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Composition, richness and floristic diversity along an elevational gradient in a semi-disturbed treeline ecotone, Bhaderwah, Jammu and Kashmir

Dinesh Singh
Institute of Mountain Environment, University of Jammu (J&K), India
Anu Sharma
Institute of Mountain Environment, University of Jammu (J&K), India
Neeraj Sharma*
Institute of Mountain Environment, University of Jammu (J&K), India

*Corresponding author. E-mail: nirazsharma@gmail.com

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Abstract
The paper deals with plant species richness - diversity relationship along the rising elevation in a semi-disturbed tree line ecotone in upper Bhaderwah, a part of lesser Himalaya. 253 plant species distributed over 170 genera and 62 families were recorded during the intensive field surveys carried during May 2014 to September 2016. These included 11 trees, 29 shrubs and 213 herb species with 247 angiosperms and 6 gymnosperms. Family Asteraceae with 37 species dominated the study area. Maximum richness (179) was observed at sub-alpine zone (Site IV) while the trees (H'=1.74) and shrubs (H'=2.48) revealed maximum diversity at Site III and herbs at Site IV (H'=4.60). The maximum evenness for trees, shrubs and herbs was exhibited by sites III (J'=0.79), V (J'=0.87) and VI (J'=0.94), respectively. The diversity and evenness showed an incremental rise along the rising elevation reaching maxima at the mid elevation with Site-IV being the species rich and Site-VII species deficit, which implies that sub-alpine and alpine forests need effective monitoring and conservation.

Keywords: Diversity, Elevation, Extreme environment, Monitoring and conservation, Richness, Sub-alpine, Vegetation composition

INTRODUCTION

The treeline ecotone, marked by the culmination of the forested zone is the most prominent ecological boundary governed by climatic factors in the high mountains (Holtmeier, 2003). In a broader sense, the alpine timberlines represent the upper limit of forest on a mountain (Wardle, 1974). A product of the stochastic nature of weather and resilience of plant life, it forms a complex transitional boundary in mountain environments harbouring unique vegetation types therein. Recent climate change has become one of the main drivers of shifts in the geographical distributions of plant species (Sykes, 2009; Parmesan *et al*., 2011; Pacifici *et al.,* 2015; Kosanic *et al.,* 2018). Changes in geographical distributions of vegetation at the local and regional scales can impact community composition, ecosystem function, and genetic diversity, which can make plants even more vulnerable to on-going environmental change (Butchart *et al.,* 2010; Richardson *et al.,* 2010; Vila and Ibanez, 2011). The dense and close forests above the tree line gradually give way to shrubs and/or meadows where trees become stunted and deformed by the severe climate. Rather than moving upward in defined bands, shifting plant assemblages are influenced by local topography and soil moisture (Hall and Fagre, 2003). Other factors mentioned as significant causes include microtopography including tree islands themselves (Holtmeier and Broll, 1992), soil composition (Cairns, 1998), fire (Rochefort *et al*., 1994), winter injury (Cairns and Malanson, 1998), and aspects of tree reproduction including seed bank location and abundance (Cairns and Malanson, 1997).

The alpine tree line ecotone, despite a long history of observations and field investigations, remain relatively poorly understood in some respects when compared to other ecosystems. Proper understanding of forest structure is a pre-requisite to describe various ecological processes and model the functioning and dynamics of forests (Elourard *et al*., 1997). The various constituents of species diversity that govern the expression of traits include the number of species present (species richness), their relative abundance (species evenness), presence of the particular species (species composition), the interactions among species, and the spatial and temporal variation in these properties. Species diversity im-

pacts the resilience and resistance of ecosystems to environmental changes as well as effecting the current functioning of ecosystems (Chapin *et al*., 2000). In an attempt to better understand the trend in species richness and diversity along the rising elevation, the field surveys were conducted along a tree line ridge in upper Bhaderwah, valley of Jammu and Kashmir. The complex physiographic and topographic complexity of the mountain ranges of upper Bhaderwah valley has resulted in extreme habitat and microclimatic heterogeneity influencing the current distribution of vegetation.

MATERIALS AND METHODS

Study area: Our study focused on topographically complex regions located along the southwestern mountain ranges of Upper Bhaderwah valley covered by floristically diverse old growth. The study area forms the south-western part of Chenab catchment namely *Kailash Kund* circuit divided into seven sites at a regular interval of 200 m each starting from Chattergalla (2800 m) to Kailash lake (4000 m) (Fig 1). The forests of the study area are mainly composed of Kharsu Oak-Conifer mixed patches leading to alpine scrub, vast meadows and rocky out crops beyond. Besides forming a typical tree line ecotone with a good diversity of vegetation, the study area is exposed to moderate disturbances in the form of unscientific TMAP extraction, fuel wood burning, timber removal, overgrazing, browsing and trampling, pollution, etc. which is attributed to myriad of situations which last for the entire summers in these highlands (Figs 2-7)

