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Floristic composition and diversity patterns of vascular plants in mountain meadow of Gurez valley, Kashmir, India

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ABSTRACT: Floristic composition and diversity patterns of vascular plants along an altitudinal transect (3300–3900m a.s.l.) in relation to anthropogenic disturbance, edaphic variables and slope were studied in an alpine rangeland of Gurez valley, Kashmir. A total of 111 plant species belonging to 36 families and 86 genera were recorded over 245 quadrats that were placed at seven sites. Evaluated on species richness, diversity (alpha and beta) and composition was negatively correlated to altitude, though the relationship was not monotonic. Matching the changes in floristic composition and richness to various environmental variables through canonical correspondence analysis further strengthened the importance of altitude in influencing species composition. Species tolerant of trampling and other disturbances were dominant at largely disturbed lower altitudes (<3500m) while at higher altitudes (>3700m) their dominance decreased considerably, suggesting that anthropogenic disturbance is also important in influencing species composition. Our results showed that species turnover rates were high at higher (>3500m) altitudes. The study provides an insight on the plant composition of this region and accentuates the need for its proper conservation.

KEY WORDS: Alpine plants, altitudinal gradient, beta diversity, Gurez valley, species composition.

INTRODUCTION

Occupying nearly 24% of the global land surface (Sharma *et al.*, 2010) and characterized by a vertical zonation into different elevation belts, mountains harbor a high level of biological diversity. Numerous studies on the sequences, differences and interactions among these elevation belts have highlighted the importance of altitude in influencing species composition, distribution and richness (Grytenes, 2003; Kessler, 2000). In Kashmir Himalaya wherein the broad distribution outline of species governed by altitude is superimposed by livestock grazing, understanding the underlying factors of species composition is particularly important. This is because in Kashmir Himalaya, due to livestock grazing, a majority of plant communities have not only been impoverished but also wholly natural stands of vegetation are either absent or are present in only restricted and inaccessible areas (Lloyd and Lloyd, 1968). Being a mega biodiversity region, the Himalayan mountain system is a unique physiogeographical region distinguishable into two distinct zones i.e. ice capped mountains and forests. While the former in the form of ice sheets accounts for about 18% of total area of Himalaya (Kala, 2000), the latter includes a multitude of vegetation formations like warm temperate grasslands, sub-alpine and cool temperate grassy slopes, alpine meadows, cold deserts and alpine dry scrub and offers unique habitats to sustain numerous threatened plant and animal taxa (Gupta and Kachroo, 1981; Kumar and Bhatt, 2006; Dvorsky *et al.*, 2010). However, most of these vegetation formations are under severe threat from climate change, invasive alien species, globalization, urbanization and other anthropogenic pressures.

Locally called as Bahks/Margs, the high altitudinal rangelands span across a broad eco-climate zone of Kashmir Himalaya at all montane, sub alpine and alpine altitudes. These rangelands contribute about 77% to the total 1,71,464 km2 area of alpine rangelands in Indian Himalayan region (Lal *et al.*,1991). These rangelands are excellent ecosystems for the study of high altitude plants as they offer an unmatched range of geological strata, altitude, topography and land use. These act as the major summer pastures for migratory livestock of low lying populace and are thus central for state's farming system, which is an amalgam of both sedentary farming and migratory livestock keeping. Most of the earlier studies on Kashmir Himalayan rangelands were restricted largely to systematics and floral accounts (Ara and Naqshi, 2003) but given the development rapidity and changing socio-political arrangement and grazing practices which are affecting these rangelands via livestock (over) grazing, medicinal plant trade and habitat conversion, there is an urgent need to correlate the floristic composition of these rangelands with various environmental factors. In this backdrop, focusing on a high altitude rangeland (3300–3900m a.s.l.) at Gurez Valley, Kashmir, we studied the vascular plant diversity with an aim to analyze the floristic composition and dominance amplitude of species along an altitudinal gradient.

Table 1 Details of seven studied sites at Minimarg, Kashmir.

Site	Alt. (m)	Co-ordinates	Slope (°)	Characteristic Species	Habitat Features	No. of Species	Major Grazers
1	3300	N 34° 32´ 23.0" E 74° 53´ 38.5"	6	*Aconitum chasmanthum, Minuratia kashmerica, Barbarea intermedia.*	Foot of the mountain	4–16	Buffaloes, Cattle
2	3400	N 34° 32´ 45.0" E 74° 52´ 11.7"	4	*Epilobium laxum, Corydalis govaniana, Malva neglecta, Scruphularia lucida.*	Plain camping site.	2–13	Horses, Buffalo, Cattle
3	3500	N 34° 32´ 38.2" E 74° 52´ 55.5"	20	*Aquilegia fragrance, Carum carvi, Oxytropis lapponica, Veronica anagallis–aquatica*	Rocky and shady area	4–15	Cattle, Horses, Buffalo
4	3600	N 34° 32´ 18.7" E 74° 53´ 14.3"	10	*Angellica glauca, Artemisia roxburghiana, Aster falconeri.*	Undulating mid hills	4–12	Sheep and Goat
5	3700	N 34° 32´ 11.8" E 74° 52´ 41.1"	10	*Cerastium ceratoides, Gentiana carinata, Phleum alpinum.*	Mid altitude camping huts at midslopes.	1–9	Sheep only
6	3800	N 34° 31´ 40.6" E 74° 52´ 32.8"	8	*Anemone obtusiloba, Primula involucrata, Rhododendron anthoopgan.*	Rolling and undulating slopes at higher altitudes	2–10	Sheep and Goat
7	3900	N 34° 31´ 33.6" E 74° 51´ 40.6"	4	*Allium humile, A.jacquemontii, Draba afghanica, Pedicularis albida, Primula rosea.*	Flatland atop grassland	4–13	Mostly sheep.

