



Plant species Richness and Phytosociological attributes of the Vegetation in the cold temperate zone of Darjiling Himalaya, India

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Abstract

The present study deals with the species richness and phytosociology in cold temperate zone vegetation of Darjiling Himalaya. The diversity indices represented the dominant species like *Rhododendron arboreum* Smith, *Daphne bholua* var. *glacialis* (Smith and Cave) Burt and *Fragaria nubicola* (Lindley ex Hooker f.) *Lacaita* and rare species like *Gamblea ciliata* C.B. Clarke, *Sambucus adnata* Wallich ex DC., *Treutlera insignis* Hooker f., *Arisaema concinuum* Schott and *Codonopsis affinis* Hooker f. and Thomson. The maximum species diversity (Shannon-Weaver Index) was marked for herbs (4.332) followed by shrubs (3.577) and lowest for trees (3.131). The highest species richness (Menhinick's Index) was estimated for herb layer (3.568) and least for the canopy (1.799). The concentration of dominance was 0.056, 0.032 and 0.014 respectively for the three layers. The species evenness was greater for herb layer (0.980) and least for the canopy (0.911). Soil parameters exhibited acidic property, the correlation between diversity and importance value indicated positive relation.

Keywords: Species richness, phytosociology, cold temperate, Darjiling.

Introduction

Species richness in the most commonly used and an easily interpretable indicator of biological diversity¹. Many interacting factors like the competition, geography, plant productivity, evolution, environmental parameters and anthropogenic activities are the reason for the pattern of species richness². The hills of Darjiling are an integral part of the Singalila Range of Eastern Himalaya and are very much a part of the IUCN recognized Himalaya Hotspot. This region (Eastern Himalayan) is one of the three mega-centres of endemic plants harbouring endemic at maximum³. They possess wide species diversity with rich endemic flora due to its ultra-varied landscape and geography⁴. The great variation in altitude and wide array of climatic conditions favours the luxuriant growth of diversified and rich vegetation throughout the area. The heterogeneity of climatic and of habitat conditions has created conducive environment for the development and evolution of species and the process is still continuing⁵. Differences in the micro-climatic conditions, inter-specific competition and available space have resulted into the development of mosaic of forest types where the occurrence of species diversity is well known⁶. Due to the rise in the global warming, studies on the vegetation of high mountains have increased⁷. The present study is to understand the plant diversity and species richness along with the phytosociological attributes of the vegetation in the cold temperate zone (2400 – 3200 m) of the Darjiling part of Eastern Himalaya.

Material and methods

Study Area: The Darjiling Himalaya extends between 26° 27'

05" and 27° 13' 10" N latitude and 87° 59' 30" and 88° 53' E longitude and is exclusively mountainous with the altitude varying between ca. 132 m (at Sukna) to 3660 m amsl (at Sandakphu – Phalut region). The major altitudinal vegetation types are tropical (below 800 m), subtropical (800 – 1600 m), temperate (1600 – 2400 m), cold-temperate (2400 – 3200 m) and sub-alpine (3200 – 4000 m) zones⁸. The Darjiling Himalaya lies between Nepal and Bhutan, and stretches from the plains of Bengal in the South to Sikkim in the North. It is bordered by Bhutan in East and Nepal in West as shown in figure -1. It is basically mountainous with elevation increasing towards the North. The hills of Darjiling are the extension of Singalila range of Eastern Himalaya that enters near Phalut from Mt. Ghosla (3800 m) at Sikkim. The highest points Sandakphu and Tonglu are the continuation of the Ghosla – Phalut ridge. The two most important rivers of Darjiling are the Teesta and the Great Rangeet. Both are glacier fed and have been originated respectively from Zemu glacier in North Sikkim and Rothong glacier in West Sikkim.

The present study was conducted during the year 2012 – 2013 in the cold temperate belt that occurs within an altitudinal range of 2400 – 3200 m in Darjiling Himalaya. An abrupt reduction in the temperature during winter with hailstones and snowfall for 1 – 3 months in a year characterizes the climate of this zone. The mean summer temperature varies between 7° to 17° C, the winter gets extremely cold from November to March with temperature dropping down to sub-zero level along with snowfall sometimes even in the month of March. The average relative humidity remains between 83 to 96 % with mean annual rainfall of about 330 cm⁹.