Methodology: The detailed floristic investigations were carried out in the study area during May 2014 to September 2016. 100 m^2 quadrats, twenty each were laid at all seven sites in an elevational range of 1200 m (2800 m to 4000 m). In each 10m x10 m quadrat, the smaller quadrats of 25 m^2 and 1 m^2 each were laid for shrubs and herbs, respectively. Plants were collected (for herbarium) and photographed on the spot for identification. Proper care was taken to avoid any loss to the plants and habitat bearing them. The plant samples were collected in newspaper and compressed with the help of herbarium press, dried and finally mounted on herbarium sheets. The voucher specimens have been kept in the herbarium of Institute of Mountain Environment. Plant identification was mostly done on the field with the help of field guide *viz.* Flowers of the Himalaya (Polunin and Stainton 1984) besides consulting taxonomic experts of the region. Three vegetation layers, *i.e.* tree, shrub and herb were analyzed for species richness, diversity and dominance. Species richness was simply considered as the number of species per unit area (Whittaker, 1972). The richness was obtained by using the formula SR = S-1/ln (N) given by Margalef (1968) and SR= s/√n (Menhinick, 1964) (where, S = number of species and N = Total number of individuals (of all species in case of Menhinick's index). The Shannon-Weiner diversity Index (Shannon and Wiener, 1963) was calculated by using formula H'= - ∑ni/n log2 ni/n (where ni is the IVI of a species and n the sum total IVI values of all species in a forest type) while the evenness (equability) was obtained using the formula E1 = H′ / ln (s) (Pielou, 1966). Dominance was calculated using Simpson's index (Simpson, 1949) using D: I-Cd, Where Cd = Simpson's concentration of dominance = $(\sum ni/n)^2$.

RESULTS

Floristic composition: The study area forms a typical tree line ecotone with the dominance of Kharsu Oak climax community (along the ridges) interspersed with Fir-Spruce-Birch-Bluepine mixture along the northern aspect. The Kharsu Oak community at sub-alpine zone is taken over by the *Rhododendron-Juniper* scrub and *Krummholtz* (stunted deformed vegetation) around 3800 m and the rocky outcrops beyond. These alpine landscapes are rich repositories of medicinal and aromatic plants presently under severe threats from different sources. The threatened medicinal plants found in the study area include *Aconitum heterophyllum, A. violaceum, Arnebia benthamii, Artemisia maritima, Bergenia stracheyi, Betula utilis, Cypripedium cordigerum, C himalaicum, Dactylorhiza hatagirea, Fritilaria roylei, Hypericum perforatum, Inula aculeata, Jurinea macrocephala, Meconopsis aculeata, Pickrorhiza kurroa, Rhodiola heterodonta, Rhododendron anthopogon, R. companulatum, Sinopodophyllum hexandrum* and *Taxus wallichiana.*

During the extensive field surveys along the tree line of upper Bhaderwah, we recorded 253 species of plants (11 trees, 29 shrubs and 213 herbs) contained in 170 genera and 62 families (Appendix 1, Table 1). Of these 247 are angiosperms (including 12 species of orchids) and 6

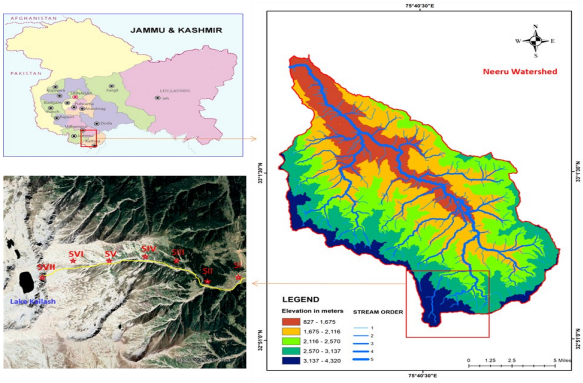

Fig. 1. *Map of the study area showing different sites along the rising elevation.*

Appendix-1. Family wise species distribution along an elevational gradient (2800-4000 m) in a treeline ecotone of Bhaderwah.