Note. Alt. (m) = Altitude in meters above sea level while characteristic species designate species which are almost exclusive or in greater proportion at a site.

MATERIALS AND METHODS

Study area

The study area is at Minimarg (34°33′ N; 74° 53′E) which is located at the farthest tip of north-western Himalaya inside the Indian territory within Gurez valley (34° 30′ to 34° 41′ N and 74° 37′ to 74° 55′ E). Located on the eastern side of Gurez valley, the area encompasses a typical alpine topography of undulating terrain, steep slopes, few upland plateaus and a long flat open meadow. The area is accessible only by foot between the snow free months of June to October and is divided between numerous nomad families who look after their respective segments based on their property rights over the area. Sub-alpine forest and timberline ecotone characterized by dense coniferous forests mixed with broad leaved species such as *Abies pindrow*, *Pinus wallichiana* and *Betula utilis* are present at the lower (<3500m) margins of the area.

Vegetation survey

The vegetation survey was conducted from June to October along the mountain from top (3900m a.s.l.), down to 3300m a.s.l. As our objective was to study and understand the species composition at different altitudes of mountain, adjoining forest was excluded and only highest possible and accessible mountain was studied. Selected mountain had a gentle continuous slope with little variation in aspect. On a 100m altitudinal interval we selected seven sites and investigated the diversity of vascular plants on those sites (Table 1). On each selected site we randomly placed quadrats, whose size (0.50×0.50m) and number (n=35) was calculated through running mean method (Mueller-Dombois and Ellenberg, 1974). Plant species were identified with the help of regional floras (Dhar and Kachroo, 1983; Duthie 1893, 1894). Within each quadrat, the number and cover (visual estimation) of each plant was recorded and used for analysis. Altitude and degree of slope were measured using GPS and a clinometer respectively.

Data analysis

Phytosociological attributes viz. density, frequency and cover, recorded for each species were summed and an Importance Value Index- IVI was obtained for each species (Cottam and Curtis, 1956). IVI was used to rank each species and the plant species with the highest importance value were considered the dominant species. At each altitudinal site, the IVI values of most dominant (calculated as the IVI values of the species present relative to total IVI values within each altitudinal interval) were plotted against altitude by univariate statistical methods.

Species richness (SR) was determined as total number of species in each altitudinal interval while to compare the species diversity Shannon- Wiener function (H') was used and calculated as

$$H' = -\sum p_i \ln p_i \qquad \text{(Eq. 1)}$$

where p_i is the proportion of all individuals in the sample that belong to the species $_i$. Species evenness was calculated by using Hulbert's Probability of Interspecific Encounter (PIE). To capture the overall differences, diversity attributes were also measured at individual quadrat level. The analysis was done by using EcoSim 7.0 (Goteli and Entsminger, 2003). All calculations were run at default values.

Beta diversity (β) or species turnover was calculated based on species replacement rate with an increasing altitude (Wilson and Schmidt, 1984).

$\beta = [g(H) + l(H) / 2\alpha]$ .... (Eq. 2)

where g (H) is the number of species gained; *l* (H) is the number of species lost moving along the altitudinal gradient and α is average richness of species at two intervals.

As a general approach to relating the floristic and structural variation, Canonical Correspondance Analysis (CCA) as included in the CANOCO package 4.5 (ter Braak and Smilauer, 2002) was applied using the importance value index (IVI) of each species in each elevation gradient as a primary variable (7 sites×111 species).

Initially altitude, disturbance (summarily quantified by primarily on percentage of unpalatable species at a site; presence and number of tracks and trails (human and animal) at a site; percent of exposed soil or bare earth due to trampling and distance of site from camping location of herdsmen), slope, soil moisture, soil acidity, soil conductivity, total soil nitrogen, soil organic carbon and longevity of snow free period were included in analyses (7 sites×9 factors) but because the snow free variable did not provided any additional independent information and acted as collinear with altitude it was removed from further analysis. The ordination diagram thus presents the species distributions and their relationship with environmental variables. The variables used in canonical correspondence analysis (CCA) were coded as MOIS= soil moisture; pH= soil acidity; COND= soil conductivity; NITR= total soil nitrogen; OCAR= soil organic carbon; SLOP = degree of slope; ALTI= altitude (m) and DIST= anthropogenic disturbance. We down weighted the rare species and plotted only the species with best fit in ordination diagrams by using Canonical Correspondance Analysis (CCA). The species drawn in the ordination diagram were abbreviated into seven characters i.e. first four letters of genus name and first three letters of species name. Statistical significance of results and CCA axes was tested with $p < 0.05$ by using global Monte Carlo Permutation test with 999 permutations.

