 (24.34), *Primula glomerata* (23.91), and *Stipa* sp. (10.82).

SPECIES RICHNESS

Mean species richness (Table 2) and dominance index (Table 1) values were higher in site II than in site I. Similarly, species evenness was higher in site I than in site II. Value of community coefficient or similarity index between two sites was 12.37%. ANOVA showed significant difference ($P < 0.001$) in species richness, soil pH and moisture between the two sites (Table 2). Species richness showed significant negative linear relationship with altitude in site I ($r^2 = 0.17$, $P < 0.001$, df = 98) (Fig. 1), for other physical parameters the relationships were statistically insignificant (data not shown). In this site, species richness declined with increasing elevation. Species richness did not show significant relationship with altitude in site II. In the site II, however, pH showed significant positive linear relationship with elevation ($r^2 = 0.04$, $p < 0.001$; df = 98) (Fig. 2).

Table 1. Species richness (S), dominance index (C), diversity index (H) and species evenness (J) in two study sites.

Parameters	Site I	Site II
Total number of species	59	50
Dominance index (C)	0.077	0.082
Species evenness (J)	0.66	0.53

Discussion

In the Himalaya, south facing slopes are relatively drier than north-facing slopes. South facing slopes receive higher solar radiation and harbor poor vegetation in comparison to north facing slopes. Quantitative analysis of grassland vegetation in south facing slope of a trans-Himalayan valley of Manang district revealed site-specific variations in species composition and richness. The similarity index value indicate low similarity between two sites in terms of species composition (Whittakar 1960). Present study could not detect a single factor which might have influenced the differences in species composition between the two sites. Species composition is influenced by climatic, topographic, edaphic and human-induced factors.

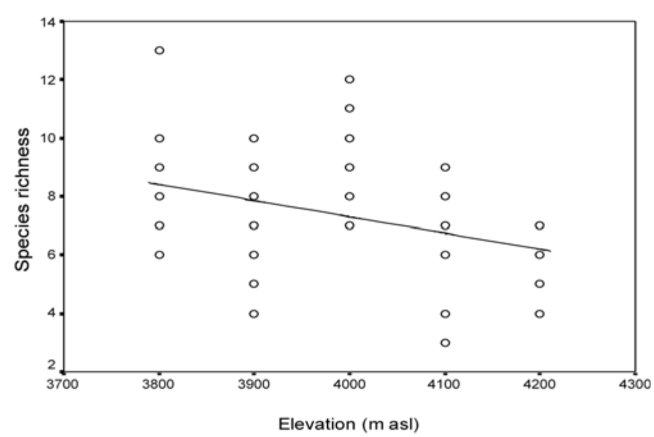

Fig. 1. Relationship between species richness and elevation in site I.

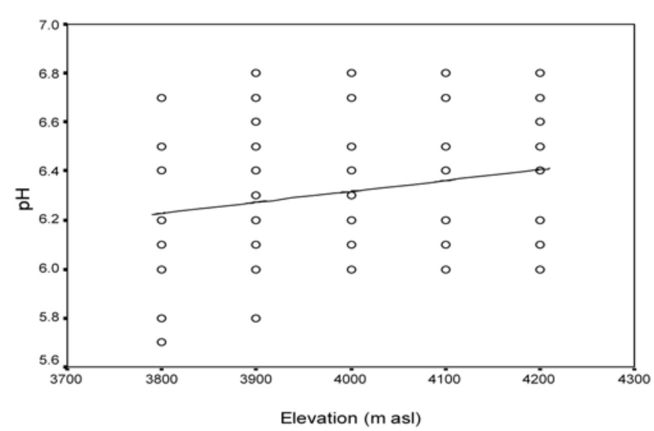

Fig. 2. Relationship between elevation and pH in site II.

Table 2. Species richness and other environmental attributes (mean ± SD) measured in two study sites.