FAMILY / SPECIES	HABIT	SI	SII	SIII	SIV	SV	SVI	SVII
Acanthaceae								
Strobilanthes urticifolia Wall.	Shrub	+	+	+	-	-	-	-
Aceraceae								
Acer acuminatum Wall.	Tree	+	+	+	-	-	-	-
Adoxaceae								
Viburnum cotinifolium D. Don	Shrub	-	+	+	-	-	-	-
Viburnum grandiflorum Wall.	Shrub	+	+	+	-	+	-	-
Amaranthaceae								
Achyranthes bidentata Blume.	Herb	+	+	-	-	-	-	-
Anacardiaceae								
Toxicodendron succedaneum (L.) Kuntze	Tree	+	+	+	+	-	-	-
Apiaceae								
Bupleurum longicaule Wall. ex DC.	Herb	+	+	+	+	+	+	-
Heracleum candicans Wall. ex DC.	Herb		+	+	+	+	-	-
Hymenidium stellatum (D. Don) M.G Pimnov & E.V Kljuykov.	Herb	-	-	-	-	+	+	+
Pleurospermum brunonis Benth. ex C.B.Clarke.	Herb	-	-	-	+	+	+	+
Selinum filicifolium (Edgew.) Nasir.	Herb	+	+	+	+	+	-	-
Selinum wallichianum (DC.) Raizada & Saxena.	Herb	-	+	+	+	-	-	-
Araceae								
Arisaema flavum (Forssk.) Schott.	Herb	+	+	+	+	+	-	-
Arisaema jacquemontii Blume.	Herb	+	+	+	+	-	-	-
Arisaema propinquum Schott.	Herb	+	+	+	+	-	-	-
Arisaema tortuosum Wall.	Herb	-	+	+	-	-	-	-
Araliaceae								
Hedera nepalensis K.Koch.	Herb	+	+	-	-	-	-	-
Asclepiadaceae								
Vincetoxicum hirundinaria Medik.	Herb	+	-	+	+	-	-	-
Asparagaceae								
Maianthemum purpureum Wall.	Herb	-	+	-	-	+	-	-
Polygonatum verticillatum Mill.	Herb	+	-	+	+	+	-	-
Asteraceae								
Achillea millefolium L.	Herb	+	+	+	+	+	-	-
Anaphalis margaritacea L.	Herb	+	+	+	+	+	-	-
Anaphalis nepalensis Hand. -Mazz.	Herb		+	+	+	+	+	+
Anaphalis triplinervis Sims ex C.B.Clarke.	Herb	+	+	+	+	+	-	-
Arctium lappa L.	Herb	-	-	+	+	+	-	-
Artemisia maritima L.	Herb	+	+	+	+	+	+	-
Artemisia roxburghiana Wall.ex Besser.	Herb	+	+	+	-	+	-	-
Aster flaccidus Bunge.	Herb	-	-	+	+	+	+	+
Aster himalaicus Ganesh.	Herb	-	-	+	+	+	+	+
Aster thomsonii C.B. Clarke	Herb		+	+	+	+	-	-
Carduus edelbergii Rech.f.	Herb	+	-	+	-	-	-	-
Cicerbita macrorhiza (Royle)	Herb	-	-	+	+	+	-	+
Cirsium falconeri (Hook.f.) Petr.	Herb	+	+	+	+	-	-	-
Cirsium wallichii (L.) Scop.	Herb	+	+	-	-	-	-	-
Cremanthodium arnicoides (DC.ex Royle)	Herb	-	+	+	-	-	-	+
Cremanthodium ellisii (Hook.f.) Kitam.	Herb	-	+	+	+	-	-	+
Dolomiaea macrocephala DC.	Herb	-	-	+	+	-	+	+
Doronicum kamaonense DC.	Herb	+	+	+	+	-	-	-
Erigeron multiradiatus Lindl.	Herb	-	+	+	+	+	-	-
Gnaphalium stewartii C.B.Clarke ex Hook.f.	Herb	+	+	-	+	+	+	-
Inula racemosa Hook.f.	Herb	-	+	+	-	-	+	+
Inula royleana DC.	Herb	+		+	+	+	-	+

Contd.....

Lactuca brunoniana (DC) Wall. ex C.B.Clarke.	Herb	-	+	-	+	+	-	-
Lactuca lessertiana DC.	Herb	-	-	+	+	+	+	-
Leontopodium himalayanum DC.	Herb	-	-	+	+	+	+	+
Ligularia amplexicaulis DC.	Herb	-	-	+	+	+	+	-
Ligularia fischeri (Ledeb.) Turcz.	Herb	+	+	+	-	+	+	-
Ligularia Jacquemontiana Col.	Herb	-	+	-	-	-	+	+
Onopordum acanthium L.	Shrub	+	+	-	-	-	-	-
Saussurea atkinsonii C.B.Clarke	Herb	-	-	+	+	+	+	-
Saussurea roylei C.B.Clarke	Herb	-	+	+		+	+	-
Saussurea taraxacifolia Wall. ex DC.	Herb	-	-	+	+	+	+	+
Senecio laetus DC.	Herb	+	-	-	-	-	-	-
Senecio raphanifolius Wall.	Herb	-	+	+	+	+	-	-
Solidago virgaurea L.	Herb	-	+	-	+	+	-	-
Tanacetum dolichophyllum Kitam.	Herb	-	-	+	+	+	+	+
Taraxacum officinale Wigg.	Herb	+	+	+	+	+	-	+
Balsaminaceae								
Impatiens edgeworthii Hook.f.	Herb	+	+	+	-	-	-	-
Impatiens glandulifera Royle.	Herb	-	+	+	+	-	-	-
Impatiens sulcata Wall.	Herb	+		+	+	+	+	-
Berberidaceae								
Berberis jaeschkeana C. K. Schneid.	Shrub	+	+	+	+	-	-	-
Berberis lycium Royle.	Shrub	+	+	-	-	-	-	-
Sinopodophyllum hexandrum Royle.	Herb	+	+	+	+	+	-	-
Betulaceae								
Betula utilis D.Don.	Tree	+	+	+	+	-	-	-
Boraginaceae								
Arnebia benthamii Wall. ex G.Don I.M.Johnst.	Herb	-	-	+	+	+	-	+
Cynoglossum wallichii Wall. ex Benth	Herb	-	+	+	+	-	-	-
Hackelia uncinata (Benth.) C.E.C.Fisch.	Herb	+	+	+	+	+	-	-
Lindelofia longiflora (Benth.)	Herb	-	+	+	-	-	+	-
Brassicaceae								
Cardamine macrophylla Willd.	Herb	-	+	+	+	+	-	-
Erysimum melicentae Dunn.	Herb	+	+	+	-	-	-	-
Thlaspi montanum DC.	Herb	-	-	+	+	+	-	-
Campanulaceae								
Campanula aristata Wall.	Herb	-	-	+	+	-	-	-
Campanula latifolia Lindl.	Herb	-	+	+	+	-	-	-
Cyananthus lobatus Wall. ex Benth.	Herb	-	-	+	+	-	+	+
Codonopsis ovata Benth.	Herb	-	+	+	-	+	-	-
Caprifoliaceae								
Dipsacus inermis Wall.	Herb	+	-	+	+	-	-	-
Lonicera obovata Royle ex Hook. f.	Shrub	-	+	+	+	-	-	-
Lonicera quinquelocularis L.	Shrub	+	+	-	-	-	-	-
Morina longifolia Wall.	Herb	+	+	+	+	+	-	-
Valeriana hardwickii Wall.	Herb	-	-	+	+	-	+	-
Valeriana pyrolaefolia Decne.	Herb	-	+	+	+	-	-	-
Caryophyllaceae								
Cerastium cerastoides (L.) Britton.	Herb	-	-	-	+	+	-	+
Gypsophila cerastioides D.Don.	Herb	-	+	+	+	+	-	-

Contd.....