RESULTS

Species Composition

One hundred and eleven vascular plant species including a gymnosperm – *Juniperus wallichiana* belonging to 86 genera and 36 families were recorded. Angiosperms were represented by 100 dicot and 10 monocot species (Appendix 1). Asteraceae was the most speciose family represented by 11 species followed by Scrophulariaceae (10 spp), Ranunculaceae (9 spp), Rosaceae (7 spp) and Lamiaceae (6 spp). Of 36 families, 22 were found with 2 species or less each while only 8 families were found with more than 5 species.

Along the altitudinal gradient floristic composition changed gradually, though few species like *Sibbaldia cuneata* (IVI= 14.61) were present along the full length. At lower altitudes (<3500m) which included mostly the foothill portion, species with a highest IVI included *Geum elatum* (4.60), *Trifolium repens* (3.28), *Frageria nubicola* (2.84), *Myosotis sylvatica* (2.68), *Tanceteum longifolium* (2.68), *Senecio chrysanthemoides* (2.50) and *Euphorbia wallichiana* (2.38) with *Rumex nepalensis* (1.95) and *Phlomis bracteosa* (1.86) also growing in a sparse manner. However towards higher altitudes (>3700m), vegetation was intermix of many species notably *Lagotis cashmeriana* (6.52) - a highly palatable perennial forb which acted as an important feed source for livestock. Flat land atop the study area was occupied by few sedges like *Juncus thomsonii* (1.84), *Rhodiola wallichiana* (1.42) and *Draba affghanica* (1.00) besides many other species.

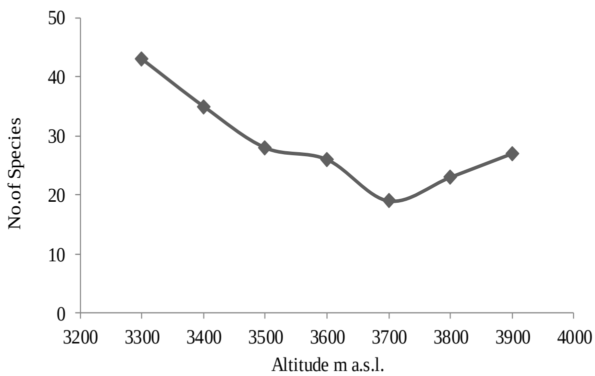

Fig. 1 Variation in species richness along the altitudinal gradient at Minimarg, Kashmir

Altitudinal gradient and species richness

Variation of species richness along the altitudinal gradient is shown in Fig 1. Although not monotonic, the curve showed a decreasing trend with increasing altitude up to 3700 m a.s.l while for the last two elevation sites i.e. 3700–3800m and 3800–3900m it again depicted an increasing trend and thus was of bimodal nature. A linear regression between species richness and altitudinal values was carried out by the numbers of species against initial altitude at each altitudinal site. The slope of regression line was -0.02893 m^{-1} with a standard error of 0.0002m^{-1} (-0.02893 m^{-1} ±0.0002 m^{-1}) which was significantly different from zero at $p< 0.05$ (F= 7.9 and $p = 0.03$).
The β-diversity index calculated for each altitudinal gradient is given in figure 2. At altitudes below 3400m, the index was 0.53 while for the next altitudinal sites it

varied less (0.42–0.48). However, for the last altitudinal sites (3600–3900m), it revealed a rapid turnover rate and fluctuated between (0.58–0.69). However, in this case a linear regression analysis did not indicated regression slopes significantly different from zero (F= 0.49 and p = 0.51).

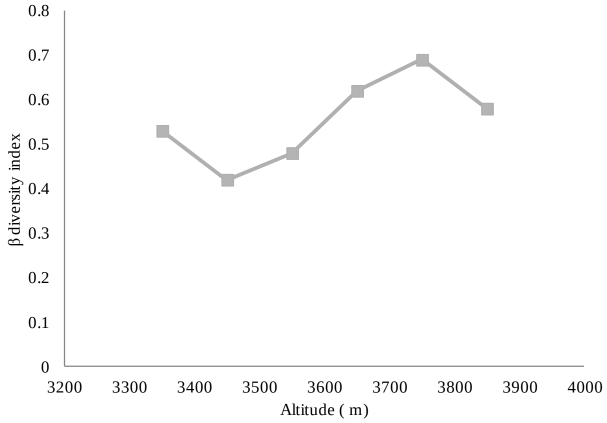

Fig. 2 Variation in the β- diversity index along the altitudinal gradient at Minimarg, Kashmir

Floristic patterns, Species diversity and Vegetation-Environment Interaction

Fig 3 represents the altitudinal profile of some selected species with a high importance value index. As is evident, for majority of species the curves overlap highly in lower altitudes (<3500m) with a more bell shaped distribution while at higher altitude (>3700m) species like *Lagotis cashmeriana* dominate in an intermixing association with other palatable forbs. Also at lower altitudes species which dominate are tolerant of trampling and other biotic and anthropogenic disturbance. A few of these species like *Sambucus wightiana* also extend further.

