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SPECIES AND COMMUNITY DIVERSITY OF VASCULAR FLORA ALONG ENVIRONMENTAL GRADIENT IN NARAN VALLEY: A MULTIVARIATE APPROACH THROUGH INDICATOR SPECIES ANALYSIS

SHUJAUL MULK KHAN[1*], DAVID HARPER[1], SUE PAGE[2] AND HABIB AHMAD[3]

[1]Department of Biology, University of Leicester, UK, [2]Department of Geography, University of Leicester, UK
[2]Department of Botany, Hazara University Mansehra, Pakistan,
[*]E-mail of the corresponding author: shuja60@gmail.com

Abstract

Quantitative and qualitative characteristics of floristic diversity at species level along environmental gradients were measured using a randomly stratified design for identifying major plant communities of Narran Valley, Pakistan. Data was collected at 144 sampling stations along 24 altitudinal transects, 12 each at southern and northern aspects. Altitudinal range transects was within the limits of 2450 to 4100 masl. Some 198 species belonging to 68 families were indentified along transects. The Two Way Cluster Analysis (TWCA) and Indicator Species Analysis (ISA) recognized 5 plant communities with significant indicator species. The communities generally showed an elevation-latitudinal gradient complex from inclined, mesic-cool temperate vegetation of Phenerophytes and Chamaephytes, to more dry cold subalpine and alpine herbaceous vegetation of Cryptophytes and Therophytes. ISA analysis revealed that the mountain aspect, altitude from the sea level and soil depth were the strongest environmental variables ($p \leq 0.05$) for determining the community structure. Species diversity was optimum at the middle altitudes (2800-3400 masl) as compared to either the lower or higher altitudes. Herbaceous vegetation had positive correlation with altitude as a function of eco-physiological pressures as generally observed on like other highly elevated peaks Himalayas.

Introduction

Classification of natural ecosystems into potential plant communities and habitat types is important for the long-term management of natural resources. Ecologists always try to understand the variation in species diversity along the environmental gradient like altitudinal gradient in mountainous ecosystems (Daubenmire, 1968; Vetaas & Grytnes, 2002). The Himalayas are the world's youngest and highest mountains, possessing diverse vegetation and hence are important locations for research into ecology and biodiversity conservation (Pei, 2001). Discovering and understanding the association of biotic and abiotic components of an ecosystem is a critical branch of ecological research (Tavili & Jafari, 2009). In mountainous regions, altitude shows the greatest effect in limiting plant species and community types (Chawla *et al*., 2008).

The use of computer-based statistical and multivariate analytical programs helps ecologists to discover structure in the data set and help them to analyse the effects of environmental factors on whole groups of species (Bergmeier, 2002; Anderson *et al*., 2006). Statistical programs reduce the complexity of data by classifying vegetation and relating the results to abiotc (environmental) components (Dufrêne & Legendre, 1997; McCune & Mefford, 1999; Terbraak & Prentice, 1988). Classification also overcomes problems of comprehension by summarizing field data in a low-dimensional space with similar samples and species near together and dissimilar ones far apart (Greig-Smith, 2010). Such approaches have rarely been used in vegetation studies of Pakistan (Malik & Husain, 2006; Saima *et al*., 2009; Wazir *et al*., 2008; Malik & Husain, 2008).

The Naran, a mountainous valley is located between 34° 54.26′N to 35° 08.76′ N latitude and 73°.38.90′ E to 74° 01.30′ E longitude with an elevation range of 2450 to 4100 masl., in the North Eastern part of District Mansehra, Pakistan. It is located on the extreme western boundary of the Himalayan range. Geologically the valley is on the extreme margin of the Indian Plate where it is still colliding against the Kohistan arc of Asian (Eurasian) plate and the location means that climatically, most of it lies out of monsoon range. The rocks of the valley can be subdivided into basement (metagranite and paragneiss) and amphibolites, marble, dolomite, quartzite and deformed granite (Najman *et al*., 2003; Parrish *et al*., 2006). The entire area is formed by transverse spurs of rugged mountains on either side of the river Kunhar. The river Kunhar emerges from the lake Lulusar near the Babusar pass at an elevation of 3455m. Its unique physiographic, climatic and geological history makes it also distinct floristically. Moreover Naran valley forms an important part of the Western Himalayan Province (Takhtadzhian & Cronquist, 1986). The climate of Naran valley as a whole is of dry temperate with heavy snowfall in winter and cool dry summers. Most of the year temperature remains below 10°C.

Most of the Himalayan valleys like Narran have not been studied with recently developed analytical tools due to the scarcity of skilled manpower, remote location, hardship in accessibility, rugged physiographic condition and critical geopolitical situation. This study was designed therefore, to quantify the abundance of species, analyze the communities and place them in such an ecological and vegetation framework acceptable in international terms, for understanding the environmental gradient responsible for the distribution of species and communities. The research hypothesis was that variation in the aspect (north- and south-facing) and altitude has a significant impact on species and community diversity of vascular plants in Naran valley, Pakistan.

Materials and Methods

In order to test the hypothesis, a phytosociological approach (Rieley & Page, 1990; Kent & Coker, 1994) was used to measure quantitative and qualitative attributes of vascular plants in quadrats along an altitudinal gradient during the summer 2009. The 60 Km long valley was divided using stratified random sampling into 12 sampling localities, each locality parting about at a distance of 5 Km. Two vertical transects, perpendicular to river

Kunhar running up both on the Northern and Southern aspects at each site was taken into consideration. The altitudinal limits covered by these transects were generally from 2450- 4100m.

Along each of the 24 transects, sampling was started from bed of the stream (in most cases the river Kunhar) and carried on till ridge of the mountain. Stations were established at 200m interval (total of 144 stations) along transects. Location map of the study area is presented in Fig. 1. At each station three quadrats each having an area of $50m^2$, $10m^2$ and $1m^2$ were placed randomly for determining the population of trees, shrubs and herbs, respectively (Daubenmire, 1968; Moore & Chapman, 1986). Species composition and abundance in each quadrat were recorded on the data sheets. Absolute and relative density, cover and frequency of each vascular plant species at each station were calculated using the formulae designed by Curtis & McIntosh (1950) using Microsoft Excel on an Asus palm-top computer. The plant specimens were mostly identified with the help of Flora of Pakistan (Nasir & Ali, 1970–1989; Ali & Nasir, 1990–1992; Ali & Qaiser, 1993–2009) and preserved in the Herbarium of Hazara University Pakistan (HUP). Plant life form assortment was done in accordance with the Raunkiaer's system (Mueller-Dombois & Ellenberg, 1974).

Altitude of the selected localities was measured GPS of Garmin eTrex· HC series, vista HCx. Soil pH was measured by BDH universal pH (0-14) paper kit. The soil depth was estimated with an iron rod of 2m length and classes 1-3 (shallow-deep) were assigned. Grazing pressure was estimated by classes 1-5 (low to high) though observing the recent signs and intensity of grazing effect. Aspect of the mountain i.e., South (S) and North (N) were determined with the help of a compass.