Myosoton aquaticum (L.) Moench	Herb	+	+	-	-	-	-	-
Silene cashmeriana (Benth. Ex Royle)	Herb	-	-	+	+	+	-	+
Silene gonosperma (Rupr.)	Herb	-	-	+	+	-	+	+
Silene vulgaris L.	Herb	-	+	+	+	-	-	-
Stellaria decumbens Wight ex Edgew.	Herb	-	-	-	+	+	-	+
Stellaria himalayensis Wight.	Herb	-	-	+	+	+	+	-
Celastraceae								
Parnassia nubicola Wall.	Herb	+	-	-	-	-	-	-
Colchicaceae								
Colchicum luteum Baker.	Herb	+	-	-	-	-	-	-
Crassulaceae								
Rhodiola fastigiata (Hook. f and Thomson)	Herb	-	-	-	-	+	+	+
Rhodiola heterodonta (Hook. f and Thomson)	Herb	-	-	+	+	+	-	-
Rhodiola himalensis (D. Don) S.H. Fu.	Herb	-	-	+	+	+	+	-
Sedum ewersii Ledeb.	Herb	+	+	-	+	+	+	-
Sedum multicaule Wall.ex Lindl.	Herb	-	+	+	+	-	-	-
Sedum oreades (Decne.) Raym.-Hamet	Herb	-	-	+	+	-	+	+
Cupressaceae								
Juniperus communis L.	Shrub	+	+	+	+	+	+	-
Juniperus recurva Buch. -Ham. ex D.Don.	Shrub	-	-	+	+	+	+	-
Cyperaceae								
Carex nivalis. L.	Herb	-	-	-	-	-	+	+
Ericaceae								
Cassiope fastigiata (Wall.) D.Don	Shrub	-	-	-	+	+	+	+
Gaultheria trichophylla Royle.	Shrub	-	-	+	+	+	+	+
Rhododendron anthopogon D.Don.	Shrub	-	-		+	+	+	-
Rhododendron campanulatum D. Don.	Shrub	-	+	+	+	+	+	-
Euphorbiaceae								
Euphorbia cornigera Boiss.	Herb	+	+	+	+	+	-	-
Euphorbia wallichii Col.	Herb	+	+	+	+	+	-	-
Fabaceae								
Campylotropis griffithii (Schindl.)	Herb	-	-	+	+	-	+	-
Desmodium elegans DC.	Shrub	+	+	-	-	-	-	-
Indigofera hebepetala Benth. ex Baker.	Shrub	-	+	+	+	-	-	-
Indigofera heterantha Wall.ex Brandis.	Shrub	-	+	-	+	+	-	-
Lathyrus laevigatus (Waldst. and Kit.)	Herb	+	+	+	-	-	-	-
Trifolium pratense L.	Herb	+	+	-	-	-	-	-
Trifolium repens L.	Herb	+	+	+	+	+	-	-
Fagaceae								
Quercus semecarpifolia D,Don.	Tree	+	+	+	+	-	-	-
Fumariaceae								
Corydalis cashmeriana Royle.	Herb	-	-	-	+	-	-	+
Corydalis cornuta Royle.	Herb	-	+	+	-	+	-	-
Corydalis govaniana Wall	Herb	+	-	+	+	-	+	-
Gentianaceae								
Gentiana carinata (D.Don) Griseb.	Herb	-	-	+	+	+	+	-
Gentiana venusta (G.Don) Wall. ex Griseb.	Herb	-	+	+	+	-	-	+
Gentianella moorcroftiana (Wall. ex G. Don) Airy Shaw	Herb	+	+	+	+	+	+	+
Jaeschkea oligosperma Knobl.	Herb	+	+	+	+	-	-	+
Swertia ciliata (D. Don ex G. Don) B.L. Burtt.	Herb	+	+	+	+	+	-	-
Swertia petiolata D.Don.	Herb	-	+	+	+	+	+	+

Contd....