Shannon Wiener Index (H') measured by pooling the data at each elevation site depicted more of a decreasing trend with increasing altitude (Fig 4). The index varied from 2.75 at 3300m a.s.l to 1.43 at 3900 m a.s.l. This decrease with altitude had a regression line slope of (-0.00246± 0.0001 m^{-1}), which was significantly different from zero at p< 0.01(F= 41.30, p= 0.001). Same trend was observed even when comparing the quadrat mean among elevation levels (r = -0.00075 and p<0.01*)* except for the last elevation site wherein it showed a slightly higher value (Fig 4). Similar decreasing pattern was observed for the Hulbert's index- PIE. Additionally this index also supported the increasing diversity of last elevation site both on quadrat mean and site basis. A Pearson's

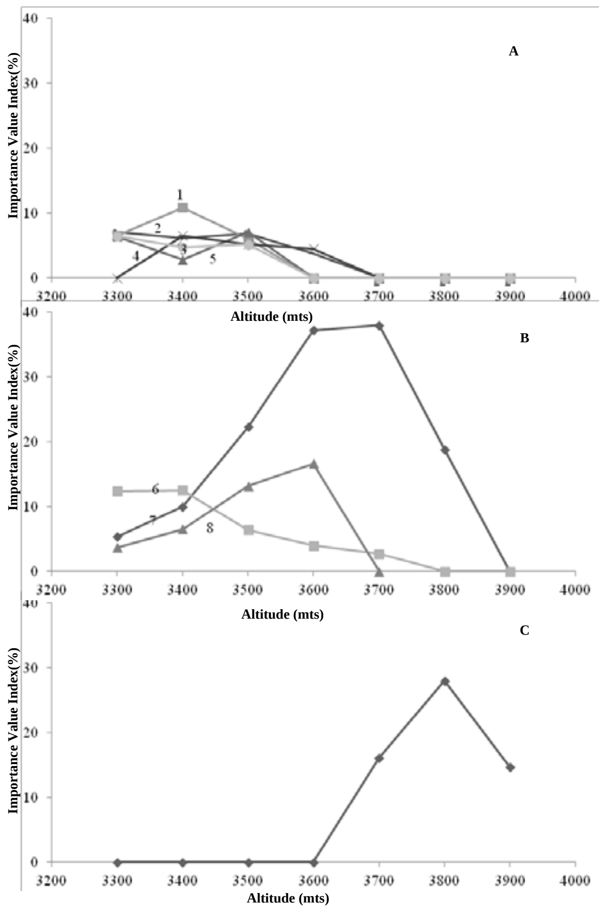

Fig. 3 Altitudinal distribution of various dominant species at Minimarg, Kashmir. Species are arranged into three groups. Species of lower altitudes grouped in subplot A are numbered 1–5 and respectively include *Rumex nepalensis, Trifolium repens, Senecio chrysanthemoides, Tanaceteum longifolium* and *Frageria nubicola*. Subplot B involves generalist species numbered 6–8 and respectively include *Sambucus wightiana, Sibbaldia cuneata* and *Poa annua*. Species restricted to higher altitudes is shown in subplot C and include solitary *Lagotis cashmeriana*.

correlation analysis showed high positive correlation between species richness and Hulbert's PIE while species turnover (β) did not depicted such correlation with any variable (Table 2). However interesting to note was the negative correlation (-0.944) between altitude and Shannon Wiener Index (H'). With regard to the effects of slope and disturbance on diversity attributes, it is quite apparent that disturbance showed a high negative correlation with both richness and diversity on both quadrat means and synthetic data of sites while slope depicted a negative correlation (-0.094) with species richness only (Table 2).

Soil across all the sites was acidic with a high electrical conductivity, while soil moisture ranged

Table 2 Pearson correlation coefficients between variables

	SR	H'	PIE	Avg.PIE	B	Avg H'	Slope	Disturbance	Altitude
SR	1	0.286	0.787$	0.853$	0.553	0.878*	-0.094	-0.927*	-0.783$
H'		1	0.702	0.591	0.317	0.753	-0.039	-0.695	-0.944*
PIE			1	0.822$	0.224	0.893*	-0.214	-0.022	-0.460
Avg.PIE				1	0.472	0.893*	-0.182	-0.056	-0.451
β					1	0.303	0.054	-0.105	-0.229
Avg H'						1	0.128	0.237	-0.602
Slope							1	-0.350	-0.111
Disturbance								1	-0.814$
Altitude									1

H´= Shannon –Wiener Index, PIE = Hulbert's Index, Avg. H´ = Average individual Shannon –Wiener Index, Avg.PIE= Average Hulbert's Index, β = Shmida and Wilson beta diversity Index.
* Correlation is significant at 0.01 level (2-tailed).
$ Correlation is significant at 0.05 level (2-tailed).