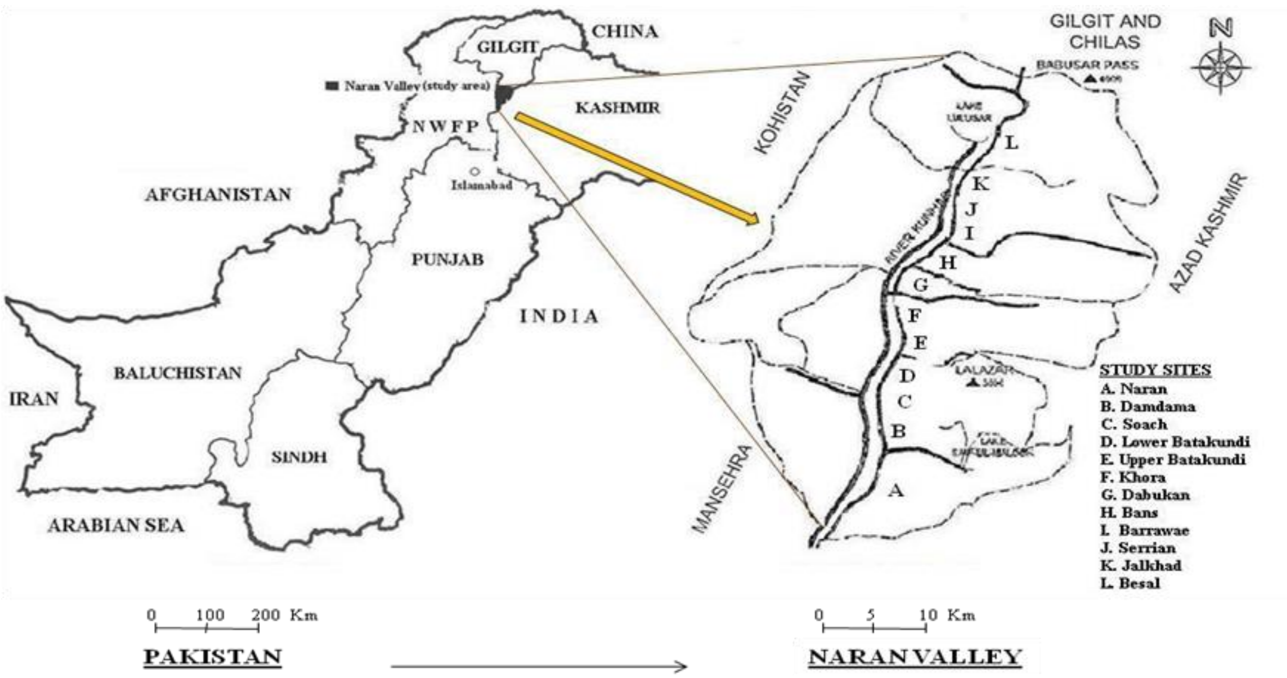

Fig. 1. Map of Pakistan, showing the location of project area the Naran Valley with 12 sampling localities (A-L).

The data collected from 144 sampling stations (1296 quadrats) and 5 environmental variables were analysed through multivariate statistics in PC-ORD version 5 (McCune & Mefford, 1999). Two Way Cluster analysis (TWCA) using Sorensen measures, based on presence/absence data (Greig-Smith, 2010) was carried out to identify pattern and order in the species and station data. Indicator Species Analysis (ISA) was subsequently used to link the floristic with environmental data. It combined information on the concentration of species abundance in a particular group and the faithfulness (fidelity) of occurrence of a species in that group. It constructed indicator values for each species in each group and tested for statistical significance using the Monte Carlo test. Indicator Species Analysis evaluated each species for the strength of its response to the environmental variables. A threshold level of indicator value 20% with 95% significance (p value ≤ 0.05) was chosen as cut off for identifying indicator species (Dufrêne & Legendre, 1997). The indicator species were used for naming the communities.

Results

Sum of 198 plant species (12 trees, 20 shrubs and 166 herbs) belong to 150 genera were recorded at the 144 stations (1296 relevés). The vegetation was dominated hemi-cryptophytes by followed by geophytes and therophytes. The phenerophytes and chamaephytes, less common; dominated the lower valley, lower altitude (2450-3200 masl) and northern slopes. The significant hemi-cryptophytic and geophytic components reflected the generalized features of alpine and subalpine nature of the vegetation of the valley.

Two Way Cluster Analyses broadly divided the plant community in to 5 assemblages which could be clearly seen in two main branches of the dendrogram; (i) the lower altitude (2450-3250 masl) including 3 communities/groups dominated by temperate vegetation and (ii) the higher altitude (3250-4100 masl) including 2 communities dominated by subalpine and alpine species (Fig. 2).