Geraniaceae								
Geranium nepalense Sweet.	Herb	+	+	+	-	-	-	-
Geranium wallichianum D.Don ex Sweet	Herb	+	+	+	+	+	-	-
Grossulariaceae								
Ribes orientale Desf.	Shrub	+	+	-	+	-	-	-
Hypericaceae								
Hypericum elodeoides Wall.	Herb	+	+	+	+	-	-	-
Hypericum perforatum L.	Herb	+	+	+	-	-	-	-
Iridaceae								
Iris hookeriana L.	Herb	-	-	-	+	+	-	-
Juncaceae								
Juncus himalensis Klotzsch.	Herb	-	+	-	+	-	-	+
Lamiaceae								
Clinopodium vulgare L.	Herb	+	+	+	-	+	-	-
Lamium album L.	Herb	+	+	-	+	+	+	+
Leonurus cardiaca L.	Herb	+	-	+	+	-	-	-
Mentha longifolia (L.) Huds. *subsp. himalayensis* (Briq.) Briq.	Herb	+	+	+	-	-	-	-
Nepeta connata Royle ex Benth.	Herb	-	+	-	+	+		+
Nepeta laevigata (D.Don)Hand.-Mazz	Herb	-	+	+	+	-	+	-
Nepeta leucophylla Benth.	Herb	+	+	+	-	+	-	-
Origanum vulgare L.	Herb	-	+	+	+	-	-	-
Phlomis bracteosa Royle ex Benth.	Herb	-	+	+	-	+	+	+
Phlomis spectablis Falc. ex Benth.	Herb	+	-	+	+	+	-	-
Prunella vulgaris L.	Herb	+	+	+	-	+	-	-
Salvia hians Royle ex Benth.	Herb	+	+	+	+	+	-	-
Salvia nubicola Wall.	Herb	+	-	+	+	+	-	+
Stachys emodi Wall.	Herb	+	+	+	-	+	+	-
Stachys melissifolia Benth.	Herb	+	-	+	+	+	-	-
Thymus linearis Benth.	Shrub	+	+	+	+	+	-	-
Leguminosae								
Lotus corniculatus L.	Herb	-	-	+	+	+	-	-
Oxytropis lapponica (Wahlenb.) Gay.	Herb	-	-	+	+	+	+	-
Liliaceae								
Fritillaria roylei Hook.	Herb	-	+	+	+	+	-	+
Oleaceae								
Syringa emodi Wall.	Shrub	-	+	+	+	-	-	-
Onagraceae								
Epilobium royleanum Hausskn.	Herb	-	+	+	+	+	-	+
Orchidaceae								
*Androcorys josephi (*Rchb.f.)	Herb	-	-	+	-	-	-	-
Calanthe tricarinata Lindl.	Herb	+	+	-	-	-	-	-
Cypripedium cordigerum D. Don	Herb	+	-	-	-	-	-	
Cypripedium himalaicum Rolfe.	Herb	-	-	+	+	-	-	-
Dactylorhiza hatagirea D.Don	Herb	+	-	+	+	-	-	-
Epipactis helleborine L.	Herb	-	-	+	+	-	-	-
Gastrodia falconeri D.L.Jones and M.A.Clem.	Herb	+	-	-	-	-	-	-
Goodyera repens (L.) R.Br.	Herb	-	-	+	-	-	-	-
Gymnadenia orchidis Lindl.	Herb	-	+	-	-	-	-	-
Herminium monorchis L.	Herb	-	-	-	+	+	-	-
Neottia listeroides Lindl.	Herb	-	+	-	-	-	-	-
platanthera edgeworthii (Hook.f. ex Collett) R.K.Gupta.	Herb	-	-	-	+	-	-	-
Orobanchaceae								
Euphrasia himalayica Wettst.	Herb	-	+	+	+	+	+	+
Pedicularis bicornuta Klotzsch	Herb	-	-	-	-	+	+	+
Pedicularis pectinata Benth.	Herb	-	+	+	+	-	+	+
Pedicularis pyramidata Royle ex Benth.	Herb	+	-	+	+	+	-	+
Pedicularis rhinanthoides Schrenk.	Herb	-	-	+	+	+	+	+

Contd....

