Alpine Vegetation of the Western Himalaya: Species Diversity, Community Structure, Dynamics and Aspects of Conservation

Thesis Submitted

For the Award of

Doctor of Science

In Botany

By

G.S. Rawat, Ph. D.

Submitted to

Kumaun University, Naini Tal

WILDLIFE INSTITUTE OF INDIA
Chandrabani, Dehra Dun

2007

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CERTIFICATE

This is to certify that the thesis entitled **'Alpine Vegetation of the Western Himalaya: Species Diversity, Community Structure, Dynamics and Aspects of Conservation'** submitted by me for the award of the D. Sc. Degree in Botany of Kumaun University Naini Tal embodies the original work.

(G.S. Rawat)

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ALPINE VEGETATION OF THE WESTERN HIMALAYA: SPECIES DIVERSITY, COMMUNITY STRUCTURE, DYNAMICS AND ASPECTS OF CONSERVATION

SUMMARY

The alpine zone covers nearly 33% of the geographical area in the Himalayan region and represents one of the most fascinating biomes in India. Of this, nearly 26 % of the area is vegetated while the remaining 7% area falls under perpetual snow or barren rocks (Anonymous 1989). The lower boundary of the alpine zone is demarcated by a distinct treeline which typically terminates at around 3300±200 m in the Western and 3800±200 m in the Eastern Himalaya. The area immediately above natural treeline is usually occupied by *krummholz* (stunted forest) formation. Above this zone the vegetation comprises closely woven and dwarf shrubs, herbaceous meadows, tussock grasslands, marsh meadows dominated by sedges and fellfields paved with mosses and lichens. The diversity of life forms, plant community structure, composition and adaptations to extreme climatic conditions in the alpine region have long attracted naturalists, phyto-geographers and ecologists.

Alpine habitats in the Himalaya are relatively young, extremely heterogeneous, fragile and dynamic. Major habitat factors in this region are summer and winter precipitation, topography, soil, altitude, aspect as well as anthropogenic pressures, which strongly influence the distribution of species and community composition. While alpine zone of the Greater Himalaya, especially south facing humid pockets support exceptionally high species diversity and vegetation cover, the adjacent Trans-Himalayan region exhibits several contrasting characters. These two zones, together, offer great opportunities for comparative ecological

research. Although a large number of eco-floristic studies have been conducted in the alpine region of Western Himalaya, several facets of ecology await detailed investigations. Most notably, there is no well defined 'holistic' picture on the patterns of plant species diversity, community structure, composition and successional trends in the region. There are also major lacunae in the current understanding of vegetation-environment relations and patterns of rarity and endemism.

Alpine zone forms the upper catchment for a majority of the Himalayan rivers. A large number of agro-pastoral communities depend on this zone for livestock grazing and others subsist off it by collecting a variety of non-timber forest products including high value medicinal and aromatic plants (MAPs). Further, this region provides crucial habitat for several rare and threatened faunal species. Therefore, the health of alpine ecosystem has a direct bearing on ecological security and on the well-bieng of humans in the region. In present times, these ecosystems are highly threatened due to increased intensity of land use and the effects of climate change caused by global warming. It is therefore pertinent to assess the current conservation status of these ecosystems and suggest appropriate management strategies.

Keeping the above information gaps in view, the present ecological investigation was carried out in the alpine zone of Western Himalaya over the past five years. The major objectives of this study were as follows:

(i) To study the patterns of plant species diversity and richness at α and ß levels,

(ii) To study the structure and composition of alpine plant communities across major landscapes,

(iii) To study the environmental correlates of vegetation, vegetation dynamics and trajectories of primary and secondary succession,

(iv) To study the patterns of rarity and endemism among the vascular plants,

(v) To assess the current conservation status of alpine habitats and suggest appropriate management strategies.

The study area spreads across the alpine region of entire Western Himalaya *sensu lato*, covering the states of Uttarakhand, Himachal Pradesh and Jammu & Kashmir. This region has been traditionally recognized as a distinct phytogeographic unit since the time of Hooker (1906). Climatically this zone is divisible into Greater Himalaya and Trans-Himalaya. Rodgers & Panwar (1988) recognize four biotic provinces in this region viz., Trans-Himalayan Mountains in the Western Ladakh and North-western Himachal Pradesh (1A), Eastern plateau of Ladakh covering Changthang and Spiti (1B), North-west Himalaya west of Satluj (2A) and Western Himalaya between Satluj and Sharada in Uttarakhand (2B). The altitudinal range of the study area is between 3300 and 5500 m above sea level.

The study area was surveyed extensively covering all representative sub-divisions during four consecutive years (2002 – 2005). Intensive sampling of vegetation were carried out at >530 sampling sites (one site = 10 random quadrats of 1 m^2). A quadrat size of 1m^2 that is appropriate for the alpine areas of Himalaya (Rawat *et al.* 2001). Various measures of richness, diversity and

evenness have been used to compare different sites and landscape units following standard analytical methods (Magurran 1988).

Plant community structure and composition in the region was studied following standard phytosociological techniques (Mueller-Dombois & Ellenberg 1974, Kent & Coker 1991). Representative sites within the Greater and Trans-Himalaya were selected for intensive sampling of vegetation. Considering the multiple objectives of the study and the vastness of area to be covered, an attempt has been made to combine the traditional approach with modern numerical analysis which relies heavily on multivariate analysis. Detailed analysis (ordination as well as cluster) was possible using two recently developed computer softwares namely TURBOVEG and JUICE (Hennekens & Schaminée 2001, Lubomír 2002). These packages comprise an easy-to-use database management system that can store a voluminous data. The program provides methods for input, import, selection, and export of data from vegetation plots or relevés.

Environmental parameters such as soil depth, type, altitude, aspect and geographical location were recorded at different locations. Relationships between these variables and vegetation parameters have been tested following Spearman's correlation coefficient (S.P.S.S. - Norussis, 1996). Canonical Correspondence Analysis (CCA) has been performed for finding out environmental correlates with various parameters of vegetation as well as response of different species and groups such as ferns, members of specialized families e.g., Asteraceae and Polygonaceae using computer programme CANOCO (ter Braak 1988). Primary and Secondary successional trends were studied in a few valleys which represented pioneer

environments, stable habitats and old field succession within comparable altitudes and topographic features.

Patterns of rarity and endemism across the Greater and Trans-Himalaya have been assessed based on the extensive survey of recent literature on regional flora corroborated with field data collected during the study period and before. The conservation status of alpine areas is based on the ancillary data collected on the current land use practices from different sectors of the Western Himalaya.

The thesis has been organized into following 7 chapters (i) **General Introduction**, which provides an introduction to alpine vegetation and plant life, palaeo-history, vegetation processes and a literature review on the subject, and lists specific objectives and study approach, (ii) **The Biophysical Features** that describes physical features, landscape, geology, soil, hydrology, flora, fauna and land use practices in the study area, (iii) **Patterns of Species Richness and Diversity** deals with detailed sampling procedures, results and discussion, (iv) **Community Structure and Composition** provides results of cluster analyses separately for the a few physiognomic units within Greater and Trans-Himalaya and compares above ground (standing) phytomass and Life-forms across major study sites, (v) **Environmental Correlates and Successional Trends** deals with results of various statistical analyses, (vi) **Patterns of Rarity and Endemism** among vascular plants and explanations of reported and observed patterns, (vii) **Conservation and Management** elaborates current conservation status, land use practices, possible impacts on alpine habitats and management strategies.

Besides the above mentioned chapters, the thesis includes an exhaustive list of literature cited, and five appendices viz., (i) Data sheet used for sampling alpine

vegetation, (ii) An annotated list of vascular plants recorded from the alpine region of Western Himalaya, (iii) Diversity, Richness and Evenness of selected sites within Greater Himalaya, (iv) Diversity, Richness and Evenness of selected sites within Trans- Himalaya, and (v) List of vascular plants endemic to alpine region of Western Himalaya along with their Red Data Book status and distribution. Colour plates, maps and figures are provided where appropriate.

The following paragraphs detail major analysis carried out and summarize major patterns and findings that have emerged in this study.

Species richness (S), Shannon-Wiener Diversity (H'), Evenness (E) and Beta Diversity have been compared across various physiognomic units, habitat types and altitudes. Mixed herbaceous formations (MHF) in the Greater Himalaya adjacent to treeline had highest species richness and diversity (S = 27 – 56 species per site; H' = 3.01 – 3.30). Lowest values for richness and diversity (S = 3 – 9; H' = <0.50) were obtained for alpine dry scrub (ADS) and desert steppe in the Trans-Himalaya. The basins of higher mountains had higher Beta Diversity compared to smaller basins. Evenness and proportions of characteristic species contributing to diversity have been compared. Relationships between species diversity and environmental correlates viz., altitude, aspect and soil properties have been analyzed and discussed in detail. Various communities have also been compared in terms of their structure (proportions of woody, herbaceous and graminoids). Biomass and Life-form structure for different sub-regions have been compared and discussed.

Cluster analysis using PC-Ord. Version 4.41 based on mean cover of individual species per site ($\simeq$ releve) yielded 15, 10 and 8 groups for MHF, ADS and

Alpine Marsh Meadows (AMM) respectively. For the entire Greater and Trans-Himalaya, presence / absence data segregated 29 and 11 clusters (communities) respectively. These communities have been compared in terms of constant, diagnostic and dominant species.

Effect of altitude, aspect and other environmental variables on overall vegetation cover and abundance of various species have been compared. As expected, there was a steady decline in vegetation cover between treeline and snowline in the Greater Himalaya. However, in the Trans-Himalaya there was a slight increase in the ground cover with increase in altitude till the beginning of snowline (nival zone). This can largely be attributed to higher precipitation and soil moisture at higher altitudes. This finding underlines the fact that altitude alone is not adequate the explain the observed patterns of vegetation in the alpine region. Similarly, herbs and graminoids showed different response with increasing altitude in the Greater and Trans-Himalaya. Ecological implications of these differences are discussed.

Landscape units and habitats in alpine areas are distinctly more dynamic due to the fragile nature of the mountains and receding glaciers. However, the rate of change in vegetation here is slower when compared with temperate and tropical regions. Long term studies following a hierarchical Geographical Information System at various spatio-temporal scales would be essential to deepen our understanding of the vegetation dynamics in this area. Trajectories of primary and secondary succession within certain gradients of environment are traceable but most alpine areas exhibit a complex mosaic of successional stages influenced by biotic and abiotic factors. Per cent organic carbon and C/N ratios in the soil are reliable indicators of early and late seral stages.

Patterns of rarity among alpine plants have been studied based on geographical range, population size and habitat specificity following Rabinowitz (1981). Various categories of rarity have been compared with earlier assessments of the species. A detailed phytogeographic analysis of the alpine flora of Western Himalaya reveals that this region has only about 135 (7.45%) endemic vascular plants which which emerges as being much less than expected. Undivided Kashmir and Nanda Devi Biosphere Reserve have highest number of narrow endemics, most of which are likely to fall under the category of neoendemic species. Highest endemism was found in the genus *Astragalus* (19%) followed by *Poa* (12%), *Saussurea* (11%), *Potentilla* (8%) and *Carex* (6.66%). *Saxifraga,* a true alpine genus, showed rather low (3%) degree of endemism. It was found that the number of endemic species decreased with increasing altitude. Most (70%) of the endemic species in the alpine areas occupied mesic and water surplus habitats and even within the Trans-Himalayan region, the majority of endemic species were confined to sheltered and protected habitats which is contrary to the findings of previous studies. Critical monographic studies on several groups and biosystematic studies on most of the endemic species would be necessary to ascertain the nature of their endemism.

The conservation status of alpine habitats in terms of protected area (PA) coverage and current land use practices have been given in detail. Various pastoral practices and densities of domestic livestock in alpine areas of various sectors have been compared. It was interesting to find out that except two PAs viz., Valley of Flowers and Nandadevi NPs, and one valley in the Gangotri region, all the alpine PAs continue to be heavily grazed by domestic livestock during summer (Trans-Himalayan PAs round the year). There are no significant

differences in the livestock densities within and outside PAs. Other land use practices such as harvest of MAPs and ill planned developmental activities and their conservation implications have been discussed. This study suggests the following major management stratigies (i) Better management of domestic livestock, (ii) Regulated and rotational harvest of MAPs, (iii) Restoration of degraded alpine areas, (iv) Identification of botanical hotspots, rare endemic plants and their habitats outside the existing PA network. There is an urgent need for research and development agencies to revamp paradigms of research and build well coordinated long-term research and monitoring systems that are appropriate for the fragile alpine landscape.

* * * * *

1.0 GENERAL INTRODUCTION

"Alpine vegetation is often like a garden, a mosaic of beauty, a small scale multitude of ways of coping with life, attractive to both naturalist and scientist..."

- Christian Korner (1999)

1.1 The Alpine Biome

The term 'alpine' is derived from the Latin word 'albus' which means white (or snow-covered), originally referring to the peaks of Alps in North Italy (Love 1970). Today this word is commonly used to denote the area above the natural treeline in the high mountains worldwide, and is no longer restricted to European Alps. Depending upon the geographical location i.e., distance from the equator, slope, aspect, topography, solar radiation, and patterns of summer and winter precipitation, alpine areas may vary in physiognomy of vegetation, species composition and richness. However, most alpine areas exhibit commonality in terms of stunted vegetation represented by dwarf shrubs, tussock or mat forming graminoids, cushion and rosette forming herbs mostly adapted to gelifluction. Generally it is believed that most of the alpine biomes begin near 10^{o} C summer isotherm with slight variation between areas. Some authors have used the term 'tundra' for the herbaceous and low shrubby vegetation in the higher latitudes (e.g., Billings 1973, 1974). Similarly, the vegetation of alpine regions in the southern hemisphere, dominated by mosses, lichens, stunted shrubs and herbs, similar in structure and function to those in the high altitudes and latitudes in the north of equator have been described as 'alpine tundra' (Mark & Bliss 1970).

The alpine biome is fascinating due to adaptability of organisms to climatic extremes, patterns of vegetation processes, phytogeography and convergence of specialized life forms (Mani 1978, 1994). The plant communities are adapted to metabolize and complete their life cycles within short growing season, intense solar radiation and extreme weather conditions. World wide, a few species such as *Oxyria digyna, Trisetum spicatum, Deschampsia caespitosa, Carex nivalis* and genera e.g., *Poa, Draba, Arenaria*, *Rhodiola* and *Saxifraga* are considered reliable indicators of the alpine biome (Billings 1978).

Alpine habitats are characterized by stark seasonality, strong winds, winter precipitation in the form of snow and nutrient poor soils. The steeper the mountain slopes and the more topographically structured the terrain, the more abundant are the typical mosaics of alpine micro-habitats exhibiting a great deal of variation among the plant communities and strategies of survival among individual species (Korner & Larcher 1988, Dahl 1990.). Even slight variation in microtopography can make a marked difference in soil temperature, depth of thaw, wind exposure, snow deposition pattern and resultant protection of leaves and buds. Frequent freeze – thaw cycles at soil surface may influence the micro-topography in the form of stone nets, solifluction terraces, hummocks and gullies (Jones 1992, Zaal 1993, Hewitt 2005, Vodnik 2006). Thus, within a small area one finds sharp gradients of moisture, topography, soil depth and snow cover or snow accumulation. The wind-swept regions or fell-fields are characterized by cushion plants and dwarf sub-shrubs while the flat areas and valley bottoms could have a series of plant communities along the gradient of moisture (Miehe 1989, 1997, Rawat & Adhikari 2005). With the increase in altitude, especially in the high mountains, there is a shorter growing season, more fragile surface topography and greater fragmentation of vegetation due to gravity induced erosion. The sub-nival and nival zones are dominated by unstable scree and rocky slopes which restrict the surface area of alpine vegetation and higher plants are confined to a few sheltered pockets and rock crevices.

Generally the floristic structure and vegetation composition is much simpler towards arctic region as compared to middle latitudes (Bliss 1966, 1971, 1985, Borgen & Joshell 1997). Several alpine species extend from Arctic down to Eurasian mountains e.g., *Bistorta vivipara, Carex atrata, Epilobium angustifolium, Kobresia caricina, Koenigia islandica, Oxyria digyna* and *Thalictrum alpinum,* so that most alpine vegetation resembles that of Tundra and Arctic areas structurally and to some extent floristically (Agakhanyantz & Lopatin 1987, Smith 1994, Smith & Young 1987, Swan 1992). On entering the tropical mountains, alpine vegetation becomes much more complex with much greater variation in life-forms exhibiting wider life history strategies and functional diversity (Leuschner 1996). Typically, the tropical alpine vegetation consists mainly of tussock grasses and small-leaved shrubs, but the most distinctive species are the giant rosette plants which grow

abundantly on the high volcanoes of East Africa and the Andes (Hedberg & Hedberg 1979, Heegard 2002).

1.2 Alpine Zone of the Himalaya

The mighty Himalaya, a colossus among the great mountains of the world, encompasses a considerable area under the alpine zone. The alpine landscape in the Himalaya is lined up as an archipelago on high mountains at the southern periphery of the high central Asia, separated from each other by deeply incised transverse valleys. Spread on either side of the Greater Himalaya or *Himadri*, this zone exhibits exceptional ecological, geohydrological, aesthetic and biological values. This zone is demarcated by a distinct treeline towards lower elevation that lies around 3300±200 m above sea level in the western and 3800 ±200 m in the eastern Himalaya. The area immediately above natural treeline is usually occupied by *Krummholz* (= stunted forest or crooked wood, German) formations. Above this zone the vegetation comprises closely woven and matted strands of shrubs, herbaceous meadows, bogs, and fell-fields paved with mosses and lichens. The alpine vegetation of the Himalaya has been a subject of considerable interest among naturalists and ecologists on account of plant species richness and patterns of adaptation to extreme environmental conditions (Smythe 1938, Rau 1975, Wadhwa *et al.* 1987, Puri *et al.* 1989).

The alpine zone in the North-western India is spread over four biogeographic provinces, viz., Ladakh Mountains, Changthang and Kibber plateaus, North-western Himalaya, and Western Himalaya (Rodgers & Panwar 1988). Of the total geographical area in the region, 48% area falls in the alpine zone that forms nearly 90% of the total alpine area within Indian territory (Table 1.1). In terms of area coverage the alpine zone forms nearly 33% of the geographical area in the Himalaya region, of which about 25.88% area is vegetated and remaining 7.12% area falls under perpetual snow (Lal *et al.* 1991). This proportion is much higher in the states of Jammu & Kashmir and Himachal Pradesh. In the state of Uttarakhand (formerly Uttaranchal), the alpine zone forms only about 24.11% of the geographical area. The highly fragmented pioneer habitat above the belt of closed alpine vegetation is termed as 'nival' zone that lies just below the permanent snowline. In the Greater

Himalaya the nival zone has remained largely unrecognized because the snow line is not clearly visible in the landscape and the relief driven scree or rock fields make altitudinal separation of vegetation often difficult. Generally, the Western and North-western Himalaya have wider alpine and nival zones (Fig 1.1a) as compared to the Central and Eastern Himalaya. In Arunachal Pradesh, the alpine zone is limited.

Table 1.1: Extent of alpine vegetation in Western Himalaya (After: Lal *et al.* 1991)

SN	State	Geographical area (km^2)	Alpine vegetation (km^2)	Permanent snow (km^2)
1	Uttarakhand	53,485	8,524	4,376
2	Himachal Pradesh	55,670	17,296	4,934
3	Jammu & Kashmir	222,240	131,851	39,097
	Total	331,395	157,671	48,407

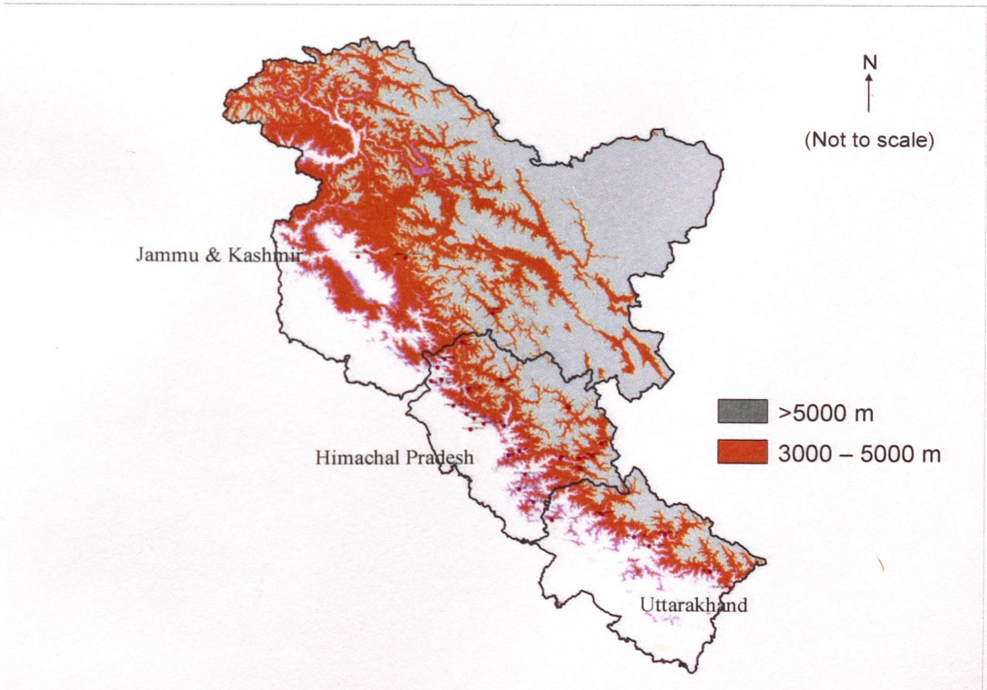


Figure 1.1a. The extent of sub-alpine / alpine zone (3000 – 5000 m) in the Western Himalaya

The gentler alpine slopes dominated by herbaceous or graminoid vegetation are commonly termed as alpine meadows or pastures and are used as summer grazing grounds by several

migratory and local pastoral communities. Alpine meadows have had an intimate association with local inhabitants in terms of cultural, religious and economic dependence. Of late, alpine areas in the Himalaya are being used for adventure tourism, recreation, and commercial exploitation of wild medicinal herbs. More importantly, this region forms the upper catchment of majority of the Himalayan rivers which support millions of people in the lower hills as well as in the Indo-Gangetic plains. Thus, the health of alpine ecosystem is closely linked with the environmental stability and human welfare in the entire region.

1.3 Palaeo-history and Vegetation Processes

In the early Cretaceous, more than 100 million years ago, the land that is now Tibet and the Himalayan region, was covered by the Tethys Sea which separated Eurasia from the southern continent, Gondwanaland. In the late Cretaceous and early Tertiary, the northern edge of Indian plate is believed to have slid a short distance beneath the southern edge of Asia. This led to great compression, folding, and thrust faulting that resulted in the uplift of Himalaya and recession of Tethys sea (Wadia 1967, Bronger et al. 1987). Palaeo-history indicates that life on land started out in sheltered warm and moist equatorial belts having rainforest like conditions and gradually expanded towards temperate and arctic-alpine environment (Korner 1999). According to Vishnu-Mittre (1984) the alpine vegetation of the Himalaya evolved only after the final phase of Himalayan uplift (20 – 25 million years ago), subsequent increase in the cold-arid climate and migration of flora from the adjoining regions. However, the forest vegetation at the lower altitudes of the Himalaya were once contiguous with the tropical rain forests and have now been transformed into present condition owing to changes in climate and increased anthropogenic pressures. It is plausible that emergence of *Himadri* System or Great Himalaya, crustal unrest and receding of Tethys sea provided corridors and land bridges for the migration of flora from the north and north-western regions resulting in a common flora between Greater Himalaya, Tibet and China. It is believed that the Himalaya has risen by about 2000 m since advent of man (Valdiya 2001). This may have resulted in the partial segregation of Tibetan and Great Himalayan flora. A large number of taxa speciated and dispersed within the Himalayan region and

some of the versatile and cold adapted species migrated upwards. In due course of time retreating glaciers, truncated spurs and amphitheatres in the alpine region were colonized by present day flora (Rau 1975).

The Himalayan uplift has had a considerable impact on the Trans-Himalayan environment and Tibetan plateau. According to Molnar (1989), the Tibetan plateau has been uplifted by 1000 – 2000 m during last 2-10 million years. The increase in elevation and subsequent glaciation during Pleistocene caused a drastic decline in temperature and depauperation of flora and fauna on the plateau. Re-establishment of the vegetation relied upon the flora of surrounding areas. After the plateau rose up to its present level during Quarternary period, it developed its own special plateau climate. Palynological studies indicate that for a part of Holocene there were stands of *Tamarix, Salix* and *Betula* in the basins of Pangong Tso, especially in protected localities with adequate moisture (Zhu *et al.* 1995, Yu *et al.* 2001). Trees and tall shrubs gradually vanished from the plateau by late Holocene. Influenced by the flora and fauna from the arid region of middle Asia, the present cold-steppe ecosystem was evolved. Much of this plateau was gradually colonized by hardy and grazing resistant grasses such as *Stipa purpurea, S. capillacea,* and a large number of cold hardy cushion forming species such as *Acantholimon lycopodioides, Salsola* spp., *Arenaria bryophylla, Thylacospermum caespitosum* and other specialized growth forms. The growing aridity and frigidity also influenced the faunal distribution. For instance, *Pantholops*, the sole endemic genus of mammals, was separated from Central Asian desert genus *Saiga* during Miocene. Other taxa such as *Ochotona* spp., *Lepus oiostolus*, *Marmota himalayana*, *Vulpes ferrilata* adapted and dispersed on the plateau. Likewise, *Tetraogallus*, a native genus of birds and a few pipits and larks specialized in the Trans-Himalayan Mountains.

Puri *et al.* (1989) have opined that while the flora of Himalaya and Tibet can be considered as Sino-Himalayan in origin, the flora of European Alps was derived from the Arctic flora. This explains the marked differences between the flora of European Alps and Himalayan alpines despite their superficial resemblance. According to Weber (2003) the Middle Asiatic and North American Floras once enjoyed a contiguous existence over a broad area involving connections between North America and Asia across the North Pole by way of Greenland.

Their present disjunctions are products of extinctions and attrition of ranges, not of long-distance migration or dispersal mechanisms. Korner (1999) suggests that glaciation may not wipe out the entire alpine flora but it may restrict the species to certain favourable micro-climates or refugia. From such refugia or "nunatakker" species may re-invade the habitats released by retreating ice shields. This is how a central Asian species, edelweiss (*Leontopodium alpinum*) is supposed to have made its way to the Alps, a rather recent addition to the flora.

Based on pollen analysis of 1 m deep sediment core from one of the high altitude bogs located at 4200 m in Himachal Pradesh, Chauhan (2006) concluded that the alpine belt of this region experienced warm and moist climate, around 1300 to 750 years BP. The glaciers receded and the treeline ascended to higher elevations. Around 750 to 450 years BP, intermittent deterioration and amelioration of climate have been witnessed. From 450 years BP onwards, the glaciers advanced and consequently the treeline descended under the impact of cold and dry climate in the region. Thus, a closer look at the present day alpine vegetation of the Himalaya reveals interesting facets of ecology, past geo-climatic changes and history of human use.

1.4 The Alpine Habits and Habitats: A Review

The growth habits of alpine plants reflect the high altitude environment. A closer examination of plant morphologies at these environments indicate their structural and functional traits and adaptive responses to cope with the climatic extremes (Burga 1988, Ferrari & Rossi 1995). One of the most striking features of alpine plants is dwarfism and morphological convergence. The lower alpine areas adjacent to timberline, especially in the Greater Himalaya, are characterized by extensive *krummholz* formations which reflect perfect adaptations to heavy snow during winter (Wardle 1974). Typical species of *krummholz* zone in the Western Himalaya are *Betula utilis*, *Rhododendron campanulatum, R. barbatum*, species of *Lonicera, Viburnum, Salix* and *Rosa.* In the eastern Himalaya many more species of *Rhododendron* co-dominate this zone. The higher alpine slopes are dominated by prostrate shrubs such as *Cassiope fastigiata,*

Cotoneaster microphylla, *Gaultheria trichophylla, Salix lindleyana* and *S. karelini*, which are well adapted to severe winters and frequent snow deposition. Dwarf shrubs have advantage of permanence, low maintenance cost and ability to cope with uncertainties of reproductive success. Evergreen shrubs such as Ericaceous members and Junipers have additional advantages as older leaves may serve as winter food storage organs from where lipids and proteins are mobilized and their stored energy is trans-located from old to new leaves during growing season.