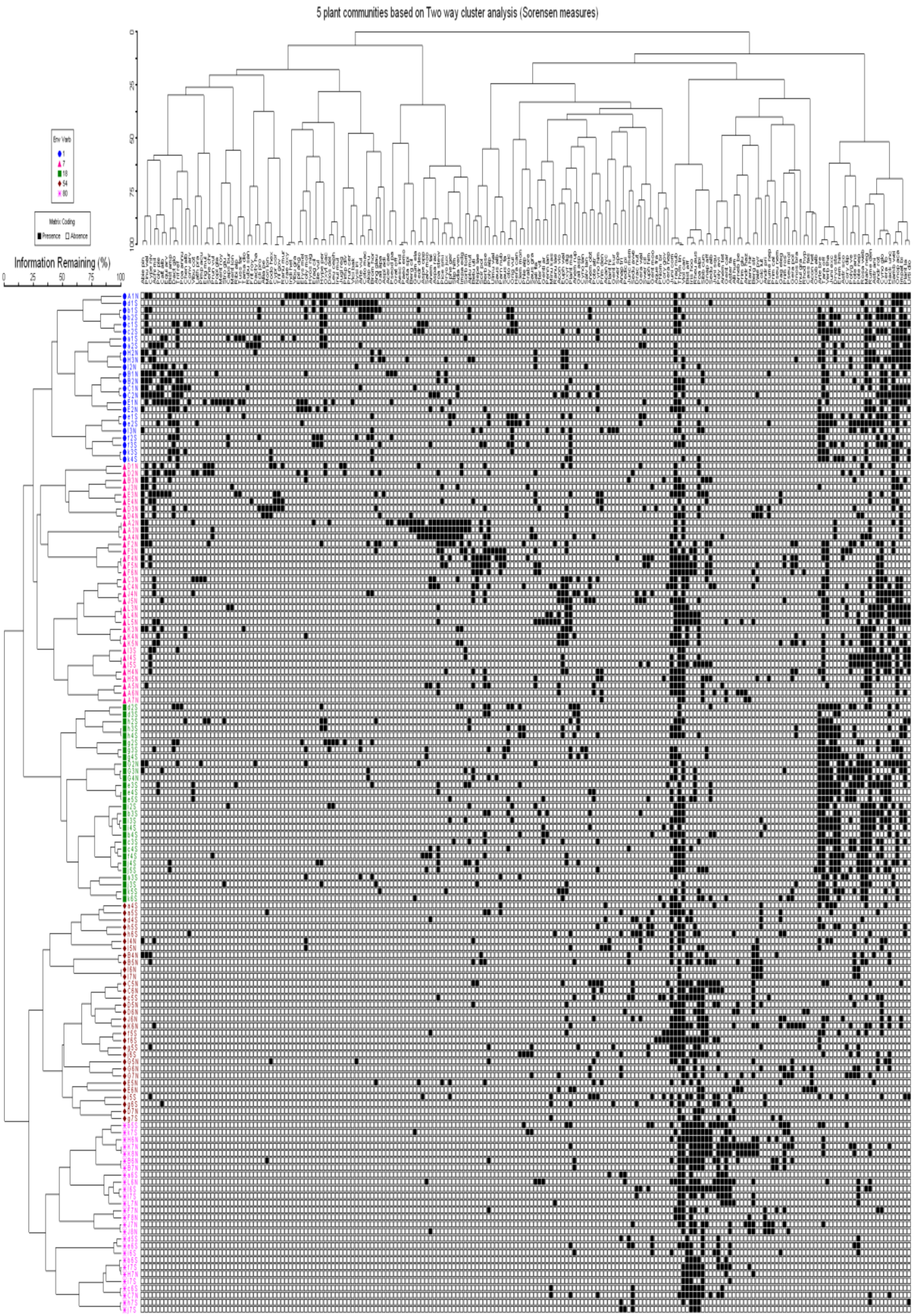

Fig. 2. Dendrogram of 144 stations and 198 plant species based on Sorensen measures showing 5 plant communities (groups), after Two Way Cluster Analysis through PC-ORD.

Indicator Species Analysis (ISA) identified indicator species and the main variables responsible for those communities. It showed that aspect, altitude and soil depth are the stronger ones among variables. It also showed the strength of the environment-species relationship using Monte Carlo procedures (Table 1). The 5 plant communities established in Naran Valley are presented as follows:

i. *Pinus wallichiana-Sambucus weightiana* community: This was the valley bottom or lower altitude plant community (indicator species identified by high soil depth classes 1 in Table 1 and Fig. 2). This community was found on either side of the River Kunhar at altitudes from 2450 to 2900 masl. The tree and shrub layer was characterised by *Pinus wallichiana* and *Sambucus wightiana* as indicator species. Other dominant species of this layer were *Cedrus deodara*, *Abies pindrow* and *Artemisia brevifolia.* Indicator species of the herb layer were *Impatiens bicolor*, *Plantago lanceolata* and *Onopordum acanthium.* Sub dominant species of herbaceous vegetation were *Trifolium repens* and *Hypericum perforatum.* Other common species of the herbaceous community includes *Dactylis glomerata*, *Urtica dioica*, *Bistorta amplexicaulis*, *Verbascum thapsus* and *Viola canescens*. The high soil depth was associated with relatively high grazing and anthropogenic pressures.

ii. *Abies pindrow-Betula utilis* community: This assemblage can be termed the plant assemblage of the middle altitude (2800-3400 masl), northern aspect (Table 1 and Fig. 2). Indicator species of the tree layers were *Abies pindrow* and *Betula utilis* while the shrub layer was characterised by *Salix flabellaris.* Which *Achillea millefolium* and *Fragaria nubicola* were the indicators species of the herb layer. Other prominent species were *Picea smithiana, Cedrus deodara, Impatiens bicolor, Oxyria digyna, Cynoglossum glochidiatum, Poa alpina, Valeriana pyrolifolia.* Shade-loving plants were quite common in this community. The most important environmental variable responsible for the formation of this community was the aspect (NW facing) associated with co-variables like a relatively high soil depth, low grazing pressure.

iii. *Juniperus excelsa-Artemisia brevifolia community*: This can also be named as the middle altitude (2800-3400 masl), southern aspect assemblage (Table 1 and Fig. 2). *Juniperus excelsa, Artemisia brevifolia, Eremurus himalaicus, Dryopteris stewartii* and *Taraxacum officinale* were the indicator species. The tree layer is almost absent as only few prostrate *Juniperus excelsa* were found on southern faces. A dominant shrub layer, characterized by *Artemisia brevifolia, Juniperus communis, Cotoneaster microphyllus* and *Rosa webbiana* was present. Other herbs were *Androsace rotundifolia, Malva neglecta, Hypericum perforatum, Onopordum acanthium, Verbascum thapsus,* and a woody climber *Clematis montana*. Trampling effect of the grazing animals was evident every where.

iv. *Rheum australe-Sibbaldia cuneata* community: This was the high altitude (3300-4000 masl) timber line plant assemblage. The indicator species were identified by altitude; (Table 1 and Fig. 2) and was comprised of subalpine and alpine vegetation characterized by the alpine *Rheum australe, Sibbaldia cuneata* and *Iris hookeriana.* The major vegetation pattern was herbaceous with a few shrub species at relatively lower altitudes (3300-3500 masl) such as *Juniperus communis, Juniperus squamata, Rhododendron hypenanthum,* and *Berberis pseudoumbellata.* Other dominant species were *Bergenia strachyei, Poa alpina, Thymus linearis, Bistorta affinis and Aconitum violaceum.* This community developed in between the timberline and alpine pastures at higher altitudes, irrespective of N and S aspects and overlapped community 5 (alpine pastures) at most of the stations.

v. *Aster falconeri-Iris hookeriana* community: This was the highest altitude (above 3700 masl), or alpine plant community with the indicator species identified by altitude; (Table 1 and Fig. 2) being *Aster falconeri, Iris hookeriana* and *Ranunculus hirtellus.* Other diagnostic species were *Anemone tetrasepala, Gentiana carinata* and *Rheum australe.* Tree and shrub (Phanerophtes and Chamaephytes) layers were completely absent. At this altitude the species richness was poor. Soil depth at these pastures was remained shallow and with exposed rocks. Grazing was the main pressure on the flora of that community.

Discussion

Drawing a sharp line in any mountain ecosystem is not easy, as rapid micro climatic and edaphic variations overlap each other due to the number of driving agencies and historical perspectives but the multivariate analyses established 5 distinct plant communities of vascular flora. Being in the Western Himalayan Province, the vegetation was mainly Sino-Japanese and was classified as different on the basis of altitude, aspect and soil depth, as has been described in other locations of this province (Takhtadzhian & Cronquist, 1986; Ali & Qaiser 1986; Champion *et el.*, 1965).

At the opening of the valley at the lowers altitudes, the vegetation has some characteristic species of moist temperate vegetation of the adjacent Kaghan valley to the south east e.g., *Pinus wallichiana, Aesculus indica, Prunus cerasoides, Indigofera heterantha, Viburnum grandiflorum, Viburnum cotinifolium, Paeonia emodi, Bistorta amplexicaulis* and *Trifolium repens* as reported from moist temperate Himalaya by Saima *et al*., (2009). Community 1 reflects the latitudinal gradient of vegetation i.e., moist temperate to dry temperate along the valley as this community found at lower altitudes. The *Abies pindrow-Betula utilis* Community and *Juniperus excelsa-Artemisia brevifolia* communities were mixtures of temperate and subalpine plant species under the influence of aspect and exhibit rich diversity. Community 4 and 5 are formed by subalpine and alpine species under the effect of high altitude characterized by alpine species like *Rheum australe, Sibbaldia cuneata, Iris hookeriana, Aster falconeri and Ranunculus hirtellus.* This type of latitudinal and altitudinal gradient complex has been found in other studies around the globe where topographic variables also influence vegetation (Chawla *et al*, 2008; Bergmeier, 2002; Sanhueza *et al*, 2009). High snowfall, short summer, low temperature, intense solar radiation and cold winds, result in xeric conditions for plant growth and hence β -diversity of species gradually decreasing both along the altitudinal and latitudinal gradients. This phenomenon of floristic occurrence has also been observed in neighour valleys (Wazir *et al.* 2008, Kharkwal *et al.*, 2005; Peer *et al.*, 2001; Sheikh *et al.*, 2002; Ahmad *et al*., 2009).