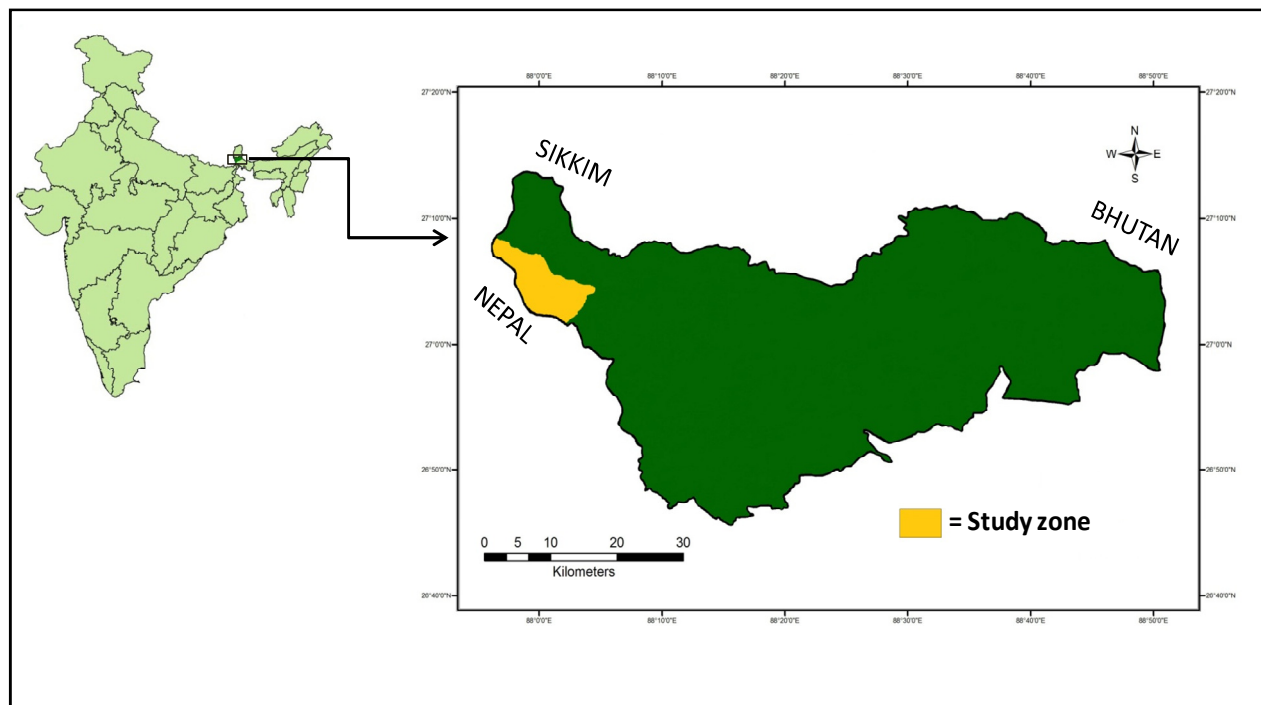


Figure -1
Map of Darjiling showing study zone

Phytosociological analysis: Phytosociological analysis was conducted to understand the overall spectrum of vegetation of the region, to have knowledge about species richness, dominance, diversity and evenness. Density, distribution, abundance and dominance are some of the quantitative measures of the species commonly used to describe community structure and to understand the vegetation dynamics in shape and time. For studying phytosociology, nested quadrat method was used for sampling. Three sizes of quadrats were used in nested manner with 20 x 20 m plots for trees, 5 x 5 m sampling plots for shrubs/climbers and 1 x 1 m plots for recording ground cover based on slope and vegetation¹⁰. In each quadrat, individuals with girth size of >15 cm cbh (circumference at breast height i.e. 1.37 m above the ground) were counted as trees. Individuals within the cbh range of 10 – 15 cm were considered as shrubs and individuals with <10 cm cbh were considered as herbs or seedlings. The location and altitude of the study area were noted using global positioning system (GPS; Garmin eTrex H).

The collected voucher specimens were processed into mounted herbarium sheets following the conventional methodology¹¹ and were identified and deposited at the NBU Herbarium. The vegetation data were computed and analyzed for the determination of frequency, density and abundance^{10,12}. The Importance Value Index (IVI) for each species was obtained by summing up the values of relative density, relative frequency and relative abundance¹³. The species with the highest IVI scores in the community were grouped as dominant species. Species other than the dominants were grouped into co-

dominants, associates and rare in the process. The species diversity was determined using Shannon-Weaver Index $H' = -\sum [(ni/N)\ln(ni/N)]$, where, 'H' is the index value, 'ni' number of individuals of a species, 'N' total number of species in the habitat type¹⁴. Species richness was calculated using Menhinick's Index $D = S/\sqrt{N}$, where, 'D' is the index value, 'S' total number of species, 'N' total number of individuals of all species¹⁵. The concentration of dominance was computed by Simpson's Index $\lambda = \sum (ni/N)^2$, where, 'λ' is the index value, 'ni' number of individuals of a species, 'N' total number of species in the habitat type¹⁶. The evenness index of the community was estimated following Pielou's Index $J' = H'/\log S$, where, 'J' is the index value, 'H' is Shannon index and 'S' is the total number of species¹⁷.

For soil-quality analysis, soil samples were collected from 5 different altitudinal sites within the study area. For each site, soils were collected from top layer (0 – 15 cm) and sub-layer (15 – 40 cm) and were analyzed for different nutrient status. Estimation of pH by McKeague method¹⁸, total organic carbon by Walkley and Black method¹⁹, Nitrogen by Kjeldahl method²⁰, Potassium by ammonium acetate extraction method²¹ and Phosphorus by Bray I method²² were followed.

Results and Discussion

A total of 157 plant species belonging to 72 families and 114 genera represented in table 3-5 were recorded from the cold temperate zone of Darjiling Himalaya through quadrat sampling. Out of these, 3 species were identified up to genus

level only. Tree species encountered 15 families, shrub/climbers 23 families and 34 families for the herb layer. The family with highest number of species in tree and shrub layer was Ericaceae with 10 species, followed by Rosaceae (8 species). In herb layer, the highest representation was of Asteraceae with 11 species followed by Polypodiaceae (6 species). The characteristic of the vegetation in the study area was basically heterogenous. It has been assumed that the dominating plant species actually determines the structure of the community and not characteristics²³. The most dominant species in the canopy layer was *Rhododendron arboreum* (IVI: 26.911). The highest frequency was also recorded for *Rhododendron arboreum* followed by *Acer campbellii*, and two species of *Lithocarpus*. The abundance to frequency ratio was highest for *Carpinus viminea* and least for *Acer campbellii*. The highest density was recorded for *Rhododendron arboreum* followed by *Rhododendron arboreum* var. *cinnamomeum* and lowest for *Gamblea ciliata*. The abundance was also highest for *Rhododendron arboreum* and least for *Merrillioanax alpinus*. In the shrub layer, 43 species of shrubs and climbers belonging to 31 genera were recorded through the process. The dominant species was *Daphne bholua* var. *glacialis* (IVI: 14.752). The highest score of abundance to frequency ratio was recorded for *Rubus splendidissimus* and *Viburnum erubescens* and lowest was calculated for *Viburnum mullaha* and *Rubus paniculatus*. The highest frequency was shown by species like *Daphne bholua*, *Daphne bholua* var. *glacialis*, *Nellia thyrsiflora*, *Rosa sericea*, *Rubus paniculatus* and *Yushania maling*. The density recorded was highest for *Daphne bholua* var. *glacialis* and the least was for *Sambucus adnata* and *Treutlera insignis*. 83 species of plants under 62 genera were recorded from the ground cover vegetation. The most dominant species was *Fragaria nubicola* (IVI: 6.263). The abundance to frequency ratio was estimated highest for *Craniogramme procera* and lowest for *Ainsliaea aptera*. The frequency recorded was highest for *Ainsliaea aptera*, *Anaphalis busua*, *Primula ianthina*, *Ranunculus diffusus* and *Viola hookeri* whereas the abundance was maximum for *Fragaria nubicola* and least for *Arisaema concinuum* and *Codonopsis affinis*. The results obtained showed that *Rhododendron arboreum* var. *cinnamomeum* (IVI: 23.879) in trees, *Daphne bholua* (IVI: 13.222) in shrub layer and *Anaphalis triplinervis* (IVI: 6.099) in herbs were the co-dominants in the study area, whereas *Gamblea ciliata* (IVI: 2.575) in the canopy, *Sambucus adnata* and *Treutlera insignis* (IVI: 2.636) in shrubs and climbers and *Arisaema concinuum* and *Codonopsis affinis* (IVI: 1.126) in ground cover were considered scarce in the study area.