A perusal of literature on the alpine life-forms (e.g., Rawat & Adhikari 2001, Klimes 2003) reveals that alpine habitats are dominated by short herbaceous perennials with relatively large roots or rhizomes (hemicryptophyte) or matted shrubs having perennating buds close to the ground (chamaephytes). The hemicryptophytes have another adaptive feature i.e., pre-formed shoot or flower bud that allows them to sprout and flower within short growing season. In extremely arid and cold environment such as Aksai Chin area, Miehe *et al.* (2002) have reported that intermediates between the hemicryptophytes and chamaephytes are common and at times difficult to classify. Quite a few species reflect opportunistic adaptability and may exhibit more than one strategy depending upon the micro-habitats available. For example, *Oxyria digyna* (Mountain sorrel), exhibits two eco-types viz., rhizomatous form at higher altitudes and seed producing form closer to low lying sandy banks. Generally, the proportion of annual herbs (therophytes) is very small in most of the alpine areas. Unlike perennials, the annuals have to complete their life cycle from germination to seed production within a short growing season. Typical annual herbs in the alpine zone of the Himalaya are *Koenigia islandica, Capsella bursa-pastoris, Arabis thaliana, Impatiens sulcata, Gentiana coronata, Microula tibetica, Euphrasia himalayica, Microgynaecum tibeticum* and *Agrostis pilosula*. Usually the proportion of annuals in the alpine floras is higher in drier habitats.

Growth habits of many alpine plants also reflect their adaptability to different micro-habitats. For example, the cushion plants such as *Androsace globifera, Thylacospermum caespitosum,* and *Arenaria festucoides* are known as most efficient heat trappers at wind swept high alpine environments. Tussock grasses e.g., *Danthonia cachemyriana* and

Deschampsia caespitosa are common on stable gentle slopes close to treeline. Such grasses modify their microclimate through deposition of dead leaves towards periphery making effective windbreak and protecting young leaves at the centre. Based on the clonal properties, Korner (1999) has recognized following eight forms of alpine plants: tussock graminoids, stoloniferous graminoids, mat-forming forbs, rhizomatous forbs, creeping dwarf shrubs, prostrate dwarf shrubs, viviparous plants and 'accidental' clonal plants. Similarly, other growth forms such as opportunistic herbs, cushion forming forbs, fleshy Crassulacean species have altogether different life history strategies for coping with the alpine microclimates. Major adaptations include seed dormancy, tolerance of low temperature extremes, higher concentration of anthocyanins, and lower temperature range for optimum photosynthesis (Amen 1966, Diggle 1977, Barbour *et al.* 1991, Chambers 1995). The bright light and low temperatures of alpine environments result in low chlorophyll content that allows production of anthocyanins in the leaf and young stem. Anthocyanins not only act as a 'sink' for excess sugars during cool, bright weather or under poor soil nitrogen and phosphorus; but also protect the mesophyll and other tissues from ultra-violet radiation (Billings 1988).

The plant forms around snowline and sub-nival zone exhibit special morphological and physiological adaptations. Woolly or prostrate growth forms such as *Saussurea gossypiphora, S. gnaphalodes*, *Christolea himalayensis* and other members of Brassicaceae and Saxifragaceae are typical species at these heights (Rawat & Pangtey 1987a). Cold climates are not necessarily cold for plants at all times, and influences of plant-growth form on canopy climate are substantial. From a general meteorological data one would be tempted to conclude that the climate around 5500 m is of arctic tundra type. However, it is plausible that the micro-habitats at which the sub-nival plants grow may have conditions that may be otherwise found at around 4000 m (Korner & Larcher 1988, Miehe 1997).

The key habitat factors governing alpine plants are altitude, relief, wind and exposure to solar radiation (Mani 1978). Altitude influences atmospheric pressure and daily fluctuations in temperature. There are such strong linkages between the slope inclination

or slope directions and the interception of solar radiation that topographic maps can be used to predict the incoming radiation per unit area and draw radiation maps (Garnier & Ohmura 1968). The relief features also strongly influence the snow deposition and thaw patterns which govern the plant community composition and productivity (Walker *et al.* 1993). It has now been established that (i) snow deposition patterns usually create consistent patterns leading to sharp boundaries between the different physiognomic units e.g., snow bed communities, fellfield, meadows and alpine heath communities, (ii) wind and relief-controlled snow distribution and melting patterns are quite consistent over the years, (iii) winter snow depth is rather variable and the timing of melting also changes from year to year, but the overall pattern of snow distribution is strictly engraved into the alpine plant cover. Thus, spatial variability in life conditions become more important than temporal variability and elevation *per se* becomes a less useful predictor of life conditions the higher one ascends in the mountains (Walker *et al.* 1989).

The alpine region of the Western Himalaya supports a considerably high density of livestock that includes sheep, goats, cattle, yak, cattle – yak hybrids, horses and donkeys (Kawosa 1988, Rawat 2000). Since the lower altitude grazing lands are limited in extent, summer migration to higher altitudes and alpine meadows has become a practice as a means to sustain the number of livestock. Some authors believe that livestock grazing is essential to maintain species diversity in the alpine areas (Naithani *et al.* 1992, Saberwal 1995) but others advocate for more rational grazing practices and policies (e.g., Sundriyal & Joshi 1990, 1992, Rawat & Uniyal 1993, Mishra & Rawat 1998). Although the alpine pastures play important role in relieving the grazing pressure on the forests and grazing lands of the lower altitudes, increased number of livestock and overuse of certain pastures can lead to degradation of high altitude grasslands including habitats of wild herbivores (Sundriyal 1989, 1992, 1995). Other human activities in the alpine areas include excessive harvest of medicinal herbs, collection of fuel wood, camping and trekking. As a result, alpine areas in many sectors show signs of degradation. In the Western Himalayan meadows exploitation pressure is particularly high on *Dactylorhiza hatagirea, Picrorhiza kurrooa, Jurinea macrocephala* and *Aconitum heterophyllum*. Extraction of fuelwood particularly from the low productive areas of trans-Himalaya is one of the burning issues

in the conservation of steppe communities. In the absence of larger trees and shrubs local people dig out the roots shrubs as fuel wood (Manjrekar 1997, Uniyal *et al.* 2003). Based on the adaptability of alpine plant communities to various anthropogenic pressures, an overall analysis of their conservation status across the larger landscape needs to be done.

Species richness in alpine habitats is a function of several factors including soil moisture, location of the mountain range (species pool in the range) and habitat heterogeneity. The glaciated valleys and mountain slopes away from the glaciers exhibit different patterns of succession which affect patterns of alpha and beta diversity. Most species rich sites are gentle herbaceous formations or meadows in the Greater Himalayan ranges. Most of the herbaceous plants in the meadows bear bright and attractive flowers in order to maximise entomophily in seemingly insect poor environments. Describing an alpine meadow in Bhyudar Valley, Frank Smythe (1939) wrote "I saw ground so closely packed with fritillaries that it seemed impossible that other plants could grow, yet when *Fritillarias* had down, they were succeeded by other plants such as *Potentilla* which grew equally closely. This cycle persisted throughout summer, one plant being replaced by another with perfect precision. With the melting of snow in May or early June, early summer flowering herbs bloom in profusion which include Crucifers. Primulas, Anemones and Saxifragas appear in late summer and towards autumn appear *Gentiana, Swertia* with *Saussurea*". Similarly, Rau (1975) has described lush carpet of alpine herbs along the right bank of Alaknanda facing Vasudhara waterfall where the main components of the meadow are grasses and multitude of colourful herbs such as species of *Anemone, Gentiana, Potentilla*, and *Primula.*

The alpine habitats are among the most heterogeneous, fragile and dynamic. Hence the vegetation in these areas exhibits a complex mosaic of successional stages ranging from pioneer lichen – moss communities to highly stable ericaceous formations. Several communities are sensitive to micro-topographic changes (Kikuchi & Ohba 1988) making successional studies more difficult. Kala *et al.* (1998) and Gaur *et al.* (2003, 2005) have given preliminary accounts of vegetation colonization along glaciated areas of Valley of Flowers and Kedarnath respectively. But the patterns of primary and secondary succession across the larger landscape both in the Greater and Trans-Himalaya are yet to be established. Based on the perusal of the published literature on the species diversity,

community structure and dynamics of alpine vegetation, it can be stated that our understanding of the subject at present is fragmentary and incomplete.

1.5 Present investigation: objectives and approach

Various factors of environment such as summer and winter precipitation, topography, soil, altitude, aspect and anthropogenic pressures are known to influence the species distribution and community composition in the alpine region (Puri *et al.* 1989). Though a large number of floristic and ecological studies have been conducted in different parts of Western Himalaya, several facets of ecology remain unclear and in-depth studies on the patterns of plant species richness and diversity across the entire landscape are lacking. Korner (1999) estimates that of all the ecological studies done on the alpine vegetation only *ca.* 6% are from Central Asia including Himalaya, and 36% from Europe. Several questions pertaining to the ecology and conservation of alpine vegetation in the region remain unaddressed *e.g.,* (i) what are the patterns of plant species richness and diversity at *alpha* and *beta* levels in the Greater and Trans-Himalaya? (ii) what are the determinants of diversity, richness and rarity among alpine plants? (iii) what are the major physiognomic units of vegetation within Greater and Trans-Himalaya and what are the patterns of species diversity and species composition within each type? (iv) what are the major communities which characterize major physiognomic types? (v) what are the values of above ground standing phytomass across major physiognomic units in the Greater and Trans-Himalaya? (vi) how do Greater and Trans-Himalaya compare in terms of Life-form structure? (vii) how are major growth forms such as shrubs, herbs, graminoids, lichens and mosses distributed across major ecological zones? (vii) what are the major environmental correlates of vegetation and how do various groups of plants respond to the gradients of environment? (viii) what are the major trajectories of primary and secondary succession in alpine areas and indicators of them? (ix) what are the trends of rarity and endemism among alpine plants of Western Himalaya compared to the larger region? (x) what is the current conservation status in the alpine areas? and (xi) what are the best land use practices in the area and best management strategies that could be adopted for long term conservation of these threatened ecosystems?

Keeping the above mentioned questions in view, and in order to give a holistic picture of the ecology of alpine vegetation, the present investigation was carried out during 2002-07. the major objectives of this study were as follows:

(i) To study the patterns of plant species diversity and richness at α and ß levels,

(ii) To study the structure and composition of alpine plant communities across major landscapes,

(iii) To study the environmental correlates of vegetation and vegetation dynamics and trajectories of primary and secondary succession,

(iv) To study the patterns of rarity and endemism among the vascular plants, and

(v) To assess the present conservation status of alpine vegetation and suggest appropriate management strategies.

Addressing the ecological questions for the entire landscape required an in-depth knowledge of the regional flora and management issues. The investigator has had prior knowledge and experience of working on the eco-floristics of region for past 25 years. Prior to carrying out field sampling a detailed catalogue of alpine plants reported from the Western Himalaya with latest nomenclature was prepared, which was updated after identification of plants collected during the extensive field surveys during 2004 -05 (Appendix - II). A compendium of artificial keys for identification of major plant groups was prepared to be used in the field with the help of standard flora and relevant literature, e.g., Hooker (1872-97), Naithani (1984), Sahni (1990), Sharma & Jamwal (1998), Aswal & Mehrotra (1994), Dar & Christensen (2003). Herbaria of Forest Research Institute, Dehra Dun (DD), Botanical Survey of India's Northern Circle (BSD) and Wildlife Institute of India (WII) were also consulted prior to as well as after field work to verify identity of several species. Detailed methodologies for different study components are given in the respective chapters. This investigation has also yielded a massive collection of plant samples from different parts of Western Himalaya which would help in updating phytogeography and refining the field keys for identification of alpine plants for the ecologists.

Prior to present investigation the author carried out a three month long survey of Trans-Himalayan vegetation using GRADSECT (Gradient Directed Transect) approach following Austin & Heylingers (1989) and Gillison & Brewer (1985). Based on the findings of this survey (Rawat & Adhikari 2001) two intensive study sites were selected in the Trans-Himalaya which were investigated during 2002 – 2005. During June to October 2004 the author conducted an extensive survey of alpine vegetation including status of medicinal and aromatic plants largely across the Greater Himalaya. The route followed during this expedition is shown in Fig. 1.5. Methods for data collection on various aspects this study are described in the chapters 3 and 4.

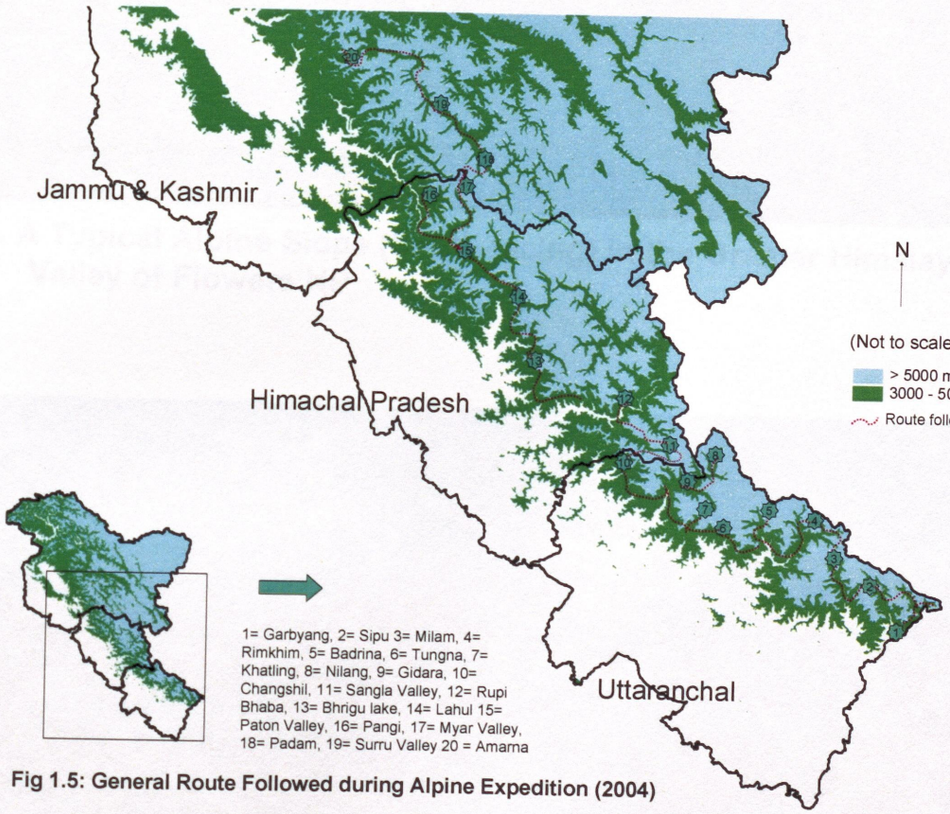


Fig 1.5: General Route Followed during Alpine Expedition (2004)

* * *

Plate 1: ALPINE LAND FORMS -1



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1. A Typical Alpine Slope (South facing) in the Greater Himalaya: Valley of Flowers NP



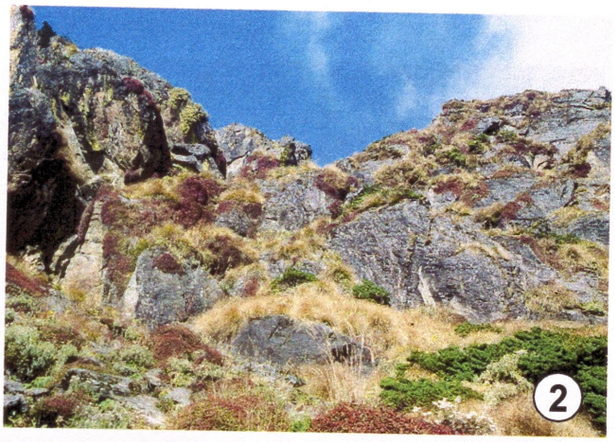
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2. Glaciated Valley, Lateral Moraines and Rocky slopes: Around Kedarnath Shrine, Garhwal Himalaya

Plate 2: ALPINE LAND FORMS - II



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1. A Natural Cave: Amarnath, Kashmir Himalaya
2. Rocky Slope: Way to Mandini, Kedarnath WS
3. Unstable old morainic deposit- Garbyang Village (3300 m) , Eastern Kumaon.
4. Stable inner dry valley in Upper Byans, Eastern Kumaon.
5. Terminal and lateral moraines near Jeolingkong (4800 m), Byans.
6. Terminal and lateral moraines, silted lake bed in Upper Jalandhri Valley, Uttarkashi

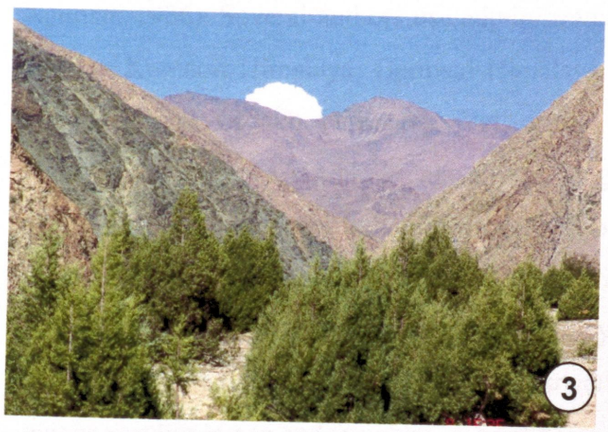
Plate 3: ALPINE LAND FORMS - III



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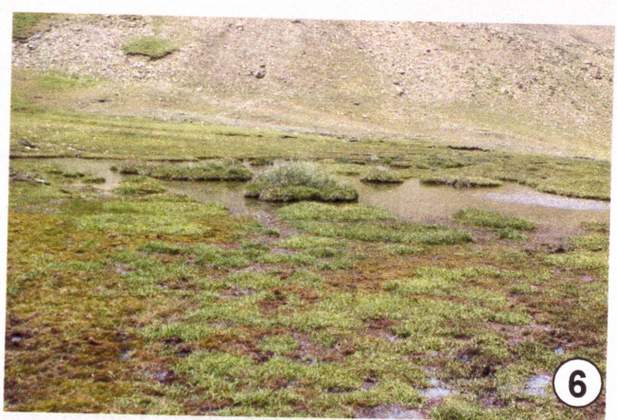
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1. A glacial lake: Nandi Kund, Kedarnath WS
2. Tso Kar Basin, Changthang Plateau (Ladakh)
3. Nelang Valley, Gangotri NP – Landscape
4. Tethyan Sea bed – North of Nanda Devi NP
5. Colluvial Deposits and Tallus
6. Alpine Marsh Meadow – Nanda Devi BR

2.0 THE BIOPHYSICAL FEATURES

"Guarding the northern frontier like a mighty sentinel, the Himalaya isolates the Indian subcontinent securely from the rest of Eurasia..."

- K.S. Valdia (2001)

2.1 Introduction

The landmass encompassing the three states of north India *viz.*, Uttarakhand (UA), Himachal Pradesh (HP) and Jammu & Kashmir (J&K) has traditionally been categorized under one phytogeographic unit i.e., Western Himalaya (Hooker 1906, Pennell 1943, Rau 1975). Subsequently, a few authors described this region as North-west Himalaya (Deva & Naithani 1986). Several authors use administrative or geopolitical terms for various sectors such as Kumaon Himalaya, Garhwal Himalaya, Punjab Himalaya (present HP), Kashmir Himalaya and Ladakh Himalaya. Yet, a few authors consider Kumaon and Garhwal Himalaya as part of Central Himalaya (e.g., Singh & Singh 1992). In this study, the entire alpine zone falling within Indian territory west of Kali (Sharada river), has been treated as Western Himalaya following Hooker (1906). With the advancement of our knowledge on the geology, phytogeography and palaeo-ecology over the last century it has become clear that the entire landmass under present investigation represents a complex array of various ranges varying in age and structure. A brief description of physical and biological features of this region follows.

2.2 Physical Features

The land forms in the alpine zone of Western Himalaya have evolved as a result of complex geodynamic processes. Based on physical features the alpine zone can be classified into the following categories.

i. Glaciated Valleys of the Greater Himalaya: The Pleistocene glaciation led to formation of U – shaped valleys, truncated spurs and troughs in the Greater Himalaya. The higher slopes in such valleys are covered with moraines which are further divisible into lateral

and terminal moraines depending upon their location. The valleys close to glaciers are deposited with post glacial mudflow.

ii. High Peaks, Escarpments and Ridges of Greater Himalaya: The principal axis of the Himalaya runs on the north-west to south-east direction. The high alpine slopes rise abruptly to the nival or aeolian heights often above 7000 m with perpetual snow or give rise to distinct ridgelines. The Greater Himalaya is known for a large number of high peaks such as Nun Kun, Kolahoi and Amarnath in the state of J&K. In HP the Greater Himalaya merges with Zanskar range near Baralacha La from where it runs to the south merging with the Parbati range on the east of the Kullu and thereafter forms a prominent landscape in the upper catchments of Jiwanal, Sainj and Tirthan rivers. Further east, these ranges are represented by Kinnar Kailash, Swargarohini, Bandarpunch, Bhagirathi group of peaks, Kedarnath, Chaukhambha, Trishul, Nandadevi, Nandakot, Hansling, and Panch Chuli. The high alpine valleys in the Greater Himalaya often lead to inter-montane and trans-alpine ranges through a few passes. These passes have historically been traversed by a large number of explorers, traders and local communities. Some of the prominent passes in these ranges are Zoji La, Umasi La, Baralacha La, Pin - Parvati Pass, Rupin Pass, Lamkhaga, Kuari, Bhyundar Pass, Barjikang, Trail's Pass and Sin La.

iii. The Kashmir Valley: The Kashmir valley, located between the Pir Panjal and Greater Himalaya, has a unique physical formation in the Himalaya. On either side of Kashmir valley there are gentle alpine slopes above the zones of upper and lower Karewas. One of the important slopes in the valley is Gulmarg which is closer to Pir Panjal range on the south leading to Banihal pass. Here the Pir Panjal meets the ridgeline separating the Kashmir valley from the Warvan valley.

iv. Alpine areas of Dhaula Dhar Range: The Dhaula Dhar ranges reaches upto 4000 m and represents a narrow fragmented alpine zone. Most prominent peak in Dhaula Dhar can be seen behind Dharamsala where it forms the divide between the Ravi and the Beas valleys. To the west it provides the divide between the Chenab valley below Kishtwar and the Tawi valley, which twists south to Jammu. To the east it extends across Himachal

Pradesh forming the high ridges of the Larji gorge and extending south of the Pin Parvati valley before forming the impressive ridgeline east of the Sutlej River. Thereon it forms the snow capped divide between the Sangla valley and upper Tons catchment area in Uttarakhand.

v. The Zanskar and other ranges of the Trans-Himalaya: The Zanskar range lies to the North of the main Himalaya. It forms the backbone of Ladakh south of the Indus River, stretching from the ridges beyond Lamayuru in the west across the Zanskar region, where it is divided from the main Himalaya by the Stod and Tsarap valleys, the populated districts of the Zanskar valley. The Zanskar range is breached where the Zanskar River flows north, creating awesome gorges until it reaches the Indus River just below Leh. To the east of the Zanskar region the range continues through Lahaul and Spiti district of Himachal Pradesh, forming a complex buffer zone between the main Himalaya and the Tibetan plateau. It continues across the North of Kinnaur before extending west across Uttarakhand, where it again forms the intermediary range between the Himalaya and the Tibetan plateau, which includes mount Kamet through Balchh and Kyo Ghatmila Dhura, Kungri-Bingri and Lisser and eventually covering the Chhota Kailash adjacent ranges in Upper Kali Valley in Byans. Besides these ranges, two more ranges can be easily identified on the north of Zanskar range, viz., Ladakh and Karakoram. The Ladakh range lies to the North of Leh and is an integral part of the Trans-Himalayan range that merges with the Kailash range in Tibet. The northernmost mountain range in the state of Jammu and Kashmir is the Karakoram which forms the geographical divide between India and Central Asia (Thomson 1849). It includes many high peaks including - Teram Kargri, Saltoro Kangri and Rimo. The Karakoram Pass was the main trading link between the markets of Leh, Yarkand and Kashgar. Presently this region is closed to the tourists.

v. The Changthang Plateau: Eastern Ladakh, popularly known as Changthang, literally means the `northern upland' or northern plains. This tableland is contiguous with the Tibetan Plateau and literally represents the `roof of the world'. The plateau is bounded by the Zanskar, Kailash and Great Himalayan ranges on the south, Karakoram Range in the west, and Kunlun and Arjin Shan in the north. The North-western part of the plateau

terminates in Aksai Chin, one of the most arid and desolate tracts in Central Asia. Within Indian territory, Changthang plateau is spread over ca. 21,000 km^2 and has been categorized under a distinct bio-geographic province, 1B (Rodgers & Panwar 1988). The Changthang plateau ranges in altitude from 4000 – 5500 m, mean elevation being about 4500 m. There are a number of lakes on the plateau such as Pangong Tso (which extends across India and China), Tso Moriri, Startsapuk Tso, and Tso Kar. A considerable proportion of the landmass comprises lake basins, characterized by alluvial fans and sandy plains. Internal drainage in some of the basins has resulted in concentration of salts and minerals over the millennia making the water bodies brackish. Administratively Indian part of Chang Thang lies in the Nyoma block of Ladakh district. At present there are four sub-units in Nyoma block *viz*., Samad, Kharnak, Korzok and Hanle.

2.3 Geo-hydrology

The alpine region of the Western Himalaya includes diverse and complex lithological features. On the southern flank Lesser Himalaya reaches alpine heights of up to 4500 m which has three principal ranges viz., the Nag Tibba, the Dhauladhar and the Pir Panjal (Thakur & Rawat 1992). The principal and central axis is formed by the Greater Himalayan range or *Himadri* that rises above 4500 m and often above 7000 m. The ranges beyond Greater Himalaya, frequently termed as Trans-Himalaya include Zanskar, Ladakh, Karakoram, Kailash and vast plateau of Tibet. Between the Pir Panjal and Greater Himalaya lies the valley of Kashmir which is 130 km long and ca. 30 km wide. Majority of the ranges run in the South-east to North-west direction.

The Greater or Higher Himalaya consists of 15 – 20 km thick slab of crystalline rocks, which thrust southward along the main central thrust (MCT) overriding the Lesser Himalaya. On either side of MCT a large number of structural formations made up of granite, gneiss, schist, quartzite, amphibolite and leucogranites bearing tourmaline (Sinha 1989, Thakur & Rawat 1992). At places sedimentary cover of chert, siliceous limestone and other plutonic rocks can be seen especially on the northern flanks of Kun Lun (Valdia 2001). The southern slopes of the Greater Himalaya are characterized by crustal

unrest, continuous surface erosion accelerated by snow and avalanche action. The southern flanks also support vast glaciated valleys and gentler stable formations which support lush alpine vegetation.

The mountain ranges north of the higher Himalaya, frequently termed as trans-Himalaya or cold deserts, are dry, exposed and generally devoid of lush green vegetation due to extremely harsh climatic conditions. One of the prominent features in the eastern part of trans-Himalaya is Changthang plateau that is underlain by continental crust that is ca. 65 km thick, made up of light granitic material at the bottom and basaltic magma at middle layer. This plateau is characterized by vast lake basins surrounded by undulating ranges. Most of the lake basins are characterized by red mudstone, silt stone and sand stones. The areas closer to the Indus suture represent compressed, uplifted wedge of oceanic crust which have several geothermal fields (Amano & Taira 1992). Within Indian Territory, the area around Rupshu plains, the rocks comprise metamorphic and granites, referred as Tso Moriri crystalline complex (Philip & Mazari 2000). Several lake basins have rich deposits of borax, alkali and common salt that make the area unfavorable for plant growth. According to Pant *et al.* (2005), the Ladakh and Karakoram ranges were dominated by regional glacial activity during Quarternery period followed by humid fluvio-lacustrine environment, which was succeeded by a renewed glacial activity though only restricted to higher altitudes due to increasing aridity (Caine 1974, Bronger *et al.* 1987). Sinha (1987) has given a detailed geological account of higher Central Himalaya.