Table 1. Indicator Species Analyses (ISA) through PC-ORD showing Indicator (Characteristic) plant species (with bold font) for each of the 5 plant communities (1-5) at a threshold level of indicator value 20% and Monte Carlo test of significance for observed maximum indicator value of species (p value ≤ 0.05).

S. No.	Botanical name	*Pinus wallichiana – S. weightiana* community			*Abies pindrow-Betula utilis* community			Juniperus excels-*A. brevifolia* community			*Rheum australe-Sibbaldia cuneata* community			*Aster falconeri-Iris hookeriana* community		
		Group was defined by values of Soil depth classes; Max grp = 3 = highest soil depth			Group was defined by values of Aspect; Max grp = 1 = Northern aspect			Group were defined by values of Aspect; Max grp = 0 = Southern aspect			Group was defined by values of Altitude at masl; Max grp = 36-41 = 3600-3900 masl i.e., higher altitudes			Group was defined by values of Altitude at masl; Max grp = 40-41 = above 4000 masl i.e., highest altitudes		
		Max grp	Obs IV	p * value	Max grp	Obs IV	p * value	Max grp	Obs IV	p * value	Max grp	Obs IV	p * value	Max grp	Obs IV	p * value
1.	[2]***Abies pindrow*** Royle	3	28	0.001	**1**	**34**	**0.000**	1	34	0.000	28	12.6	0.2102	28	12.6	0.2102
2.	*Acer caesium* Wall ex Brandis	3	4	0.193	1	4	0.246	1	4	0.246	24	17	0.131	24	17	0.131
3.	*Aesculus indica* (Wall. Ex Camb) Hook.	3	2	1.000	1	1	1.000	1	1	1.000	26	25	0.0524	26	25	0.0524
4.	[2]***Betula utilis*** D. Don	2	10	0.201	**1**	**24**	**0.000**	1	24	0.000	32	12.6	0.2629	32	12.6	0.2629
5.	*Cedrus deodara* (Roxb. Ex Lamb.) G. Don	3	12	0.031	1	6	0.284	1	6	0.284	24	15	0.218	24	15	0.218
6.	*Crataegus oxycantha* L.	3	2	1.000	1	1	1.000	1	1	1.000	24	50	0.0256	24	50	0.0256
7.	*Juglans regia* L.	3	4	0.214	1	2	1.000	1	2	1.000	24	25.6	0.094	24	25.6	0.094
8.	*Picea smithiana* (Wall.) Boiss.	3	9	0.156	1	15	0.001	1	15	0.001	28	25.4	0.0314	28	25.4	0.0314
9.	[1]***Pinus wallichiana*** Jackson	**3**	**32**	**0.000**	**1**	22	0.001	1	22	0.001	25	18.1	0.0638	25	18.1	0.0638
10.	*Poplus glauca* H. Haines	3	3	0.617	1	3	0.494	1	3	0.494	26	19.4	0.096	26	19.4	0.096
11.	*Prunus cerasioides* D. Don	3	2	1.000	0	2	0.463	0	2	0.463	25	16.7	0.3151	25	16.7	0.3151
12.	*Ulmus wallichiana* Planch.	3	2	1.000	1	1	1.000	1	1	1.000	29	6.7	0.7664	29	6.7	0.7664
13.	[3]***Artemisia brevifolia*** Wall. ex DC	3	26	0.052	0	50	0.000	**0**	**50**	**0.000**	33	13.8	0.229	33	13.8	0.229
14.	*Artemisia vulgaris* L.	3	8	0.115	0	10	0.013	0	10	0.013	25	16.4	0.1818	25	16.4	0.1818
15.	*Berberis pseudoumbellata* Parker	2	10	0.346	1	12	0.318	1	12	0.318	32	8.9	0.5021	32	8.9	0.5021
16.	*Cotoneaster cashmiriensis* G.Klotz	3	6	0.146	0	6	0.040	0	6	0.040	25	43.5	0.0024	25	43.5	0.0024
17.	*Cotoneaster microphyllus* Wall. ex Lindl	3	12	0.063	0	19	0.000	0	19	0.000	27	15.9	0.1786	27	15.9	0.1786
18.	*Ephedra gerardiana* Wall. Ex Stapf	3	10	0.114	1	6	0.544	1	6	0.544	26	32.3	0.0114	26	32.3	0.0114
19.	*Indigofera heterantha* Wall. Ex Brand	3	2	1.000	1	1	1.000	1	1	1.000	24	50	0.0256	24	50	0.0256
20.	*Juniperus communis* L.	2	32	0.009	0	22	0.719	0	22	0.719	34	9.7	0.4577	34	9.7	0.4577
21.	[3]***Juniperus excelsa*** M. Bieb	3	15	0.124	0	35	0.000	**0**	**35**	**0.000**	27	5.8	0.8542	27	5.8	0.8542
22.	*Juniperus squamata* Buch.-Ham. ex D. Don	2	20	0.005	0	6	0.703	0	6	0.703	37	4.5	0.9346	37	4.5	0.9346
23.	*Rhododendron hypenanthum* Balf.f	2	8	0.081	1	8	0.026	1	8	0.026	36	7.1	0.5899	36	7.1	0.5899
24.	*Ribies alpestre* Decne	3	4	0.268	0	2	0.620	0	2	0.620	24	15.5	0.196	24	15.5	0.196
25.	*Rosa webbiana* Wallich ex Royle	3	19	0.126	0	17	0.495	0	17	0.495	31	10.2	0.4175	31	10.2	0.4175
26.	*Rubus sanctus* Schreber	3	3	0.611	0	1	0.747	0	1	0.747	26	19.4	0.087	26	19.4	0.087
27.	[2]***Salix flabellaris*** Andersson in Kung	3	7	0.508	**1**	**20**	**0.000**	1	20	0.000	30	5.8	0.7906	30	5.8	0.7906
28.	[1]***Sambucus wightiana*** Wall. ex Wight & Arn	**3**	**59**	**0.000**	1	21	0.282	1	21	0.282	25	22.9	0.03	25	22.9	0.03
29.	*Sorbaria tomentosa* (Lindl.) Rehder	3	12	0.058	0	4	0.962	0	4	0.962	24	49.5	0.0036	24	49.5	0.0036
30.	*Tamarix dioica* Roxb. ex Roch	3	6	0.160	0	2	1.000	0	2	1.000	24	23.6	0.1308	24	23.6	0.1308
31.	*Viburnum cotinifolium* D. Don	3	4	0.437	1	3	0.781	1	3	0.781	32	12.7	0.2691	32	12.7	0.2691
32.	*Viburnum grandiflorum* Wall. ex DC.	3	3	0.633	1	1	1.000	1	1	1.000	24	100	0.0004	24	100	0.0004

Table 1. (Cont'd.).