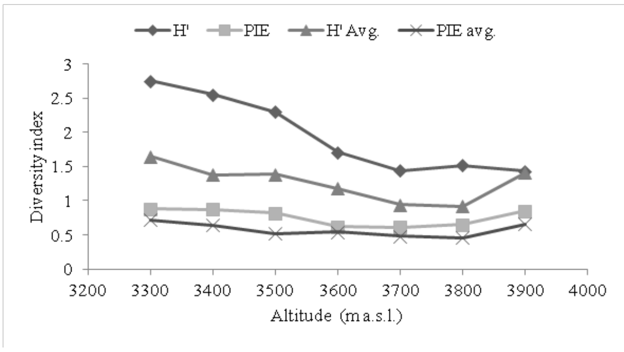

Fig. 4 Relationship between different diversity indices and various variables at Minimarg, Kashmir (H'= Shannon Weiner index, PIE = Hulbert's index, H' Avg. and PIE Avg. are their values averaged at individual quadrate level respectively)

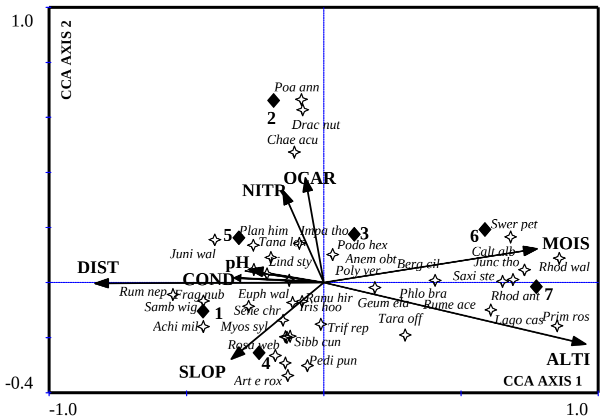

Fig.5 Canonical correspondence analysis (CCA) of species distribution overlaid with seven study sites at Minimarg, Gurez valley. Only the dominant species are displayed and are abbreviated as Achi mil= Achillea millefolium, *Anem obt= Anemone obtusiloba, Arte rox= Artemisia roxburghiana, Berg cil= Bergenia ciliata, Calt alb= Caltha alba, Chae acu= Chaerophyllum acuminatum, Drac nut= Dracocephalum nutans, Euph wal= Euphorbia wallichiana, Frag nub= Frageria nubicola, Geum ela= Geum elatum, Impa tho= Impatiens thomsonii, Iris hoo= Iris hookeriana, Junc tho= Juncus thomsonii, Juni wal= Juniperus wallichiana, Lago cas= Lagotis cashmeriana, Lind sty= Lindelofia stylosa, Myos syl= Myosotis sylvatica, Pedi pun= Pedicularis punctata, Phlo bra= Phlomis bracteosa, Plan him= Plantago himalaica, Poa ann= Poa annua, Podo hex= Podophyllum hexandrum, Poly ver= Polygonatum verticillatum, Prim ros= Primula rosea, Ranu hir= Ranunculus hirtellus, Rhod ant= Rhododendron anthopogan, Rhod wal= Rhodiola wallichiana, Rosa web= Rosa webbiana, Rume ace= Rumex acetosa, Rume nep= Rumex nepalensis, Samb wig= Sambucus wightiana, Saxi ste= Saxifraga stenophylla, Sene chr= Senecio chrysanthemoides, Sibb cun= Sibbaldia cunneata, Swer pet= Swertia petiolata, Tana lon= Tanaceteum longifolium, Tara off= Taraxacum officinale, Trif rep= Trifolium repens*

between 21–46 %. The total soil nitrogen content ranged between 0.22 and 1.06%. Soil carbon content of the sampled sites ranged between 1.01 and 2.12%. The association between species composition and environmental factors was analyzed by CCA. The first and second axis accounted, respectively, for 20.3 and 13.1% of the total variation, with a cumulative percentage variation of 43.9% in species-environment correlation (Table 3). In total, chosen explanatory variables explained 42.3% of the total variation and this relation is significant (P=0.003, with 999 permutations). The first CCA axis is positively correlated with the altitude and negatively correlated with the disturbance level. Slope is correlated both with the first and second axis. But the species of heavily grazed and disturbed habitats, like Rumex nepalensis and S. wightiana are placed in the ordination diagram (Fig 5) at positions distant to species like Lagotis cashmeriana and Rhodiola wallichiana which are characteristic of higher altitudes.

Table 3 Eigenvalues and percentage of variance explained by CCA along with the correlation (canonical and intra-set) co-efficient of environmental variables with CCA co-ordinates. Values in bold are significant at P<0.05.

CCA	Axis 1	Axis 2	EV	Canonical co-efficient		Intra-set Correlation	
				Axis 1	Axis 2	Axis 1	Axis 2
Eigenvalues	0.705	0.459	MOIS	0.247	0.128	**0.774**	0.119
Species-environment correlations	0.996	0.979	pH	0.023	-0.146	-0.286	0.041
Cumulative %age variance of species data	20.3	33.4	COND	0.037	-0.645	-0.192	0.032
of species-environment relation	26.6	43.9	SLOP	-0.208	-0.271	-0.334	-0.272
			ALTI	0.588	-0.585	**0.950**	-0.218
			NITR	-0.099	0.406	-0.147	0.326
			OCAR	0.193	-0.502	-0.066	0.371
			DIST	-0.325	**-0.907**	**-0.835**	-0.002