The higher Himalaya houses largest snow mass outside the polar region and also gives rise to most important glacier systems. Therefore, the Himalayan peaks have been rightly termed as 'water towers' on earth. According to the Geological Survey of India, there are more than 5000 glaciers in the Indian Himalaya covering an area of about 38,000 km^2. The distribution of glaciers in the Himalaya is uneven due to complexity of mountain ranges, altitudinal variation and different climatic environment. Generally, the north-western Himalaya has higher concentration of glaciers as compared to the eastern Himalaya. Some of the important glaciers in the region are listed in the Table 2.3.

Table 2.3: Important glaciers of the Western Himalaya

SN	Name of Glacier	Length (km)	Geographical /Location	Altitudinal Range (m)
1.	Siachen	72	Karakoram	3800-7000
2.	Hispar	62	Karakoram	3400-6000
3.	Baifo	69	Karakoram	3500-6200
4.	Batura	59	Karakoram	3600-6200
5.	Kolahai	06	Kashmir	3600-5100
6.	Machai	08	Kashmir	3400-5000
7.	Shishram	06	Kashmir	3800-5200
8.	Liddar	05	Kashmir	3600-5200
9.	Bara Shigri	30	Lahaul	4000-6200
10.	Chhota Shigri	09	Lahaul	4000-6000
11.	Sara Umga	17	Pir Panjal	3900-6000
12.	Parvati	08	Kullu	4000-5800
13.	Samudra Tapu	09	Kinnaur	4000-5900
14.	North Nanda Devi	19	Garhwal	4000-6000
15.	South Nanda Devi	19	Garhwal	4100-6100
16.	Trisul	15	Garhwal	3900-5800
17.	Gangotri	30	Garhwal	4000-6200
18.	Dokriani	05	Garhwal	3900-6200
19.	Chorabari	07	Garhwal	3900-6200
20.	Khatling	6	Garhwal	3800-6200
21.	Chowkhamba	12	Garhwal	4000-5900
22.	Satopanth	13	Garhwal	4000-6200
23.	Pindari	08	Kumaon	4200-5600
24.	Milam	19	Kumaon	3400-5600
25.	Burphu	5	Kumaon	4000-5600
26	Ralam	3	Kumaon	4200-5000
27	Panch Chuli W & E	5	Kumaon	3000 - 4800

Recession of the Himalayan glaciers due to global warming and possible increase in aridity in the alpine regions has been a cause of concern during recent years. Surveys based on satellite images and ground investigations by the Space Application Centre (SAC), Ahmedabad have established that in Himachal Pradesh alone, glaciers have reduced from 2,077 km^2 to 1,628 km^2 – an overall deglaciation of 21% in four decades. According to SAC as many as 127 glaciers of less than 1 km^2 size have lost 38% of their geographical area since 1962. The larger glaciers, which are progressively becoming fragmented, have receded by as much as 12% which is truly alarming. Data on glacial

recession reveal that the Himalayan glaciers are retreating at an average rate of 18-20 m per year (Raina 2005).

2.4 Soil

The diversity of geological formations and extremely variable topography has given rise to a variety of edaphic conditions in the alpine region. In the Greater Himalaya, especially at higher altitudes the weathering of the bed rocks provide enormous amount of loose material in the form of scree, which give rise to talus slopes that form coarse and gravely soil. Similarly, in the glaciated valleys enormous amounts of debris and sandy soil are deposited along terminal and lateral moraines which are further consolidated along river and stream courses in the form of alluvial fans and clayey soil (Fort *et al.* 1989). With the evolution of land forms and consolidation of alpine habitats, soil gets transformed into various grades of ranging from Lithic Entisols i.e., skeletal soil to Cryoborols or mountain meadow soil (Gupta 1983). Generally the soil in the high rainfall zone of Greater Himalaya has lower pH as compared to that of the arid Trans-Himalaya. A comparison of various soil parameters based from two regions is given in table 2.4a.

Table 2.4a: A comparison of soil parameters between the Greater and Trans-Himalaya

SN	Parameter	Greater Himalaya (N=27)	Trans-Himalaya (N=61)
1.	Altitude (m)	3746.33± 287.73	4211.42±441.33
2	pH	5.32±0.67	6.65±1.18**
3	% Sand	54.48± 13.54	70.75±13.98
4	% Silt	27.81±9.19	16.81±9.51
5	% Clay	17.73±5.59	12.58±6.13
6	% OC	5.92±2.02	4.39±4.47**
7	% N	0.56±0.17	0.42±0.37**
8	C/N Ratio	10.45±1.44	11.35±10.26
9	P (ppm)	11.98±7.45	17.47±33.87
10	K (ppm)	242.92±152.46	224.88±146.15

** Significant differences (1 Way ANOVA, $p < 0.001$)

The Changthang plateau in eastern Ladakh has largely alpine desert soils except in moist meadows. The soil texture in majority of the lake basins varies from sandy to sandy loam and to a limited extent clayey. The soil under most of the lake basins is basic in nature.

The physico-chemical properties of soil under various landscape units in the Tso Kar basin of Ladakh, as reported by Rawat & Adhikari (2001) are given below (Table 2.4b).

Table 2.4b: Analysis of soil composition from Tso Kar Basin, Changthang plateu
[WHC = Water holding capacity, OC = Organic Carbon, N = Nitrogen; Source: Rawat & Adhikari 2001].

Landscape Unit	Sand	Silt	Clay	Texture	pH	WHC (%)	OC (%)	N (%)
Camping sites	98.4	0	1.6	Sandy	8.3	20.4	0.042	0.005
Lower slopes	98.2	0.2	1.6	Sandy	8.2	20.8	0.048	0.005
Lower slopes	84.4	8	7.6	Loamy Sand	8.4	24.3	0.156	0.017
Lower slopes	80.6	5.5	14	Sandy Loam	8.2	27.5	0.262	0.029
Lower slopes	91.4	3.4	5.2	Sandy	8.3	23.7	0.222	0.025
Middle slopes	92.8	3.2	4	Sandy	8.1	20.6	0.121	0.013
Higher slopes	87.4	5.2	7.4	Loamy Sand	8.0	27.8	0.51	0.057
Higher slopes	74.7	13	12	Sandy Loam	7.9	24.5	0.06	0.007
Alluvial fans	86.4	6.3	7.3	Loamy Sand	8.1	28.6	0.375	0.042
Alluvial fans	98.4	0.3	1.3	Sandy	8.0	19.6	0.034	0.004
Valley bottom	70.8	11	18	Sandy Clay	9.3	43.6	1.68	0.198
Sandy plains	98	0.2	1.8	Sandy	7.9	22.6	0.124	0.014
Moist meadows	88.2	5.2	6.6	Sandy Clay	9.1	30.9	0.442	0.049
Marsh meadows	93.8	2.2	4	Sandy	9.2	109.2	5.3	0.623

2.5 Climate

The Western Himalaya is the farthest from the Indian Ocean and also latitudinally higher than rest of the Himalaya. Hence it shows a climatic pattern closer to the Temperate - Alpine type, especially towards north-western region. Lower latitudes i.e., eastern parts of UA exhibit similarities with the tropical mountains. Towards North-west there is greater amount of precipitation during winter months from the Western disturbances. The mean annual precipitation declines from SE to NW and also from south to north (Fig. 2.5a). The Great Himalayan massif all across the range blocks much of the summer precipitation causing rain shadow effects on the north.

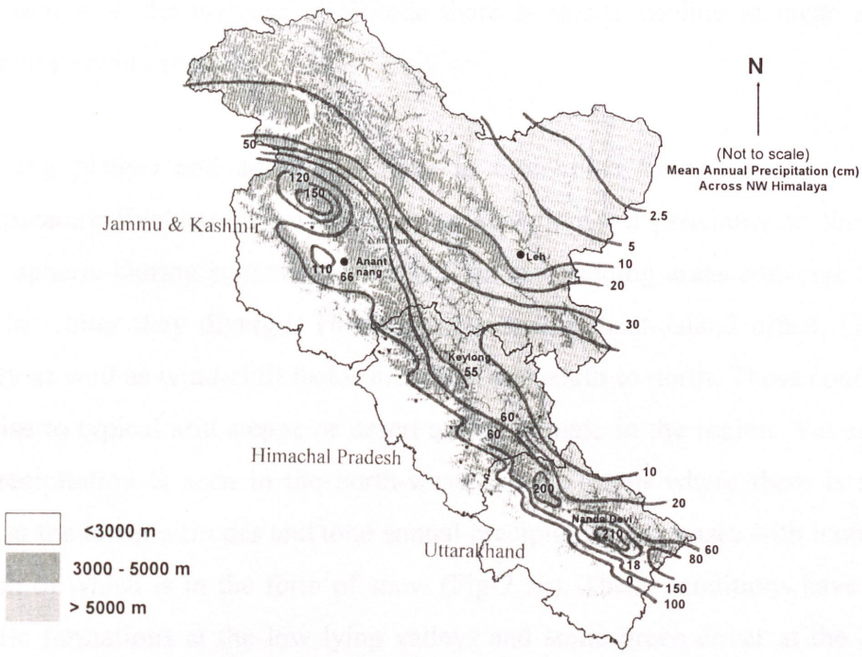


Fig. 2.5a: Mean Annual Precipitation in the Western Himalaya (Source: Forest Atlas of India 1976).

Weather data from the alpine region of Western Himalaya are available only from a few localities (Table 2.5). Based on the available data on alpine climate, it can be generalized that the effect of monsoon is prominent in the south-eastern part, and winter precipitation in the form of snow is more pronounced towards north-west.

Table 2.5 Mean annual temperature (°C) and precipitation at various localities in the Western Himalaya (Source: Miehe *et al.* 1996, 2001)

Locality / Altitude (m)	Mean Ann. Temp. (°C)	Temp Range	Mean Ann. Precipitation (mm)	Months with Mean Min T < 0 °C	Driest Months
Hemkund (4267)	-0.8	-20 to15	2179	Nov. - April	October
Keylong (3500)	5.4	-10 to 25	545	Dec - Feb	May - July
Gechang*, Pin Valley (3700)	5	-40 to 30	1300	Nov. - March	Sept – Dec.
Dras (3066)	1.8	-44 to 23.2	651	Oct - April	May - Aug
Leh (3500)	5.7	-32 to 23.2	83	Oct - April	May - Aug
Aksai Chin (4840)	- 7.8	-45 to 5	24	Sept - July	March - Dec

* Bhatnagar (1997)

It is evident that with the increase in altitude there is steady decline in mean annual temperature and growing period.

The Changthang plateau and adjacent regions in the Indian Trans-Himalaya exhibit extreme temperature fluctuations owing to sheer elevation and proximity to the outer layer of troposphere. During summer the winds from surrounding areas converge on the plateau and in winter they diverge. This creates a special heat–island effect. On this plateau aridity as well as wind-chill factor increase from south to north. These conditions have given rise to typical arid steppe or desert steppe climate in the region. Yet another pattern of precipitation is seen in the north-western Karakoram where there is scanty precipitation at the lower altitudes and total annual precipitation increases with increasing altitude, much of which is in the form of snow (Fig 2.5b). These conditions have given rise to desertic formations at the low lying valleys and some green cover at the higher altitudes.

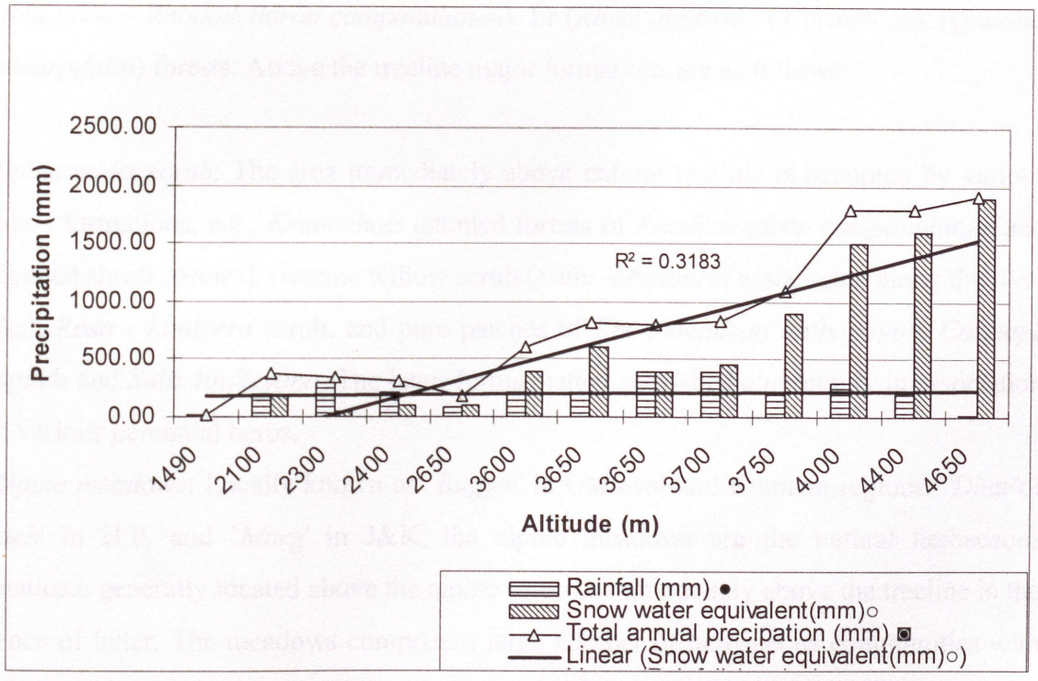


Fig 2.5b: Trends in annual precipitation in Western Karakoram (Source: Miehe et al. 2001).

2.6 Flora and vegetation

The alpine region of Western Himalaya is well known for its floral diversity and interesting phytogeography. The flora has close affinities with Tibet and Central Asia. The dominant families of flowering plants in the region are Asteraceae, Poaceae, Brassicaceae, Scrophulariaceae, Ranunculaceae, Fabaceae, Rosaceae and Ranunculaceae (Rau 1975). Several genera have more than 20 species e.g., *Astragalus, Potentilla, Polygonum Pedicularis, Corydalis, Primula, Saussurea, Gentiana* and *Carex*. The vegetation of this region has been described and classified by various authors e.g., Mani (1978), Schweinfurth (1984) and Puri *et al*. (1989). Broad physiognomic classes of vegetation within the Greater and Trans-Himalaya are given below:

2.6.1. Alpine vegetation of the Greater Himalaya: The alpine vegetation in the Greater Himalaya is generally separated by a distinct treeline characterized by birch - rhododendron (*Betula utilis - Rhododendron campanulatum*), fir (*Abies pindrow*) or brown oak (*Quercus semecarpifolia*) forests. Above the treeline major formations are as follows:

i. Alpine moist scrub: The area immediately above natural treeline is occupied by various shrubby formations, e.g., *Krummholz* (stunted forests of *Rhododendron campanulatum* and associated shrub species), riverine willow scrub (*Salix -Myricaria* association along the river banks), *Rosa - Lonicera* scrub, and pure patches of *Rhododendron anthopogon, Cassiope fastigiata* and *Salix lindleyana.* The latter forms matted snow-bed community in association with various perennial herbs.

ii. Alpine meadows: Locally known as `*Bugyal*' in Garhwal and Kumaon regions, `*Dhar*'or `*Thach*' in H.P. and `*Marg*' in J&K, the alpine meadows are the natural herbaceous formations, generally located above the alpine scrub or immediately above the treeline in the absence of latter. The meadows comprise a large number of herbaceous communities with varying proportions of tussock forming grasses, and sedges. Traditionally the alpine meadows have been categorised under one type of grass cover (*Deyeuxia – Deschampsia* type). However, it is generally seen that grasses are low in abundance in alpine meadows of Greater Himalaya and many herbaceous plants belonging to various dicot families

predominate in these areas. Rawat (2005) identified the following major formations within the alpine meadows of Great Himalaya as tall forbs, short forbs or mixed herbaceous formations, matted shrubs/shrubberies, *Danthonia* grasslands, *Kobresia* meadow, and marsh meadows.

iii. Fell-fields and cushionoid vegetation: The morainic environs and areas generally above 4500 m represent the pioneer environments, including fell-fields dominated by mosses and lichens. No attempts have been made to identify plant communities in such areas. The angiospermic taxa typical of such areas include species of *Rheum, Saxifraga, Sedum, Rheum, Corydalis* and *Androsace*. Rawat & Pangtey (1987a) studied the floristic structure of snowline vegetation in Kumaon Himalaya and found that Brassicaceae, Asteraceae and Ranunculaceae were the dominant families in terms of species number above 5000 m. These areas are equivalent to cold deserts of Trans-Himalaya.

2.6.2. Vegetation of the Trans-Himalayan Mountains: Almost all the areas in the Trans-Himalaya are devoid of forest vegetation. Hence, it is difficult to find a clear ecotone of treeline unlike main Himalaya. However, a few patches of *Juniperus macropoda* and *Salix* woodlands can be seen in the parts of Lahul valley (Aswal & Mehrotra 1994). The Trans-Himalayan vegetation is otherwise distinguishable from those of Himalayan alpines by virtual absence of *Krummholz* formations, and extensive moist meadows. The major formations in this area include:

i. Alpine Dry Scrub: Majority of the plateaus and gentle slopes in the Trans-Himalaya exhibit Mediterranean type of climate and steppe vegetation i.e. scattered low shrubs with sparse grasses and forbs (Wang 1981). Several communities are reported from the cold arid regions of Ladakh and Spiti regions, e.g., *Artemisia - Caragana, Ephedra - Juniperus, Salix - Myricaria,* and *Lonicera - Rosa* (Chundawat & Rawat 1994).

ii. Herbaceous and grassy formations: A few patches close to the valley bottoms with moist clayey soil in the Trans-Himalaya are dominated by herbaceous communities similar to the main Himalayan meadows. These communities are often termed as alpine arid pastures (*cf.* alpine moist meadows of main Himalaya) and include *Potentilla - Geranium* type, *Festuca -*

Stipa grass communities, *Carex* dominated meadows, etc. Quantitative studies on the community structure and composition in these areas are lacking except for a few surveys, e.g., Kachroo *et al*. (1977), Hartmann (1984, '87, '95, 99) and Rawat & Adhikari (2001).

iii. Sub-nival vegetation: Rocky and scree areas above 5000 m in the Trans-Himalayan mountains support very sparse (< 5%) vegetation cover. Characterisitc species are *Carex nivalis*, species of *Leontopodium*, *Melica*, *Christolea, Rhodiola*, *Draba*, and *Saussurea.* Moist and stable slopes have cushion-like growth forms e.g., *Thylacospermum caespitosum, Arenaria bryophylla*, *Androsace aizoon* and scattered mosses and lichens.

2.6.3 Vegetation of Changthang Plateau: The vegetation of the Changthang plateau can be broadly grouped as scrub formations, desert steppe and marsh meadows. Rawat & Adhikari (2001) have reported the following major plant communities from the More Plains of Changthang: *Caragana – Eurotia*, *Artemisia – Tanacetum*, *Stipa – Oxytropis – Alyssum,* and *Carex melanantha – Leymus secalinus*. Stream banks and marsh meadows around the lakes have characteristic sedge dominated vegetation represented by species of *Carex, Kobresia, Scirpus, Triglochin, Pucciniella, Ranunculus* and *Polygonum*. Water bodies and shallow lakes support dense growth of aquatic plants such as *Hippuris vulgaris*, *Potamogeton pectinatus*, *P. perfoliatus*, *Zannichellia palustris*, and *Ranunculus natans*. In addition, a large number of other communities and associations can be seen locally distributed across gradients of soil moisture, altitude and micro-topography.

2.7 Fauna

The alpine region of the Western Himalaya harbours over 52 species of mammals (Menon 2003). Most important species include the endangered snow leopard (*Uncia uncia*), Himalayan brown bear (*Ursus arctos*) and a variety of ungulates such as Himalayan tahr (*Hemitragus jemlahicus*), Himalayan musk deer (*Moschus chrysogaster*), blue sheep (*Pseudois nayaur*), hangul (*Cervus elaphus hanglu*), serow (*Nemorhaedus sumatraensis*), Tibetan argali or nyan (*Ovis ammon hodgsoni*), wild yak (*Bos grunniens*; locally known as dong), goral (*Nemorhaedus goral*) and Tibetan wild ass (*Equus kiang*). Other species include Asiatic black bear (*Selenarctos thibetanus*), Himalayan yellow-throated marten

(*Martes flavigula*), red fox (*Vulpes vulpes*), Himalayan marmot (*Marmota himalayana*), long-tailed marmot (*Marmota caudata*), Himalayan weasel (*Mustela sibirica*), Himalayan palm civet (*Paguma larvata*), Tibetan woolly hare (*Lepus oiostolus*), Royle's pika (*Ochotona roylei*), Large-eared pika (*O. macrotis*) and mountain vole (*Alticola argentatus*).

The prominent avifauna of the alpine region include Himalayan monal (*Lophophorus impejanus*), Himalayan snowcock (*Tetraogallus himalayensis*), golden eagle (*Aquila chrysaetos*), kestrel (*Falco tinnunculus*), chukar partridge (*Alectoris chukar*), Tibetan partridge (*Perdix hodgsoniae*), Tibetan sand grouse (*Syrrhaptes tibetanus*), snow pigeon (*Columba leuconota*), choughs (*Pyrrhocorax* spp.) and a variety of lesser species such as dippers, redstarts, thrushes, pipits, finches and accentors. The high altitude wetlands in eastern Ladakh are especially known for a large number migratory water birds including bar-headed goose (*Anser indicus*) and the threatened waterfowl including black-necked crane (*Grus nigricollis*). Inventory of lower vertebrates in alpine areas is far from complete and only a few faunal surveys have been conducted so far (Anonymous 2001).

2.8 Land Use

The alpine regions of the Western Himalaya have been used for livestock grazing by a large number of agro-pastoral communities for several centuries (Tucker 1986). Since the lower altitude grazing lands are limited in extent, summer migration to higher altitudes and alpine meadows has become a practice as a means to sustain the large livestock populations. However, increase in number of livestock and overuse of certain pastures has led to degradation of high altitude grasslands. Five distinct pastoral practices are prevalent across the alpine landscape in the region: nomadic, semi-nomadic, nuclear transhumance, trans-migration and sedentary or resident. True nomadic pastoralism is practiced mainly by the *Changpa* herders in the Changthang plateau of Ladakh. *Gujjars*, the buffalo herders in the southern slopes of Greater Himalaya and Shivaliks, have over the years shifted from nomadic to semi-nomadic life style. *Gaddis* and *Bakarwals* of HP and J&K follow semi-nomadic life style where only few members of a family move long distances with their livestock. Nuclear transhumance is practiced in many agro-pastoral communities in UA and HP. In this system, a part of the family moves to higher altitudes

closer to treeline along with surplus cattle. Trans-migration (seasonal altitudinal movement by the entire family along with the livestock) is practiced mainly by the *Bhotiya* communities in various parts of UA such as Byans, Darma, Johar, upper basins of Alanknanda and Bhagirathi. Presently, only 20-30% of the original house holds and only a few members from each family migrate to the distant alpine valleys. In the process, several alpine pastures are now available for other communities belonging to the lower parts of the state and *Gaddi* herders from HP. In the high altitude villages of Kinnaur, Spiti, Lahul, Pangi and Zanskar there is round the year grazing by the resident livestock in addition to migratory livestock. In Chamoli, Tehri, Uttarkashi and Kinnaur districts of UA several families drive their scrub cattle to sub-alpine and alpine areas for free grazing during snow free period (June – October). Such a practice leads to faster degradation of meadows and will need immediate reversal if conservation has to succeed in and around the nearby PAs.

Other human activities in the alpine areas include extraction of wild medicinal plants for local as well as commercial use, pilgrimage and recreation such as trekking, camping, and skiing (Rawat 2005). A large number of rare and endangered wild fauna e.g., snow leopard, blue sheep, Himalayan tahr among others inhabit the alpine areas during one season or the other. The alpine areas are also regarded as important repositories of a large number of medicinal and aromatic plants (MAPs) which are used in local medicine as well as for sale to the herbal industries (Samant *et al.* 1998, 2001, Nautiyal *et al.* 2000). In the Greater Himalaya, exploitation pressure is high especially on Salam Panja (*Dactylorhiza hatagirea*), Kutki (*Picrorhiza kurrooa*), Dhoop (*Jurinea macrocephala*) and Atis (*Aconitum heterophyllum*). Some other human activities in the alpine areas include collection of fuel wood, recreation (camping, trekking and skiing mentioned above) and cultivation on steep slopes. In recent years there has been a sudden influx of tourism in the meadows. Cumulative effect of various anthropogenic activities on these fragile environments can be irreparable. Several environmentalists and conservationists have raised concern over degradation of alpine habitats, loss of catchment capabilities, rapid retreat of glaciers and local extinction of endangered species.

Plate 4: FIELD INVESTIGATION













Vegetation Surveys, Camping, Quadrat sampling, local guides and adventure !
- GS Rawat

Plate 5: VEGETATION TYPES & COMMUNITIES - I



©G.S. Rawat

1. Mixed Herbaceous Formation (SF): Pandoh ki Kheti (Tehri)



©G.S. Rawat

2. Alpine Dry Scrub – Niti Valley, Nanda Devi BR

Plate 6: VEGETATION TYPES & COMMUNITIES – II



©G.S. Rawat

1. *Hyssopus officinalis* and *Cicer microphyllum* association on stable scree – NDBR



© J.S. Jalal

2. Avalanche track dominated by *Anaphalis nubigena,* Ericaceous mat on the NE and *Kobresia* meadow on the S aspects (Kyarkoti, 4000 m, Uttarkashi)

Plate 7: VEGETATION TYPES & COMMUNITIES – III



©S. Uniyal

1. Alpine Moist Scrub: *Salix karelinii* and *Anemone polyanthes*



©G.S. Rawat

2. *Danthonia* grassland – Johar Valley, Kumaon

3.0 PATTERNS OF PLANT SPECIES RICHNESS AND DIVERSITY

"Diversity is rather like an optical illusion. The more it is looked at, the less clearly defined it appears to be and viewing it from different angles can lead to different perceptions of what is involved..."

- Anne E. Magurran (1988)

3.1 Introduction

Habitat complexity and heterogeneity strongly influence the species distribution, abundance and diversity (Rosenzweig 1995, Hewitt *et al.* 2005). However, habitat heterogeneity is scale dependent and may operate from patch to landscape levels. Generally small or local scales are assumed to be homogeneous, whereas the regional scales embrace many habitats (Whittaker 1975, Gaston 1994). Diversity within a single habitat is commonly referred to as alpha diversity and between-habitat diversity as beta diversity (Magurran 1988). In this context, the alpine habitats in the Himalaya exhibit a great deal of heterogeneity owing to factors such as sharp gradients of altitude, glacial and avalanche action, snow melt and deposition pattern, aspect, and soil characteristics (Chapter 2). These gradients are sharper in the Greater Himalaya as compared to the Trans-Himalaya because the latter has a wider latitudinal range, more homogeneous landforms and different palaeo-history. Therefore, defining a 'habitat' or habitat type and understanding the patterns of plant species richness and diversity across various scales require both intensive studies at a local level and extensive surveys across the landscape level. This chapter deals with the patterns of plant species diversity in the alpine zone of Western Himalaya at alpha and beta levels. The chapter also attempts to synthesize the existing information on the determinants of diversity in the region using empirical data from selected alpine sites as well as landscape level surveys.

3.2 Material and Methods

3.2.1 Field methods

Data on plant species richness and abundance were collected from a wide range of alpine habitats and vegetation types across Greater and Trans-Himalaya. Given the limited growth season in the alpine region (May – October) when most of the plants are easier to identify, and the vast distances required to be covered on foot, a rapid sampling approach was adopted. Information from two intensive studies conducted by the author within two protected areas of the Western Himalaya i.e., Valley of Flowers (VoF) and Great Himalayan National Park (GHNP) were also pooled in, wherever necessary. In order to fulfill certain objectives of this study, a trans-alpine expedition was carried out from June to October 2004 (Section 1.5). The survey routes were planned in such a way that they covered both the glaciated and non-glaciated valleys, protected and non-protected sites and areas of varied land use practices (Chapter 2). Since most of the sampling was done during summer, monsoon and early autumn months, it is assumed that a majority of habitat types and representative taxa have been covered by this sampling design.