Table -1 provides the nutrient status analysis of the soil sample collected from five different sites. pH ranged from 4.89 to 5.16 with an average pH of 5.0. The soil indicated more acidic property as the altitude is increased. This increased acidity may be due to the dominance of conifers, as coniferous canopy brings about long term changes in soil chemistry through the

acidification of slowly decomposing forest floor litter²⁴. The organic carbon content ranged from 1.38 to 1.61 % with an average value of 1.45 % indicating suitable for species growth. The average percent of Nitrogen was 0.20 and Phosphorus and Potassium were present at 16.5 ppm and 74.4 ppm respectively.

Species richness is one vital aspect for the conservation of an area²⁵. At the study sites, species richness differed with the change in altitude and slope. Towards the higher belt, above 3000 m, the species richness was low especially in the ground cover which explains the pattern of decrease in species richness with the increase of altitude²⁶. The increase in the population of the *Yushania maling* was quite high inside the forest at certain areas and this has caused a decline of diversity in the under storey vegetation resulting low species richness. Even, it creates difficulty for tree seedlings and saplings to grow up at the initial establishment phases. Tree species exhibited heterogeneous pattern of distribution along the altitude as because the higher zones were dominated mostly by *Abies densa* and species of *Rhododendron*. Species like *Lyonia ovalifolia*, *Berberis aristata* and *Fragaria nubicola* exhibited wide ecological amplitude whereas *Abies densa*, *Treutlera insignis* and *Bistorta emodi* exhibited narrow ecological amplitude showing limited distribution.

The vegetation of this zone houses numerous medicinal plants including *Rhododendrons*, *Daphne bholua*, *Mahonia napaulensis*, *Fragaria nubicola* and *Swertia bimaculata*²⁷ which are used by the local people for various purposes and also some poisonous species such as *Lyonia ovalifolia*²⁸ *Pieris formosa*, *Aconitum lethale* and *Meconopsis paniculata*. Few species like *Aconitum lethale*, *Rosa sericea*, *Codonopsis affinis* and *Swertia bimaculata* were found to be in RET categories²⁷.

The diversity of species in the study area was high upto an altitude of 2800 m exhibiting richness in all the three tiers and it gradually decreased towards the higher zones. The reason may be due to the slope and aspect of the area. Towards higher belt there was much wind velocity and therefore the surface soil on the slope facing the harsh wind were eroded frequently resulting in the decline of ground cover vegetation. At 3200 m, which was dominated by conifers like *Abies densa*, the forest floor was thickly covered with partially decomposed litter which might be an important reason for poor vegetation development for shrubs and ground cover tiers. The low temperature and accumulation of snow for few months may also be the reason for the poor ground cover vegetation at this altitude.

The ecosystem can be evaluated on the basis of species diversity²⁹. The species diversity, concentration of dominance, species richness and evenness for different layers of plant species determined in the present study has been depicted in table -2.

Table-1
Physicochemical characteristics of soil from different sites of the study area

Layer	Site 1		Site 2		Site 3		Site 4		Site 5	
	Top	Sub	Top	Sub	Top	Sub	Top	Sub	Top	Sub
pH	5.16	5.01	5.08	5.11	5.10	4.96	4.90	4.94	4.89	4.93
O.C (%)	1.41	1.38	1.38	1.40	1.56	1.50	1.61	1.46	1.49	1.38
N (%)	0.19	0.19	0.19	0.19	0.22	0.21	0.22	0.20	0.21	0.19
P (ppm)	18.5	12.5	20.0	15.0	18.5	12.0	20.0	18.0	15.5	15.0
K (ppm)	80.0	74.8	78.0	72.5	79.8	70.0	76.8	74.0	70.2	68.1

Table -2
Determined indices for different habit groups

Layers	Species diversity (H')	Species richness (D)	Concentration of dominance (λ)	Species evenness (J')
Tree	3.131	1.799	0.56	0.911
Shrub/Climber	3.577	2.974	0.032	0.951
Herb	4.332	3.568	0.014	0.983