Papaveraceae								
Meconopsis aculeata Royle.	Herb	-	-	-	+	+	+	+
Meconopsis bella Prain.	Herb	-	-	-	-	+	+	+
Phytolaccaceae								
Phytolacca acinosa L.	Herb	+	-	+	+	-	-	-
Pinaceae								
Abies pindrow Royle.	Tree	+	+	+	+	-	-	-
Picea smithiana Wall.	Tree	+	+	+	-	-	-	-
Pinus wallichiana A.B.Jacks.	Tree	+	+	+	-	-	-	-
Plantaginaceae								
Digitalis lanata Ehrh.	Herb	+	-	-	-	-	-	-
Digitalis purpurea L.	Herb	+	-	-	-	-	-	-
Picrorhiza kurroa Royle ex Benth.	Herb	-	-	-	-	+	+	-
Plantago himalaica Pilg.	Herb	+	+	+	-	+	+	-
Plantago major L.	Herb	+	+	-	-	-	-	-
Veronica laxa. L.	Herb	-	+	+	+	-	-	-
Wulfeniopsis amherstiana Benth.	Herb	+	+	-	-	-	-	-
Poaceae								
Hierochloe laxa Hook.f	Herb	-	-	-	-	+	+	-
Polemoniaceae								
Polemonium caeruleum L.	Herb	+	-	+	+	-	-	-
Polygonaceae								
Bistorta vivipara (L.) Delarbre *subsp. vivipara.*	Herb	-	-	+	+	+	+	-
Oxyria digyna L.	Herb	-	+	+	+	+	+	+
Persicaria alpina (All.) H.Gross.	Herb	+	-	+	+	-	-	-
Persicaria amplexicaulis (D.Don) Ronse Decr.	Herb	-	+	+	-	+	+	-
Persicaria capitatum D.Don.	Herb	+	-	+	+	+	-	-
Persicaria wallichii Wall.	Herb	+	+	+	+	-	-	-
Polygonum affine D. Don.	Herb	-	-	+	+	+	-	+
Polygonum vacciniifolium. L.	Herb	-	-	+	+	+	-	+
Rheum australe D.Don Prodr.	Herb	-	-	+	+	+	-	-
Rheum spiciforme Royle.	Herb	-	-	+	+	-	+	+
Rumex acetosa L.	Herb	+	+	+	+	+	+	-
Primulaceae								
Androsace muscoidea DC.	Herb	-	-	-	+	+	-	+
Androsace rotundifolia Hardw.	Herb	+	+	+	+	-	-	-
Androsace sarmentosa Wall.	Herb	+	+	+	-	-	-	-
Primula macrophylla D. Don.	Herb	-	-	-	+	+	+	-
Primula primulina (Spreng.)	Herb	-	-	-	-	+		+
Primula rosea Royle.	Herb	+	+	+	-	+	-	-
Primula stuartii Wall.	Herb	-	-	-	+	+	-	-
Ranunculaceae								
Aconitum heterophyllum Wall. ex Royle	Herb	+	+	-	+	+	+	-
Aconitum leave Royle.	Herb	+	+	+	+	-	-	-
Aconitum violaceum Jacquem. ex Stapf.	Herb	+	+	+	-	+	+	-
Actaea spicata L.	Herb	+	+	-	+	-	-	-
Anemone obtusiloba D.Don	Herb	+	+	+	+	+	-	-
Anemone rupicola Cambess ex. Jacquem.	Herb	-	-	+	+	-	-	+
Anemone tetrasepala Royle.	Herb	-	+	+	+	-	-	-
Aquilegia pubiflora Wall.	Herb	+	+	+	-	-	-	-
Caltha palustris L.	Herb	-	-	+	+	+	+	-
Clematis grata Wall.	Herb	+	-	-	-	-	-	-
Delphinium vestitum Wall. ex Royle.	Herb	+	+	+	+	+	-	+
Paraquilegia microphylla (Royle) J.R Drumm.	Herb	-	-	-	-	+	-	+
Ranunculus hirtellus Royl.	Herb	-	-	-	-	+	+	+
Ranunculus laetus Wall. ex, Hooker.	Herb	+	+	+	-	-	-	-
Thalictrum foliolosum DC.	Herb	-	+	+	+	-	-	-
Rosaceae								
Agrimonia pilosa Ledeb.	Herb	+	+	+	+	-	-	-
Cotoneaster nummularius Fisch. and C.A. Mey.	Shrub	+	+	-	-	-	-	-
Cotoneaster rotundifolius Wall. ex Lindl.	Shrub	-	+	+	+	+	-	-
Fragaria daltoniana J.Gay.	Herb	-	+	+	-	+	-	-
Fragaria nubicola L.	Herb	+	+	+	+	+	-	-

Contd...

Geum elatum Wall. ex G. Don	Herb		+	+	+	+	+	-
Geum roylei Wall.	Herb	+	+	+	+	-	-	-
Geum urbanum L.	Herb	+	+	-	-	-	-	-
Potentilla atrosanguinea Lodd., G. Lodd. and Wild. Lodd.	Herb	-	+	+	+	-	-	-
Potentilla cuneata Wall. ex, Lehm.	Herb	-	-	+	+	-	+	+
Potentilla nepalensis Hook.	Herb	-	-	+	+	+	+	-
Prunus cornuta (Wall. ex Royle) Steud.	Tree	+	+	+	+	-	-	-
Rosa macrophylla Lindl.	Shrub	+	+	+	+	+	-	-
Rosa webbiana Lindl.	Shrub	-	+	+		+	+	-
Sibbaldia cuneata Hornem. ex Kuntze	Herb	-	-	+	+	+	+	+
Sorbus cuspidata (Spach) Hedl.	Tree	-	+	+	-	-	-	-
Sorbus microphylla Wallich.	Tree	-	-	+	+	+	+	-
Spiraea canescens D.Don	Shrub	+	+	+	-	-	-	-
Rubiaceae								
Galium aparine L.	Herb	-	+	+	+	+	-	-
Galium asperuloides Edgew.	Herb	+	+	-	-	-	-	-
Himalrandia tetrasperma (Wall. ex Roxb.)	Shrub	-	+	+	+	-	-	-
Salicaceae								
Salix elegans Wall.	Shrub	+	+	+	+	+	+	-
Salix lindleyana Wall. ex Andersson.	Shrub	-	-	+	+	+	+	-
Saxifragaceae								
Bergenia ciliata Haworth.	Herb	-	+	+	+	+	-	+
Bergenia stracheyi (Hook.f. and Thomson) Engl.	Herb	-	-	+	+	+	+	+
Saxifraga moorcroftiana Wall.	Herb	-	-	-	+	+	+	+
Saxifraga sibirica L.	Herb	-	-	+	+	+	+	+
Saxifraga stenophylla Royle.	Herb	-	-	+	+	-	+	+
Scrophulariaceae								
Lagotis cashmeriana Rupr.	Herb	-	-	+	+	+	+	-
Scrophularia decomposita (Royle ex Benth.)	Herb	+	+	+	-	-	-	-
Verbascum thapsus L.	Herb	+	+	+	-	-	-	-
Solanaceae								
Atropa acuminata L.	Herb	-	-	-	+	+	-	-
Taxaceae								
Taxus wallichiana Zucc.	Tree	-	-	+	-	-	-	-
Thymelaeaceae								
Wikstroemia canescens Wall. ex Meisn.	Shrub	+	+	+	-	-	-	-
Trilliaceae								
Trillidium govanianum Wall. ex D.Don	Herb	-	-	+	+	-	+	-
Urticaceae								
Pilea umbrosa Wedd.	Herb	+	+	-	-	-	-	-
Violaceae								
Viola biflora L.	Herb	-	-	+	+	+	-	+