The sites for vegetation quantification along survey route were selected in such a way that maximum gradient of altitude, all aspect and terrain types were covered. The various landscape units covered during field sampling included lateral and terminal moraines, tallus and scree slopes, rocky slopes, river beds, plateaus, river terraces, undulating land masses, agricultural fallows, avalanche traps, valley bottoms, steep slopes, broken slopes, marsh meadows, stream banks, ridge lines, alluvial fans and sandy plains.

Standard phyto-sociological approach was used for sampling the vegetation parameters at each site (Mueller-Dumbois & Ellenberg 1974, Kent & Coker 1992). At each sampling site, terrain features, major physiognomy of vegetation and other environmental parameters were recorded aided by the Survey of India's toposheets (1:50,000 scale). Information on land use practices, such as extraction of medicinal herbs, current and past cultivation, livestock camping and tourism, were also recorded based on direct observations, as well as with the help of local guides and informers. Sample sites were located well within uniform vegetation patches. As far as possible, ecotones, edges and patches smaller than $10m^2$ were avoided for quantification of vegetation parameters. However, uniform efforts were made to look for rare, endangered or economically

important taxa throughout. At each site various abiotic variables such as altitude, degree of slope, aspect, terrain types, soil texture and geographical coordinates were recorded in a standard format (Appendix 1) using the appropriate equipment (Suunto® Magnetic Compass and Garmin® Global Positioning System). Data on species richness, abundance and species-wise cover were collected at each site within 10 random quadrats of 1m x 1m. The one-square-meter quadrat was considered appropriate for sampling herbaceous, graminoid and stunted scrub vegetation (Rawat & Adhikari 2001). For the sake of consistency, 10 quadrats were laid uniformly per site. The number of sites sampled for various physiognomic units is shown in Fig 3.2.1a. These numbers generally correspond to proportion of the area under each physiognomic category.

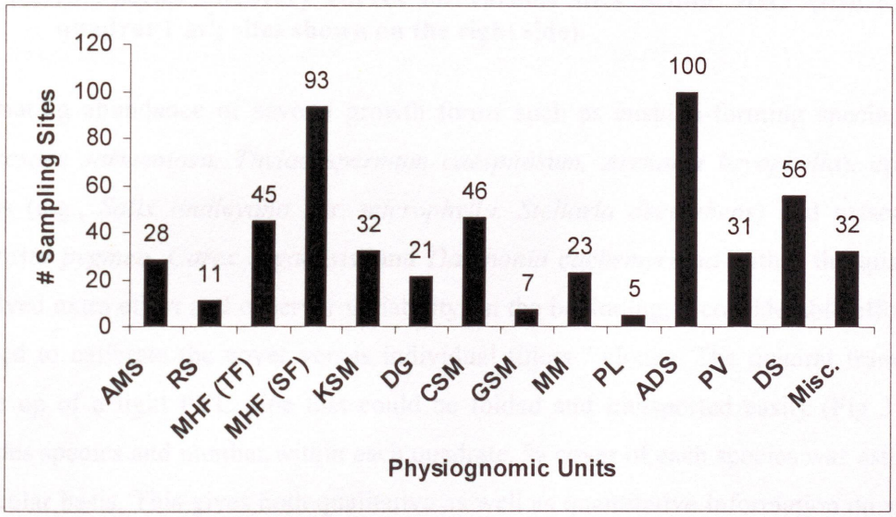


Fig 3.2.1a. Number of sampling sites for various physiognomic units [AMS = Alpine moist scrub, RS = riverine scrub, MHF = Mixed Herbaceous Formation, TF = Tall Forbs, SF = Short Forb, KSM = Kobresia sedge meadow, DG = Danthonia grassland, CSM= Carex Sedge meadow, GSM = Grass-sedge mixed, MM = Marsh meadow, PL = Plantation, ADS = Alpine Dry Scrub, PV = Pioneer Vegetation, DS = Desert Steppe, Misc = Miscellaneous]

This sampling effort was considered adequate for most of the physiognomic units as evident from the species discovery curve obtained in species rich herbaceous formations (Fig. 3.2.1b).

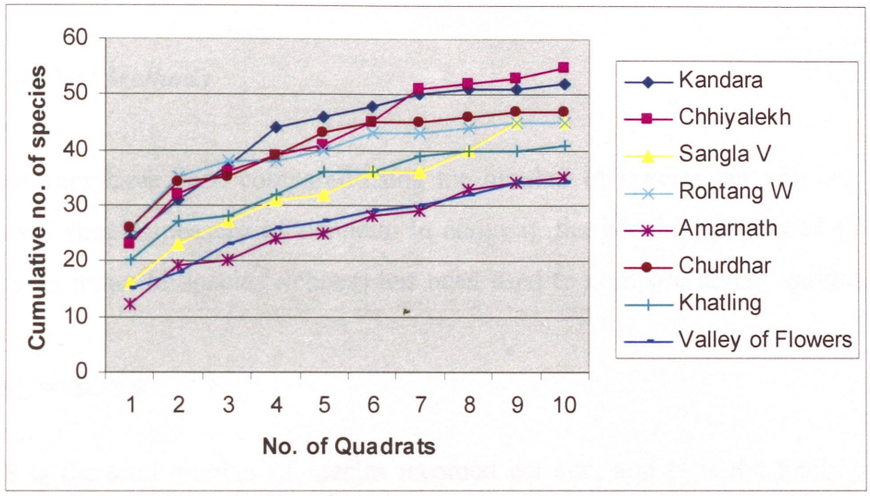


Fig. 3.2.1b Species discovery curves for various sites within MHF (size of each quadrat 1 m^2; sites shown on the right side).

Estimating abundance of several growth forms such as cushion-forming species (e.g., *Androsace sarmentosa, Thylacospermum caespitosum, Arenaria bryophylla*), creeping forms (e.g., *Salix lindleyana* var. *microphylla, Stellaria decumbens*) and tussocks of *Kobresia pygmea*, *Carex sagaensis*, and *Danthonia cachemyriana* within the quadrates involved extra effort and observer variability. In the beginning, a considerable effort was needed to calibrate the cover versus individual tillers / clones. The quadrat frame was made up of a light PVC pipe that could be folded and transported easily (Fig 3.2.1c). Besides species and number within each quadrate, % cover of each species was estimated on ocular basis. This gives both qualitative as well as quantitative information on species for each site.

Vascular plants (angiosperms, gymnosperms and ferns) were enumerated systematically at each site as well as along the survey route. Most of the plants were identified to the closest genera and species in the field using the regional floras available viz., Polunin & Stainton (1984), Aswal & Mehrotra (1994), Murty (2001), and also, a field key for the alpine plants of Western Himalaya (Rawat *in prep.*). Voucher specimens of unidentified plants were collected and later verified from other monographs and various herbaria at Dehra Dun viz., herbaria at the Forest Research Institute (DD), Botanical Survey of India

northern circle (BSD), and Wildlife Institute of India (WII).

3.2.2 Analytical Methods

i. Different sites have been compared using the number of species per site i.e., *'S'* that serves as a simple measure of richness. In addition, the Menhinick's index (Whittaker 1977) as an index of species richness has been used to compare across various sites as follows:

$$D_{Mn} = S/\sqrt{N}$$

where S is the total number of species recorded per site, and N is the total number of individuals summed over all *S* species.

ii. **Species diversity** was computed for different communities using the Shannon-Wiener Index (H') using the formula, $\mathbf{H' = -\sum^{s}_{i=1} (Ni/N) \log (Ni/N)}$

where H' = Shannon-Wiener information index of species diversity, Ni = total number of individuals of the species i, and N = total number of individuals of all the species in one stand (Shannon & Weaver 1949).

iii. **Evenness (Equability)** was calculated using the equation, **Evenness = H' log S,** following Magurran (1988), where S = number of species and H' = diversity. Most of these computations were made done using the computer software Microsoft® Excel.

iv. Beta diversity (β_w), a measure of species turnover with change in habitat, was computed for various valleys / watersheds using the formula $\beta_w = \gamma/\alpha$,

where γ (gamma) = number of species in all the sites, and α (alpha) is the number of species per site or plot (Magurran 1988).

iv. Stand / plot level diversity were correlated with various parameters of soil following Spearman's correlation (Vodnik *et al.* 2006) coefficient and using the computer software SPSS 8.0 for Windows (Norussis 1996, Anonymous 1997).

3.3 Patterns of Species Richness and Diversity

3.3.1 Species Richness

Highest number of species per site was recorded in the MHF of Greater Himalaya. Such sites were mostly located in the high rainfall zone on the south or south-west facing slopes, having deeper soil, and closer to alpine scrub. The number of species per site in this formation ranged from 27–56. Some of the sites representing species-rich mixed herbaceous formations include lower alpine meadows in the Valley of Flowers NP (35-42 species per site), Kandara *Bugyal* in Uttarkashi (36–52), Upper Chyang Kuttang in Sangla Valley (40-45 species per site), north-east facing slopes in Churdhar WS (27–47 species per site), south-west facing slopes near Rohtang pass (29-45 species per site), and the gentle slopes near Amarnath in Kashmir (31 -35). *Danthonia* grasslands (3300–4000 m) in the Greater Himalaya rank second in terms of species richness with the number of species per site ranged from 20–30. Other physiognomic types in the descending order of mean number of species per site include, marsh meadows (18–23 species per site), cushionoid vegetation at higher altitudes (16–22), *Kobresia* meadows (15–21), alpine dry scrub (11–15), and desert steppe of Trans-Himalaya (3–9). Overall, number of species per site in the Greater Himalaya (30.48$\pm$8.33) was much higher as compared to the Trans-Himalaya (11.14$\pm$6.66). In addition, quite a few sites represented the transition zone (25.51$\pm$8.30 species per site) between the Greater and Trans-Himalaya.

As expected, overall species richness in the Greater Himalaya (D_{Mn} = 0.88 $\pm$ 0.33) was much higher as compared to transitional zone (D_{Mn} =0.81+0.31) and Trans-Himalaya (D_{Mn} = 0.45+0.24). Since the index of species richness (D_{Mn}) used here is dependent on the abundance of all individuals, the density figures need to be examined critically. Higher density figures in the Trans-Himalaya (with very high standard deviation) reveal that this region has greater variation in the life-forms and size of individuals. Indeed, the total count of individuals within one square meter, especially those of *Kobresia pygmaea, Glaux maritima* and *Scirpus* species comes to over 1000. On the other hand, density estimates were

more uniform in the Greater Himalaya. This is reflected in higher correlation between the number of species and richness index in Greater Himalaya (R^2 = +0.540) as compared to trans-Himalaya (R^2 = +0.320). The Greater Himalaya, Trans-Himalaya and intermediate (transition) zones have been compared in terms of number of species per site, richness index and density of individual plants in the following table (Table 3.3.1.)

Table 3.3.1. A comparison of species richness and density of alpine plants across major landscapes in the Western Himalaya

Parameters	Greater Himalaya N = 55	Transition Zone N= 35	Trans-Himalaya N=211
1. No. of Species per site (Mean ± SD)	30.48 ± 8.33	25.51 ±8.30	11.14 ± 6.66
2. Density (m^{-2})	152.40 ± 89.45	137. 60± 107.87	155.64± 331.41
3. Species Richness (D_{Mn} ± SD)	0.88±0.33	0.81±0.31	0.45±0.24

There were low negative correlations between the altitude and species richness in the Greater (R^2 = - 0.354) as well Trans-Himalaya (R^2 = -0.032), indicating that that altitude alone is not the key determinant of species richness. Such relationships are to some extent clearer within smaller geographical range (Fig 3.3.1a).

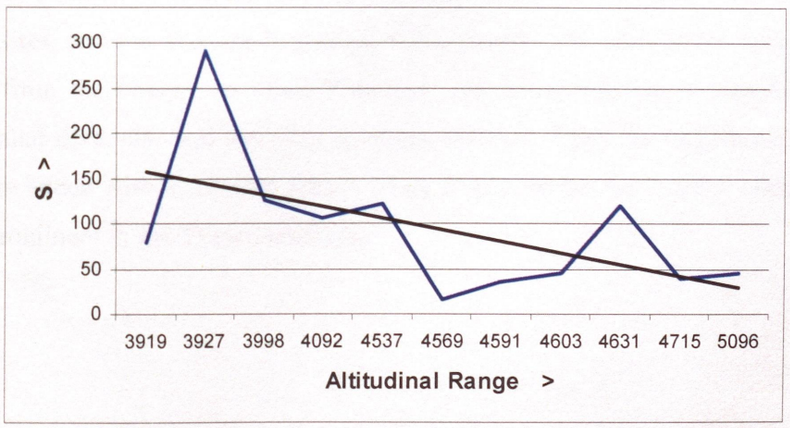


Fig. 3.3.1a: Number of species (S) per locality with increasing altitude in the trans-Himalaya

With the change in watershed, species accumulation curves showed sudden jumps, indicating changes in the floristic composition (Fig 3.3.1b).

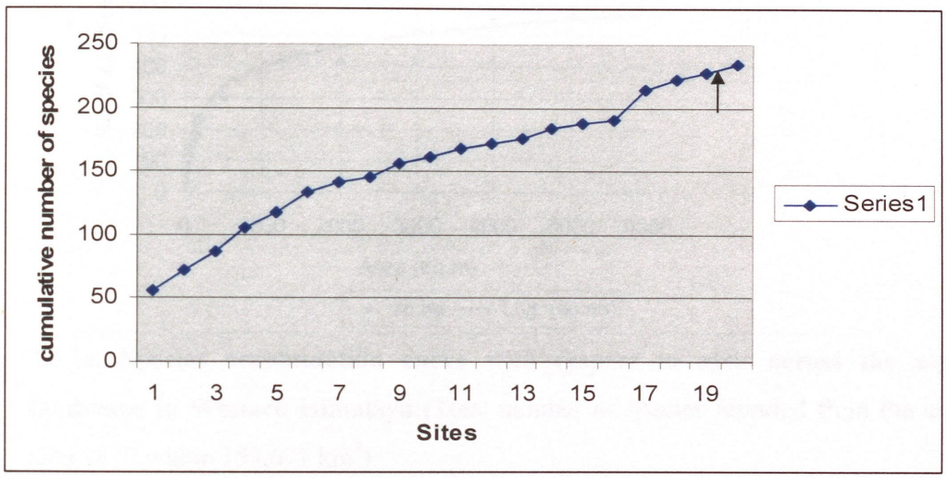


Fig 3.3.1b. Cumulative number of species vs sampling sites in alpine zone of Eastern Uttarakhand (Site no. 18 represents change in watershed from Byans to Darma Valley).

Species–area curve for the entire alpine landscape is shown in fig 3.3.1c. It reveals that, initially the number of species increases steadily with the increase in the number of sampling sites, and the increase is gradual subsequently. The sites in the curve follow a sequence from the Greater to Trans-Himalaya, indicating that the former has a much higher habitat diversity, and therefore a steady increase. Thus the hypothesis that more habitats are added with increasing area is likely to be true for the Greater Himalaya, and it is less prominent in the Trans-Himalaya.

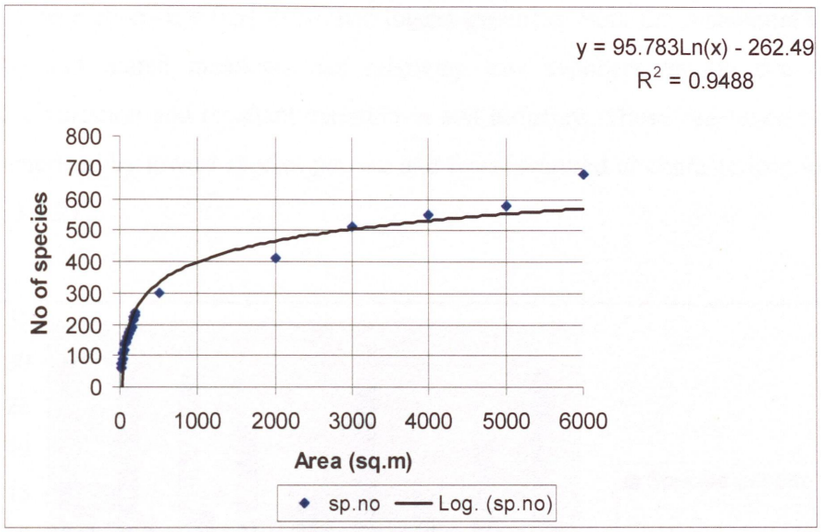


Fig. 3.3.1c. Species accumulation curve with respect to area across the alpine landscape in Western Himalaya (Total number of species reported from the entire area 1810 within 157,671 km^2).

3.3.2 Species Diversity and Evenness

The alpha diversity and evenness for various sites within Greater and Trans-Himalaya have been given in Appendix 2 and 3 respectively. In the Greater Himalaya high values of Shannon index (H'= 3.01 – 3.30) were obtained for the sites located between elevations 3300–3900 m asl. Such sites were characterized by mixed herbaceous formations, alpine moist scrub and a few *Danthonia* slopes. Highest diversity (H'= 3.30) was observed at Kandara Bugyal (3591 m) in Uttarkashi. This site, located on the SE aspect, yielded 52 species. Of these, 27 species had equal proportion (characteristic species) and the rest were relatively rare. Medium diversity values were obtained for alpine moist scrub (H'=1.37 – 2.23) and *Danthonia* grasslands (H' = 1.56 – 3.18). Cushionoid vegetation (H'= 1.34 – 1.84) and marsh meadows (H'= 1.32 – 1.49) had relatively low diversities per sampling sites.

The mixed herbaceous formations (both tall and short forbs), especially at heavily grazed sites had high values of evenness (>0.80). The sites with low evenness values were usually located on the steeper slopes on higher altitudes. The marsh meadows (E= 0.47 – 0.60) and

cushionoid vegetation (E = 0.51–0.70) had lowest evenness. Both the cushionoid vegetation (fell-fields) and marsh meadows had relatively low evenness largely due to micro-topographic variation and resultant variation in soil moisture. These vegetation types were also characterized by lowest species per site and fewer featured or characteristic species per site (Fig., 3.3.2).

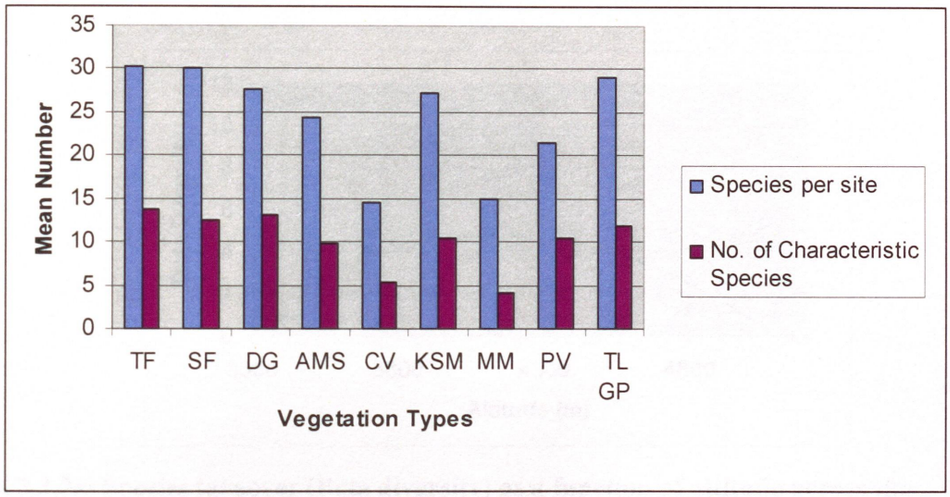


Fig 3.3.2: Number and proportion of characteristic species major physiognomic units in alpine areas of Greater Himalaya (TF = Tall Forbs, SF = Short Forbs, DG = Danthonia Grasslands, AMS = Alpine Moist Scrub, CV = Cushionoid Vegetation, KSM = Kobresia meadows, MM = Marsh Meadows, TL Gp = Treeline Gap)

3.3.3 Beta Diversity

The β diversity for the entire range (Greater and Trans-Himalaya combined) turned out to be higher in the middle altitudes (3900–4300 m) compared to lower and higher ranges (Fig 3.3.3 a). Highest value (β_w = 10.720) was obtained at around 4000-4100 m. Around this altitude, there is a greater transition between the mixed herbaceous formations and other physiognomic units, especially in the Greater Himalaya. If analyzed separately for the Greater and Trans-Himalaya, the trends of β diversity values along the altitudinal gradient were not clear, largely due to varying sample size and a significantly large transition zone between the two.

A comparison of ß diversity across various watersheds, across the larger landscape, has been given in Table 3.3.3. The analysis reveals that highest turnover of species are exhibited by those areas which form the basins of larger mountain ranges (greater transition and variation in habitat types), such as the Byans Valley and north-eastern basin of Nanda Devi BR in Uttarakhand, the Nun Kun area in Zanskar, and the Nubra Valley beyond Khardung La in Ladakh.

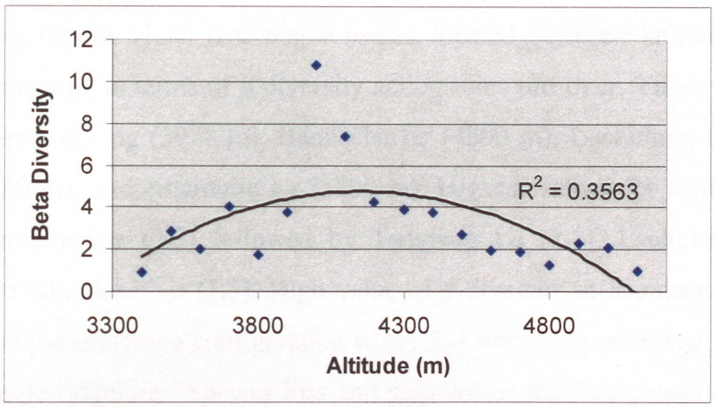


Fig. 3.3.3a: Species turnover (Beta diversity) as a function of altitude across the entire range in Western Himalaya *($p < 0.05$)*

Table 3.3.3: A comparison of *ß* diversity across various alpine valleys /watersheds in the Western Himalaya.

Watershed / Basin	N	Mean No. of Spp / site	Total species in all the sites	Beta diversity (β_W)
1. Byans Valley	22	21.95	217	9.88
2. Darma Valley	14	26.50	186	7.01
3. Johar Valley	16	22.22	161	7.24
4. Nanda Devi, North	15	17.6	151	8.57
5. Nelong Valley	11	13.81	47	3.40
6. Sangla Valley	11	26	151	5.80
7. Churdhar Peak	7	29.42	90	3.05
8. Rohtang Slope	11	30.81	151	4.90
9. Patan Valley, Lahaul	10	15.8	75	4.74
10. Myar Valley, Lahaul	9	14.55	66	4.53
11. Nun Kun basin	16	12	106	8.83
12. Changthang	45	8.2	48	5.58

13. Khardung – North Polu	13	12	64	5.33
14. Nubra Valley	26	5.78	45	7.78

Since alpine plants are known to follow a predictable pattern of distribution along the specific landscape units and geo-botanical units, it may be hypothesized that similar habitats, despite their geographical isolation, will have a considerable similarity, and that there would be a gradual turnover of species along the increasing latitude. For example, major ridge lines and higher passes would be similar in terms of species composition and diversity. Keeping this in view, five major passes located between latitudes 32°21' to 34°16' N were compared in terms of β diversity and species turnover. These passes, from south to north, are Rohtang (3978 m), Baralacha La (4800 m), Lachulung La (5065 m), Tanglang La (5360 m), and Khardung La (5400 m). Highest values for β diversity were obtained for Baralacha La (2.3) followed by Tanglang La (2.1), Lachulung La (1.9), Rohtang (1.9) and Khardung La (1.5). High value of β-diversity at Baralacha La may be attributed to its unique landscape configuration where 3-4 ridgelines converge. Other passes are located on single ridgeline. Species loss and gain across the five passes are shown in Fig. 3.3.3c. It reveals that between Rohtang (offshoot of Pir Panjal) and Baralacha La (junction of Zanskar and Greater Himalaya), there is maximum loss of species. Maximum gain in species (new species added) was seen at Tanglang La.

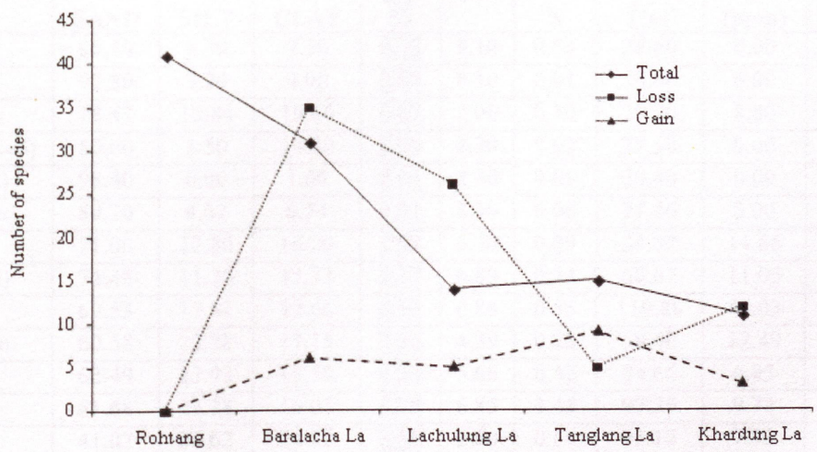


Fig. 3.3.3c: Species gain and loss across five major mountain passes (Rawat & Adhikari, Unpublished)

3.4 Determinants of Diversity

3.4.1 Edaphic Factors and Species Diversity

A comparative analysis of soil parameters for various vegetation types and corresponding species diversity (H') has been given in the Table 3.4.1a. The soil texture varied from sandy gravel (terminal and lateral moraines) to clayey loam (stable gentle slopes adjacent to treeline) and sandy, skeletal and murram (in the Trans-Himalaya). Maximum diversity and richness of plant species were seen in the clayey loam areas, and least in high alpine gravel and murram (active scree). Generally, the high rainfall areas in the Greater Himalaya, especially on the steep slopes having pioneer communities, had low soil pH (4.39) and low organic carbon (2.86 %). Such sites had relatively low species diversity (H'=1.63). *Danthonia* grasslands had moderate pH (6.14) and relatively high organic carbon (8.27 %) and high species diversity (H'= 2-3). In the Trans-Himalaya, the species diversity did not vary considerably with change in soil pH.

Table 3.4.1 a: Soil parameters across various habitat / vegetation types vis-à-vis species diversity in the alpine zone of Western Himalaya. [Vegetation / Habitat Types: ADS = Alpine Dry Scrub, CSM = *Carex* Sedge Meadow, DF = Desert Steppe, KSM = *Kobresia* sedge meadow, AMS = Alpine Moist Scrub, MHF = Mixed Herbaceous Formation, CV = Cushionoid Vegetation, DG = *Danthonia* grassland, RS = Riverine Scrub, TH = Trans-Himalaya, GH = Greater Himalaya; H' = Shannon Index of Diversity]

Vegetation / Habitat Type	Soil Parameters									H'
	% SAND	% SILT	% CLAY	OC %	pH	% N	WHC (%)	P (ppm)	K (ppm)	
ADS (*Artemisia*)	86.40	6.30	7.30	0.38	8.10	0.04	28.60	0.00	0.00	0.73
ADS (*Caragana*)	92.80	3.20	4.00	0.12	8.10	0.01	20.60	0.00	0.00	1.22
ADS (*Tanacetum*)	78.47	10.84	10.66	0.87	7.06	0.10	29.20	8.80	158.40	1.67
ADS (*Eurotia* mixed)	80.60	5.50	14.00	0.26	8.20	0.03	27.50	0.00	0.00	1.68
DS (*Leymus* stand)	98.40	0.00	1.60	0.04	8.30	0.01	20.40	0.00	0.00	0.73
DS (*Stipa-Alyssum*)	89.20	4.02	6.74	0.51	8.30	0.06	27.46	0.00	0.00	0.75
DS (Mixed)	71.00	12.80	16.20	1.02	5.70	0.09	34.37	14.66	125.00	0.99
Alluvial Fans (TH)	74.48	11.70	13.73	2.17	6.89	0.24	60.67	11.05	315.00	1.89
CSM (TH)	69.53	17.81	12.66	6.16	6.86	0.55	119.88	48.03	154.83	1.67
Pioneer Vegetation	60.58	22.28	17.15	2.86	4.39	0.28	58.60	12.49	165.50	1.63
KSM (GH)	62.49	23.93	13.59	4.34	5.66	0.42	84.66	6.05	149.50	2.22
MM (GH)	61.68	22.28	16.05	7.78	6.85	3.48	97.39	9.72	449.50	2.27
AMS (GH)	41.07	34.62	24.32	5.51	5.50	0.54	93.12	7.93	207.33	2.31
MHF (GH)	59.35	24.75	16.18	6.13	5.66	0.57	87.61	15.88	276.92	2.38
CV (GH)	66.68	20.50	12.82	5.49	6.36	0.22	54.65	8.38	91.33	2.45
DG (GH)	67.60	20.17	12.23	8.27	6.14	0.70	114.58	12.27	269.80	2.53
RS (GH)	85.00	5.80	9.20	0.11	7.78	0.01	17.39	5.34	42.00	2.62

The Spearman's correlation matrix and corresponding significance values have been given in Tables 3.4.1b and c. The analysis reveals that % sand and soil pH show negative correlations with species diversity ($p<0.05$). However, % organic carbon was positively correlated with species diversity (Fig 3.4.1). Other factors such as % clay, % silt, water holding capacity, phosphorus and potassium had no significant correlation with species diversity.