Characters	Sample size	Site I			Site II			One way ANOVA	
		Range		Mean (± SD)	Range		Mean (± SD)	*F*	*P*
		Min.	Max.		Min.	Max.		df = 1, 199	
Species richness	100	3.0	13.0	7.3 ± 1.8	4.0	13.0	9.4 ± 1.8	65.8	0.000
Soil pH	100	5.2	6.9	6.1 ± 0.3	5.7	6.8	6.3 ± 0.3	7.8	0.006
Soil moisture	100	16.5	49.1	40.6 ± 10.1	18	42	29.4 ± 9.0	67.6	0.000
Altitude	100	3700	4300	4000	3700	4300	4000	-	-

Total number of species (gamma diversity) within site I was found to be higher than site II. Although the two study sites were located in the same altitudinal range, the difference in gamma diversity may be due the effect of spatial heterogeneity. The spatial heterogeneity of an area is strongly correlated with the number of species present (Huston 1992). The heterogeneity on small scale is contributed by climate, pattern of topography that influences the distribution of water, soil nutrients and solar energy. In the nature, optimum energy and maximum moist condition always promote photosynthesis, which ultimately influences ecophysiological processes and promote species diversity (Bhattarai *et al*. 2004). In contrast to gamma diversity, the mean species richness and the dominance index were found higher in site II than in site I. Although soil moisture content was higher in site I than in site II, the higher mean species richness in site II can be explained in terms of intermediate level of disturbances and a combination of habitat heterogeneity. Species richness significantly declined with increasing elevation in site I. Alternatively, in site II, pH had significant positive linear relationship with elevation. Similar results were also obtained by Gurung (1995) in Tahr grazing area of Annapurna and Bhattarai *et al* (2004) in subalpine grassland of Central Himalayas. Although the present study was conducted covering a small geographical area, the findings are in accordance with Stevens (1992) and others who reported that species richness generally decreases with increasing elevation. However, Rahbek (1995) showed that approximately half of the studies regarding the relationship between species richness and elevation had a mid-altitude peak in species richness.

From the study it can be concluded that various physical and biological factors interact differently in different sites to create habitat heterogeneity which determine the distribution pattern of various plant species and influence variations in species composition and diversity.

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Appendix 1. Quantitative characters of plant species recorded at site I.