DISCUSSION

Because of its remoteness and strategic location (too close to the line of control between India and Pakistan) not many studies on species diversity are available for the region except for those which are exclusively qualitative (Ara and Naqshi 1992; 2003). This makes our study even more important and significant because it not only documents the floristic composition of an unexplored area but also highlights affecting factors. The study recorded 111 plant species belonging to 86 genera and 36 families, which compares well with the species richness of neighboring alpine pastures of Pakistan (Shaheen *et al.*, 2011). Presence of a greater number of species from families like Asteraceae, Rosaceae and Lamiaceae is also consistent with studies from alpine pastures of Western Himalaya (Chawla *et al.*, 2008). Relative to the altitudinal location of sites, our study observed that at species level the dominance of species (measured by their importance value index) changed greatly (Fig 3) and species like *Sibbaldia cunneata, Trifolium repens* and *Poa annua* depicted wide amplitude while other species like *Lagotis cashmeriana* recorded narrow amplitude. Such differences reflect the distribution pattern, numerical strength and pattern of species association within a community. Of all recorded species, *S. cunneata* – a rhizomatous perennial forb is most notable and ubiquitous (Ge *et al.*, 2005) and so has been reported as a dominant species in other west Himalayan grasslands also (Dad and Khan, 2010; Shaheen *et al.*, 2011).

Although our results further provide evidence that altitude plays an important role in regulating species composition and distribution but yet for whole elevational gradient, no monotonic relationship between altitude and species richness could be detected. This could possibly be due to the absence of several ecotone regions and greater species richness at the highest elevation site, in our study area. While many previous studies reporting a monotonic relationship between altitude and species richness in mountains usually involve many ecotone regions (Austrheim, 2002; Wang *et al.*, 2006) no such feature is present in our study area except at the foothill which is delimited by an adjacent forest patch. Second, at the highest elevation site species richness is higher due to the occurrence of various species like *Allium humile*, *A. jacquemontii*, *Potentilla atrosanguinea, Sedum ewersii* and *Pedicularis albida* which are exclusive to this site. This higher richness in last elevation site joins to the variation in species richness curve, fluctuates it and adds to its non monotonic character (Fig 1). In consistent with these observations, an initial high fluctuation in β- diversity index (Fig 2) reflects the decreasing adjoining forest herbaceous species such as *Valeriana hardwickii*, *V. jatamansi*, *Heracleum candicans*, *Bupleurum candollei* and increasing grassland species; the near stable index at middle altitudes (3500–3700m) highlight the floristic similarity between lower and middle altitudinal sites while the latter portion describes a low and limited species overlap at higher altitudes (>3700m).

In both mountainous (Kala and Uniyal, 1999) and non-mountainous areas (Hortal *et al.*, 2009; Hortal *et al.*, 2013), species richness has been reported to increase with habitat diversity. In our study area, along the elevational gradient, both Shannon Weiner index (H') and species richness (SR) showed a statistically significant decreasing trend (Fig1, 4 & Table 2). A decreasing diversity at large could possibly be due to decreasing habitat heterogeneity which in turn offers reduced available area for plants to grow and decreases species diversity. However, in the last elevation site while a short growing season limits a few species to be dominant and suppress other species; a low grazing pressure seems to promote species co-existence via adding many rare and uncommon species which increases diversity at both quadrat average and synthetic data of high elevational site.

Cognizant of numerous factors along an elevational gradient which influence species richness and composition, the role of various environmental variables has been described previously (Colwell and Lees, 2000; Kessler, 2001; Grytnes 2003). In our study, the absence of any clustering in centre of CCA biplot is suggestive that all factors had an influence on species composition pattern. Furthermore, as reflected by high cumulative percentages of variance and high species-environment correlations, the measured environmental variables explained a major part of gradient variation; with altitude being most important (Fig 5). These results are consistent with studies conducted in other Himalayan grasslands wherein altitude and steepness of slopes are stated responsible for influencing species composition (Kala, 1998). Slope steepness has also been reported to be an important factor in affecting species distribution in other mountainous regions (Zhang, 2002). In our study area, besides affecting the composition, slope steepness depicted a negative correlation with species richness (Table 2). This may be because steep slope not only constrain the overall vegetation development but also accrete or degrade soil nutrient and organic matter and affect soil water content which indirectly influence species composition. Similarly, disturbance in the form of overgrazing and human interferrence greatly influences the vegetation distribution and composition across different ecosystems (Angassa and Oba, 2010) including alpine pastures of Himalayas (Nautiyal *et al.*, 2004). In our study area, disturbance (measured as number of camping sites, grazing intensity, presence of unpalatable species etc) showed a negative correlation with both species richness and diversity while its affect on species composition was more evident at altitudes below 3500 m. A possible explanation for the effect on species composition could be by way of influencing soil properties because disturbance is reported to alter the nutritional status of soils and thereby the identity of plants developing in them (Canals and Sebastia, 2000). A strong negative correlation between disturbance and altitude in our study area (Table 2) suggest that at altitudes <3500m, years of grazing, trampling and fuel-wood cutting have affected species composition greatly. Hamilton and Perrot, (1981) also opined that on highest portions of mountain slopes, the structure and distribution of plant species is related more to temperature and other climatic factors while those at lower elevations is attributed to more benign biotic or abiotic factors. Therefore, in our study area, along an elevational gradient the observed relation between species composition and environmental variables suggest that it could be a joint effect and not to an independent effect, although the influence of disturbance is more at lower altitudes. In summary, our results provide an insight on the species composition of this unexplored region by highlighting how it changes along an altitudinal and disturbance gradient and thus accentuates the need for its proper conservation.