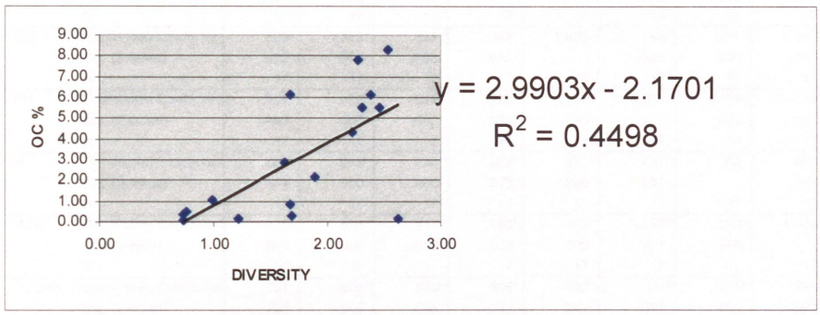


Fig. 3.4.1: Correlation between soil organic carbon and species diversity

Table 3.4.1b: Spearman's Correlation matrix of soil parameters and species diversity

Spearman's rho										
	H'	% SAND	% SILT	% CLAY	% OC	pH	% N	% WHC	P (PPM)	K (PPM)
DIVERSITY	1.0000	-0.5742	0.5549	0.3521	0.5202	-0.5569	0.4834	0.4245	0.3267	0.5404
%SAND	-0.5742	1.0000	-0.9822	-0.8456	-0.8284	0.8926	-0.8452	-0.8015	-0.6700	-0.7743
%SILT	0.5549	-0.9822	1.0000	0.7811	0.8314	-0.9238	0.8482	0.8105	0.6394	0.7536
%CLAY	0.3521	-0.8456	0.7811	1.0000	0.5613	-0.7366	0.5921	0.5858	0.5981	0.6353
%OC	0.5202	-0.8284	0.8314	0.5613	1.0000	-0.7489	0.9754	0.9632	0.7321	0.7916
pH	-0.5569	0.8926	-0.9238	-0.7366	-0.7489	1.0000	-0.7311	-0.7293	-0.6626	-0.6762
%N	0.4834	-0.8452	0.8482	0.5921	0.9754	-0.7311	1.0000	0.9631	0.7289	0.8607
% WHC	0.4245	-0.8015	0.8105	0.5858	0.9632	-0.7293	0.9631	1.0000	0.7395	0.8016
P(PPM)	0.3267	-0.6700	0.6394	0.5981	0.7321	-0.6626	0.7289	0.7395	1.0000	0.7613
K(PPM)	0.5404	-0.7743	0.7536	0.6353	0.7916	-0.6762	0.8607	0.8016	0.7613	1.0000

Table 3.4.1c: Corresponding significance values for Spearman's Correlation Matrix between soil and species diversity:

Correlations

			DIVERSI	SAND	SILT	CLAY	OC	PH	N	WHC	P.PPM	K.PPM
Spearman's rho	DIVERSI	Correlation Coefficient	1.000	-.574*	.555*	.352	.520*	-.557*	.483*	.425	.327	.540*
		Sig. (2-tailed)	.	.016	.021	.166	.032	.020	.049	.089	.201	.025
		N	17	17	17	17	17	17	17	17	17	17
	SAND	Correlation Coefficient	-.574*	1.000	-.982**	-.846**	-.828**	.893**	-.845**	-.801**	-.670**	-.774**
		Sig. (2-tailed)	.016	.	.000	.000	.000	.000	.000	.000	.003	.000
		N	17	17	17	17	17	17	17	17	17	17
	SILT	Correlation Coefficient	.555*	-.982**	1.000	.781**	.831**	-.924**	.848**	.811**	.639**	.754**
		Sig. (2-tailed)	.021	.000	.	.000	.000	.000	.000	.000	.006	.000
		N	17	17	17	17	17	17	17	17	17	17
	CLAY	Correlation Coefficient	.352	-.846**	.781**	1.000	.561*	-.737**	.592*	.586*	.598*	.635**
		Sig. (2-tailed)	.166	.000	.000	.	.019	.001	.012	.013	.011	.006
		N	17	17	17	17	17	17	17	17	17	17
	OC	Correlation Coefficient	.520*	-.828**	.831**	.561*	1.000	-.749**	.975**	.963**	.732**	.792**
		Sig. (2-tailed)	.032	.000	.000	.019	.	.001	.000	.000	.001	.000
		N	17	17	17	17	17	17	17	17	17	17
	PH	Correlation Coefficient	-.557*	.893**	-.924**	-.737**	-.749**	1.000	-.731**	-.729**	-.663**	-.676**
		Sig. (2-tailed)	.020	.000	.000	.001	.001	.	.001	.001	.004	.003
		N	17	17	17	17	17	17	17	17	17	17
	N	Correlation Coefficient	.483*	-.845**	.848**	.592*	.975**	-.731**	1.000	.963**	.729**	.861**
		Sig. (2-tailed)	.049	.000	.000	.012	.000	.001	.	.000	.001	.000
		N	17	17	17	17	17	17	17	17	17	17
	WHC	Correlation Coefficient	.425	-.801**	.811**	.586*	.963**	-.729**	.963**	1.000	.740**	.802**
		Sig. (2-tailed)	.089	.000	.000	.013	.000	.001	.000	.	.001	.000
		N	17	17	17	17	17	17	17	17	17	17
	P.PPM	Correlation Coefficient	.327	-.670**	.639**	.598*	.732**	-.663**	.729**	.740**	1.000	.761**
		Sig. (2-tailed)	.201	.003	.006	.011	.001	.004	.001	.001	.	.000
		N	17	17	17	17	17	17	17	17	17	17
	K.PPM	Correlation Coefficient	.540*	-.774**	.754**	.635**	.792**	-.676**	.861**	.802**	.761**	1.000
		Sig. (2-tailed)	.025	.000	.000	.006	.000	.003	.000	.000	.000	.
		N	17	17	17	17	17	17	17	17	17	17

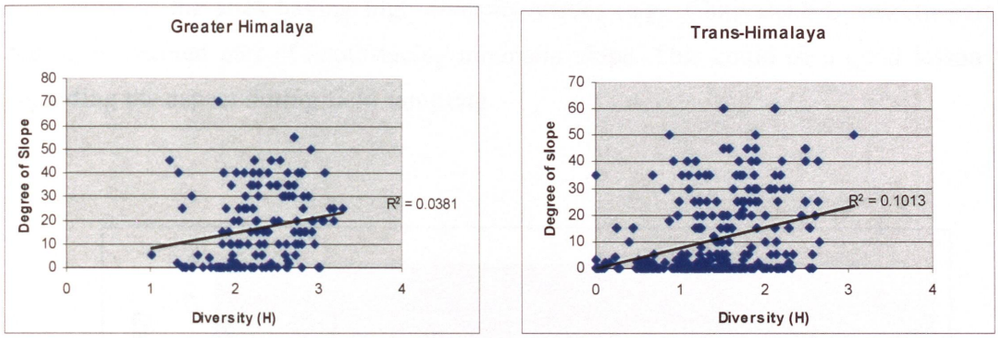
*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

3.4.2 Diversity along the gradients of slope

The degree of mountain slope as an ecological parameter has rarely been dealt in Plant Ecology. Several parameters of plant environment are auto-correlated with the degree of slope, such as soil type, soil moisture, soil depth, pH, stability of land surface and intensity of land use by human beings and faunal communities. The valley bottoms near frequently-inundated streams, and glacial outwash with flat terrain (0 degree slope), are likely to be low in species diversity, as compared to steeper and stable slope. Given the numerous local factors that may mask the effect of slope, the degree of slope cannot be correlated with species diversity directly. Nevertheless, it was expected that the moderate slopes would have higher species diversity, as compared to flat or steep slopes, yielding a curvilinear relationship. However, the data showed a low positive correlation between the species

diversity and degree of slope across the Greater as well as Trans-Himalaya (Fig. 3.4.2 a and b).



Figs. 3.4.2a &b: Pattern of Plant Species Diversity with varying degree of slope in the Greater (a) and Trans-Himalaya (b)

There are inherent differences in the patterns of diversity with respect to slope angle in between Greater and Trans-Himalaya. It is generally seen that the flat alpine valleys in the Greater Himalaya are moist and rich in soil nutrients and depth. On the other hand, the flat areas in the Trans-Himalaya represent the sandy plains or salt pans, except in case of few marsh meadows, which constitute less than 2 % of the entire landscape in the region. The middle to upper slopes in the trans-Himalaya generally exhibit higher species diversity, as compared to the valley bottom or flat basin that are more arid. Such a trend is more prominent when the mountain peaks end in perpetual snow or nival zone. The same trend is not very clear in the Greater Himalaya, where the higher slopes are dominated by unconsolidated landmass and scree.

3.4.3 Species Diversity along the Aspects

In the Greater Himalaya, highest diversity values were attained in the eastern slope (mean H'=2.07$\pm$0.63) and south-eastern (mean H'= 2.09$\pm$0.82) aspects. The north-facing slopes had least mean diversity values (H'=1.73) (Fig 3.4.3). The diversity values for zero aspect varied greatly (0 to 3.01). It was evident that true zero aspect was seen only in the Trans-Himalaya (Changthang plateau), where diversity values were very low due to edaphic factors. In case of Greater Himalaya, zero aspect at sampling site may not be necessarily free from the influence of general inclination of mountain slope. For example, quite a few localities representing smaller table lands or plateaus located on the south- or

north-facing mountain slopes were categorized under zero aspect during sampling. However, they may, in true sense be representing south or north aspect respectively. In fact, most of the sites having high diversity values (e.g., Chhiyalekh in eastern part of Kumaon) formed part of south-facing mountain slope. This could be a good lesson for recording the aspect during field sampling.

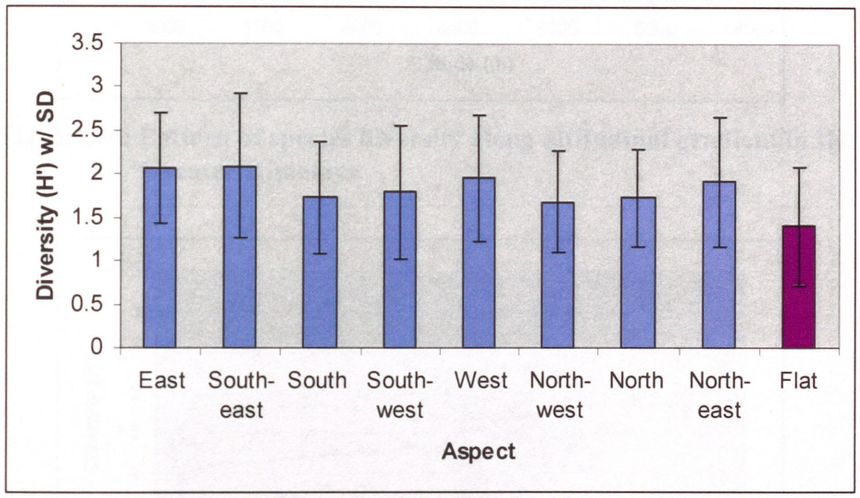


Fig. 3.4.3: Pattern of species diversity in various aspects

3.4.4 Diversity along the Altitudinal Gradient

As expected, there was a gradual decline in the species diversity with increasing altitude in the Greater Himalaya (Fig. 3.4.4a). However, in the Trans-Himalaya, the trend was quite different and there was no correlation between the altitude and species diversity (Fig. 3.4.4b). The data set for the snowline environment (above 5000m) from the Greater Himalaya is limited, and more rigorous sampling on the south-facing single mountain slopes is warranted.

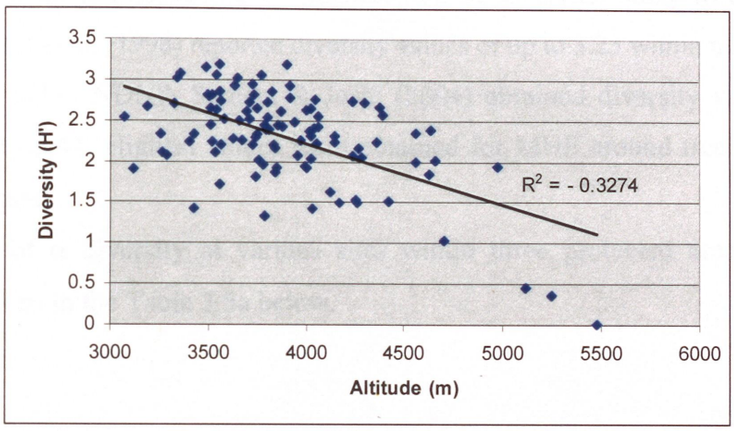


Fig. 3.4.4a: Pattern of species diversity along altitudinal gradient in the Greater Himalaya

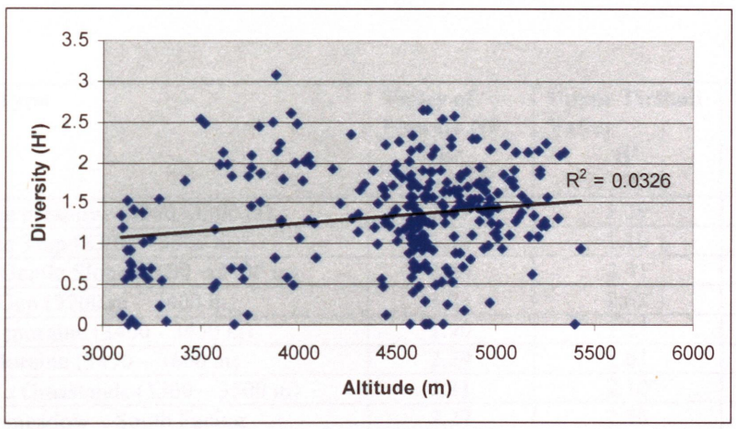


Fig. 3.4.4b: Pattern of species diversity along the altitudinal gradient in the Trans- Himalaya

3.5 Discussion

The patterns of plant species richness and diversity at α (site) level in this study reveal that mixed herbaceous formations (MHF) on the south to south-east facing slopes (3600–4200 m asl) of the Greater Himalaya had the highest number of species per unit area. On an average, such sites yielded 25-30 species of angiosperms within one m^2 (quadrat of 1 x 1 m) during peak growing season (highest 36). As expected, in the Trans-Himalaya, the diversity values as well as number of species per quadrat were much lower and mean number of species

within a quadrat ranged between 5-15 (highest 24). In an earlier study in the Valley of Flowers NP, Kala *et al.* (1998) reported diversity values of up to 3.23 within treeline gap. In another study within NDNP, Samant & Joshi (2004) obtained diversity values ranging between 0.29 to 3.41. Highest values were obtained for MHF around treeline gaps and lower alpine areas.

A comparison of α diversity at various sites within three protected areas of Greater Himalaya is given in the Table 3.5a below.

Table 3.5a: A comparison of α Diversity (H') across various alpine sites in Valley of Flowers NP (Kala *et al.*, 1997) Tirthan Valley, Great Himalayan National Park (Singh 1999), and Sarson Patal, Core area of Nanda Devi NP (Adhikari 2004).

SN	Habitat Type	Valley of Flowers NP H'	Upper Tirthan Valley H'	Sarson Patal (Nanda Devi NP) H'
1	Sub-alpine meadow (3200 -3300 m)	2.47	2.39	-
2	Avalanche Trap (3300 - 3500 m)	1.54	1.10	-
3	MHF on Gentle Slope (3600 – 4400 m)	2.86	2.41	1.75
4	Treeline Gap (3200 m – 3400 m)	3.23	2.62	-
5	Terminal moraine (3400 - 3450 m)	1.90	1.25	1.62
6	Lateral Moraine (3450 – 3600 m)	2.29	1.61	1.63
7	*Danthonia* Grasslands (3300 – 3500 m)	2.81	2.10	-
8	*Kobresia* meadow – South Facing	2.27	2.26	1.76
9	Alpine Moist Scrub (3400 - 4000 m)	1.48	2.50	1.57
10	High Alpine Slope (>4500 m)	1.88	1.25	1.65

Tambe (2007), based on a detailed study in the alpine landscape of Khangchendzonga NP (KNP), Sikkim Himalaya, has reported much lower values of plant species diversity (H'= 1.44 - 2.48), as compared to the values obtained from comparable sites in the Western Himalaya. In KNP, highest species diversity (H'=2.48) was obtained for *Kobresia*–mixed forb community in Zemu Valley (Table 3.5b). The latter site represented a mid-seral stage. The number of species at such sites ranged from 15–21 per m^2. In all the cases, sites with high evenness values were dominated by one or the other species e.g., *Rhododendron anthopogon*, *Salix calyculata* and *Kobresia nepalensis*.

Table 3.5b: Richness, Evenness and values of α diversity in various alpine habitats of Khangchendzonga NP, Sikkim Himalaya (Source: Tambe 2007).

Vegetation Community	Diversity (H')	Simpson`s DI (1-D)	Evenness (E)
Juniper scrub	1.73	0.69	0.76
Rhododendron scrub	1.76	0.71	0.85
Morainic scrub	2.39	0.89	0.96
Riverine scrub	1.62	0.76	0.91
Kobresia duthiei moist meadow	1.74	0.78	0.91
Kobresia nepalensis moist meadow	1.70	0.73	0.88
Deschampsia caespitosa marsh meadow	1.44	0.72	0.91
Potentilla peduncularis moist meadow	1.44	0.72	0.91
Sedge- Herb Mixed Community	2.48	0.91	0.97

What limits the species number in some communities and which factors allow co-occurrence of large number of species in alpine areas? This question can be answers partly with the help of prevailing *intermediate disturbance hypothesis* (Grime 1979, Huston 1979). It is well known that most of the lower alpine slopes in the Greater Himalaya undergo regimes of natural disturbances in the form of avalanches, soil working by smaller mammals such as voles and pikas, intensive herbivory by wild or domestic ungulates, and continuous flush of nutrients from the higher altitudes. Size of the plants also influences the number of species per unit area. Since mean size of alpine plants decreases with increasing altitude in theory, some of the alpine sites could support over 50 species per m^2 at a given time. However, such sites are rare to find.

How do these figures compare with other alpine areas of the world? Korner (1999, 2004) reported about 250 species within one km^2 at a major alpine research sites in Swiss Alps, and as many as 34 species of plants including mosses and lichens within an area of 25 x 35 cm in an alpine landscape of North Sweden (67° N). Though mosses and lichens were not enumerated systematically during this study, some of the stable and moist alpine slopes do have high moss and lichen cover (up to 25%). However, MHF especially on

lower alpine sites, support very little mosses and lichens. In the European Alps, presence of limestone seems to influence species diversity significantly because both calcicole and calcifuge taxa can be found on such sites (Ch. Korner, *personal communication*). Since species richness at such sites does not increase significantly with increase in the area, it would be better to compare larger areas of about 200 m^2 or 1 km^2, to compare species richness across various alpine areas of the world.

A few authors e.g., Smythe (1939) and Mani (1978) have reported, during a rapidly advancing summer i.e., between May (snow melt) and October (complete senescence), that two to three sets of alpine herbs grow and complete their lifecycles in a sequence at some alpine sites. This would mean that richness and diversity values at alpine sites could change from season to season. A closer look at the phenology and growth habits of alpine plants reveals that most of the alpine plants have perennial–annual growth habit. Even though a few species do sprout and flower early in the season, they do not completely disappear from the surface, so that they go un-noticed to the eyes of experienced botanists. Hence, given the limited time available for the study and large areas to be covered, one-time sampling during June to September would be adequate to record the presence of over 95% of the plant species in the alpine area.

While species richness and diversity at alpha level are governed by various environmental factors such as altitude, aspect and edaphic parameters (section 3.3), the beta or watershed-level diversity is strongly influenced by the overall gradient of the above parameters in an area. In addition, levels of alpha and beta diversity in an area would also be determined by the overall pool of species available in the region. At a global scale, it is estimated that the alpine zone occupies nearly 3% of the land surface and harbours about 10,000 species of angiosperms that comprises about 4% of the total angiosperms described so far. It is pertinent to mention here that the alpine flora of the Western Himalaya is almost 2-3 times richer as compared to other alpine zones of the world. For example, the European Alps, the New Zealand Alps and the Rocky Mountains of United States have about 600-650 alpine species each (Korner 1999). Total number of

alpine plants recorded from different areas of Western Himalaya have been compared in Table 3.5c.

Table 3.5c. Number of alpine angiosperm species reported from different floristic sub-regions of Western Himalaya. [GH = Greater Himalaya, TH = Trans-Himalaya; Overall Estimate: 1500 species in 20,000 km^2 in GH and 1000 species in 100,000 km^2 in TH].

Name (Location)	Approx. Area (km^2)	Altitudinal Range (m)	Total species (Angiosperms)	* Reference
Churdhar WS (GH)	20	3300 - 3600	190	Subramani, 2007
Valley of Flowers (GH)	87	3200-6675	499	Kala *et al.* 1998
Kumaun Himalaya (GH+TH)	6,830	3300 - 5600	830	Rawat 1984
Nandadevi NP (GH+TH)	520	3300 - 4600	362	Samant 1993
Dah – Hanu (TH)	400	2750 - 4100	346	Klimes & Dickore 2005
Tso Kar (TH)	500	4400 - 5500	248	Rawat & Adhikari 2005
Aksai Chin (TH)	27,000	4500 -5000	79	Miehe *et al.* 2002
Lahaul – Spiti (TH + 10 % GH)	12,210	2000 - 6600	987	Aswal & Mehrotra 1994
Ladakh (TH)	100,000	3000 - 6000	1061	Klimes 2006
Entire Western Himalaya	157,671	3300 – 5600	1810	Present Study

The effect of altitude on species richness and diversity in the Greater Himalaya was predictable. Grabherr *et al.* (1995) suggested that in the central Alps, the decline in species with increasing altitude is not gradual but in big steps, which is largely due to distinct zonation. That is, if the communities are arranged altitudinally, wave-like trends would be seen along the altitudinal gradient. Since alpine habitats in the Greater Himalaya are much more complex and several habitats are aligned vertically (e.g., avalanche traps, lateral moraines and truncated spurs), such a trend has not been established yet. Local topography, soil conditions and snow deposition pattern can have stronger influence on the species diversity than altitude alone (Chapin & Korner 1995, Grytnes & Vetaas 2002), as evident from the data on Trans-Himalaya in this study (section 3.3).

Partel (2002), based on extensive literature search, showed that there was a positive relationship between the species richness and soil pH. In this study, there was a low negative correlation between species diversity and soil pH ($R^2 = 0.322$). Such a reverse

trend is likely to be due to species-poor habitats in the Trans-Himalaya, which represent the Tethyan sea bed or lake basins having high alkalinity. Partel (2002) argues that if the pool of species that is suited for high soil pH is larger than the pool of species suited for low soil pH, a positive correlation is expected between richness and pH at a local level. In contrast, if the pool of species that is suited for low soil pH is larger than the high soil pH adapted species, a negative relationship is expected between richness and pH. Going by this hypothesis, it can be stated that the pool of species in the Greater Himalaya is certainly larger, and a majority of alpine species in the region are adapted for low soil pH.

One of the reasons for high species diversity in the alpine meadows of Valley of Flowers NP has been ascribed as high Landscape Heterogeneity (Kala *et al.* 1998). During the present investigation, this variable could not be quantified, as it requires detailed spatial analysis involving GIS and remote sensing techniques supported by ground truth information. However, patterns of beta diversity that reflect the changes in habitat types and topographic gradient, can be taken as surrogate for landscape heterogeneity.

3.6 Conclusion

Mixed herbaceous formations adjacent to natural treelines in the Greater Himalaya, especially on south or south-east facing slopes, had highest species richness (S = 27–56 species per site) and alpha diversity (H' = 3.01 – 3.30). Richness and diversity values at such sites are much higher than most of the alpine sites in the world including alpine meadows of the Eastern Himalaya. Least richness and diversity values were obtained in case of alpine dry scrub vegetation in the Trans-Himalaya (S = 2-9, H'= 0.0–0.5). Values for the remaining sites and vegetation types ranged in between. The Byans Valley in eastern Kumaon, NDBR in Garhwal, the Nun-Kun basin in Zanskar and Nubra Valley in Ladakh exhibited higher beta diversity compared to several adjacent landscape units, largely due to sharper gradients of moisture and altitude. Within the limits of alpine vegetation, the species diversity decreased with increasing altitude (3300–5200 m) in the Greater Himalaya, but interestingly the trend is reverse in the Trans-Himalaya. This is largely due to higher aridity in the lower valleys in the Trans-Himalaya. Soil pH and % organic carbon are important

determinants of species diversity. It is estimated that the alpine zone of the Greater-Himalaya harbours about 1500 species of vascular plants within 20,000 km^2 while the Trans-Himalaya harbour only 300 – 350 species within the comparable geographical area. Both the floristic sub-regions form the sub-sets of overall 1810 species in the entire Western Himalaya that constitutes about 18 % of world's alpine flora.

Plate8: ALPINE PLANT ADAPTATIONS - I



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1. *Stipa* species – Among the hardiest alpine growth forms
2. *Saussurea obvallata* (Brahmakamal) – Hot-house plant specialized bracts to facilitate pollination
3. Deep roots of *Aconogonum tortuosum* to ensure perennation
4. *Epilobium latifolium* – Maximize pollinator visit

4.0 COMMUNITY STRUCTURE AND COMPOSITION

"Neither organisms nor species populations exist by themselves in nature; they are always part of an assemblage of populations living together in the same area..."

Charles J. Krebs (2001)

4.1 Introduction

The alpine habitats support specialized growth forms and groups adapted to highly seasonal and resource poor environment. Both the edaphic and climatic gradients are sharp, especially in the Greater Himalaya, which are manifested by multitude of plant communities and vegetation types each representing structural and functional attributes of the environment. Characterizing such diverse communities require detailed information on their populations, habitats and relative cover of individual species (Kent & Coker 1992). Even though, basic nature of plant communities have long been debated, the plant ecologists have always felt need to identify and characterize the communities. Currently, most of the ecologists regard the communities as `open systems' which generally exhibit a transient, non-equilibrium condition for a long period (DeAngelis & Waterhouse 1987). Gleasonian school argues that communities can be recognized and classified but any classification is for the convenience of the human observer and description of the obligate interactions may not tie the communities together.