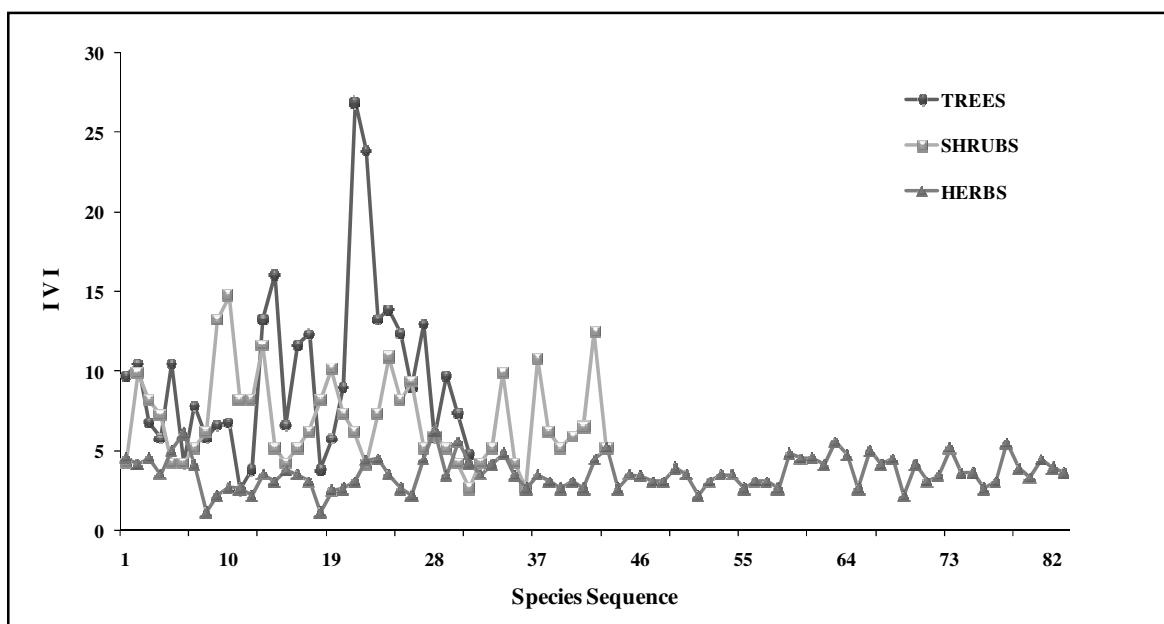


Figure -2
Dominance-diversity curve for different layers

The species diversity was recorded highest for herbs (4.332) and lowest for tree layers (3.131). The species richness was also highest for the herb layer (3.568). Moreover the concentration of dominance was inversely proportional to the species diversity showing highest for trees (0.056) and lowest for herbs (0.014). The greater the value of dominance index, the lower the species diversity and *vice versa* in the scale of zero to one³⁰. The evenness pattern for the species was highest for herbs (0.980) and least for the tree layer (0.911). Figure -2 shows the dominance-diversity curve that has been plotted on the basis of IVI. The correlation between species diversity and importance value index for all the three layers showed a much positive correlation as shown in figure -3.

Conclusion

The present study from the cold temperate zone of Darjiling Himalaya revealed quite a good scenario of species richness and diversity. Many species depicted a very high richness whereas some were sparsely populated. The study zone is also rich in possessing medicinal and poisonous plants. Due to the inconvenience in transportation in the higher belt, the inhabitants living in and around the region are fully dependant on the forest for fuel and this causes degradation in the vegetation, especially in the under-storey. Therefore, it is expected that the mass of quantitative data produced through the present study will be useful for the management to build up appropriate conservation strategies in this zone in participation

with the local inhabitants. Moreover, different parameters like the altitude, aspect, slope and the climate play important role in the formation of healthy vegetation in this region of Darjiling Himalaya.

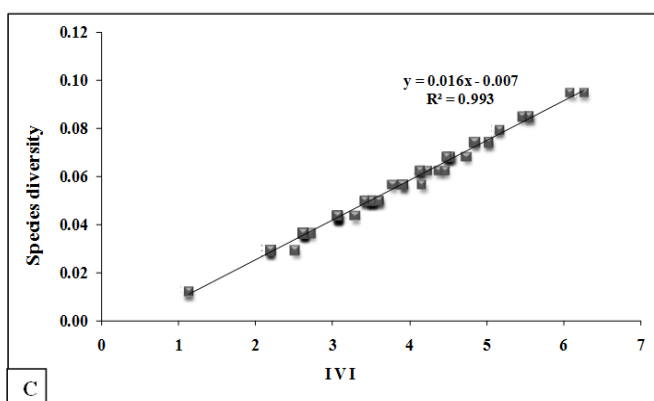
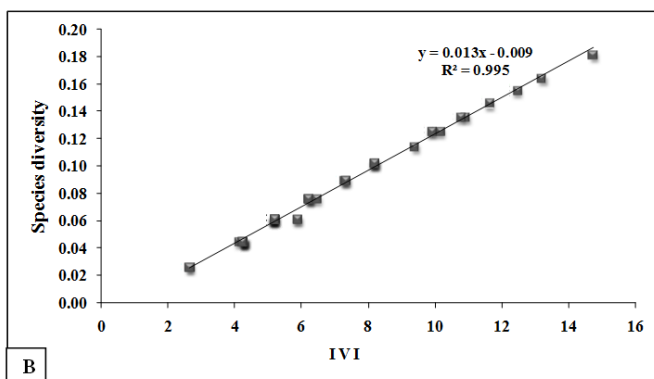
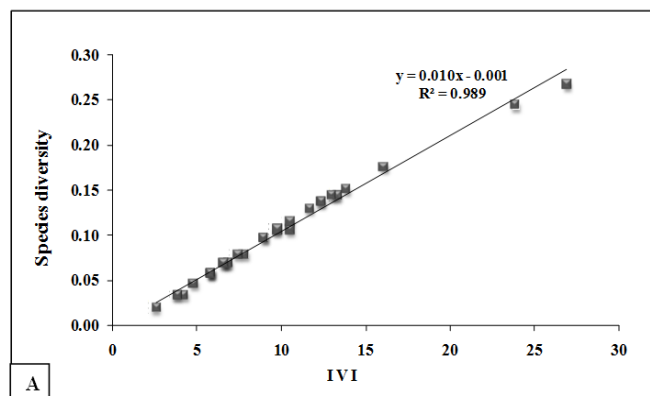