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Appendix 1. List of plant species collected from the study area with added information on their density (ind/m^2), cover (cm^2m^2), frequency (sample quadrats containing species i/ total sample quadrats) and IVI (%).

S.No	Species	Cover	Density	Frequency	IVI (%)
1	*Achillea millefolium* L.	0.23	0.40	6.53	0.77
2	*Aconitum chasmanthum* Stapf ex Holmes	0.10	0.02	1.22	0.15
3	*A. heterophyllum* Wall. x Royle	0.09	0.10	4.08	0.46
4	*Actaea spicata* L	0.29	0.26	4.08	0.50
5	*Allium humile* Kunth	0.25	0.17	4.49	0.53
6	*A.jacquemontii* Kunth	0.39	0.20	4.49	0.55
7	*Anemone obtusiloba* D. Don	0.50	0.21	4.49	0.56
8	*A. tetrasepala* Royle	0.56	0.23	4.08	0.53
9	*Angelica glauca* Edgew	0.16	0.08	1.63	0.20
10	*Aquilegia fragrans* Benth.	0.10	0.05	0.82	0.10
11	*Artemisia roxburghiana* Besser	1.14	0.34	6.53	0.87
12	*Aster falconeri* (Cl.) Hutch	0.07	0.08	2.04	0.24
13	*A. thomsonii* Cl.	0.07	0.07	2.45	0.28
14	*Barbarea intermedia* Boreau	0.11	0.19	3.67	0.43
15	*Bergenia ciliate* (Haw) Stemb	1.38	0.52	4.08	0.65
16	*Bupleurum candollei* Wall ex. DC	0.14	0.12	3.27	0.38
17	*Callianthemum pimpinelloides* (D. Don ex Royle) Hook.f. & Thom.	0.34	0.21	3.27	0.41
18	*Caltha alba* Camb	0.67	0.14	2.86	0.40
19	*Capsella bursa- pastoris(* L) Medic	0.05	0.07	1.63	0.19
20	*Carex nivalis* Boott.	0.13	0.11	2.45	0.29
21	*Carum carvi* L.	0.16	0.26	3.27	0.40
22	*Cerastium cerastoides* (L.) Britton	0.07	0.12	2.45	0.28
23	*C. vulgatum* L.	0.07	0.12	1.63	0.20
24	*Chaerophyllum acuminatum* Lindl	0.49	0.50	6.94	0.86
25	*Corydalis diphylla* Wall	0.33	0.12	2.45	0.31
26	*C. govaniana* Wall	0.07	0.11	1.34	0.16
27	*Dipsacus inermis* Wall	0.13	0.04	1.63	0.19
28	*Draba affghanica* Boiss	1.18	3.94	4.08	0.99
29	*Dracocephalum nutans* L	0.49	2.08	9.39	1.29
30	*Epilobium laxum* Royle	0.09	0.04	0.81	0.10
31	*Conyza canadensis* Cronquist	0.15	0.50	3.27	0.42
32	*Erysimum hieracifolium* L.	0.12	0.10	1.63	0.20
33	*Eritrichium canum* (Benth.) Kitamura	0.62	0.80	4.90	0.68
34	*Euphorbia wallichii* Hook. f.	1.35	1.74	18.8	2.36
35	*Fragaria nubicola* Lindl. ex Lacaita	2.27	5.46	18.4	2.82
36	*Fritillaria roylei* Hook	0.12	0.12	4.90	0.56
37	*Galium aparine* L.	0.12	0.23	0.82	0.13
38	*Gentiana carinata* (D.Don) Griseb	0.09	0.08	2.45	0.28
39	*G. moorcroftiana* Wall. ex G. Don	0.14	0.10	3.27	0.38
40	*Geranium nepalense* Sweet	0.25	0.14	4.08	0.48
41	*G. pratense* L.	0.04	0.03	0.82	0.10
42	*Geum elatum* D.Don	12.4	2.94	26.9	4.57
43	*G. urbanum* L.	1.41	0.39	6.53	0.90
44	*Heracleum candicans* Wall.ex DC	0.05	0.01	0.82	0.10
45	*Impatiens thomsonii* Hook f & Thoms.	0.23	1.14	3.27	0.50
46	*Iris hookeriana* Foster	1.90	5.41	20.8	3.04
47	*Jaeschkea canaliculata* (Royle) Knobl	0.23	0.09	0.78	0.12
48	*Juncus thomsonii* Buchen	1.52	5.19	10.2	1.83
49	*Juniperus wallichiana* Hook. f. & Thomson	0.92	0.07	2.45	0.37
50	*Jurinea ceratocarpa* (Decne) Benth.	0.69	0.22	8.57	1.02
51	*Lagotis cashmeriana* (Royle) Rupr.	7.63	25.4	26.9	6.47
52	*Lamium album* L.	0.15	0.30	4.08	0.49
53	*Lepyrodicilis holosteoides* (Mey.) Fenzl ex Fisch & Mey	0.07	0.08	0.82	0.10
54	*Lathyrus laevigatus* (Waldst. & Kit.) Gren	0.22	0.23	3.67	0.44
55	*Leontopodium himalayanum* DC.	0.01	0.01	0.41	0.05
56	*Lindelofia longiflora* (Benth.) Baill	0.92	0.41	6.94	0.89
57	*L. stylosa* (Ka. & Kir) Brand	1.05	0.26	4.49	0.63
58	*Malva neglecta* Wall	0.47	0.91	1.32	0.29
59	*Minuartia kashmirica* (Edgew.) Matt	0.18	0.76	4.49	0.59
60	*Myosotis sylvatica* Ehrh. ex Hoffm	1.07	1.52	22.0	2.66
61	*Nepeta cataria* L.	0.47	0.74	7.76	0.97
62	*N. nervosa* Royle ex Benth	0.19	0.20	5.31	0.62
63	*Oxytropis lapponica* (Wahl.) Gay	0.15	0.04	1.22	0.15