33.	*Acantholimon lycopodioides* Boiss.	1	2	0.650	0	2	0.365	0	2	0.365	30	14.6	0.1564	30	14.6	0.1564
34.	[2]***Achillea millefolium* L.**	3	27	0.002	**1**	**25**	**0.001**	1	25	0.001	26	8	0.5693	26	8	0.5693
35.	*Aconitum heterophyllum* Wall.	2	7	0.108	1	5	0.125	1	5	0.125	40	9.3	0.3971	40	9.3	0.3971
36.	*Aconitum violaceum* Jacquen ex. Stapf	2	6	0.380	1	12	0.011	1	12	0.011	34	9.7	0.4517	34	9.7	0.4517
37.	*Actaea spicata* L.	3	3	0.513	1	3	0.499	1	3	0.499	26	23.2	0.0592	26	23.2	0.0592
38.	*Adiantum venustum* D. Don	3	17	0.011	1	10	0.089	1	10	0.089	24	24.4	0.0496	24	24.4	0.0496
39.	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	3	3	0.506	1	3	0.493	1	3	0.493	31	4.6	0.9448	31	4.6	0.9448
40.	*Allium humile* Kunth.	1	4	0.816	1	8	0.105	1	8	0.105	38	15.4	0.2062	38	15.4	0.2062
41.	*Alopecurus arundinaceus* Poir.	1	3	0.799	1	4	0.699	1	4	0.699	28	7.6	0.5681	28	7.6	0.5681
42.	*Anaphalis triplinervis* (Sims) C. B. Clarke	2	13	0.017	0	8	0.086	0	8	0.086	40	14.1	0.2635	40	14.1	0.2635
43.	*Androsace hazarica* R.R. Stewart ex Y. Nasir	2	4	0.358	1	7	0.059	1	7	0.059	41	22.1	0.1194	41	22.1	0.1194
44.	*Androsace primuloides* Duby	1	11	0.033	1	3	0.859	1	3	0.859	41	19.7	0.1506	41	19.7	0.1506
45.	*Androsace rotundifolia* Watt	3	20	0.086	0	16	0.611	0	16	0.611	28	8.2	0.5859	28	8.2	0.5859
46.	*Anemone falconeri* Thoms.	3	5	0.678	1	7	0.542	1	7	0.542	41	12.2	0.2833	41	12.2	0.2833
47.	*Anemone obtusiloba* D.Don	2	6	0.490	0	5	0.945	0	5	0.945	40	3.1	0.9906	40	3.1	0.9906
48.	*Anemone rupicola* Cambess	2	6	0.452	1	5	0.673	1	5	0.673	32	5.1	0.8554	32	5.1	0.8554
49.	*Anemone tetrasepala* Royle	1	14	0.034	1	8	0.380	1	8	0.380	41	14.1	0.1858	41	14.1	0.1858
50.	*Angelica glauca* Edgew.	3	10	0.063	1	5	0.513	1	5	0.513	29	7.7	0.6317	29	7.7	0.6317
51.	*Apluda mutica* (L.) Hack	3	18	0.007	0	6	0.558	0	6	0.558	28	16.1	0.174	28	16.1	0.174
52.	*Aqueligea fragrans* Benth.	3	1	1.000	1	1	1.000	1	1	1.000	39	5.1	0.8312	39	5.1	0.8312
53.	*Arnebia benthamii* Wallich ex G. Don	2	14	0.018	1	12	0.003	1	12	0.003	41	15.9	0.201	41	15.9	0.201
54.	*Asparagus racemosus* Willd.	3	9	0.040	1	8	0.029	1	8	0.029	26	9.2	0.3601	26	9.2	0.3601
55.	*Asperula oppositifolia* Reg. & Schmalh.	3	6	0.264	0	4	0.487	0	4	0.487	27	7.4	0.6331	27	7.4	0.6331
56.	*Asplenium adiantum-nigrum*	3	3	0.573	1	3	0.489	1	3	0.489	30	11.5	0.4199	30	11.5	0.4199
57.	[5]***Aster falconeri*** **(C. B. Clarke) Hutch**	1	20	0.005	0	9	0.225	0	9	0.225	41	43.2	0.0056	**41**	**43.2**	**0.0056**
58.	*Astragalus anisocanthus* Boiss.	3	16	0.028	0	7	0.848	0	7	0.848	24	12.2	0.2775	24	12.2	0.2775
59.	*Astragalus scorpiurus* Bunge	3	11	0.207	1	9	0.499	1	9	0.499	26	13	0.223	26	13	0.223
60.	*Bergenia ciliata* (Haw.) Sternb.	3	4	0.209	1	4	0.237	1	4	0.237	28	12.4	0.2841	28	12.4	0.2841
61.	[4]***Bergenia strachyei*** (Hook. f. & Thoms) Engl	1	32	0.001	1	31	0.000	1	31	0.000	**38**	**14.7**	**0.1614**	41	14.7	0.1614
62.	*Bistorta affinis* (D.Don) Green	2	21	0.052	1	14	0.790	1	14	0.790	36	16.2	0.155	36	16.2	0.155
63.	*Bistorta amplexicaulis* (D. Don)	3	18	0.008	1	5	0.990	1	5	0.990	26	9.4	0.4779	26	9.4	0.4779
64.	*Bromus hordeaceus* L.	3	16	0.024	0	10	0.122	0	10	0.122	26	9.6	0.4453	26	9.6	0.4453
65.	*Caltha alba* Jack. Ex Comb	3	16	0.023	1	12	0.043	1	12	0.043	25	14.2	0.2284	25	14.2	0.2284
66.	*Capsella bursa-pastoris* (L.) Medic.	3	10	0.053	0	4	0.562	0	4	0.562	24	20.4	0.1232	24	20.4	0.1232
67.	*Cassiope fastigiata* (Wallich) D. Don	2	4	0.414	1	3	0.493	1	3	0.493	36	12.1	0.3937	36	12.1	0.3937
68.	*Cerastium fontanum* Baumg.	3	11	0.575	0	11	0.773	0	11	0.773	27	11.7	0.3079	27	11.7	0.3079
69.	*Chenopodium album* L.	3	10	0.057	1	5	0.476	1	5	0.476	25	10.4	0.3865	25	10.4	0.3865
70.	*Clematis montana* Buch.-Ham. ex DC.	3	4	0.581	0	12	0.002	0	12	0.002	28	19.2	0.1112	28	19.2	0.1112
71.	*Colchicum luteum* Baker	2	7	0.358	1	6	0.710	1	6	0.710	31	4.4	0.9182	31	4.4	0.9182
72.	*Convolulus arvensis* L.	3	2	0.826	0	2	0.751	0	2	0.751	25	12	0.3107	25	12	0.3107
73.	*Corydalis diphylla* Wall.	2	5	0.738	0	7	0.461	0	7	0.461	32	11.4	0.3359	32	11.4	0.3359
74.	*Corydalis govaniana* Wall.	2	11	0.037	0	6	0.269	0	6	0.269	30	9.2	0.4655	30	9.2	0.4655

Table 1. (Cont'd.).