Figure-3
Correlation between Species diversity and Importance Value Index: A. Tree species; B. Shrub/climber species; C. Herb species

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Table-3
Phytosociological characteristics of the Tree Species

TREES	FAMILY	F	D	A	RF	RD	RA	IVI	A/F
<i>Abies densa</i> Griffith	Pinaceae	15.0	0.45	3.00	2.752	3.030	3.962	9.745	0.20
<i>Acer campbellii</i> Hooker f. and Thomson ex Hiern	Sapindaceae	30.0	0.45	1.50	5.505	3.030	1.981	10.516	0.05
<i>Acer caudatum</i> Wallich	Sapindaceae	10.0	0.25	2.50	1.835	1.684	3.302	6.820	0.25
<i>Acer pectinatum</i> Wallich ex Nicholson	Sapindaceae	10.0	0.20	2.00	1.835	1.347	2.641	5.823	0.20
<i>Acer sikkimense</i> Miquel	Sapindaceae	15.0	0.50	3.33	2.752	3.367	4.402	10.521	0.22
<i>Carpinus viminea</i> Lindley	Betulaceae	5.0	0.10	2.00	0.917	0.673	2.641	4.232	0.40
<i>Daphniphyllum himalense</i> (Bentham) Müller Argoviensis	Daphniphyllaceae	10.0	0.30	3.00	1.835	2.020	3.962	7.817	0.30
<i>Elaeagnus conferta</i> Roxburgh	Elaeagnaceae	10.0	0.20	2.00	1.835	1.347	2.641	5.823	0.20
<i>Enkianthus deflexus</i> (Griffith) C.K. Schneider	Ericaceae	15.0	0.25	1.67	2.752	1.684	2.201	6.637	0.11
<i>Eurya cavinervis</i> Vesque	Pentaphylacaceae	10.0	0.25	2.50	1.835	1.684	3.302	6.820	0.25
<i>Gamblea ciliata</i> Clarke	Araliaceae	5.0	0.05	1.00	0.917	0.337	1.321	2.575	0.20
<i>Ilex fragilis</i> Hooker f.	Aquifoliaceae	10.0	0.10	1.00	1.835	0.673	1.321	3.829	0.10
<i>Lithocarpus fenestratus</i> (Roxburgh) Rehder	Fagaceae	30.0	0.70	2.33	5.505	4.714	3.082	13.300	0.08
<i>Lithocarpus pachyphyllus</i> (Kurz) Rehder	Fagaceae	30.0	0.95	3.17	5.505	6.397	4.182	16.084	0.11
<i>Litsea elongata</i> (Nees) Hooker f.	Lauraceae	15.0	0.25	1.67	2.752	1.684	2.201	6.637	0.11
<i>Lyonia ovalifolia</i> (Wallich) Drude	Ericaceae	20.0	0.60	3.00	3.670	4.040	3.962	11.672	0.15
<i>Magnolia campbellii</i> Hooker f. and Thomson	Magnoliaceae	20.0	0.65	3.25	3.670	4.377	4.292	12.339	0.16
<i>Merrillioanax alpinus</i> (Clarke) C.B. Shang	Araliaceae	10.0	0.10	1.00	1.835	0.673	1.321	3.829	0.10
<i>Pieris formosa</i> (Wallich) D. Don	Ericaceae	10.0	0.20	2.00	1.835	1.347	2.641	5.823	0.20
<i>Quercus lamellosa</i> Smith	Fagaceae	20.0	0.40	2.00	3.670	2.694	2.641	9.005	0.10
<i>Rhododendron arboreum</i> Smith	Ericaceae	35.0	1.95	5.57	6.422	13.131	7.358	26.911	0.16
<i>Rhododendron arboreum</i> var. <i>cinnamomeum</i> (Wallich ex G. Don) Lindley	Ericaceae	30.0	1.65	5.50	5.505	11.111	7.264	23.879	0.18
<i>Rhododendron barbatum</i> Wallich ex G. Don	Ericaceae	30.0	0.70	2.33	5.505	4.714	3.082	13.300	0.08
<i>Rhododendron falconeri</i> Hooker f.	Ericaceae	30.0	0.75	2.50	5.505	5.051	3.302	13.857	0.08
<i>Rhododendron grande</i> Wight	Ericaceae	25.0	0.65	2.60	4.587	4.377	3.434	12.398	0.10
<i>Rhododendron griffithianum</i> Wight	Ericaceae	20.0	0.40	2.00	3.670	2.694	2.641	9.005	0.10
<i>Rhododendron hodgsonii</i> Hooker f.	Ericaceae	25.0	0.70	2.80	4.587	4.714	3.698	12.999	0.11
<i>Salix daltoniana</i> Anderson	Salicaceae	10.0	0.20	2.00	1.835	1.347	2.641	5.823	0.20
<i>Sorbus vestita</i> (Wallich ex G. Don) Loddiges	Rosaceae	15.0	0.45	3.00	2.752	3.030	3.962	9.745	0.20
<i>Symplocos dryophila</i> Clarke	Symplocaceae	15.0	0.30	2.00	2.752	2.020	2.641	7.414	0.13
<i>Tsuga dumosa</i> (D. Don) Eichler	Pinaceae	10.0	0.15	1.50	1.835	1.010	1.981	4.826	0.15