S.N.	Name of species	Family	F	RF	D	RD	C	RC	IVI
1.	*Anaphalis contorta* (D. Don) Hook. f.	Asteraceae	20	0.76	5000	0.38	5	0.59	1.73
2.	*Anaphalis triplinervis* (Sims.) C.B. Clarke	Asteraceae	65	2.49	15500	1.18	15	1.79	5.46
3.	*Androsace muscoidea* Duby.	Primulaceae	93	3.57	181000	13.87	55	6.58	24.02
4.	*Androsace robusta* (Kunth) Hand-Mazz.	Primulaceae	60	2.30	83400	6.46	25	2.99	11.75
5.	*Anemone vitifolia* Buch.-Ham. ex DC.	Ranunculaceae	26	0.99	17800	1.36	5	0.59	2.94
6.	*Arabidopsis himalaica* (Edgew.) O.E. Scultz	Brassicaceae	68	2.61	1803.44	0.13	25	2.99	5.73
7.	*Aster heliopsis* Grierson	Asteraceae	26	0.99	10100	0.77	5	0.59	2.35
8.	*Aster himalaicus* CB. Clarke	Asteraceae	17	0.65	8700	0.66	5	0.59	1.9
9.	*Astragalus multiceps* Wall. ex Hook. f.	Fabaceae	8	0.30	3800	0.29	5	0.59	1.18
10.	*Bistorta affinis* (D. Don.) Greene	Polygonaceae	15	0.57	5800	0.44	5	0.59	1.6
11.	*Bistorta vivipara* (L.) S.F. Gray	Polygonaceae	65	2.49	21200	1.62	15	1.79	5.9
12.	*Caragana jubata* (Pall.) Poir.	Fabaceae	48	1.84	15200	1.16	15	1.79	4.79
13.	*Carex uncinoides* (Boott) C. B. Clarke	Cyperaceae	35	1.34	11200	0.85	5	0.59	2.78
14.	*Carum carvi* L.	Apiaceae	41	1.57	8000	0.61	5	0.59	2.77
15.	*Corydalis juncea* Wall.	Papaveraceae	68	2.61	32700	2.50	15	1.79	6.9
16.	*Cynoglossum zeylanicum* (Vahl ex Hornens.) Lehm	Boraginaceae	58	2.22	23200	1.77	15	1.79	5.78
17.	*Cyperus* sp.	Cyperaceae	67	2.57	18000	1.37	15	1.79	5.73
18.	*Epilobium wallichianum* ssp. *soulie* (H. Lev.) P.H. Raven	Onagraceae	42	1.61	13700	1.05	15	1.79	4.45
19.	*Euphorbia stracheyi* Boiss	Euphorbiceae	71	2.72	103400	7.92	45	5.38	16.02
20.	*Euphrasia himalaica* Wettst	Scrophulariaceae	35	1.34	9600	0.73	5	0.59	2.66
21.	*Gentiana capitata* Burkil	Gentianaceae	48	1.84	12700	0.97	15	1.79	4.6
22.	*Gentiana robusta* King. ex Hook. f.	Gentianaceae	70	2.68	21600	1.65	15	1.79	6.12
23.	*Gerbera nivea* (DC.) Sch. Bip.	Asteraceae	63	2.41	41800	3.20	15	1.79	7.4
24.	*Gueldenstaedtia himalaica* Baker	Fabaceae	55	2.11	39200	3.00	25	2.99	8.1
25.	*Hedysarum campylocarpon* H. Ohashi	Fabaceae	42	1.61	25700	1.97	25	2.99	6.57
26.	*Hedysarum* sp. 1	Fabaceae	76	2.91	25000	1.91	25	2.99	7