Beginning from treeline to snowline the alpine vegetation of the Western Himalaya is divisible into several physiognomic units which are discernible to a common eye. Prominent physiognomic units in the Greater Himalaya include: (i) *Krummholz* formation dominated by *Rhododendron campanulatum*, (ii) Alpine moist scrub (AMS) comprising dwarf junipers (*Juniperus indica, J. communis*), *Berberis – Cotoneaster*, *Lonicera – Rosa*, *Salix karelinii* and *Cassiope fastigiata* - *Rhododendron anthopogon* communities, (iii) Riverine scrub (RS) primarily comprising *Salix – Myricaria* community, (iv) *Danthonia* grasslands (DG), (v) Mixed herbaceous formations (MHF; tall and dwarf types), (vi) *Kobresia* sedge meadows (KSM), (vii) Alpine marsh meadows (AMM) dominated by various sedges and rushes, (viii) Fellfields (Scotish, *Fell* = stone) characterized by low

cushionoid vegetation among wind blown rocky substrate, and (ix) Pioneer communities around sub-nival or snowline with < 2 % cover of angiosperms and sparse mosses and lichens. In the trans-Himalaya timberline is inconspicuous and a few tree species such as *Juniperus semiglobosa* (= *J. macropoda* auct.) and chilgoza pine (*Pinus gerardiana*) represent the sub-alpine forest and krummholz formations are virtually absent. Major formations in the Trans-Himalaya are (i) Alpine dry scrub (ADS) represented by *Ephedra gerardiana*, *Artemisia – Tanacetum, Krascheninnikovia ceratoides - Caragana versicolor, Lonicera spinosa, Acantholimon lycopodioides,* (ii) Riverine scrub characterized by *Hippophae rhamnoides* subspecies *turkestanica, Myricaria elegans, M. germanica, Salix* species, (iii) Mixed alpine communities mesic localities, (iv) Desert steppe with sparse cover of *Stipa* species, *Oxytropis microphylla, O. tatarica*, *Carex* species, (v) Fellfields and (vi) Moss – Lichen Communities.

Some of the prominent woody formations in the alpine areas of Himalaya have been described by Schweinfurth (1957) and Champion & Seth (1968). However, majority of the herbaceous formations have not been classified and studied so far. A number of basic questions pertaining to community ecology in this region remain unanswered, e.g., what is the spatial distribution and extent of each physiognomic types and what are the processes underlying these patterns? How are communities organized along the gradients of environment? How do various communities compare in terms of standing phytomass? How do Greater- and Trans-Himalayan alpine habitats compare in terms of major growth forms, life-forms or functional types? Although some of these questions have been addressed by earlier workers at a local level, a landscape level analysis of alpine plant communities have not been attempted for the Western Himalaya. This chapter deals with the classification of alpine plant communities, biomass and Life-Form structure.

4.2 Material and Methods

Data collected on species presence, abundance and cover from various physiognomic units and land forms (Chapters 1, 2) were subjected to various statistical analyses. The number of sampling sites within Greater and Trans-Himalaya are shown in Fig 4.2a.

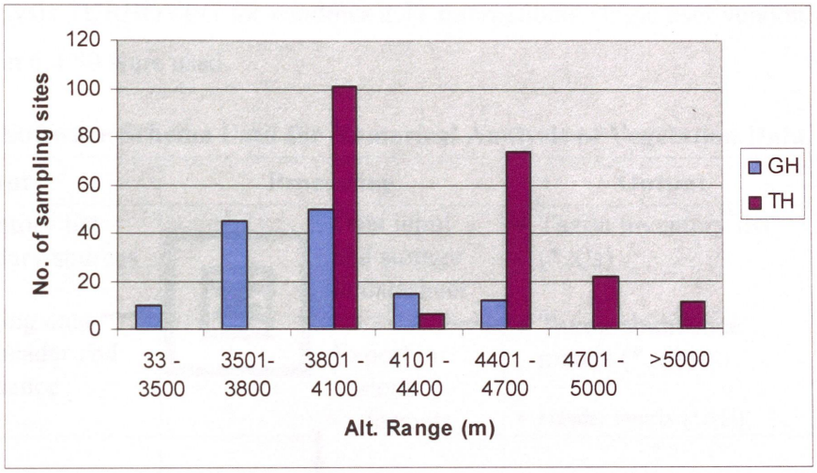


Fig. 4.2a. Number of sampling sites for community analysis within Greater Himalaya (GH) and Trans- Himalaya (TH).

Traditionally, European phytosociologists have classified plant communities using releve' and table transfer method (Zurich-Montpellier method as described in Mueller-Dombois & Ellenberg 1974). However, such a method is labour intensive and more appropriate for a smaller study area. Considering the multiple objectives of the study and a vast area to be covered, an attempt has been made to combine the traditional approach with modern numerical analysis, which rely more on multivariate analysis. Detailed analysis (ordination as well as cluster) was possible using two recently developed computer softwares namely TURBOVEG and JUICE (Hennekens & Schaminée 2001, Lubomír 2002). These packages comprise an easy-to-use database management system that can store a voluminous data. The program provides methods for input, import, selection, and export of data from vegetation plots or relevés. TURBOVEG has been a well established and standard computer package for the European Vegetation Survey since 1994 and it is being used in more than 25 countries of Europe and other countries. The program JUICE developed in 1998 is designed as a Microsoft Windows application for editing, classification and analysis of large phytosociological tables or other ecological data (Fig. 4.2b). It is optimized for use in association with TURBOVEG, however, other import formats are also available.The software is freely distributed as an original package and can be downloaded from the website www.sci.muni.cz/botany/juice.htm. Various options include classification using cluster approach with TWINSPAN and PC-ORD, preparation of synoptic tables, automatic sorting of relevé tables, and export of table data into other applications (Hill 1979, McCune & Mefford 1999). For

the present analysis TURBOVEG for windows 2.41 international single user version and JUICE software version 6.4.50 were used.

Figure 4.2b: Software Scheme Used for Numerical Analysis of Vegetation Data

Input	Processing	Output
• Taxon inventory list from secondary sources • Field sampling data containing header and taxon abundance information →	Data input and storage in datasheet Export in various formats →	• Taxon inventory list (*.xls) • Taxon abundance matrix (*.xls) • Header matrix (*.xls)
	↓	
• Taxon inventory list (*.DBF 4) • Taxon abundance matrix (*.CSV) • Header matrix (*.DBF 4) →	Turboveg 2.0 Data input and storage in database, taxon names validation Export in various formats →	• Combined taxon abundance and header matrix (*.xml)
	↓	
• Combined taxon abundance and header matrix (*.xml) →	JUICE Version 6.3.22 Data editing, vegetation classification, Synoptic tables TWINSPAN, PC-ORD, Multivariate analysis →	• Synoptic tables (*.doc) • Diagnostic species (*.doc) • Vegetation classification

For preparing the synoptic table after hybrid classification the threshold fidelity value for diagnostic species is taken as (3), threshold frequency value for constant species as 60. In the absence of national standards on vegetation classification for India, the standards for associations and alliances of the U.S. National Vegetation Classification (NVC) system was followed wherever possible (Jennings *et al.* 2002).

associations and alliances of the U.S. National Vegetation Classification (NVC) system was followed wherever possible (Jennings *et al.* 2002).

Plant communities are named based on the diagnostic and constant species. The species which is diagnostic (values more than 3, which is significant) and more constant (may not be dominant) in the releves is said to form the community (Mueller-Dombois & Ellenberg 1974). In the natural community species will have higher diagnostic, constant and dominance values, whereas in the disturbed community, species may not be dominant but may have the higher constancy and diagnostic values. The numerical method of cluster analysis was carried out in PC-ORD, Version 4.41. Considering the volume of data only three major physiognomic units were subjected to this analysis viz., mixed herbaceous formations (MHF) especially short forbs mostly above 4000 m pooled for both Greater and Trans-Himalaya, alpine dry scrub (ADS) and alpine marsh meadows (AMM). The hierarchical cluster analysis with the linkage method as "Ward's" and the distance measure as Euclidean (Pythagorean) was chosen to classify the releve matrices.

Above ground standing phytomass was quantified at two long term research sites of WII. These sites are Kedarnath Wildlife Sanctuary in Greater Himalaya and Tso Kar basin, Trans-Himalaya. While laying the random samples (10 x 1 m^2 quadrats) at various sites three quadrats at each site were harvested for estimating above ground phytomass during peak summer and autumn seasons following Misra (1968). Fresh weights of entire areial shoots were recorded in the field using 'Pesola' spring balance. Subsequently, the samples were oven dried in the WII laboratory to get the dry weight. Below ground biomass was not estimated due to time constraint and destructive nature of sampling required.

4.3 Community Classification

Cluster analysis based on per cent cover of species identified 15 groups in MHF, 10 in ADS and 8 in AMM. The dendrograms showing clusters for these categories are shown in Figs 4.3a, b, and c respectively. For each cluster, number of releves along with

characteristic (diagnostic, dominant and constant) species have been shown in Tables 4.3a, b, and c respectively.

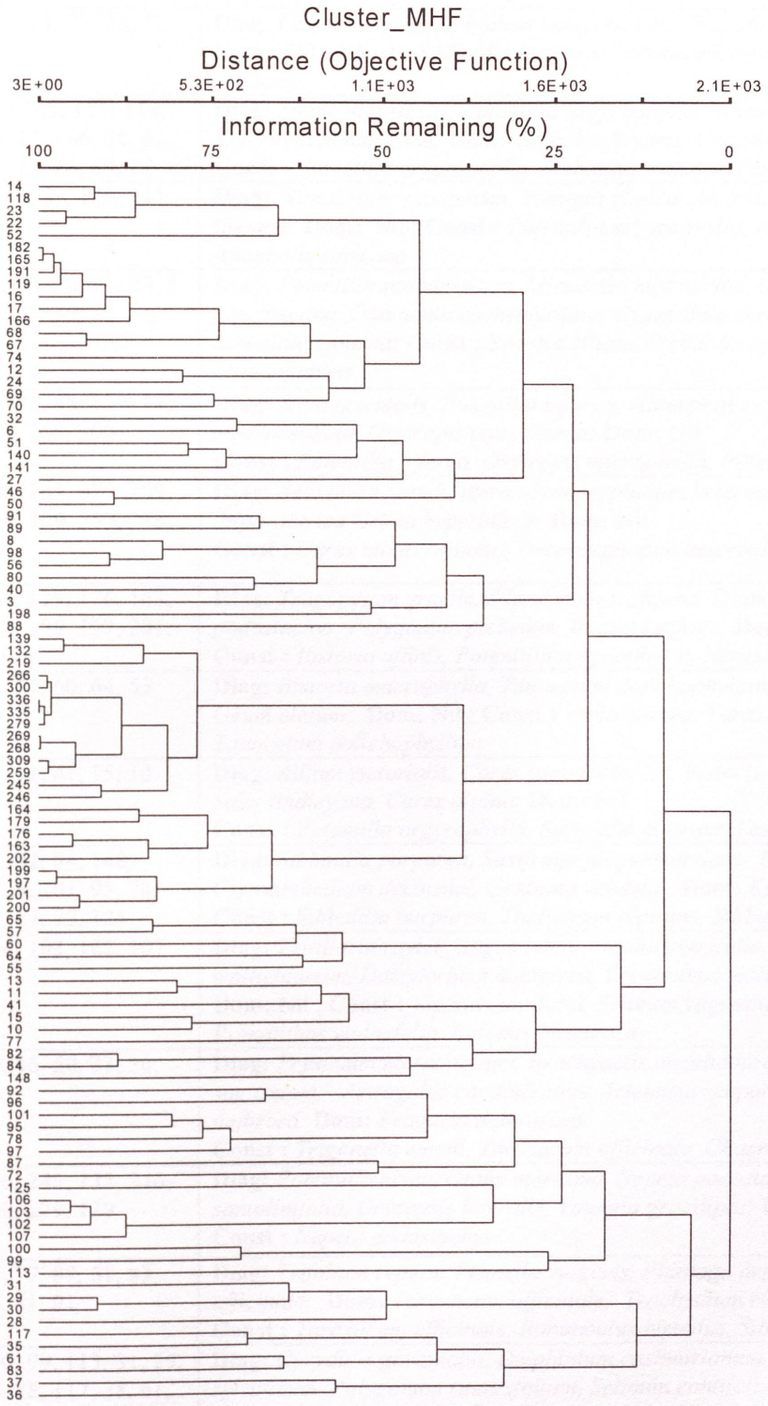


Fig 4.3a: Cluster analysis of Mixed Herbaceous Formation – Short Forbs (>4000 m asl)

Table 4.3a: Major clusters of vegetation within MHF (Explanation for fig. 4.3a):

Cl & (No of Releves)	Releve IDs	Diagnostic (Diag), Dominant (Dom) & Constant (Const) Species
1 (5)	14, 118, 23, 22, 52	**Diag**: *Carex setosa, Delphinium kumaonense, Sisymbrium himalaicum* **Dom:** Nil ; **Const** : *Sibbaldia cuneata, Taraxacum officinale, Thalictrum alpinum*
2 (14)	182,165, 191, 119, 16, 17, 166, 68, 67, 74, 12, 24, 69, 70	**Diag:** *Silene nigrescens, Potentilla argyrophylla, Anemone obtusiloba, Valeriana himalayana;* **Dom**: *Salix lindleyana, Geranium himalayense;* **Const :** *Potentilla argyrophylla, Sibbaldia cuneata, Festuca valesiaca*
3 (5)	32, 6, 51, 140, 141	**Diag:** *Tanacetum nubigenum, Youngia glauca, Androsace globifera, Thymus linearis;* **Dom:** Nil ; **Const :** *Potentilla argyrophylla, Eritrichum canum, Anaphalis royleana*
4 (10)	27, 46, 50, 91, 89, 8, 98, 56, 80, 40	**Diag:** *Potentilla saundersiana, Minuartia kashmirica, Galium exile, Berberis jaeschkeana, Danthonia cachemyriana, Gypsophila cerastioides;* **Dom:** *Sibbaldia cuneata;* **Const :** *Swertia ciliata, Sibbaldia cuneata, Potentilla atrisanguinea*
5 (8)	3, 198, 88, 139, 132, 219, 266, 300	**Diag:** *Stipa orientalis, Potentilla bifurca, Halerpestes cymbalaria, Artemisia macrocephala, Oxytropis platysemma;* **Dom:** Nil **Const :** *Potentilla bifurca, Oxytropis microphylla, Potentilla multifida*
6 (9)	336, 335, 279, 269, 268, 309, 259, 245, 246	**Diag:** *Saussurea glanduligera, Dracocephalum heterophyllum, Poa attenuata Stipa sibirica,Urtica hyperborea;* **Dom:** Nil **Const :** *Carex moorcroftiana, Dracocephalum heterophyllum*
7 (9)	164, 179, 176, 163, 202, 199, 197, 201, 200	**Diag:** *Tragopogon gracile, Silene moorcroftiana, Dianthus angulatus, Nepeta podostachys, Polygonum plebeium, Bistorta affinis;* **Dom:** Nil **Const :** *Bistorta affinis, Potentilla argyrophylla, Nepeta podostachys*
8 (5)	65, 57, 60, 64, 55	**Diag:** *Bistorta macrophylla, Tanacetum dolichophyllum, Cyananthus lobatus, Geum elatum;* **Dom:** Nil ; **Const :** *Viola biflora, Taraxacum officinale, Tanacetum dolichophyllum*
9 (5)	13, 11, 41, 15, 10	**Diag:** *Allium victorialis, Carex pseudobicolor, Bistorta affinis, Poa alpina, Salix lindleyana, Carex alpina;* **Dom:** Nil **Const :** *Potentilla argyrophylla, Sibbaldia cuneata, Festuca valesiaca*
10 (13)	77, 82, 84, 148, 92,96,101, 95, 78, 97, 87, 72, 125	**Diag:** *Sibbaldia purpurea, Saxifraga jacquemontiana, Polygonum emodi, Cremanthodium decaisnei, Gentiana venusta ;* **Dom:** *Kobresia nepalensis* **Const :** *Sibbaldia purpurea, Thalictrum alpinum, Sibbaldia cuneata*
11 (4)	106, 103, 102, 107	**Diag:** *Fritillaria roylei, Gagea lutea, Vicatia coniifolia, Geranium wallichianum, Dactylorhiza hatagirea, Prenanthus violaefolia,* **Dom:** Nil ; **Const :** *Vicatia coniifolia, Selinum vaginatum, Rumex acetosa, Prenanthus violaefolia, Phlomis bracteosa*
12 (6)	29, 46, 50, 28, 30, 31	**Diag:** *Erysimum hieracifolium, Brachyactis menthadora, Typhonium sagittatum, Astragalus candolleanus, Artemisia scoparia, Calamintha umbrosa;* **Dom:** *Fragaria daltoniana* **Const :** *Trigonella emodi, Taraxacum officinale, Chaerophyllum villosum*
13 (7)	266, 245, 132, 246, 300, 279, 139	**Diag:** *Potentilla nivea, Glaux maritima, Nepeta podostachys, Artemisia santolinifolia, Oryzopsis lateralis, Youngia gracilipes;* **Dom:** Nil **Const :** *Nepeta podostachys*
14 (8)	98, 77, 89, 61, 83, 56, 51, 91	**Diag:** *Trifolium repens, Prunella vulgaris, Plantago depressa, Taraxacum officinale;* **Dom:** *Taraxacum officinale, Trachydium roylei* **Const :** *Taraxacum officinale, Ranunculus hirtellus, Sibbaldia cuneata*
15 (13)	100, 99, 113, 31, 29, 30, 28, 117, 35, 61, 83, 37, 36	**Diag:** *Corydalis govaniana, Delphinium cashmirianum, Brachypodium sylvaticum, Polygonum rumicifolium, Selinum coniifolium* **Dom:** *Persicaria polystachya, Impatiens sulcata, Dryopteris barbigera* **Const :** *Potentilla atrisanguinea, Viola biflora, Epilobium royleanum*

It is noteworthy that a few species, characteristic of Trans-Himalayan wet meadows and ADS have also figured out in a few clusters. This could be due to inclusion of certain mesic sites in the Trans-Himalaya under the category of MHF and such sites could have been adjacent to ADS or AMM. Similarly, within ADS a few species typical of marsh meadows e.g., *Phragmites australis, Calamogrostis holciforms* and *Triglochin maritima* showed co-occurrence with species of typical dry scrub such as *Lycium ruthenicum* and *Caragana versicolor*.

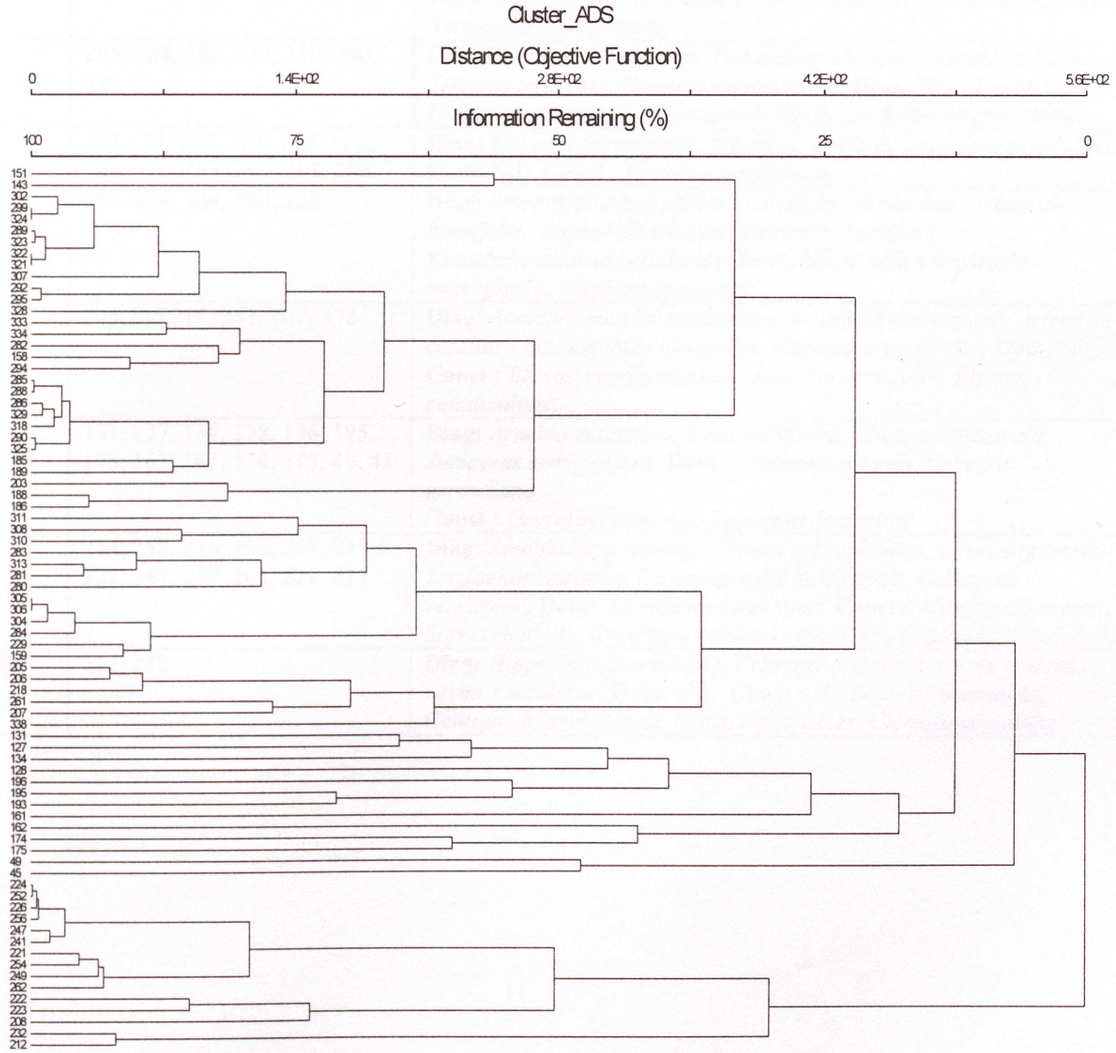


Fig 4.3b: Dendrogram showing communities under Alpine Dry Scrub Vegetation (See legends in Table 4.3b).

Table 4.3b: Clusters obtained for Alpine Dry Scrub (See Fig. 4.3b)

Cl. No & No. of Releves	Releve IDs	Diagnostic (Diag), Dominant (Dom) & Constant (Const) Species
1 (10)	151,143,302, 299, 324, 289, 323, 322, 321, 307	**Diag:** *Lonicera spinosa, Thymus linearis, Rosularia alpestris* **Dom:** *Juniperus communis* ; **Const :** *Oryzopsis laterale*
2 (2)	292,295	**Diag:** *Phragmites australis, Lycium ruthenicum, Perovskia abrotanoides, Haloxylon thomsonii;* **Dom:** Nil; **Const :** *Phragmites australis, Lycium ruthenicum*
3 (3)	328, 333, 334, 282, 158, 294	**Diag:** *Astragalus zanskarensis, Silene moorcroftiana, Psychrogeton andryaloides, Artemisia sieversiana, Nepeta podostachys, Artemisia salsoloides.* **Dom:** Nil; **Const :** *Carex infuscata, Dianthus angulatus, Astragalus zanskarensis*
4 (7)	285, 288, 286, 329, 318, 290, 325	**Diag:** *Haloxylon thomsonii, Tanacetum tibeticum, Matthiola flavida, Tribulus terrestris, Tamarix ramocissima;* **Dom:** Nil; **Const :** *Haloxylon thomsonii, Tanacetum tibeticum, Ephedra gerardiana*
5 (12)	185,189, 203, 188, 186, 311, 308, 310, 283, 313, 281, 280	**Diag:** *Ephedra gerardiana, Artemisia gmelinii, Artemisia salsoloides;* **Dom:** Nil; **Const :** *Ephedra gerardiana*
6 (5)	305, 306, 304, 284, 229	**Diag:** *Artemisia santolinifolia, Astragalus rhizanthus, Artemisia brevifolia, Euphorbia tibetica, Oxytropis humifusa, Krascheninnikovia ceratoides;* **Dom:** Nil; **Const :** *Oxytropis microphylla, Stipa jacquemontii*
7 (6)	205,206,218, 261, 207, 338	**Diag:** *Acantholimon lycopodioides, Artemisia wallichiana, Artemisia capillari, Aconogonum tortuosum, Caragana versicolor;* **Dom:** Nil; **Const :** *Elymus canaliculatus, Caragana versicolor, Elymus canaliculatus.*
8 (13)	131, 127, 134, 128, 196, 195, 193, 161, 162, 174, 175, 49, 45	**Diag:** *Arnebia euchroma, Rosa webbiana, Rhamnus prostrata, Juniperus semiglobosa;* **Dom:** *Lonicera spinosa, Ephedra gerardiana* **Const :** *Oryzopsis lateralis, Nepeta podostachys*
9 (12)	224, 252, 226, 256, 247, 241, 221, 254, 249, 262, 222, 223	**Diag:** *Scrophularia dentata, Elymus schrenkianus, Carex sagaensis, Triglochin maritima, Calamogrostis holciformis, Caragana versicolor;* **Dom:** *Caragana versicolor;* **Const :** *Alyssum canescens, Stipa orientalis, Krascheninnikovia ceratoides, Oxytropis microphylla*
10 (2)	212, 232	**Diag:** *Hippophae rhamnoides, Clematis orientalis, Carex cruenta, Leymus secalinus;* **Dom:** Nil; **Const :** *Hippophae rhamnoides, Gentiana leucomelaena, Equisetum species, Clematis orientalis*

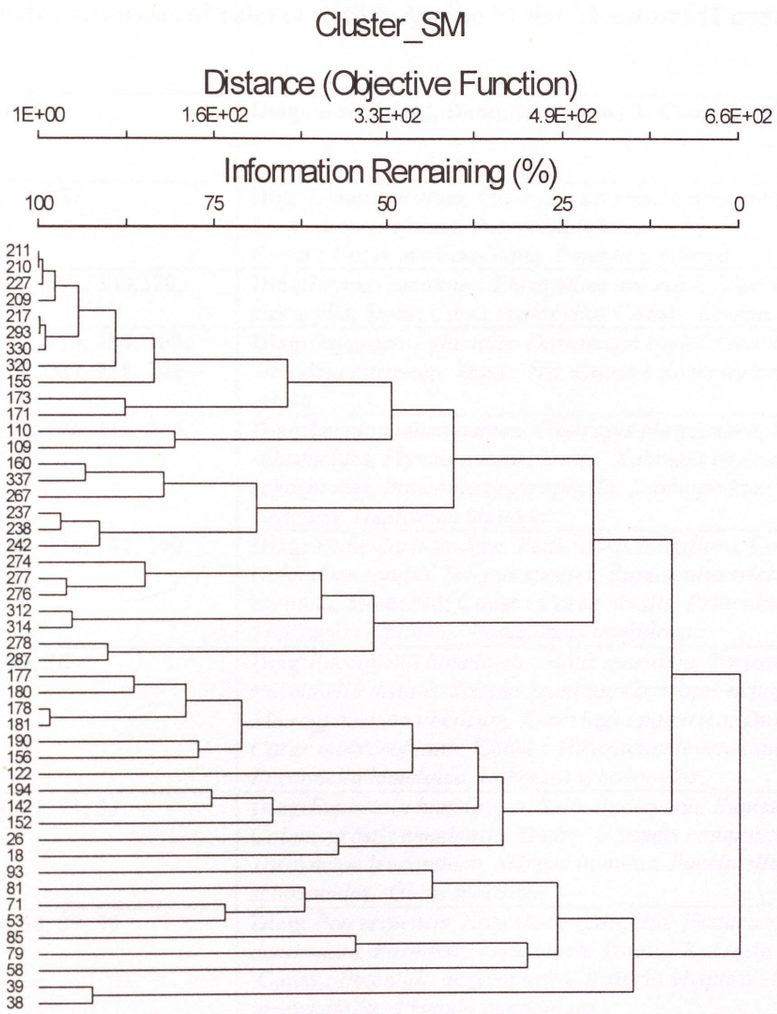


Fig. 4.3c: Dendrogram showing major communities within Marsh Meadows (see details in Table 4.3c)

Table 4.3c: Cluster Analysis of releves within Alpine Moist Meadows (Corresponding clusters in Fig 4.3c)

Cl No & No. of Releves	Releve IDs	Diagnostic (Diag), Dominant (Dom) & Constant (Const) Species
1 (3)	211, 210, 227	**Diag:***Glaux maritima, Oxytropis tatarica, Carex moorcroftiana;* **Dom:** *Carex moorcroftiana, Potentilla bifurca*; **Const :** *Carex moorcroftiana, Potentilla bifurca*
2 (6)	209, 217, 293, 330,320, 155	**Diag:***Leymus secalinus, Phragmites australis, Stipa splendens, Carex stenopylla;* **Dom:** *Carex stenopylla;* **Const :** *Leymus secalinus*
3 (10)	173, 171, 110, 109, 160, 337, 267, 237, 238, 242	**Diag:***Oxygraphis glacialis, Doronicum roylei, Gaultheria trichophylla, Sibbaldia purpurea;* **Dom:** Nil; **Const :** *Kobresia nepalensis, Carex setosa*
4 (7)	274, 277, 276, 312, 314, 278, 287	**Diag:***Leontopodium nanum, Oxytropis platysemma, Kobresia schoenoides, Elymus nutans;* **Dom:** *Kobresia royleana;* **Const:** *Kobresia schoenoides, Potentilla argyrophylla, Leontopodium nanum, Kobresia royleana, Thalictrum alpinum*
5 (7)	177, 180, 178, 181, 190 156, 122	**Diag:** *Pedicularis nodosa, Pedicularis longiflora, Carex nivalis, Colpodium nutans, Scirpus species, Ranunculus trichophyllus, Gentiana carinata;* **Dom:** Nil; **Const :** *Carex nivalis, Pedicularis nodosa, Thalictrum alpinum, Pedicularis longiflora*
6 (3)	142, 152, 26	**Diag:***Pucciniella himalaica, Glaux maritima, Taraxacum leucanthum, Pucciniella distans, Scirpus pumilus, Oxytropis hypoglottoides, Microgynaecum tibeticum, Knorringia pamirica;* **Dom:** *Glaux maritima, Carex moorcroftiana;* **Const :** *Taraxacum leucanthum, Scirpus pumilus, Pucciniella himalaica, Kobresia schoenoides*
7 (5)	81, 93, 81, 71, 53	**Diag:***Euphrasia himalayica, Salix lindleyana, Bupleurum jucundum, Calamogrostis emodensis;* **Dom:** *Blysmus compressus;* **Const:** *Taraxacum leucanthum, Scirpus pumilus, Pucciniella himalaica, Kobresia schoenoides, Glaux maritima*
8 (5)	85, 79, 58, 39, 39	**Diag:** *Poa pratensis, Kobresia capillifolia, Festuca valesiaca, Primula denticulata, Parnassia kumaonica;* **Dom:** *Kobresia royleana* **Const :** *Potentilla argyrophylla, Bistorta vivipara, Saussurea taraxacifolia, Primula denticulata*

When cluster analysis was performed based on over all frequency (presence – absence) as well as cover for the Greater (119 sites) and Trans-Himalaya (219 sites), 29 clusters in the former and 11 in the latter region were obtained. Based on diagnostic and constant species major plant communities have been named. These communities along with their Diagnostic, dominant and constant species have been given in Tables 4.3 d and e. The dominant species (with frequency > 50% and cover >25%), which figure out as important elements in the communities were *Ranunculus hirtellus*, *Cotoneaster microphyllus, Danthonia cachemyriana, Thymus linearis , Prenanthus violaefolia , Origanum vulgare, Potentilla atrisanguinea , Jurinea dolomiaea, Prunella vulgaris, Sibbaldia cuneata, Berberis jaeschkeana, Astragalus candolleanus, Anaphalis royleana, Fragaria daltoniana, Persicaria polystachya, Geranium wallichianum, Cyananthus lobatus, Impatiens sulcata, Juniperus communis, Kobresia capillifolia , Kobresia nepalensis , Trachydium roylei, Salix karelinii , Rhododendron anthopogon, Gaultheria trichophylla, Cassiope fastigiata, Bistorta affinis , Salix lindleyana , Potentilla argyrophylla , Juniperus indica, Hippophae tibetana, Festuca valesiaca, Calamogrostis epigejos,* and *Polygonum macrophyllum.* A large number of other species which are constant (>80 % frequency across several communities and habitats) were not taken into consideration while naming the community.