Table -4
Phytosociological characteristics of the Shrub/climber

SHRUBS/CLIMBERS	FAMILY	F	D	A	RA	RD	RA	IVI	A/F
<i>Aristolochia nakaai</i> Maekawa	Aristolochiaceae	2.5	0.05	2.00	1.010	0.956	2.297	4.263	0.80
<i>Berberis aristata</i> DC.	Berberidaceae	7.5	0.20	2.67	3.030	3.824	3.062	9.917	0.36
<i>Berberis insignis</i> Hooker f. and Thomson	Berberidaceae	7.5	0.15	2.00	3.030	2.868	2.297	8.195	0.27
<i>Biswarea tonglensis</i> (C.B. Clarke) Cogniaux	Cucurbitaceae	5.0	0.13	2.50	2.020	2.390	2.871	7.281	0.50
<i>Buddleja colvilei</i> Hooker f.	Scrophulariaceae	2.5	0.05	2.00	1.010	0.956	2.297	4.263	0.80
<i>Cayratia pedata</i> (Lamarck) Gagnepain	Vitaceae	2.5	0.05	2.00	1.010	0.956	2.297	4.263	0.80
<i>Clematis buchananiana</i> DC.	Ranunculaceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30
<i>Crawfordia speciosa</i> C.B. Clarke	Gentianaceae	5.0	0.10	2.00	2.020	1.912	2.297	6.229	0.40
<i>Daphne bholua</i> Buch.-Ham. ex D. Don	Thymelaeaceae	10.0	0.30	3.00	4.040	5.736	3.445	13.222	0.30
<i>Daphne bholua</i> var. <i>glacialis</i> (Smith and Cave) Burt	Thymelaeaceae	10.0	0.35	3.50	4.040	6.692	4.019	14.752	0.35
<i>Elsholtzia fruticosa</i> (D. Don) Rehder	Lamiaceae	7.5	0.15	2.00	3.030	2.868	2.297	8.195	0.27
<i>Gaultheria fragrantissima</i> Wallich	Ericaceae	7.5	0.15	2.00	3.030	2.868	2.297	8.195	0.27
<i>Gaultheria nummularioides</i> D. Don	Ericaceae	7.5	0.25	3.33	3.030	4.780	3.828	11.638	0.44
<i>Holboellia latifolia</i> Wallich	Berberidaceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30
<i>Leycesteria stipulata</i> (Hooker f. and Thomson) Fritsch	Caprifoliaceae	2.5	0.05	2.00	1.010	0.956	2.297	4.263	0.80
<i>Ligustrum confusum</i> Decaisne	Oleaceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30
<i>Lonicera hispida</i> P.S. Pallas ex Schultes	Caprifoliaceae	5.0	0.10	2.00	2.020	1.912	2.297	6.229	0.40
<i>Mahonia napaulensis</i> DC.	Berberidaceae	7.5	0.15	2.00	3.030	2.868	2.297	8.195	0.27
<i>Neillia thyrsoiflora</i> D. Don	Rosaceae	10.0	0.20	2.00	4.040	3.824	2.297	10.161	0.20
<i>Prinsepia utilis</i> Royle	Rosaceae	7.5	0.13	1.67	3.030	2.390	1.914	7.334	0.22
<i>Ribes glaciale</i> Wallich	Grossulariaceae	5.0	0.10	2.00	2.020	1.912	2.297	6.229	0.40
<i>Ribes</i> sp.	Grossulariaceae	5.0	0.05	1.00	2.020	0.956	1.148	4.125	0.20
<i>Ribes takare</i> D. Don	Grossulariaceae	7.5	0.13	1.67	3.030	2.390	1.914	7.334	0.22
<i>Rosa sericea</i> Wallich ex Lindley	Rosaceae	10.0	0.23	2.25	4.040	4.302	2.584	10.926	0.23
<i>Rubus lineatus</i> Reinwardt ex Blume	Rosaceae	7.5	0.15	2.00	3.030	2.868	2.297	8.195	0.27
<i>Rubus paniculatus</i> Smith	Rosaceae	10.0	0.18	1.75	4.040	3.346	2.010	9.396	0.18
<i>Rubus</i> sp.	Rosaceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30
<i>Rubus splendidissimus</i> H. Hara	Rosaceae	2.5	0.08	3.00	1.010	1.434	3.445	5.889	1.20
<i>Rubus wardii</i> Merrill	Rosaceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30
<i>Sabia campanulata</i> Wallich	Sabiaceae	2.5	0.05	2.00	1.010	0.956	2.297	4.263	0.80
<i>Sambucus adnata</i> Wallich ex DC.	Adoxaceae	2.5	0.03	1.00	1.010	0.478	1.148	2.636	0.40
<i>Schefflera rhododendrifolia</i> (Griffith) Frodin	Araliaceae	2.5	0.05	2.00	1.010	0.956	2.297	4.263	0.80
<i>Schisandra grandiflora</i> (Wallich) Hooker f. and Thomson	Schisandraceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30
<i>Senecio scandens</i> Buchanan-Hamilton ex D. Don	Asteraceae	7.5	0.20	2.67	3.030	3.824	3.062	9.917	0.36
<i>Smilax elegans</i> Wallich ex Kunth	Smilacaceae	2.5	0.05	2.00	1.010	0.956	2.297	4.263	0.80
<i>Treutlera insignis</i> Hooker f.	Apocynaceae	2.5	0.03	1.00	1.010	0.478	1.148	2.636	0.40
<i>Vaccinium retusum</i> (Griffith) Hooker f. ex C.B. Clarke	Ericaceae	7.5	0.23	3.00	3.030	4.302	3.445	10.778	0.40
<i>Vaccinium vacciniaceum</i> (Roxburgh) Sleumer	Ericaceae	5.0	0.10	2.00	2.020	1.912	2.297	6.229	0.40
<i>Viburnum cotinifolium</i> D. Don	Adoxaceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30
<i>Viburnum erubescens</i> Wallich	Adoxaceae	2.5	0.08	3.00	1.010	1.434	3.445	5.889	1.20
<i>Viburnum mullaha</i> Buchanan-Hamilton ex D. Don	Adoxaceae	7.5	0.10	1.33	3.030	1.912	1.531	6.474	0.18
<i>Yushania maling</i> (Gamble) Majumdar and Karthikeyan	Poaceae	10.0	0.28	2.75	4.040	5.258	3.158	12.457	0.28
<i>Zanthoxylum oxyphyllum</i> Edgeworth	Rutaceae	5.0	0.08	1.50	2.020	1.434	1.723	5.177	0.30