gymnosperms. Family Asteraceae with 37 species dominated the area followed by Rosaceae (18 species), Lamiaceae (16), Ranunculaceae (15) Orchidaceae (12) and Caryophyllaceae (8). The conifers are widely distributed especially along the lower elevations. *Pinus wallichiana*, *Picea smithiana* and *Abies pindrow* with interspersed patches of *Taxus wallichiana* dominate the ridge bases especially along the northern aspects (Sites I, II and III). Kharsu-Oak, *Quercus semecarpifolia* forms the climax treeline community along the ridge tops mostly facing the southern aspects (Sites III and IV). The northern aspects however harbor a mix of *Betula utilis* and *Abies pindrow* patches at lower slopes. The bare ridge tops harbor immensely rich and unique herbaceous diversity mostly comprising the threatened medicinal and aromatic plants.

Richness and Diversity: Species richness and diversity for the trees, shrubs and herbs at all the 7 sites exhibited the interesting results along the rising elevation. Maximum species richness (178 species) was recorded at Site-IV with the dominance of herbs (149 species) followed by Site-III (139 species), Site-V (121 species), Site-II (113 species), Site-I (100 species) and Site-VI (82 species). Site-VII at the highest elevation of 4000 m with the extreme conditions offers least survival rates and thus recorded the lowest species richness of 61 (Fig 8a) The trend in species richness followed a decreasing trend with maximum number of herbs followed by trees and shrubs at all the 7 sites (Table 2).

The values for Margalef's and Menhinick's indices have been recorded highest for the herbs (19.78, 3.53), shrubs (3.91, 1.38) and trees (1.63, 0.78) at sites IV, II and III, respectively. The evenness was recorded highest for the herbs (0.94), shrubs

Fig. 2. *Infrastructure built up at Kailash lake at 3900 m.*

Fig. 3. *Camp site for annual Kailash Yatra at 3900 m.*

Fig. 4. *Extraction of fuel wood for community kitchens.*

Fig. 5. *Plastic pollution / trampling of ground flora .*

Table 1. Floristic pattern along the elevational gradient in the study area.

Attributes	Whole study area	Site I (2800 m)			Site II (3000 m)			Site III (3200 m)			Site IV (3400 m)			Site V (3600 m)			Site VI (3800 m)			Site VII (4000 m)		
		T	S	H	T	S	H	T	S	H	T	S	H	T	S	H	T	S	H	T	S	H
Species	253	8	14	78	8	23	82	9	20	110	9	20	149	1	14	106	0	6	76	0	2	59
Genera	170	8	13	63	8	18	66	9	16	82	8	15	98	1	10	78	0	4	59	0	2	49
Families	62	5	10	30	6	15	32	6	14	34	6	12	38	1	7	32	0	2	23	0	1	21

Where, T – Trees, S - Shrubs and H- Herbs

Table 2. Species richness along the rising elevation.

Life form	Study sites							Whole study area (nos)
	I	II	III	IV	V	VI	VII	
Trees	8	8	9	9	1	0	0	11
Shrubs	14	23	20	20	14	6	2	29
Herbs	78	82	110	149	106	76	59	213
Total	**100**	**113**	**139**	**178**	**121**	**82**	**61**	**253**

Table 3. Plant species richness, diversity, dominance and evenness along the rising elevation in the study area.

Parameter	Taxa	Site I	Site II	Site III	Site IV	Site V	Site VI	Site VII
Species richness	**Trees**	8	8	9	9	1	0	0
	Shrubs	14	23	20	20	14	6	2
	Herbs	78	82	110	149	106	76	59
Total		100	113	139	178	121	82	61
Shanon Wiener's Index	**Trees**	1.533	1.494	1.745	1.029	0	0	0
	Shrubs	2.308	2.452	2.485	2.419	2.307	1.234	0.4101
	Herbs	3.966	3.945	4.27	4.604	4.355	4.086	3.805
Pielou's Evenness Index	**Trees**	0.7370	0.7184	0.7942	0.4681	0	0	0
	Shrubs	0.8744	0.7819	0.8295	0.8074	0.8741	0.6889	0.5917
	Herbs	0.9102	0.8953	0.9084	0.9201	0.9338	0.9436	0.9333
Simpson's Index	**Trees**	0.7215	0.7055	0.7983	0.4566	0	0	0
	Shrubs	0.8748	0.8581	0.8911	0.8775	0.8779	0.6167	0.2449
	Herbs	0.9697	0.9725	0.9806	0.9863	0.9844	0.9801	0.9718
Menhinick's Index	**Trees**	0.7493	0.7396	0.7804	0.7324	0.5	0	0
	Shrubs	1.043	1.387	1.339	0.9975	0.6585	0.5324	0.252
	Herbs	3.305	2.636	2.994	3.537	2.915	2.79	2.995
Margalef's index	**Trees**	1.478	1.47	1.636	1.594	0	0	0
	Shrubs	2.503	3.917	3.514	3.169	2.126	1.032	0.2414
	Herbs	12.18	11.78	15.12	19.78	14.61	11.35	9.73