75.	*Cynoglossum glochidiatum* Wall. Ex Benth .	3	31	0.008	1	24	0.245	1	24	0.245	27	16.5	0.108	27	16.5	0.108
76.	*Cynoglossum himaltoni*	3	7	0.536	1	7	0.739	1	7	0.739	24	14.4	0.1938	24	14.4	0.1938
77.	*Cynoglossum lanceolatum* L.	3	2	1.000	0	2	0.470	0	2	0.470	31	5.9	1	31	5.9	1
78.	*Cyperus niveous*	3	14	0.080	1	13	0.155	1	13	0.155	24	9.2	0.5087	24	9.2	0.5087
79.	*Cypripedium cordigerum* D. Don	3	4	0.385	1	5	0.122	1	5	0.122	30	7.8	0.6163	30	7.8	0.6163
80.	*Dactylis glomerata* L.	3	22	0.004	1	6	0.883	1	6	0.883	27	14.1	0.1522	27	14.1	0.1522
81.	*Dactylorhiza hatagirea* (D. Don) Soo	3	6	0.158	0	2	0.815	0	2	0.815	24	24.8	0.1084	24	24.8	0.1084
82.	*Dioscorea deltoidea* Wall.	3	7	0.085	0	2	1.000	0	2	1.000	24	14.8	0.2248	24	14.8	0.2248
83.	*Draba oreades* Schrenk	3	3	0.788	0	6	0.161	0	6	0.161	30	4.2	0.946	30	4.2	0.946
84.	*Dracocephalum nutans* L.	1	3	0.829	0	6	0.151	0	6	0.151	40	7.7	0.5017	40	7.7	0.5017
85.	*Dryopteris juxtapostia* Christ	3	7	0.209	1	11	0.011	1	11	0.011	26	10.1	0.3943	26	10.1	0.3943
86.	[3]***Dryopteris stewartii*** Fras.-Jenk.	3	26	0.008	0	40	0.000	**0**	**40**	**0.000**	28	10.8	0.2961	28	10.8	0.2961
87.	*Eclipta prostrata* L.	3	9	0.044	0	7	0.053	0	7	0.053	24	20.4	0.1432	24	20.4	0.1432
88.	*Epilobium angustifolium* L.	3	6	0.150	1	5	0.122	1	5	0.122	24	17.5	0.1558	24	17.5	0.1558
89.	*Equisetum arvense* L.	3	10	0.051	1	7	0.108	1	7	0.108	24	17.3	0.1908	24	17.3	0.1908
90.	*Eragrostis cilianensis* (All.) Lut. ex F.T. Hubbard	3	9	0.050	0	2	0.917	0	2	0.917	24	34.2	0.0302	24	34.2	0.0302
91.	[3]***Eremurus himalaicus*** Baker	3	12	0.350	0	35	0.000	**0**	**35**	**0.000**	27	9.2	0.4671	27	9.2	0.4671
92.	*Erigeron multiradiatus* (Lindl. Ex DC) C.B. Clarke	3	7	0.098	1	4	0.230	1	4	0.230	26	9	0.4277	26	9	0.4277
93.	*Erysimum melicentae* Dunn.	3	9	0.037	0	3	0.664	0	3	0.664	24	20.8	0.126	24	20.8	0.126
94.	*Euphorbia wallichii* Hook. f.	2	8	0.181	0	11	0.019	0	11	0.019	36	8.4	0.5323	36	8.4	0.5323
95.	*Euphrasia himalayica* Wetts.	3	17	0.046	1	10	0.649	1	10	0.649	26	8.3	0.5799	26	8.3	0.5799
96.	[2]***Fragaria nubicola*** Lindl. ex Lacaita	3	49	0.000	**1**	**47**	**0.000**	1	47	0.000	25	10.6	0.4115	25	10.6	0.4115
97.	*Fritillaria roylei* Hook. f.	2	1	1.000	0	1	1.000	0	1	1.000	26	15.9	0.1146	26	15.9	0.1146
98.	*Gagea elegans* Wall. Ex D. Don	2	14	0.029	0	6	0.765	0	6	0.765	37	13.7	0.2194	37	13.7	0.2194
99.	*Galium aparine* L.	3	9	0.096	1	5	0.557	1	5	0.557	31	10.9	0.5091	31	10.9	0.5091
100.	*Galium asperuloides*	3	13	0.032	0	6	0.457	0	6	0.457	27	26.2	0.033	27	26.2	0.033
101.	*Gentiana carinata* Griseb	1	22	0.003	1	10	0.392	1	10	0.392	40	13.8	0.1648	40	13.8	0.1648
102.	*Gentiana kuroo* Royle	3	2	0.681	1	1	1.000	1	1	1.000	31	4.2	0.9532	31	4.2	0.9532
103.	*Gentiana moorcroftiana* (Wallich ex G. Don) Airy Shaw	2	14	0.027	0	12	0.023	0	12	0.023	32	4.3	0.9166	32	4.3	0.9166
104.	*Gentianodes argentia* Omer, Ali & Qaiser	2	3	0.702	0	5	0.187	0	5	0.187	38	2.6	0.993	38	2.6	0.993
105.	*Geranium nepalense* Sweet.	2	4	0.419	0	2	0.803	0	2	0.803	39	1.9	0.9994	39	1.9	0.9994
106.	*Geranium polyanthes* Edgew & Hook. F	2	10	0.230	1	16	0.007	1	16	0.007	28	11	0.3847	28	11	0.3847
107.	*Geranium wallichianum* D. Don ex. Sweet	3	3	0.979	0	7	0.494	0	7	0.494	26	9.3	0.4721	26	9.3	0.4721
108.	*Geum elatum* Wall. Ex G. Don	3	3	0.680	0	3	0.815	0	3	0.815	28	6.5	0.7011	28	6.5	0.7011
109.	*Gnaphalium affine* D. Don	2	11	0.506	1	20	0.022	1	20	0.022	36	7.4	0.6835	36	7.4	0.6835
110.	*Gratiola officinalis* L.	3	3	0.627	1	3	0.494	1	3	0.494	28	10.9	0.5101	28	10.9	0.5101
111.	*Hackelia uncinata* (Royle ex Benth) Fischer	3	11	0.842	1	15	0.649	1	15	0.649	36	13.2	0.1882	36	13.2	0.1882
112.	*Heracleum candicans* Wall. ex DC.	3	6	0.149	0	6	0.046	0	6	0.046	26	6.6	0.7187	26	6.6	0.7187
113.	*Hyoscyamus niger* L.	3	2	1.000	1	1	1.000	1	1	1.000	28	20	0.1938	28	20	0.1938
114.	*Hypericum perforatum* L.	3	24	0.002	0	18	0.001	0	18	0.001	24	29.8	0.0218	24	29.8	0.0218
115.	*Impatiens edgeworthii* Hook.f.	3	12	0.028	1	10	0.035	1	10	0.035	28	14.3	0.233	28	14.3	0.233
116.	[1]***Impatiens bicolor*** Royle	**3**	**50**	**0.000**	1	27	0.020	1	27	0.020	24	32	0.016	24	32	0.016

Table 1. (Cont'd.).