Table-5
Phytosociological characteristics of the Herb Species

HERBS	FAMILY	F	D	A	RF	RD	RA	IVI	A/F
<i>Aconitum lethale</i> Griffith	Ranunculaceae	4.0	0.09	2.25	1.724	1.664	1.149	4.536	0.56
<i>Ainsliaea aptera</i> DC.	Asteraceae	5.0	0.07	1.40	2.155	1.294	0.715	4.164	0.28
<i>Ainsliaea latifolia</i> (D. Don) Schultz-Bipontinus	Asteraceae	4.0	0.09	2.25	1.724	1.664	1.149	4.536	0.56
<i>Ajuga lobata</i> D. Don	Lamiaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Anaphalis busua</i> (Buchanan-Hamilton) DC.	Asteraceae	5.0	0.10	2.00	2.155	1.848	1.021	5.025	0.40
<i>Anaphalis triplinervis</i> (Sims) Sims ex C.B. Clarke	Asteraceae	4.0	0.14	3.50	1.724	2.588	1.787	6.099	0.88
<i>Anemone rupicola</i> J.Cambessèdes	Ranunculaceae	3.0	0.08	2.67	1.293	1.479	1.361	4.133	0.89
<i>Arisaema concinnum</i> Schott	Araceae	1.0	0.01	1.00	0.431	0.185	0.511	1.126	1.00
<i>Arisaema consanguineum</i> Schott	Araceae	2.0	0.03	1.50	0.862	0.555	0.766	2.182	0.75
<i>Arisaema griffithii</i> Schott	Araceae	3.0	0.04	1.33	1.293	0.739	0.681	2.713	0.44
<i>Arisaema propinquum</i> Schott	Araceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Arisaema speciosum</i> (Wallich) Martius	Araceae	2.0	0.03	1.50	0.862	0.555	0.766	2.182	0.75
<i>Belvisia henryi</i> (Hieronymus ex C. Christensen) Raymond	Polypodiaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Bistorta emodi</i> (Meisner) H. Hara	Polygonaceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Boenninghausenia albiflora</i> (Hooker) Reichenbach ex Meisner	Rutaceae	3.0	0.07	2.33	1.293	1.294	1.191	3.778	0.78
<i>Chlorophytum nepalense</i> (Lindley) Baker	Asparagaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Cirsium falconeri</i> (Hooker f.) F. Petrak	Asteraceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Codonopsis affinis</i> Hooker f. and Thomson	Campanulaceae	1.0	0.01	1.00	0.431	0.185	0.511	1.126	1.00
<i>Craniogramme procera</i> Fée	Hemionitidaceae	1.0	0.03	3.00	0.431	0.555	1.532	2.517	3.00
<i>Cynoglossum wallichii</i> G. Don	Boraginaceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Dennstaedtia scabra</i> (Wallich ex Hooker) Moore	Dennstaedtiaceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Dryopteris redactopinnata</i> Basu and Panigrahi	Dryopteridaceae	2.0	0.08	4.00	0.862	1.479	2.042	4.383	2.00
<i>Dryopteris sparsa</i> (D. Don) Kuntze	Dryopteridaceae	3.0	0.09	3.00	1.293	1.664	1.532	4.488	1.00
<i>Epilobium wallichianum</i> Haussknecht	Onagraceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Euonymus frigidus</i> Wallich	Celastraceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Euonymus tingens</i> Wallich	Celastraceae	2.0	0.03	1.50	0.862	0.555	0.766	2.182	0.75
<i>Fragaria daltoniana</i> J. Gay	Rosaceae	3.0	0.09	3.00	1.293	1.664	1.532	4.488	1.00
<i>Fragaria nubicola</i> (Lindley ex Hooker f.) Lacaïta	Rosaceae	3.0	0.14	4.67	1.293	2.588	2.382	6.263	1.56
<i>Fritillaria cirrhosa</i> D. Don	Liliaceae	3.0	0.06	2.00	1.293	1.109	1.021	3.423	0.67
<i>Gentiana capitata</i> Buchanan-Hamilton ex D. Don	Gentianaceae	3.0	0.12	4.00	1.293	2.218	2.042	5.553	1.33
<i>Gentiana pedicillata</i> (D. Don) Wallich	Gentianaceae	4.0	0.08	2.00	1.724	1.479	1.021	4.224	0.50
<i>Goniophlebium krameri</i> Panigrahi and Singh	Polypodiaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Helwingia himalaica</i> Hooker f. and Thomson ex C.B. Clarke	Helwingiaceae	3.0	0.08	2.67	1.293	1.479	1.361	4.133	0.89
<i>Hemiphragma heterophyllum</i> Wallich	Plantaginaceae	3.0	0.10	3.33	1.293	1.848	1.702	4.843	1.11
<i>Himalaiella deltoidea</i> (DC.) Raab-Straube	Asteraceae	3.0	0.06	2.00	1.293	1.109	1.021	3.423	0.67