27.	*Hedysarum* sp. 2	Fabaceae	57	2.18	21100	1.61	25	2.99	6.78
28.	*Kobresia* sp. 1	Cyperaceae	32	1.22	9700	0.74	5	0.59	2.55
29.	*Kobresia* sp. 2	Cyperaceae	68	2.61	24800	1.90	25	2.99	7.5
30.	*Lancea tibetica* Hook. f. & Thomson	Scrophulariaceae	21	0.80	8400	0.64	5	0.59	2.03
31.	*Leontopodium monocephalum* Edgew	Asteraceae	28	1.07	8600	0.65	5	0.59	2.31
32.	*Leontopodium stracheyi* (Hook. f.) C.B. Clarke ex Hemsl.	Asteraceae	25	0.96	12100	0.92	5	0.59	2.47
33.	*Lloydia serotina* var. *parva* (C.Marquand & Airy Shaw)	Liliaceae	29	1.11	15700	1.20	15	1.79	4.1
34.	*Myricaria* sp.	Tamaricaceae	22	0.84	11600	0.88	5	0.59	2.31
35.	*Nardostachys grandiflora* DC.	Valerianaceae	42	1.61	17800	1.36	15	1.79	4.76
36.	*Oxytropis williamsii* Vas.	Fabaceae	24	0.92	6500	0.49	5	0.59	2
37.	*Pedicularis pectinata* Wall. ex Benth.	Scrophulariaceae	18	0.69	5800	0.44	5	0.59	1.72
38.	*Poa* sp.	Poaceae	23	0.88	5200	0.39	5	0.59	1.86
39.	*Polygonatum hookeri* (L.) All	Liliaceae	58	2.22	27200	2.08	15	1.79	6.09
40.	*Polygonum aviculare* L.	Polygonaceae	63	2.41	32100	2.46	25	2.99	7.86
41.	*Potentilla eriocarpa* Wall. ex Lehm.	Rosaceae	40	1.53	17700	1.35	15	1.79	4.67
42.	*Potentilla fruticosa* L.	Rosaceae	70	2.68	139000	10.65	35	4.19	17.52
43.	*Potentilla macrophylla* D. Don.	Rosaceae	65	2.49	28900	2.21	25	2.99	7.69
44.	*Potentilla multifida* D. Don	Rosaceae	24	0.92	6300	0.48	5	0.59	1.99
45.	*Primula wigramiana* W.W. Sm.	Primulaceae	20	0.76	5800	0.44	5	0.59	1.79
46.	*Ranunculus brotherusii* Freyn.	Ranunculaceae	25	0.96	9200	0.70	5	0.59	2.25
47.	*Rhodiola bupleuroides* (Wall. ex Hook. f. & Thoms.) Fu.	Crassulaceae	22	0.84	10400	0.79	5	0.59	2.22
48.	*Rumex* sp.	Polygonaceae	52	1.99	18000	1.37	15	1.79	5.15
49.	*Saxifraga hirculoides* Decne.	Saxifragaceae	65	2.49	23500	1.80	25	2.99	7.28
50.	*Saxifraga parnassifolia* D. Don	Saxifragaceae	30	0.72	9000	0.68	5	0.59	1.99
51.	*Spiraea canescens* D. Don	Rosaceae	19	0.70	8400	0.64	5	0.59	3.03
52.	*Stipa* sp.	Poaceae	47	1.80	12500	0.95	15	1.79	2.74
53.	*Thymus linearis* Benth.	Lamiaceae	76	2.91	44800	3.43	25	2.99	9.33
54.	Unidentified grass 1	Poaceae	34	1.30	11800	0.90	15	1.79	3.99
55.	Unidentified grass 2	Poaceae	55	2.11	18900	1.44	25	2.99	6.54