117.	*Inula grandiflora* Willd.	3	2	1.000	1	1	1.000	1	1	1.000	37	9.1	0.5627	37	9.1	0.5627
118.	*Inula multiradiata*	3	2	1.000	0	2	0.466	0	2	0.466	29	6.7	0.7754	29	6.7	0.7754
119.	[5]***Iris hookeriana*** Foster	1	38	0.001	0	16	0.853	0	16	0.853	41	20	0.0702	**41**	**20**	**0.0702**
120.	*Juncus membranaceus* Royle ex D. Don	2	7	0.313	0	7	0.234	0	7	0.234	36	13.7	0.3535	36	13.7	0.3535
121.	*Lathyrus pratensis* L.	3	4	0.201	1	2	0.487	1	2	0.487	27	8.3	0.6169	27	8.3	0.6169
122.	*Leucas cephalotes* (Roth) Spreng.	3	4	0.207	0	2	0.733	0	2	0.733	26	18.4	0.1272	26	18.4	0.1272
123.	*Malva neglecta* Wallr.	3	26	0.042	0	25	0.181	0	25	0.181	24	22.8	0.0268	24	22.8	0.0268
124.	*Mentha longifolia* (L.) Hudson	3	4	0.196	1	4	0.246	1	4	0.246	30	8.1	0.6395	30	8.1	0.6395
125.	*Mentha royleana* Benth.	3	2	1.000	1	1	1.000	1	1	1.000	26	25	0.0564	26	25	0.0564
126.	*Minuartia kashmirica* (Edgew) Mattf	2	3	0.853	1	3	0.917	1	3	0.917	36	8.5	0.5081	36	8.5	0.5081
127.	*Morina longifolia* Wall. ex. Dc.	3	2	0.773	1	4	0.301	1	4	0.301	29	3.4	0.9614	29	3.4	0.9614
128.	*Nepeta laevigata (D. Done) Hand.-Mazz.*	3	5	0.571	1	7	0.163	1	7	0.163	34	5	0.871	34	5	0.871
129.	[1]***Onopordum acanthium*** **L.**	**3**	**34**	**0.001**	0	18	0.606	0	18	0.606	24	14	0.1664	24	14	0.1664
130.	*Onosma bracteatum* Wall.	3	8	0.199	1	8	0.199	1	8	0.199	30	5.4	0.7708	30	5.4	0.7708
131.	*Origanum vulgare* L.	3	14	0.030	0	17	0.000	0	17	0.000	27	27.2	0.0218	27	27.2	0.0218
132.	*Orobanche alba* Stephen ex Wallid	3	1	1.000	0	1	0.747	0	1	0.747	36	8.6	0.6151	36	8.6	0.6151
133.	*Oxyria digyna* L.	3	22	0.019	1	21	0.010	1	21	0.010	33	9	0.4993	33	9	0.4993
134.	*Oxytropis cachemiriana* Camb.	3	19	0.006	0	7	0.384	0	7	0.384	24	18.5	0.0994	24	18.5	0.0994
135.	*Paeonia emodi* Wall. ex Royle	3	2	1.000	1	1	1.000	1	1	1.000	26	25	0.0524	26	25	0.0524
136.	*Parnassia nubicola* Wall.	2	7	0.169	1	3	0.931	1	3	0.931	30	8.2	0.4709	30	8.2	0.4709
137.	*Pedicularis pectinata* Wall. ex. Benth	2	3	0.514	0	2	0.806	0	2	0.806	38	6.6	0.7295	38	6.6	0.7295
138.	*Pennisetum lanatum* Klotzsch	3	3	0.563	0	2	0.757	0	2	0.757	31	4.9	0.8816	31	4.9	0.8816
139.	*Phleum alpinum* L.	3	4	0.478	0	4	0.313	0	4	0.313	28	6.5	0.6191	28	6.5	0.6191
140.	*Phlomis bracteosa* Royle ex Benth.	2	5	0.092	0	4	0.103	0	4	0.103	37	4.7	0.9016	37	4.7	0.9016
141.	*Pimpinella acuminate* (Edgew.) C.B. Clarke	3	4	0.215	1	2	0.495	1	2	0.495	29	8.9	0.5585	29	8.9	0.5585
142.	*Pimpinella diversifolia* (Wall.) DC	3	7	0.088	0	3	0.446	0	3	0.446	25	34.1	0.0106	25	34.1	0.0106
143.	*Plantago himalaica* Pilger	1	7	0.112	1	3	0.700	1	3	0.700	34	3.9	0.9722	34	3.9	0.9722
144.	[1]***Plantago lanceolata*** **L.**	**3**	**30**	**0.002**	0	18	0.309	0	18	0.309	24	20.9	0.0496	24	20.9	0.0496
145.	*Plantago major* L.	3	16	0.098	0	10	0.986	0	10	0.986	36	14.1	0.2062	36	14.1	0.2062
146.	[4]***Poa alpina*** L.	2	24	0.146	1	28	0.174	1	28	0.174	**38**	**15.5**	**0.079**	38	15.5	0.079
147.	*Poa annua* L.	3	7	0.100	1	3	0.446	1	3	0.446	27	39.1	0.0074	27	39.1	0.0074
148.	*Poa stewartiana* Bor.	3	20	0.010	1	14	0.090	1	14	0.090	27	13.5	0.2547	27	13.5	0.2547
149.	*Podophyllum hexandrum* Royle	3	4	0.602	1	5	0.356	1	5	0.356	31	5.8	0.7638	31	5.8	0.7638
150.	*Polygonum aviculare* L.	3	10	0.364	1	10	0.459	1	10	0.459	26	13.9	0.2178	26	13.9	0.2178
151.	*Polygonum alpinum* (All.) Schur	2	18	0.036	0	13	0.229	0	13	0.229	38	13.8	0.2042	38	13.8	0.2042
152.	*Polygonum molle* (D.Don) Hara	3	7	0.458	1	11	0.069	1	11	0.069	28	12.2	0.3267	28	12.2	0.3267
153.	*Polygonum plebeium* R. Br.	3	14	0.033	1	9	0.190	1	9	0.190	26	11.7	0.3391	26	11.7	0.3391
154.	*Polygonatum verticillatum (*L.) Allioni	3	11	0.336	0	11	0.663	0	11	0.663	34	4	0.9872	34	4	0.9872
155.	*Potentilla anserina* L.	2	10	0.779	0	13	0.709	0	13	0.709	36	4.9	0.9536	36	4.9	0.9536
156.	*Potentilla atrosanguinea* Lodd.	2	8	0.269	1	8	0.246	1	8	0.246	34	16.8	0.1292	34	16.8	0.1292
157.	*Potentilla nepalensis* Hook. f.	1	13	0.280	0	15	0.248	0	15	0.248	36	15.6	0.1236	36	15.6	0.1236
158.	*Primula calderana* Balf. F & cooper	1	6	0.149	1	4	0.306	1	4	0.306	38	21.5	0.1234	38	21.5	0.1234

Table 1. (Cont'd.).