<i>Hypericum choisyianum</i> Wallich ex Robson	Hypericaceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Isodon scrophularioides</i> (Wallich ex Benth) Murata	Lamiaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Lepisorus nudus</i> (Hooker) Ching	Polypodiaceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Ligularia amplexicaulis</i> DC.	Asteraceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Lobelia montana</i> Reinwardt ex Blume	Campanulaceae	3.0	0.05	1.67	1.293	0.924	0.851	3.068	0.56
<i>Loxogramme cuspidata</i> (Zenker) Price	Polypodiaceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Maianthemum oleraceum</i> (Baker) LaFrankie	Asparagaceae	3.0	0.09	3.00	1.293	1.664	1.532	4.488	1.00
<i>Meconopsis paniculata</i> (D. Don) Prain	Papaveraceae	4.0	0.11	2.75	1.724	2.033	1.404	5.161	0.69
<i>Microlepia</i> sp.	Dennstaedtiaceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Mimulus tenellus</i> var. <i>nepalensis</i> (Benth.) Tsoong	Phrymaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Myriactis nepalensis</i> Less.	Asteraceae	3.0	0.06	2.00	1.293	1.109	1.021	3.423	0.67
<i>Ophiopogon intermedius</i> D. Don	Asparagaceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Paris polyphylla</i> Smith	Melanthiaceae	3.0	0.05	1.67	1.293	0.924	0.851	3.068	0.56
<i>Parochetus communis</i> D. Don	Leguminosae	4.0	0.07	1.75	1.724	1.294	0.893	3.911	0.44
<i>Persicaria chinensis</i> (Linnaeus) Gross	Polygonaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Persicaria campanulata</i> (Hooker f.) Ronse Decraene	Polygonaceae	2.0	0.03	1.50	0.862	0.555	0.766	2.182	0.75
<i>Phymatosorus cuspidatus</i> (D. Don) Pichi Sermolli	Polypodiaceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Pichisermolodes stewartii</i> (Bedd.) Fraser-Jenkins	Polypodiaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Pilea symmeria</i> Weddell	Urticaceae	2.0	0.06	3.00	0.862	1.109	1.532	3.503	1.50
<i>Pimpinella diversifolia</i> DC.	Apiaceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Pleurospermum dentatum</i> (Benth) Clarke	Apiaceae	3.0	0.05	1.67	1.293	0.924	0.851	3.068	0.56
<i>Polygonatum brevistylum</i> Baker	Asparagaceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Polygonatum verticillatum</i> (Linnaeus) Allioni	Asparagaceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Potentilla polyphylla</i> Wallich ex Lehmann	Rosaceae	3.0	0.10	3.33	1.293	1.848	1.702	4.843	1.11
<i>Potentilla sundaica</i> (Blume) Kuntze	Rosaceae	3.0	0.09	3.00	1.293	1.664	1.532	4.488	1.00
<i>Primula capitata</i> Hooker	Primulaceae	4.0	0.09	2.25	1.724	1.664	1.149	4.536	0.56
<i>Primula denticulata</i> Smith	Primulaceae	3.0	0.08	2.67	1.293	1.479	1.361	4.133	0.89
<i>Primula gracilipes</i> Craib	Primulaceae	3.0	0.12	4.00	1.293	2.218	2.042	5.553	1.33
<i>Primula ianthina</i> Balfour f. and Cave	Primulaceae	5.0	0.09	1.80	2.155	1.664	0.919	4.738	0.36
<i>Prunella vulgaris</i> Linnaeus	Lamiaceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Ranunculus diffusus</i> DC.	Ranunculaceae	5.0	0.10	2.00	2.155	1.848	1.021	5.025	0.40
<i>Rubia wallichiana</i> Decne	Rubiaceae	3.0	0.08	2.67	1.293	1.479	1.361	4.133	0.89
<i>Sanicula elata</i> Buchanan-Hamilton ex D. Don	Apiaceae	3.0	0.09	3.00	1.293	1.664	1.532	4.488	1.00
<i>Satyrium nepalense</i> var. <i>ciliatum</i> (Lindley) Hooker f.	Orchidaceae	2.0	0.03	1.50	0.862	0.555	0.766	2.182	0.75
<i>Selinum wallichianum</i> (DC.) Raizada and H.O. Saxena	Apiaceae	3.0	0.08	2.67	1.293	1.479	1.361	4.133	0.89
<i>Senecio raphanifolius</i> Wallich ex DC.	Asteraceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Strobilanthes wallichii</i> Nees	Acanthaceae	3.0	0.06	2.00	1.293	1.109	1.021	3.423	0.67
<i>Swertia bimaculata</i> (Siebold and Zuccarini) Hooker f. and Thomson ex C.B. Clarke	Gentianaceae	4.0	0.11	2.75	1.724	2.033	1.404	5.161	0.69

<i>Swertia nervosa</i> (Wallich ex G. Don) C.B. Clarke	Gentianaceae	4.0	0.06	1.50	1.724	1.109	0.766	3.599	0.38
<i>Swertia paniculata</i> Wallich	Gentianaceae	4.0	0.06	1.50	1.724	1.109	0.766	3.599	0.38
<i>Synotis tetrantha</i> (DC.) Jeffrey and Y.L. Chen	Asteraceae	2.0	0.04	2.00	0.862	0.739	1.021	2.622	1.00
<i>Synotis wallichii</i> (DC.) Jeffrey and Y.L. Chan	Asteraceae	2.0	0.05	2.50	0.862	0.924	1.276	3.063	1.25
<i>Tiarella polyphylla</i> D. Don	Saxifragaceae	4.0	0.12	3.00	1.724	2.218	1.532	5.474	0.75
<i>Trollius pumilus</i> D. Don	Ranunculaceae	4.0	0.07	1.75	1.724	1.294	0.893	3.911	0.44
<i>Valeriana jatamansi</i> Jones	Caprifoliaceae	4.0	0.05	1.25	1.724	0.924	0.638	3.286	0.31
<i>Viola hookeri</i> Thomson ex Hooker f.	Violaceae	5.0	0.08	1.60	2.155	1.479	0.817	4.451	0.32
<i>Viola pilosa</i> Blume	Violaceae	4.0	0.07	1.75	1.724	1.294	0.893	3.911	0.44
<i>Viola wallichiana</i> Gingins	Violaceae	4.0	0.06	1.50	1.724	1.109	0.766	3.599	0.38

[F = Frequency, D = Density, A = Abundance, RF = Relative Frequency, RD = Relative Density, RA = Relative Abundance, IVI = Importance Value Index, A/F = Abundance/Frequency]