Fig. 6. *Live stock grazing around Kaialsh Lake .*

Fig. 7. *Extraction of medicinal plants.*

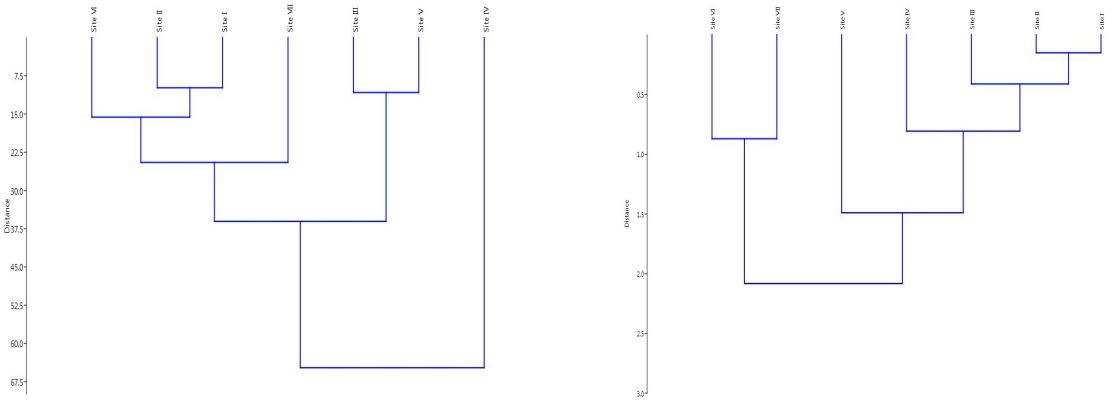

Fig. 8. *Hierarchal cluster analysis a) Species richness b) Species diversity.*

(0.87) and trees (0.79) at sites VI, I and III, respectively. The species diversity was recorded maximum for herbs (H'=4.60) at site IV, shrubs (H'=2.48) at site III and trees (H'=1.74) at site III, respectively (Fig 8b). The value of Simpson's index was recorded maximum for herbs (1D=0.98) at Site IV, for shrubs (0.89) and trees (0.79) at site III (Table 3).

DISCUSSION

The study area is represented by sub-alpine to alpine vegetation with broadleaved-conifer mixed stands at lower elevations taken over by Kharsu-Oak climax community and alpine scrub along the rising elevation from 2800 m to 4000 m in upper Bhaderwah catchment. During their floristic analysis in Bhaderwah and vicinity, Kumar (1987), Kumar (1997), Singh and Rawat (2000), Kour (2001), Dutt (2005), Raina and Kumar (2011), Sharma *et al*. (2016) and Sharma (2018) reported similar trend in species composition, richness, and dominance with a characteristic mid-domain effect exhibited by Sites III, IV and V (Fig 8a). Our observation is in consonance with the results obtained from similar landscapes (Singh and Rawat, 2000; Kessler, 2000; Grytnes and Vetaas, 2002; Chawla *et al.,* 2008 and Habib *et al.,* 2011). The herbs contribute maximum in terms of species richness and diversity recorded highest at mid-elevations (Site IV) with a corresponding decline along the rising elevation (Kharkwal *et al.,* 2005). A sharp dip in species richness is observed beyond Site IV with a minima recorded at Site VII (62 species). The reduction in species at higher altitudinal gradient could be due to the effect of eco-physiological constraints, such as short period of growing season, extremely low temperature, and geographical barriers (Grytnes and Beaman, 2006).

In terms of species diversity, various indices (Shannon-Wiener's, Margalef's, Menhinick's and Simpson's index) were calculated for all the layers *i.e.,* trees, shrubs and herbs. . The richness and diversity values showed an incremental rise from hill base (Site I) till mid-altitude (Site IV) with a gradual fall corresponding to the rising elevation further. The higher diversity values in terms of Margalef's Index (1.63 for trees / 19.78 for herbs), Menhinick's Index (0.78 / 3.53) were observed at sites III and IV, respectively. Shrubs on the other hand showed a bit different trend where the richness and diversity were recorded maximum at lower elevation (Margalef's Index =3.91 / Menhinick's Index = 1.38) at Site II with a slight dip in

species richness with the rising elevation. The dendrogram for diversity (Fig 8b) clearly explains this trend. This finding is in agreement with the studies by Kumar and Ram (2005), Kharkwal *et al.* (2005), Sharma *et al.* (2009), Bargali *et al.* (2013) and Sharma and Raina (2013). In terms of trees, *Quercus semecarpifolia* singly dominates Site IV while Site VII indicated the prevalance of shrubs. The herbs dominated all the seven sites. The reason for dominance of single or few species at these sites may be due to sudden changes in the extreme weather conditions in this zone resulting in the occurrence of only the tolerant species (Singh and Rawat, 2000). The occurrence of *Quercus semecarpifolia* and *Betula utilis* along the sub-alpine altitudinal gradient suggests their tolerance to biotic pressures and wider ecological amplitude wherein Kharsu-Oak is a climatic climax (Champion and Seth, 1968).

Conclusion

The investigations revealed that mid-elevations support higher species richness and diversity than the cold and higher elevational cover types, which implies that sub-alpine and alpine forests need effective monitoring and conservation. The study suggests that the distribution and species richness pattern of different tree species are largely regulated by altitude and climatic factors.

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