159.	*Primula denticulata* Smith	1	11	0.073	1	16	0.000	1	16	0.000	34	5.8	0.7223	34	5.8	0.7223
160.	*Primula glomerata* Pax.	2	6	0.215	1	8	0.029	1	8	0.029	41	22.2	0.1172	41	22.2	0.1172
161.	*Primula rosea* Royle	2	11	0.115	1	14	0.019	1	14	0.019	38	15.1	0.135	38	15.1	0.135
162.	*Prunella vulgaris* L.	3	6	0.183	1	6	0.148	1	6	0.148	25	5.6	0.7652	25	5.6	0.7652
163.	*Pseodomertensia parvifolia* (Decne)	3	6	0.141	1	4	0.311	1	4	0.311	26	43	0.0114	26	43	0.0114
164.	*Pseodomertensia moltkioides* Royle & Kazmi	1	6	0.275	1	3	0.726	1	3	0.726	41	27.8	0.0354	41	27.8	0.0354
165.	*Pseodomertensia nemerosa* (DC.) R. Stewart & Kazmi	1	2	0.962	1	7	0.056	1	7	0.056	37	8.3	0.4811	37	8.3	0.4811
166.	*Pteris vittata* L.	3	3	0.780	1	6	0.149	1	6	0.149	36	7.7	0.5213	36	7.7	0.5213
167.	[5]***Ranunculus hirtellus*** Royle ex D. Don	1	14	0.008	1	7	0.066	1	7	0.066	41	67.1	0.0022	**41**	**67.1**	**0.0022**
168.	*Ranunculus laetus* Wall. Ex Hook.f. & Thoms	3	3	0.827	1	5	0.255	1	5	0.255	36	3.8	0.9666	36	3.8	0.9666
169.	*Ranunculus muricatus* L.	3	5	0.269	1	2	1.000	1	2	1.000	24	31	0.0396	24	31	0.0396
170.	[4]***Rheum australe*** D.Don	1	32	0.004	1	21	0.231	1	21	0.231	**38**	**20.3**	**0.0588**	41	20.3	0.0588
171.	*Rumex dentatus* L.	3	32	0.014	1	26	0.340	1	26	0.340	28	10.1	0.4855	28	10.1	0.4855
172.	*Rumex nepalensis* Spreng.	3	5	0.646	1	7	0.235	1	7	0.235	24	14.5	0.2282	24	14.5	0.2282
173.	*Salvia lanata* Roxb.	3	7	0.104	1	3	0.716	1	3	0.716	32	3.4	0.9818	32	3.4	0.9818
174.	*Salvia moorcroftiana* Wall. ex Benth.	3	5	0.518	0	5	0.414	0	5	0.414	38	5.2	0.7676	38	5.2	0.7676
175.	*Saussurea albescens* Hook. f. & Thoms.	3	6	0.233	1	4	0.518	1	4	0.518	24	15.6	0.195	24	15.6	0.195
176.	*Saussurea fastuosa* (Decne.) Schultz-Bip	1	4	0.340	1	4	0.249	1	4	0.249	31	2.8	0.9922	31	2.8	0.9922
177.	*Saussuregraminifolia* Wall. ex DC.	1	3	0.701	0	3	0.786	0	3	0.786	30	5.3	0.8038	30	5.3	0.8038
178.	*Scirpus palustris* L.	3	7	0.260	1	10	0.022	1	10	0.022	26	9.3	0.4385	26	9.3	0.4385
179.	*Sedum album* L.	2	10	0.461	1	12	0.355	1	12	0.355	41	9.2	0.4759	41	9.2	0.4759
180.	*Sedum ewersii* Ledeb	2	18	0.008	0	8	0.320	0	8	0.320	36	8.4	0.5751	36	8.4	0.5751
181.	*Senecio chrysanthemoides* DC.	3	6	0.126	1	3	0.420	1	3	0.420	27	11.6	0.3789	27	11.6	0.3789
182.	[4]***Sibbaldia cuneata*** O. Kuntze	2	29	0.013	1	25	0.048	1	25	0.048	**39**	**20**	**0.0584**	41	19.7	0.0584
183.	*Silene vulgaris* Garck	3	7	0.090	0	3	0.612	0	3	0.612	24	23.6	0.0972	24	23.6	0.0972
184.	*Stipa himalaica* Rozhev.	3	10	0.038	1	3	0.824	1	3	0.824	26	25.7	0.0598	26	25.7	0.0598
185.	*Strobilanthes glutinosus* Nees	3	4	0.211	0	2	0.362	0	2	0.362	30	10.2	0.4137	30	10.2	0.4137
186.	*Swertia ciliata* (D. Don ex G. Don) B. L. Burtt	3	11	0.047	1	4	0.798	1	4	0.798	26	46.2	0.0058	26	46.2	0.0058
187.	*Swertia speciosa* D. Don	3	3	0.632	1	3	0.493	1	3	0.493	31	11.8	0.4251	31	11.8	0.4251
188.	*Sisymbrium irio* L.	1	3	0.543	0	2	0.754	0	2	0.754	25	7.2	0.6433	25	7.2	0.6433
189.	[3]***Taraxacum officinale*** Weber	3	44	0.001	0	36	0.033	**0**	**36**	**0.033**	27	9.1	0.6165	27	9.1	0.6165
190.	*Thymus linearis* Benth.	2	32	0.101	1	33	0.992	1	33	0.992	32	12.7	0.1444	32	12.7	0.1444
191.	[1]***Trifolium** repens* **L.**	**3**	**28**	**0.000**	0	8	0.884	0	8	0.884	24	22.3	0.0512	24	22.3	0.0512
192.	*Trillidium govanianum* (Wall. ex D. Don) Kunth	3	1	1.000	1	4	0.246	1	4	0.246	32	7.7	0.6701	32	7.7	0.6701
193.	*Tussilago farfara* L.	3	4	0.205	1	2	0.749	1	2	0.749	24	21.7	0.1044	24	21.7	0.1044
194.	*Urtica dioica* L.	3	15	0.061	0	9	0.708	0	9	0.708	24	34.7	0.011	24	34.7	0.011
195.	*Valeriana pyrolifolia* Decne	1	6	0.631	1	21	0.000	1	21	0.000	41	5.5	0.8296	41	5.5	0.8296
196.	*Verbascum thapsus* L.	3	23	0.055	0	20	0.466	0	20	0.466	24	17.8	0.0766	24	17.8	0.0766
197.	*Vicia bakeri* Ali	3	3	0.627	1	1	1.000	1	1	1.000	26	17.9	0.1072	26	17.9	0.1072
198.	*Viola canescens* Wall. ex Roxb.	1	31	0.252	1	42	0.133	1	42	0.133	40	9	0.6625	40	9	0.6625

Species diversity was optimum at the middle altitudes (2800-3400 masl) as compared to the lower where direct anthropogenic activities are continuous and high altitudes (3400-4100) where diversity reaches to its minimum is mainly due to xeric condition but the high grazing pressure also trigger this decrease. Such kind of species distributional phenomenon has also been observed in other mountainous ecosystems (Anderson *et al*., 2006; Nogués-Bravo *et al*., 2008). Moreover increase in herbaceous vegetation is positively correlated to the increase in altitude that seems to be a function of eco-physiological pressures associated with these elevations. Finding of this paper clearly indicate that lower valley exhibit moist temperate type of floristic element which gradually change on one hand to dry temperate types in upper valley (along latitudinal gradient) and on the other hand to sub alpine and alpine types along the elevation gradient.

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