56.	Unidentified grass 3	Poaceae	68	2.61	10900	0.83	15	1.79	5.23
57.	Unidentified grass 4	Poaceae	32	1.22	7600	0.58	5	0.59	2.39
58.	Unidentified hairy-leaved herb 1		68	2.61	43500	3.33	35	4.19	10.13
59.	Unidentified herb 2		58	2.22	27200	2.08	15	1.79	6.09

F = frequency (%); D = density (pl/ha); C = coverage (%); RF = relative frequency (%); RD = relative density (%); IVI = importance value index.

Appendix 2. Quantitative characters of plant species recorded at site II.

S.N.	Name of species	Family	F	RF	D	RD	C	RC	IVI
1.	*Aconitum naviculare* (Brunl) Stapf	Ranunculaceae	28	1.35	9200	0.86	5	0.6	2.81
2.	*Allium* sp. 1	Liliaceae	77	3.73	123800	11.58	65	8.60	23.91
3.	*Allium* sp. 2	Liliaceae	68	3.29	11200	1.04	15	1.98	6.31
4.	*Androsace* sp.	Primulaceae	32	1.55	3500	0.32	5	0.6	2.47
5.	*Androsace strigillosa* Franch.	Primulaceae	96	4.65	182800	17.10	85	11.25	33
6.	*Arisaema* sp.	Araceae	62	3.00	13500	1.26	15	1.98	6.24
7.	*Aster himalaicus* C.B. Clarke	Asteraceae	60	2.96	20400	1.90	25	3.31	8.11
8.	*Astragalus multiceps* Wall. ex Hook. f.	Asteraceae	86	4.16	16800	1.57	15	1.98	7.71
9.	*Astragalus* sp.	Asteraceae	76	3.68	25600	2.39	25	3.31	9.38
10.	*Betula utilis* D. Don.	Betulaceae	48	2.32	18000	1.68	15	1.98	5.98
11.	*Chenopodium album* L.	Chenopodiaceae	45	2.18	13800	1.29	15	1.98	5.45
12.	*Cotoneaster affinis* Lindl.	Rosaceae	32	1.55	9600	0.89	5	0.6	3.04
13.	*Cremanthodium* sp.	Asteraceae	22	1.06	12200	1.14	5	0.6	2.8
14.	*Cremanthodium* sp.	Asteraceae	53	2.56	19200	1.79	25	3.31	7.66
15.	*Carum carvi* L.	Apiaceae	23	1.11	6900	0.64	5	0.6	2.35
16.	*Cyananthus* sp.	Campanulaceae	55	2.66	17500	1.63	15	1.98	6.27
17.	*Delphinium brunonianum* Royle	Ranunculaceae	8	0.38	2000	0.18	5	0.6	1.16
18.	*Elsholtzia eriostachya* (Benth.) Benth.	Lamiaceae	18	0.87	3200	0.29	5	0.6	1.76
19.	*Ephedra gerardiana* Wall. ex Stapf	Ephedraceae	78	3.78	12000	1.12	5	0.6	5.5
20.	*Epilobium wallichianum* ssp. *souliei* (H. Lev.) P.H. Ravan	Onagraceae	23	1.11	13800	1.29	25	3.31	5.71
21.	*Erigeron* sp.	Asteraceae	36	1.74	5400	0.50	5	0.6	2.84
22.	*Juniperus squamata* Buch.-Ham. ex D. Don.	Cupressaceae	25	1.21	7500	0.70	5	0.6	2.51
23.	*Lonicera* sp.	Caprifoliaceae	55	2.66	13500	1.26	15	1.98	5.9
24.	*Lonicera tomentella* Hook. f. & Thoms.	Caprifoliaceae	15	0.72	2500	0.23	5	0.6	1.55
25.	*Neopicrorhiza scrophulariiflora* Pennell	Scrophulariaceae	69	3.34	30500	2.85	35	4.63	10.82
26.	*Poa* sp.	Poaceae	62	3.00	28500	2.66	25	3.31	8.97
27.	*Potentilla argyrophyla* Wall ex Lehm.	Rosaceae	15	0.72	3000	0.28	5	0.6	1.6
28.	*Potentilla fruticosa* (Wall. ex Lehm.) Wolf	Rosaceae	10	0.48	2200	0.20	5	0.6	1.28
29.	*Potentilla saundersiana* Royle	Rosaceae	22	1.06	4800	0.44	5	0.6	2.1
30.	*Primula glomerata* Hook. f.	Primulaceae	28	1.35	4200	0.30	5	0.6	2.34
31.	*Primula wigramiana* W.W. Sm.	Primulaceae	34	1.64	6500	0.60	5	0.6	2.84
32.	*Ranunculus brotherusii* Freyn.	Ranunculaceae	12	0.58	2800	0.26	5	0.6	1.44
33.	*Rheum moorcroftiana* Royle	Polygonaceae	42	2.03	9800	0.91	5	0.6	3.54
34.	*Salix calyculata* Hook.f. ex Anderson	Saliaceae	55	2.66	10700	1.00	5	0.6	4.26
35.	*Saxifraga andersonii* H. Smith	Saxifragaceae	52	2.52	12400	1.16	15	1.98	5.66
36.	*Spiraea canescens* D. Don.	Rosaceae	50	2.42	14000	1.31	15	1.98	5.71
37.	*Stipa* sp.	Poaceae	46	2.22	8200	0.76	5	0.6	3.58
38.	*Swertia ciliata* (Roxb. ex Fleming) Karsten	Gentianaceae	47	2.27	8600	0.80	5	0.6	3.67
39.	*Tanecetum gracile* Hook. f. & Thoms.	Asteraceae	25	1.21	5400	0.50	5	0.6	2.31
40.	*Taxus wallichiana* Zucc.	Taxaceae	10	0.48	6000	0.56	5	0.6	1.64
41.	*Thalictrum* sp.	Ranunculaceae	18	0.87	7600	0.71	15	1.98	3.56
42.	*Thymus linearis* Benth.	Lamiaceae	14	0.67	5200	0.48	5	0.6	1.75
43.	Unidentified grass 1	Poaceae	20	0.96	9000	0.86	5	0.6	2.42
44.	Unidentified grass 2	Poaceae	57	2.76	22500	2.10	15	1.98	6.84
45.	Unidentified herb 1		19	0.92	4500	0.42	5	0.6	1.94
46.	Unidentified herb 2		50	2.42	14500	1.35	15	1.98	5.75
47.	Unidentified herb 3		56	2.71	12500	1.16	5	0.6	4.47
48.	Unidentified herb 4		91	4.41	143500	13.43	55	7.28	25.12
49.	Unidentified herb 5		82	3.97	125800	11.77	65	8.60	24.34
50.	Unidentified herb 6		8	0.38	1800	0.16	5	0.6	1.14

F = frequency (%); D = density (pl/ha); C = coverage (%); RF = relative frequency (%); RD = relative density (%); IVI = importance value index.