Similarly, in the Trans-Himalaya the dominant and diagnostic species forming distinct communities are *Artemisia brevifolia, Artemisia salsoloides, Artemisia santolinifolia, Blysmus compressus, Ephedra gerardiana, Lonicera spinosa, Caragana versicolor, Androsace aizoon, Phragmites australis, Lycium ruthenicum , Hippophae rhamnoides* ssp. *turkestanica, Cicer microphyllum , Kobresia pygmaea, Kobresia royleana, Kobresia schoenoides, Carex moorcroftiana, Carex parva, Carex sagaensis, Glaux maritima, Leymus secalinus, Thalictrum alpinum, Puccinellia himalaica , Puccinellia distans, Calamogrostis holciformis, Scirpus pumilus, Krascheninnikovia ceratoides, Potentilla bifurca, Stipa orientalis,* and *Stipa jacquemontii* among others.

Table 4.3d : Major communities and corresponding diagnostic, constant and dominant species in MHF in Greater Himalaya [F = % Frequency; C = % Cover]:

Name of the Community & No. of Releves	Diagnostic Species & % Frequency	Constant Species (F > 80 %)	Dominant Species (F >50%, C>25%)
1. *Ranunculus hirtellus-Potentilla peduncularis – Cotoneaster acuminatus* (1)	*Potentilla peduncularis 18.4, Cotoneaster acuminatus 12.8 Artemisia dubia 18.4, Poa nepalensis 18.4, Viola betonicifolia 12.8, Roscoea alpina 12.8, Hedysarum kumaonense 12.8, Cirsium verutum 12.8*	*Viola biflora, Viola betonicifolia, Trigonella emodi,Thymus linearis, Thalictrum alpinum , Taraxacum officinale, Swertia ciliata , Stachys melissaefolia*	*Ranunculus hirtellus*
2.*Cotoneaster microphyllus – Danthonia cachemyriana-Berberis kemaonensis* (1)	*Berberis kumaonensis 18.4, Viola betonicifolia 12.8, Roscoea alpina 12.8, Hedysarum kumaonense 12.8, Drosera peltata 18.4, Gentiana carinata 12.8, Aster flaccidus 11.5, Cotoneaster microphyllus 10.8*	*Viola betonicifolia , Thymus linearis, Thalictrum alpinum, Taraxacum officinale, Roscoea alpina , Prenanthus violaefolia , Polygonatum hookerii*	*Cotoneaster microphyllus Danthonia cachemyriana ,*
3. *Danthonia cachemyriana - Cicerbita macrorhiza- Spiraea arcuata* (3)	*Cicerbita macrorhiza 16.0, Equisetum debile 14.9, Polygonum plebeium 13.1, Spiraea arcuata 10.5, Salix elegans 10.5*	*Thymus linearis , Taraxacum officinale , Ranunculus hirtellus , Nepeta laevigata, Lotus corniculatus , Danthonia cachemyriana , Cicerbita macrorhiza , Callianthemum pimpinelloides*	*Danthonia cachemyriana*
4.*Thymus linearis – Berberis jaeschkeana – Nomocharis oxypetala* (2)	*Nomocharis oxypetala 15.4, Cynoglossum microglochin 12.9, Campanula lacei 11.1, Allium wallichii 11.1, Parochetus communis 10.3, Thesium himalense 9.2, Berberis jaeschkeana 8.5*	*Thymus linearis , Swertia ciliata , Ranunculus hirtellus , Polygonatum hookerii , Parochetus communis , Origanum vulgare , Nomocharis oxypetala , Nepeta laevigata , Iris kumaonensis*	*Thymus linearis , Prenanthus violaefolia , Origanum vulgare*
5. *Potentilla atrisanguinea – Osmunda claytoniana-Prunella vulgaris* (2)	*Osmunda claytoniana 10.8, Galium exile 12.9, Potentilla lineata 11.3, Carex nubigena 9.9, Jurinea dolomiaea 9.7, Euphorbia stracheyi 9.5, Sibbaldia micropetala 8.4, Rumex nepalensis 8.1*	*Taraxacum officinale, Swertia ciliata, Sibbaldia micropetala , Sibbaldia cuneata , Rumex nepalensis , Ranunculus hirtellus , Poa pratensis , Phlomis bracteosa , Jurinea dolomiaea , Iris kemaonensis*	*Potentilla atrisanguinea , Jurinea dolomiaea, Prunella vulgaris*
6. *Sibbaldia cuneata - Elsholtzia eriostachya- Potentilla saundersiana* (2)	*Elsholtzia eriostachya 17.4, Potentilla saundersiana 12.9, Carex nubigena 9.9, Orobanche alba 9.6, Calamintha umbrosa 8.3, Carex obscura 8.2*	*Swertia ciliata , Sisymbrium himalaicum , Sibbaldia cuneata , Ranunculus hirtellus , Potentilla atrisangunea, Polygonatum hookerii, Phleum alpinum , Origanum vulgare*	*Sibbaldia cuneata*
7. *Berberis jaeschkeana - Rosa macrophylla - Pedicularis punctata* (2)	*Pedicularis punctata 16.4, Rosa macrophylla 16.3, Koenigia delicatula 12.9, Tanacetum gracile 12.0, Euphrasia himalayica 10.4 Juniperus indica 8.4,*	*Swertia ciliata , Senecio chrysanthemoides, Rosa macrophylla, Potentilla argyrophylla , Pedicularis punctata , Iris kumaonensis , Galium aparine , Euphrasia himalayica , Erigeron multiradiatus*	*Berberis jaeschkeana, Danthonia cachemyriana , Thymus linearis*
8. *Astragalus candolleanus- Anaphalis royleana- Typhonium sagittatum- Fragaria daltoniana* (4)	*Typhonium sagittatum 15.8, Poa pagophila 15.3, Fragaria daltoniana 12.9, Silene vulgaris 12.2, Dubaea hispida 11.8, Scutellaria prostrata 11.5, Potentilla cuneifolia 11.0, Dactylis glomerata 10.2*	*Taraxacum officinale , Silene vulgaris , Poa pratensis, Dubaea hispida, Chaerophyllum villosum , Calamintha umbrosa*	*Astragalus candolleanus , Anaphalis royleana Fragaria daltoniana , Thymus linearis ,*

9.*Pedicularis hoffmeisteri-Pimpinella diversifolia – Aconogonum rumicifolium* (1)	*Pedicularis hoffmeisteri 18.4, Pimpinella diversifolia 18.4, Malaxis muscifera 18.4, Lathyrus laevigatus 18.4, Cuscuta europaea 18.4, Aconogonum rumicifolium 18.4, Polygonatum verticillatum 17.9, Rosa sericea 17.3*	*Viola biflora , Valeriana hardwickii , Thalictrum cultratum , Sisymbrium himalaicum , Silene vulgaris , Senecio laetus , Saussurea auriculata , Rumex acetosa*	-
10. *Berginia stracheyi-Primula edgeworthii--Androsace villosa* (1)	*Primula edgeworthii 18.4, Impatiens racemosa 18.4, Androsace villosa 14.9, Rhodiola heterodonta 13.8, Berginia stracheyi 12.4, Arisaema jacquemontii 12.0, Helictotrichon virescens 11.7, Astragalus chlorostachys 11.4, Thalictrum cultratum 11.3, Heracleum lanatum 10.3*	*Viola biflora , Thalictrum cultratum , Sibbaldia cuneata , Selinum vaginatum , Selinum coniifolium , Saussurea taraxacifolia , Rhodiola heterodonta , Primula edgeworthii , Primula denticulata , Potentilla atrisanguinea*	*Berginia stracheyi*
11. *Persicaria polystachya - Polemonium caeruleum-Saussurea piptathera* (4)	*Polemonium coeruleum 12.9, Saussurea piptathera 11.7, Polygonum rumicifolium 9.6, Polystichum lonchitis 9.1, Podophyllum hexandrum 9.1, Phleum alpinum1 9.1, Lysimachia prolifera 9.1*	*Potentilla atrisanguinea, Selinum vaginatum, Selinum coniifolium , Saussurea piptathera, Rumex acetosa, Polygonum rumicifolium , Persicaria polystachya , Epilobium royleanum , Delphinium cashmirianum, Rumex nepalensis*	*Persicaria polystachya*
12. *Polystichium bakerianum – Senecio kunthianus - Delphinium cashmirianum* (3)	*Polystichum bakerianum 17.9, Senecio kunthianus 14.9, Hackelia uncinata 11.7, Delphinium cashmirianum 10.9, Polygonatum multiflorum 10.5, Bistorta amplexicaulis 10.5, Anaphalis triplinervis 10.5, Polygonum rumicifolium 8.4*	*Primula denticulata , Potentilla atrisanguinea , Polystichum species1, Hackelia uncinata , Geum elatum , Geranium collinum , Delphinium cashmirianum , Viola biflora , Tanacetum dolichophyllum, Sibbaldia cuneata , Senecio kunthianus , Selinum vaginatum*	-
13. *Myriactis wallichii –Onosma echioides-Ajuga brachystemon -Morina longifolia* (2)	*Myriactis wallichii 16.4, Onosma echioides 12.9, Ajuga brachystemon 12.9, Saxifraga parnassifolia 12.1, Hackelia uncinata 11.7, Ligularia arnicoides 11.1, Arnebia benthamii 9.9, Morina longifolia 9.5*	*Viola biflora , Swertia ciliata, stachys melissifolia, Selinum coniifolium , Saxifraga parnassifolia, Primula denticulata , Potentilla atrisanguinea , Myriactis wallichii, Morina longifolia , Ligularia arnicoides , Iris kumaonensis 100, Hackelia uncinata, Gypsophila cerastioides*	-
14. *Geranium wallichianum - Fritillaria roylei- Cyananthus lobatus* (5)	*Fritillaria roylei 15.3, Dactylorhiza hatagirea 15.0, Vicatia coniifolia 11.9, Selinum wallichianum 11.5, Saussurea piptathera 9.2, Gagea lutea 8.4, Solidago virga-aurea 8.1, Prenanthus brunoniana 8.1*	*Vicatia coniifolia , Rumex acetosa , Geranium wallichianum , Selinum vaginatum , Prenanthus violaefolia, Potentilla atrisanguinea , Phlomis bracteosa , Persicaria polystachya, Fritillaria roylei0, Epilobium royleanum, Dactylorhiza hatagirea*	*Geranium wallichianum , Cyananthus lobatus*
15. *Impatiens sulcata -Thalictrum chelidonii – Rheum australe – Megacarpaea polyandra* (1)	*Thalictrum chelidonii 18.4, Megacarpaea polyandra 18.4, Dryopteris chrysocoma 18.4, Rheum australe 18.2, Swertia speciosa 17.8, Thlaspe alpestris 17.4, Barbarea intermedia 17.3, Valeriana pyrolaefolia 16.4*	*Vicatia coniifolia , Valeriana pyrolaefolia, Valeriana hardwickii , Thlaspe alpestris , Thalictrum chelidonii , Swertia speciosa , Swertia ciliata, Stipa roylei , stachys melissifolia , Sisymbrium himalaicum , Sibbaldia cuneata*	*Impatiens sulcata*
16. *Juniperus communis- Kobresia capillifilia - Botrychium lunulatum* (5)	*Botrychium lunulatum 12.0, Herminium monorchis 8.8, Juniperus communis 8.3, Stipa brandisii 8.1, Polygonatum graminifolium 8.1, Parnassia kumaonica 6.4, Poa pseudamoena 6.3,*	*Taraxacum officinale , Festuca valesiaca , Bupleurum longicaule1 , Thalictrum alpinum, Sibbaldia cuneata, Primula denticulata , Geranium collinum, Bistorta vivipara , Anaphalis nepalensis, Saussurea taraxacifolia, Jurinea dolomiaea*	*Juniperus communis, Kobresia capillifolia , Danthonia cachemyriana ,*

17. *Anemone rivularis-Spiraea bella – Gentianella moorcroftiana* (8)	*Spiraea bella 9.1, Gentianella moorcroftiana 6.4, Viola serpens 6.4, Rubus alpestris 6.4, Juniperus squamata 6.4, Alchemilla psilotoma 6.4, Adiantum capillus-veneris 6.4*	*Taraxacum officinale , Sibbaldia cuneata, Poa pratensis , Ranunculus hirtellus , Agrostis pilosula , Fragaria nubicola, Anemone rivularis , Trifolium repens , Thalictrum alpinum*	*Anemone rivularis*
18. *Rhododendron lepidotum - Petasites tricholobus - Hierochloa laxa* (1)	*Rhododendron lepidotum 18.4, Petasites tricholobus 18.4, Hierochloa laxa 16.3, Trigonella pubescens 14.9, Cerastium dahuricum 14.9, Betula utilis 14.8, Anemone rupicola 14.6*	*Trigonella pubescens , Tillaea pharnaceoides, Thalictrum alpinum , Taraxacum officinale , Sisymbrium himalaicum , Silene species1, Sibbaldia cuneata, Rhododendron lepidotum*	-
19. *Potentilla argyrophylla - Lysimachia prolifera- Hemiphragma heterophyllum-* (2)	*Lysimachia prolifera 18.4, Sedum linearifolium 12.9, Potentilla fulgens 12.9, Hypericum nepaulens 12.9, Hemiphragma heterophyllum 12.9*	*Taraxacum officinale, Ranunculus hirtellus, Poa species1, Lysimachia prolifera , Epilobium royleanum, Bistorta vivipara , Valeriana himalayana*	*Potentilla argyrophylla*
20. *Kobresia nepalensis- Trachydium roylei- Plantago depressa* (4)	*Plantago depressa 9.3, Satyrium nepalense 9.1, Majus serculosus 9.1, Chrysopogon echinulatus 9.1, Andropogon munroi 9.1, Trifolium repens 8.6, Tanacetum nubigenum 6.8, Selinum vaginatum 6.5*	*Taraxacum officinale , Swertia ciliata , Sibbaldia cuneata, Selinum vaginatum , Plantago depressa , Anemone rivularis, Agrostis pilosula*	*Kobresia nepalensis , Trachydium roylei*
21. *Sibbaldia cuneata- Carex pseudobicolor-Bistorta affinis* (9)	*Carex pseudobicolor 13.6, Bistorta affinis 9.6, Lomatogonium species2 6.8, Primula atrodentata 6.1, Oxygraphis glacialis 6.1, Myosotis silvatica 6.1*	*Bistorta affinis , Trachydium roylei , Thalictrum alpinum, Sibbaldia cuneata, Primula denticulata , Geranium collinum , Carex pseudobicolor , Viola biflora*	*Sibbaldia cuneata , Trachydium roylei, Callianthemum pimpinelloides , Androsace globifera*
22. *Salix karelinii-Kobresia nepalensis- Polygonum emodi-Saxifraga flagellaris* (7)	*Polygonum emodi 9.7, Saxifraga flagellaris 8.3, Lagotis kunawarensis 7.7, Juncus thomsonii 7.5, Sibbaldia purpurea 7.0, Pseudomertensia nemorosa 6.9, Meconopsis aculeata 6.9*	*Bistorta vivipara, Agrostis pilosula , Saxifraga flagellaris, Juncus thomsonii, Anaphalis nepalensis , Thalictrum alpinum , Sibbaldia purpurea , Rhododendron anthopogon*	*Salix karelinii , Kobresia nepalensis*
23. *Rhododendron anthopogon-Gaultheria trichophylla-Cassiope fastigiata-Trollius acuaulis* (4)	*Trollius acaulis 14.8, Saussurea taraxacifolia 10.0, Salix karelinii 9.2, Fritillaria stracheyi 9.1, Aster diplostephioides 9.1, Cassiope fastigiata 8.4, Gentiana phyllocalyx 8.2, Aconitum violaceum 7.5*	*Saussurea taraxacifolia , Kobresia nepalensis , Viola biflora , Trollius acaulis , Sibbaldia cuneata , Festuca valesiaca , Anemone polyanthes , Aconitum violaceum , Thalictrum alpinum , Salix karelinii , Rhododendron anthopogon , Cyananthus lobatus , Cicerbita lessertiana , Cassiope fastigiata*	*Rhododendron anthopogon , Gaultheria trichophylla, Cassiope fastigiata*
24. *Bistorta affinis -Oxyria digyna-Salix lindleyana* (19)	*Oxyria digyna 6.4*	*Sibbaldia cuneata, Anaphalis nepalensis , Festuca valesiaca , Potentilla argyrophylla , Calamogrostis emodensis , Bistorta vivipara , Ranunculus hirtellus ,*	*Bistorta affinis , Salix lindleyana , Potentilla argyrophylla*
25. *Stellara chamaejasme-Youngia glauca-Sisymbrium irio* (2)	*Stellara chamaejasme 12.9, Youngia glauca 12.9, Sisymbrium irio 12.9, Silene gonosperma 11.2, Poa angustifolia 11.2, Androsace delavayi 11.2*	*Thymus linearis , Lomatogonium carinthiacum , Carex obscura , Callianthemum pimpinelloides , Calamogrostis species, Anaphalis royleana*	-

26. *Juniperus indica- Allium victorialis-Bistorta affinis* (6)	*Allium victorialis 8.0, Veronica capitata 7.4, Thlaspe montanum 7.4, Minuartia kashmirica 7.4, Scabiosa speciosa 7.1, Bistorta affinis 7.0*	*Viola biflora , Thymus linearis , Thalictrum alpinum , Taraxacum officinale , Polygonatum hookerii , Poa pratensis , Danthonia cachemyriana , Arenaria serpyllifolia , Bistorta affinis*	*Juniperus indica Danthonia cachemyriana , Thymus linearis , , Geranium himalayense*
27. *Hippophae tibetana - Thymus linearis - Festuca valesiaca* (8)	*Potentilla polyphylla 11.2, Oryzopsis munroi 11.2, Gentiana stipitata 9.1, Scrophularia decomposita 6.4, Oryzopsis wendelboi 6.4,*	*Thymus linearis , Festuca valesiaca , Taraxacum officinale , Cynoglossum nervosum , Astragalus candolleanus, Trigonella emodi , Arenaria serpyllifolia , Sisymbrium himalaicum, Danthonia cachemyriana*	*Hippophae tibetana Thymus linearis , Festuca valesiaca , Calamogrostis epigejos*
28. *Polygonum macrophyllum- Trachydium roylei- Tanacetum dolichophyllum* (7)	*Tanacetum dolichophyllum 9.0, Saussurea leontodontoides 8.0, Kobresia nepalensis 7.2, Anaphalis cuneifolia 7.1, Trachydium garhwalicum 6.9, Saxifraga moorcroftiana 6.9, Saussurea atkinsonii 6.9*	*Viola biflora , Taraxacum officinale , Parnassia nubicola , Kobresia nepalensis , Tanacetum dolichophyllum , Polygonum macrophyllum , Geum elatum , Cyananthus lobatus , Anaphalis cuneifolia*	*Polygonum macrophyllum, Trachydium roylei , Cyananthus lobatus*
29. *Gaultheria trichophylla- Kobresia capillifolia- Pleurospermum brunonis* (3)	*Pleurospermum brunonis 14.2, Androsace sempervivoides 13.5, Saussurea leontodontoides 12.8, Aster falconeri 9.7, Primula minutissima 9.6, Ponerorchis chusua 8.7, Hedysarum microcalyx 7.8*	*Viola biflora , Taraxacum officinale , Tanacetum dolichophyllum , Saussurea leontodontoides , Ranunculus hirtellus , Kobresia capillifolia , Geum elatum , Trachydium roylei , Thalictrum alpinum , Sibbaldia cuneata , Pleurospermum brunonis , Phlomis bracteosa , Gentianella moorcroftiana*	*Gaultheria trichophylla, Kobresia capillifolia*

Table 4.3e: Trans-Himalayan Communities along with their diagnostic, constant and dominant species

Community # Releves	Diagnostic Species & % F	Constant Species (F > 80 %)	Dominant Species (F >50%, C>25%)
1. *Phragmites australis-, Lycium ruthenicum- Hippophae rhamnoides- Haloxylon thomsonii* (76)	*Haloxylon thomsonii 6.6*	-	*Phragmites australis , Lycium ruthenicum , Hippophae rhamnoides , Cicer microphyllum , Chenopodium glaucum*
2. *Lonicera spinosa- Caragana versicolor - Oryzopsis lateralis* (8)	*Oryzopsis lateralis 17.1, Heracleum pinnatum 11.0, Eritrichum nanum 10.9, Cicer microphyllum 10.1, Cousinia thomsonii 9.9, Elymus hispidus 9.1*	*Oryzopsis lateralis , Artemisia santolinifolia , Nepeta laevigata , Eritrichum canum , Cousinia thomsonii , Astragalus candolleanus , Heracleum pinnatum , Ephedra gerardiana*	*Lonicera spinosa , Caragana versicolor*
3. *Kobresia pygmaea- Gentianopsis paludosa- Pedicularis oederi* (13)	*Gentianopsis paludosa 11.3, Euphorbia tibetica 10.1, Pedicularis oederi 9.3, Saussurea graminifolia 8.7, Rheum moorcroftianum 7.8, Potentilla biflora 7.8, Leontopodium himalayanum 7.6*	*Poa tibetica , Leontopodium himalayanum , Gentianopsis paludosa , Potentilla bifurca , Pedicularis oederi , Kobresia royleana , Euphorbia stracheyi , Alyssum canescens*	*Kobresia pygmaea , Androsace aizoon*
4. *Kobresia royleana- Leontopodium himalayanum- Potentilla desertorum* (17)	*Leontopodium himalayanum 9.8, Brachyactis pubescens 8.8, Potentilla desertorum 7.2, Bupleurum hoffmeisteri 6.2*	*Potentilla argyrophylla , Leontopodium himalayanum , Oryzopsis species2 , Kobresia royleana , Nepeta podostachya , Cousinia thomsonii , Potentilla multifida, Brachyactis pubescens*	*Kobresia royleana*

5. *Kobresia schoenoides-Carex sagaensis-Kobresia royleana* (15)	*Kobresia royleana 8.9, Gentiana coronata 6.6, Hippophae rhamnoides 6.1 Salix species 6.1*	*Kobresia royleana , Potentilla bifurca , Kobresia schoenoides , Taraxacum leucanthum , Potentilla multifida , Leontopodium nanum , Carex parva , Carex infuscata*	*Kobresia schoenoides, Carex sagaensis, , Hippophae rhamnoides , Glaux maritima , Carex parva,*
6. *Thalictrum alpinum-Saussurea gnaphalodes – Trisetum aenium* (7)	*Saussurea gnaphalodes 15.5, Trisetum aenium 13.5, Waldhemia glabra 12.9, Alyssum canescens 12.6, Oxytropis platysemma 10.8, Carex borii 10.4, Saxifraga aristulata 10.3, Nepeta longibracteata 9.7*	*Potentilla nivea , Draba altaica, Saussurea gnaphalodes , Leontopodium nanum , Kobresia schoenoides , Waldhemia glabra , Trisetum aenium , Thalictrum alpinum , Potentilla desertorum , Poa attenuata, Kobresia royleana , Aster flaccidus*	*Thalictrum alpinum , Kobresia royleana*
7. *Carex moorcroftiana , Blysmus compressus Pucciniella himalaica* (12)	*Pucciniella himalaica 12.2, Pucciniella distans 10.2, Glaux maritima 9.8, Knorringia pamirica 8.8, Polygonum sibiricum 8.7, Microgynaecum tibeticum 8.6, Carex moorcroftiana 7.1, Scirpus pumilus 6.7*	*Pucciniella himalaica , Glaux maritima , Knorringia pamirica , Carex moorcroftiana , Scirpus pumilus , Taraxacum leucanthum, Microgynaecum tibeticum , Halerpestes tricuspis , Calamogrostis holciformis , Blysmus compressus , Leymus secalinus , Kobresia schoenoides*	*Carex moorcroftiana , Blysmus compressus , Pucciniella himalaica , Pucciniella distans , Calamogrostis holciformis , Scirpus pumilus*
8. *Elymus canaliculatus-Oxytropis chiliophylla - Calamogrostis* (1)	*Saxifraga pseudopallida 18.4, Physochlaina praealta 18.2, Thesium alpinum 18.1, Oxytropis chiliophylla 17.6, Sonchus oleraceus 17.2, Silene graminifolia 17.1, Primula nutans 17.1, Microula tibetica 16.4 Sophora moorcroftiana 12.9*	*Thesium alpinum , Sophora moorcroftiana , Sonchus oleraceus , Potentilla bifurca , Potentilla anserina , Poa species2 , Physochlaina praealta , Phragmites australis , Oxytropis chiliophylla , Nepeta podostachya , Microula tibetica*	*Elymus canaliculatus, Oxytropis chiliophylla , Calamogrostis holciformis*
9. *Carex parva-Pedicularis longiflora Halerpestes tricuspis* (5)	*Pedicularis longiflora 17.6, Carex parva 15.3, Halerpestes tricuspis 15.3, Juncus bufonius 15.2, Carex infuscata 14.6, Blysmus compressus 9.3, Glaux maritima 8.8, Triglochin maritima 8.4, Triglochin palustris 7.9*	*Pedicularis longiflora , Carex parva , Carex orbicularis , Carex infuscata , Scirpus pumilus , Kobresia capillifolia , Knorringia pamirica , Juncus bufonius , Halerpestes tricuspis , Glaux maritima, Blysmus compressus*	*Carex parva , Carex infuscata , Scirpus pumilus , Carex orbicularis , Potentilla nivea*
10. *Krascheninnikovia ceratoides - Caragana versicolor* (43)	*Euphorbia tibetica 7.8, Krascheninnikovia ceratoides 7.6, Dracocephalum heterophyllum 6.1 Stipa jacquemontii 6.7, Oxytropis microphylla 6.1,*	*Krascheninnikovia ceratoides, Oxytropis microphylla , Carex moorcroftiana , Potentilla bifurca , Dracocephalum heterophyllum , Stipa jacquemontii , Elymus canaliculatus , Stipa orientalis , Oxytropis tatarica*	*Krascheninnikovia ceratoides, Caragana versicolor , Stipa sibirica, , Artemisia santolinifolia , Potentilla bifurca*
11. *Stipa orientalis-Alyssum canescens - Oxytropis microphylla* (22)	*Alyssum canescens 16.3, Stipa orientalis 15.7, Oxytropis tatarica 12.1, Oxytropis microphylla 11.6, Chamaerhodos sabulosa 8.3*	*Stipa orientalis , Alyssum canescens , Oxytropis microphylla , Krascheninnikovia ceratoides , Oxytropis tatarica , Chamaerhodos sabulosa , Dracocephalum heterophyllum*	*Stipa orientalis , Caragana versicolor , Artemisia salsoloides , Stipa jacquemontii , Leymus secalinus,*

4.4 Community Structure and Composition

The communities segregated based on the cluster analysis in this study represent only an abstract of the broad spectrum of vegetation seen in the field. These communities varied greatly in the proportion of woody, herbaceous, graminoids, mosses and lichens (Figs 4.4a, b). In the Greater Himalaya AMS is represented by following communities (Alpine Moist Scrub): *Ranunculus hirtellus - Potentilla peduncularis - Cotoneaster acuminatus, Cotoneaster microphyllus - Danthonia cachemyriana - Berberis kumaonensis, Berberis jaeschkeana - Rosa macrophylla - Pedicularis punctata, Juniperus communis - Kobresia capillifilia - Botrychium lunulatum, Rhododendron anthopogon - Gaultheria trichophylla - Cassiope fastigiata - Trollius acuaulis, Juniperus indica - Allium victorialis - Bistorta affinis,* and *Hippophae tibetana - Thymus linearis - Festuca valesiaca.* Highest proportions of mosses and liches are seen in *Rhododendron anthopogon - Cassiope fastigiata* and *Bistorta affinis - Oxyria digyna - Salix lindleyana* communities.