64	*Pedicularis albida* Pennel	0.64	0.19	5.71	0.71
65	*P. bicornuta* Klotz. Ex Garcke	0.20	0.06	2.04	0.25
66	*P. punctata* Decne	0.40	0.17	4.49	0.55
67	*P. siphonantha* D.Don	0.85	0.28	4.90	0.65
68	*Phleum alpinum* L	0.09	0.29	2.45	0.31
69	*Phlomis bracteosa* Royle ex Benth	1.07	2.19	13.9	1.85
70	*Picrorhiza kurroa* Royle ex Benth	1.04	0.66	2.45	0.45
71	*Plantago himalaica* Pilger	0.26	0.08	2.45	0.30
72	*P. major* L.	1.22	0.41	7.76	1.01
73	*Poa annua* L.	2.48	1.30	30.6	4.98
74	*P. bulbosa* L.	0.24	0.17	1.22	0.18
75	*Podophyllum hexandrum* Royle	0.35	0.12	3.67	0.45
76	*Polemonium coeruleum* L.	0.10	0.06	0.98	0.12
77	*Polygonatum verticillatum* (L.) All.	0.17	0.11	2.45	0.30
78	*Polygonum viviparum* L	0.17	0.12	2.45	0.30
79	*Potentilla atrosanguinea* Lodd. ex D. Don	1.24	0.54	6.94	0.94
80	*Primula denticulata* Smith	1.18	0.34	6.53	0.87
81	*P. involucrata* Wall. ex. Duby	0.15	0.28	3.67	0.44
82	*P. rosea* Royle	1.52	0.46	5.71	0.83
83	*Ranunculus hirtellus* Royle ex D.Don	0.22	0.32	8.16	0.94
84	*Rheum webbianum* Royle	0.63	0.09	3.67	0.47
85	*Rhododendron anthopogan* D.Don	0.34	0.03	1.22	0.17
86	*Roripa islandica* Oeder. (Marry) Borbas	0.09	0.08	2.04	0.24
87	*Rosa webbiana* Wall. ex Royle	0.30	0.12	4.08	0.49
88	*Rubus irritans* Focke	0.32	0.12	2.45	0.31
89	*Rumex acetosa* L.	0.35	0.28	5.71	0.68
90	*R. nepalensis* Spreng.	2.91	0.78	14.3	1.94
91	*R. patientia* L.	0.08	0.09	1.63	0.19
92	*Sambucus wightiana* Wall ex Wt & Arn.	0.54	0.08	2.04	0.29
93	*Saxifraga stenophylla* Royle	0.42	0.57	2.04	0.33
94	*Scrophularia polyantha* Royle ex Benth.	0.40	0.15	3.27	0.41
95	*S. decomposita* Royle ex Benth	0.23	0.09	0.11	0.05
96	*Rhodiola wallichiana* (Hook.) Fu	1.54	1.79	9.80	1.42
97	*Sedum ewersii* Ledeb	0.15	0.09	0.12	0.04
98	*Senecio chrysanthemoides* DC.	2.27	1.17	19.6	2.49
99	*S. jacquemontianus* (Decne.) Benth	1.25	0.29	7.76	1.00
100	*Sibbaldia cuneata* Hornem. ex Kuntze	20.2	57.8	56.3	14.5
101	*Stachys floccosa* Benth	0.42	0.11	3.67	0.45
102	*Swertia petiolata* D.Don	2.23	1.09	8.98	1.33
103	*Tanacetum longifolium* Wall.ex DC	0.93	4.18	19.6	2.67
104	*Taraxacum officinale* Weber	0.39	0.10	4.08	0.49
105	*Thlaspi cochleariforme* DC.	0.09	0.17	4.49	0.51
106	*T. coclearioides* Hook. f & Thoms.	0.12	0.30	4.08	0.49
107	*Trifolium repens* L.	2.14	10.1	18.0	3.26
108	*Valeriana hardwickii* Wall	0.12	0.06	2.04	0.24
109	*V. jatamansi* Jones	0.09	0.03	1.63	0.19
110	*Veronica anagallis-aquatica L.*	0.48	0.08	1.63	0.24
111	*V. serpyllifolia* L	0.25	0.03	1.63	0.21