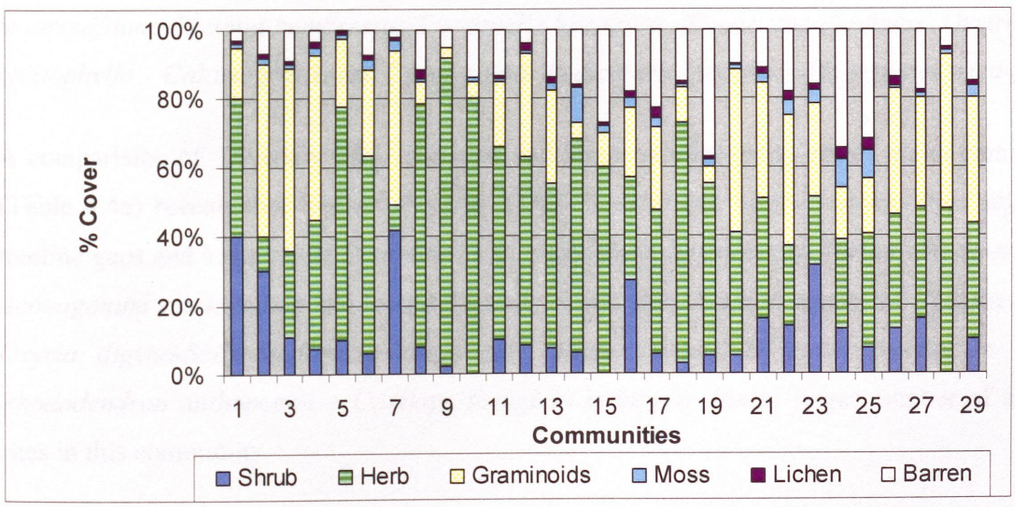


Fig 4.4a: Proportion of shrubs, herbs, graminoids, mosses and lichens in the some communities of the Greater Himalaya [Communities 1-29 as identified through cluster analysis, Table 4.3d].

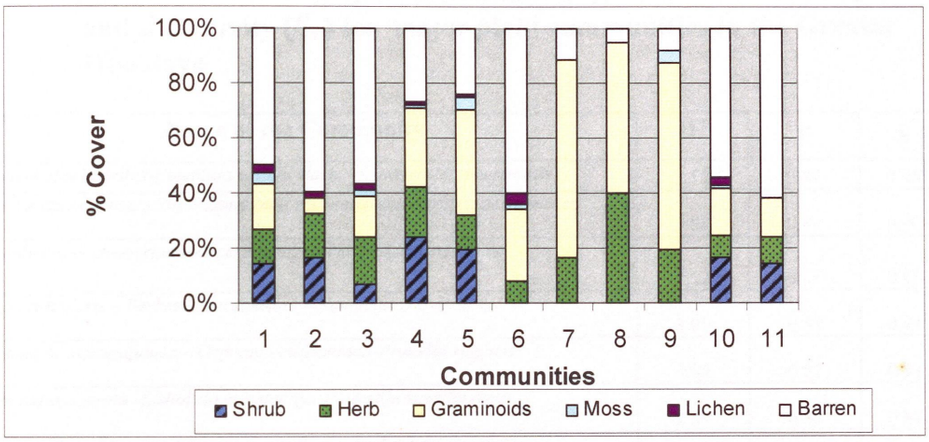


Fig 4.4b: Proportions of shrubs, herbs, graminoids, mosses and lichens in the major communities identified in the Trans-Himalaya [Communities as listed in Table 4.3e]

In the Trans-Himalaya, four communities out of 11 identified through cluster analysis had no shrubby elements viz., *Thalictrum alpinum- Saussurea gnaphalodes – Trisetum aenium, Carex moorcroftiana-Blysmus compressus-Pucciniella himalaica, Elymus canaliculatus- Oxytropis chiliophylla – Calamogrostis* and *Carex parva- Pedicularis longiflora-Halerpestes tricuspis.*

A comparision of Diversity (H'), Evenness and Simpson's Diversity across major communities (Table 4.4a) reveals that highest diversity (3.67) is exhibited by the communities adjacent to treeline gaps and krummholz formations viz., *Pedicularis hoffmeisteri- Pimpinella diversifolia – Aconogonum rumicifolium* and lowest diversity (2.02) was obtained in case of *Bistorta affinis – Oxyria digyna-Salix lindleyana* community. Higher values of beta diversity in case of *Rhododendron anthopogon – Cassiope fastigiata* is largely due to larger number of sampling sites in this community.

Among the Trans-Himalayan communities *Lonicera spinosa- Caragana versicolor -Oryzopsis lateralis* and *Thalictrum alpinum- Saussurea gnaphalodes – Trisetum aenium* showed highest diversity (2.27 and 2.37 respectively*) and lowest* (1.12) by *Phragmites australis – Lycium ruthenicum* community.

Table 4. 4 a: S-W Diversity (H'), Evenness (E), Simpson's Diversity Index (S) and β diversity (β_w) for major plant communities in the Greater Himalaya

Name of the Community	H'	E	S	β_w
1. *Ranunculus hirtellus-Potentilla peduncularis – Cotoneaster acuminatus*	3.58	0.89	0.95	-
2.*Cotoneaster microphyllus – Danthonia cachemyriana-Berberis kemaonensis*	2.85	0.84	0.90	0.941
3. *Danthonia cachemyriana -Cicerbita macrorhiza- Spiraea arcuata*	2.72	0.81	0.85	0.522
4.*Thymus linearis – Berberis jaeschkeana – Nomocharis oxypetala*	3.05	0.87	0.94	0.6
5. *Potentilla atrisanguinea – Osmunda claytoniana-Prunella vulgaris*	3.04	0.87	0.93	0.628
6. *Sibbaldia cuneata -Elsholtzia eriostachya-Potentilla saundersiana*	2.89	0.84	0.89	0.742
7. *Berberis jaeschkeana - Rosa macrophylla - Pedicularis punctata*	2.37	0.69	0.77	1.439
8. *Astragalus candolleanus- Anaphalis royleana- Fragaria daltoniana*	2.99	0.86	0.91	-
9.*Pedicularis hoffmeisteri- Pimpinella diversifolia – Aconogonum rumicifolium*	3.67	0.93	0.96	-
10. *Berginia stracheyi-Primula edgeworthii--Androsace villosa*	2.96	0.86	0.91	2.022
11. *Persicaria polystachya -Polemonium caeruleum- Saussurea piptathera*	2.42	0.81	0.82	0.95
12. *Polystichium bakerianum –Senecio kunthianus - Delphinium cashmirianum*	2.84	0.90	0.92	0.571
13. *Myriactis wallichii –Onosma echioides-Ajuga brachystemon -Morina longifolia*	3.14	0.91	0.94	2.03
14. *Geranium wallichianum -Fritillaria roylei- Cyananthus lobatus*	2.68	0.86	0.89	-
15. *Impatiens sulcata -Thalictrum chelidonii – Rheum australe*	2.89	0.79	0.88	1.563
16. *Juniperus communis- Kobresia capillifilia - Botrychium lunulatum*	2.73	0.85	0.90	4.029
17. *Anemone rivularis-Spiraea bella – Gentianella moorcroftiana*	2.18	0.82	0.81	-
18. *Rhododendron lepidotum - Petasites tricholobus - Hierochloa laxa*	3.10	0.91	0.94	0.917
19. *Potentilla argyrophylla -Lysimachia prolifera-Hemiphragma heterophyllum-*	2.92	0.92	0.93	1.194
20. *Kobresia nepalensis- Trachydium roylei- Plantago depressa*	2.29	0.75	0.79	4.206
21. *Sibbaldia cuneata- Carex pseudobicolor-Bistorta affinis*	2.36	0.82	0.84	3.768
22. *Salix karelinii-Kobresia nepalensis- Polygonum emodi-Saxifraga flagellaris*	2.17	0.77	0.78	1.5
23. *Rhododendron anthopogon- Gaultheria trichophylla- Cassiope fastigiata*	2.16	0.71	0.81	10.723
24. *Bistorta affinis -Oxyria digyna-Salix lindleyana*	2.02	0.77	0.77	0.739
25. *Stellara chamaejasme-Youngia glauca-Sisymbrium irio*	2.71	0.92	0.92	2.868
26. *Juniperus indica- Allium victorialis-Bistorta affinis*	2.36	0.76	0.82	2.836
27. *Hippophae tibetana - Thymus linearis - Festuca valesiaca*	2.38	0.84	0.85	1.765
28. *Polygonum macrophyllum- Trachydium roylei- Tanacetum dolichophyllum*	2.82	0.85	0.90	0.982
29. *Gaultheria trichophylla- Kobresia capillifolia- Pleurospermum brunonis*	2.63	0.80	0.85	-

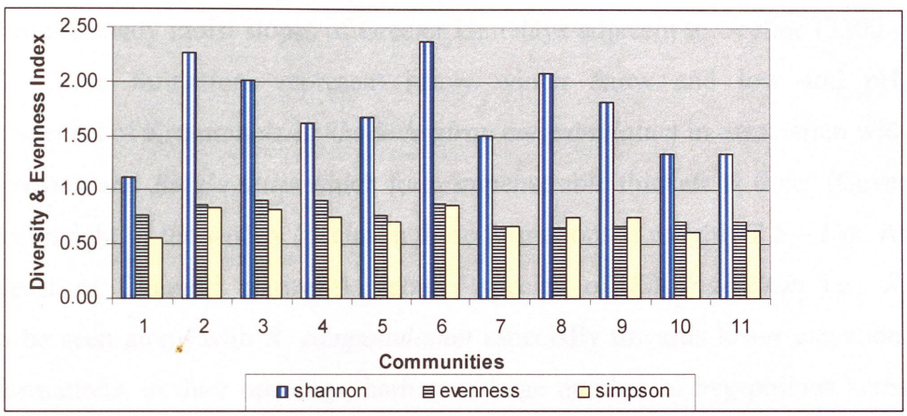


Fig. 4.4c: Diversity and Evenness of various communities in the alpine zone of Trans- Himalaya

The communities identified as above are based on the sample plots or releves. However, based on the broad physiognomy and spacing pattern of vegetation (Fosberg 1961) the plant communities across the alpine region of Greater and Trans-Himalaya can be grouped into the following matrix (Table 4.4a).

Table 4.4b : Broad Physiognomic Categories of Alpine Vegetation, Western Himalaya [MHF = Mixed Herbaeous Formations]

Spacing Pattern	Woody Formations	Herbaceous Formations	Graminoid Formations	Moss-Lichens
Closed	*Krummholz* Formation Rhododendron Scrub Willow Scrub Matted Scrub *Hippophae - Myricaria*	MHF – Tall Forbs MHF – Short Forbs (including grazophil communities)	*Danthonia* Grasslands *Kobresia* Meadows Alpine Marsh Meadow	-
Open	Juniper Scrub *Potentilla fruticosa* Mixed *Rosa – Lonicera – Berberis* *Lonicera spinosa* Mixed *Caragana – Eurotia* *Artemisa – Astragalus* *Potentilla biflora*	*Hyssopus* Mixed *Cicer* Mixed Fell-fields or Cushionoid Vegetation	*Festuca cashmeriana* *Oryzopsis lateralis* *Carex moorcroftiana* *Calamogrostis emodensis*	-
Sparse	*Ephedra* Scrub *Capparis* Scrub *Acantholimon* Scrub *Haloxylon* Scrub	Peri-glacial, morainic and Subnival Communities	Desert Steppe *Carex nivalis – C. borii* formations	Nival / Subnival formations

The plant community structure and compositon within these groups are described below:

i. Krummholz and Alpine Moist Scrub Communities: *Krummholz* formations are largely found in the shady moist slopes of Greater Himalaya adjacent to treeline (3300 – 3800 m asl). These formations represent heavy winter snow and low soil pH. Characteristic species of Krummholz is *Rhododendron campanulatum* in association with *Vibernum nervosum* and *Betula utilis* which form impenetrable thickets at times (Cover >80%). General height of the woody species in these formations is roughly 2.5 – 2 m. At few places (east of Chamoli Garhwal), another species of *Rhododendron* i.e., *R. barbatum* can be seen along with *R. campanulatum* especially towards lower elevation. *Krummholz* formations, in their openings, harbour a large number of hygrphilous herbs many of them being being of high medicinal value.

Woody communities forming dense vegetation adjacent to *Krummholz* frequently classified under AMS include (i) *Rhododendron anthopogon – Cassiope fastigiata* (ii) *Salix denticulata – Syringa emodi* mixed (iii) Matted scrub of *Salix karelinii*, *S. lindleyana, S. calyculata* and *Gaultheria trichophylla*. Most of the closed woody formations are found on stable, northfacing slopes characterized by low diversity (<1.50) and and high evenness values (>0.75). Of these, highest diversity is shown by *Salix denticulata – Syringa emodi* community which occupies broken slopes closer to riverine areas.

Three riverine woody communities forming dense thickets in alpine areas are (i) *Hippophae tibetana* (terminal moraines of Greater Himalaya), (ii) *H. rhamnoides* subspecies *turkestanica* along the alluvial and frequently inundated banks of Nubra-Shyok, Indus and Spiti rivers, and (iii) *Myricaria elegans* (= *Myrtamma elegans*) and *M. prostrata* along most of the glacial rivers both in Greater and Trans-Himalaya.

ii. Open Scrub:

On south facing slopes of Greater Himalaya which are frequented by biotic (grazing, fuelwood collection, fire) and abiotic (avanlanches, landslips) factors a few open woody scrub formations are prominent e.g., *Juniperus indica* scrub, *Berberis jaeschkeana - Rosa*

macrophylla - *Ribes glaciale, Rosa – Lonicera – Berberis*, and *Potentilla fruticosa – Rhododendron lepidotum.* Most of these communities harbour a great variety of herbaceous plants and often the cover of herbaceous or graminoid vegetation in such categories is more than 50%. However, owing to size and prominence of woody species herbaceous communities are less discernible at a landscape level.

ii. Alpine Dry Scrub: Major communities forming open alpine dry scrub in the Trans-Himalaya include (i) *Caragana – Eurotia*, (ii) *Artemisa – Tanacetum*, (iii) *Lonicera spinosa* - Mixed, (iv) *Astragalus candolleanus*. Of these most prominent and extensive formations are made by *Caragana versicolor* which can be regarded as a climax species in much of the Changthang part of Trans-Himalaya. In Zanskar and western Ladakh, three species of spiny *Astragalus* (*A. candolleanus, A. rhizanthus* and *A. zanskarensis*) form the extensive dry scrub vegetation. Common elements of *Artemisia – Tanacetum* community are *Artemisia dracunculus, A. santolinifolia, A. brevifolia, A. minor, A. salsoloides, Tanacetum nubigenum* and *T. gracile.* In the inner dry ranges of Uttarakhand, especially towards Tibetan plateau (Rajhoti, Chorhoti, Rimkhim, Topidhunga and Wilsia Dhura in Kutti Valley) pure patches of a dwarf woody *Potentilla* i.e., *P. biflora* can be seen.

iii. Desert Scrub:

Four species of dwarf or prostrate shrubs viz., *Ephedra gerardiana, Haloxylon thomsonii, Capparis spinosa* (ssp. *himalayensis*) and *Acantholimon lycopodioides* form sparse scrub vegetation in extremely dry and desertic formations of Trans-Himalaya especially in sandy, rocky or colluvial deposits. These formations support very low species diversity. Of these, *Acantholimon* formation can be relatively dense and may support a few herbs and grasses.

Cluster analysis of the data collected from the ADS (Table 4.3b) segregated as many as 10 distinct groups and associated constant and diagnostic species.

iv. Mixed Herbaceous Formations: A considerably large proportion of alpine landscape in the Greater Himalaya is occupied by herbaceous communities including hygrophilous fast growing biennual or perennial herbs, gregarious and opportunistic herbs of Polygonaceae, Balsaminaceae, and Apiaceae, a few nitrophilous species which occupy the livestock camps and myriad of other species across a range of habitats. These communities are frequently described under alpine moist pastures by various authors and have very high species diversity (>2.80), low evenness (<0.70) and high beta diversity. Typical communities at the lower alpine (<4000 m) in the deeper soil include (i) *Geranium wallichianum – Potentilla atrisanguinea – Selinum vaginatum*, (ii) *Persicaria polystachya – Heracleum thomsonii – Phlomis bracteosa*, (iii) *Impatiens sulcata – Hackelia uncinata- Rumex nepalensis*, (iv) *Osmunda claytoniana – Geranium wallichianum*, (v) *Rumex nepalensis – Polygonum rumicifolium – Polygonatum verticillatum*, (vi) *Persicaria polystachya - Polemonium caeruleum- Saussurea piptathera*, (vii) *Pedicularis hoffmeisteri- Pimpinella diversifolia – Aconogonum rumicifolium- Morina longifolia*, (viii) *Ranunculus hirtellus-Potentilla peduncularis – Artemisia dubia*, (ix) *Impatiens sulcata -Thalictrum chelidonii – Rheum australe – Megacarpaea polyandra*, (x) *Polygonum macrophyllum- Trachydium roylei- Tanacetum dolichophyllum*, and (xi) *Potentilla atrisanguinea – Osmunda claytoniana-Prunella vulgaris* to name a few.

Towards higher altitudes (>4000 m) the gentle slopes with deeper soil and frequent biotic and abiotic disturbances give rise to various other communities viz., *Sibbaldia cuneata - Elsholtzia eriostachya - Potentilla saundersiana, Bistorta affinis -Oxyria digyna-Salix lindleyana, Geranium wallichianum -Fritillaria roylei- Cyananthus lobatus*, and several intermediate (mixed grass - forb) communities. Frequently grazed alpine sites are dominated by a number of grazophil or grazing resistant communities such as *Trachydium roylei – Vicatia cuneifolia, Potentilla argyrophylla – Iris kemaonensis*, and *Ranunculus hirtellus – Anemone rivularis – Prunella vulgaris*.

v. Other Herbaceous Communities: Frequently eroded slopes such as avalanche trails, stable terminal moraines, and gentle but high snow fall areas in the Trans-Himalaya

harbour several mixed herbaceous communities with 20 – 40% vegetation cover. Typical communities include *Nepeta podostachys - Aster falconeri, Waldheimia tomentosa - Anaphalis nubigena – Corydalis meifolia, Arnebia benthamii - Epilobium latifolium, Oxygraphis endlicheri - Ranunculus pulchellus, Arenaria festucoides - Aster falconeri* and *Saussurea obvallata - Delphinium brunonianum - Primula stuartii.* These communities range in species diversity from 1.21 to 2.20 and density varies considerably from place to place and depending upon the size of individuals. For example, *Oxygraphis endlicheri* and *Anaphalis nubigena,* two miniature herbs can contribute upto 250 individuals per m^2. Towards the cold arid areas other prominent open herbaceous communities are *Hyssopus officinalis – Scutellaria prostrata, Rubia tibetica – Nepeta floccosa, Cicer microphyllum* mixed, among others.

vi. Graminoid Formations of the Greater Himalaya: Grasses, sedges and rushes altogether comprise over 15 % of the alpine flora in the region. Of these a few species viz., *Danthonia cachemyriana, Festuca kashmiriana, Oryzopsis lateralis, Poa attenuata, Stipa orientalis, S. jacquemontii, Kobresia nepalensis, K. capillifolia, K. fissiglumis, K. schoenoides, K. pygmaea, K. royleana, Carex sagaensis, C. maritima, C. nubigena* and *Blysmus compressus* form extensive formations and bulk of the graminoid communities. Predominant among them include *D. cachemyriana* in the lower alpine regions of the Greater Himalaya which forms association with a number of herbaceous and woody species e.g., *Cotoneaster microphyllus – Danthonia cachemyriana-Berberis kemaonensis and Danthonia cachemyriana -Cicerbita macrorhiza- Spiraea arcuata* (Table 4.3 d). In addition, two species of *Kobresia* (*K. nepalensis* and *K. capillifolia*) form extensive meadows on south facing slopes above 4000 m. *K. fissiglumis* forms single species stand on colluvial deposits in the high snow fall areas of Greater Himalaya around 3500 – 3700 m asl. In terms of species diversity *Danthonia* grasslands have much higher diversity as compared to *Kobresia* meadows.

Both within the Greater and Trans-Himalaya the silted lake banks and marsh meadows comprise a special formation (Alpine Marsh Meadow) with several graminoid communities (Table 4.3). The species diversity in such meadows are low (<1.00) and

evenness very high (>0.80). In the Changthang plateau vast sandy plains which represent ancient lake basins are dominated by tufts of *Carex moorcroftii*. This community is poor in species and ground cover.

vii. Graminoid Formations of Trans-Himalaya: The prominent graminoid communities in the Trans-Himalaya are (i) *Festuca kashmiriana* formations, (ii) *Kobresia royleana – Calamogrostis* mixed formations, (iii) *Carex moorcroftiana – Leymus secalinus – Elymus nutans,* and (iv) *Oryzopsis lateralis – Poa attenuata* mixed. These communities have usually 20 – 40% cover of graminoids and relatively low (10 -20%) cover of forbs. Species diversity and evenness are consistently low as compared graminoid formations of Greater Himalaya.

viii. Desert steppe: The flat and the sandy areas in the Trans-Himalaya are characterized by a low vegetation cover (<20%). Owing to small size of plants especially *Alyssum canescens, Chamaerhodos sabulosa, Oxytropis microphylla* and *Stipa orientalis* much of the desert steppe may appear barren from a distance. Spatially this category forms largest proportion in the Tso Kar and Tso Moriri areas. Most prominent communities include *Stipa – Alyssum – Oxytropis, Leymus secalinus* and *Carex melanantha.* These communities have low species diversity (<1.0) and evenness (<0.632).

ix. Fellfields and Subnival Communities: The areas between closed alpine vegetation and snow line often exposed to wind and blizzards support low (<40% vegetation cover). In certain areas where gravel has stabilized over a long period of time, rudimentary soil may be formed which support stunted cushionoid vegetation dominated by species of *Androsace*, *Arenaria* and *Saxifraga* intermixed with mosses and lichens. Rocky and gravely areas closer to snowline have very sparse (<2%) vegetation cover with characteristic species such as *Carex nivalis, Arenaria serpyllifilia, Saussurea gossypiphora, Saussurea gnaphalodes, Primula macrophylla, Corydalis gortschakovii, C. boweri, Christolea himalayensis*, several species of *Saxifraga, Draba* and *Rhodiola*. Most of these species tend to occur in loose aggregations and it is often difficult to recognize a well formed community.

4.5 Biomass Structure

Distribution of standing phytomass in the alpine region closely follows the matrix of vegetation based on the spacing pattern (Table 4.4b). Although biomass structure for a majority of woody communities in the alpine region of Western Himalaya has not been quantified so far, based on the cover and stem density it can be ascertained that *Krummholz* formations adjacent to alpine scrub have highest standing phytomass. Other woody communities in the descending order of phytomass per unit area would be *Hippophae rhamnoides* ssp *turkestanica*> *Salix denticulata* > *Myricaria elegans* > *Rhododendron anthopogon* > *Juniperus indica* > *Rosa – Lonicera – Berberis* > *Salix karelinii* > *Lonicera spinosa* > *Caragana – Eurotia* > *Salix lindleyana* > *Ephedra gerardiana*. *Cotoneaster microphyllus* and *Rhamnus prostratus* also rank among the species of higher wood density and they may rank among the top five woody species in terms of biomass at certain localities. Other species such as *Potentilla fruticosa, Potentilla biflora, Artemisia, Tanacetum, Haloxylon thomsonii* and *Acantholimon lycopodioides* have relatively low woody biomass per plant. Total standing biomass of woody species in various areas largely depends on the intensity of fuel wood extraction by the local and migratory pastoral communities. *Juniperus indica, J. communis, J. semiglobosa, Myricaria germanica, Rhododendron campanulatum, Rhododendron anthopon, Rosa sericea, Rosa webbiana, Salix* species, *Lonicera purpurascens, L. spinosa, Caragana versicolor,* and *Krascheninnikovia ceratoides* are some of the highly preferred fuel wood species in the region. Many of these species have drastically declined and even faced local extinction (e.g., *Juniperus indica*) from certain localities where pastoral communities have been camping since centuries.

Distribution of above ground biomass among herbaceous communities varies considerably depending upon the altitude, degree of slope and season. The above ground biomass during peak summer in the moist meadows of Greater Himalaya varies from 85 to 284 g m^{-2}. Generally, there is a gradual decline in the standing biomass with the increase in altitude (within same community). Also, the steeper slopes tend to have lower above ground biomass largely due to poor soil. Similarly, with the onset of autumn and

winter there is rapid senescens and translocation of nutrients to the underground parts (tubers, rhizomes, bulbs) leading to decline in above ground standing biomass. A comparision of above ground biomass (g m^{-2}) at various altitudes and slope classes in parts of Kedarnath Wildlife Sanctuary, Garhwal Himalaya, for summer and autumn seasons has been given in Table 4.5a. The major species contributing towards the biomass in descending order are *Danthonia cachymeriana, Polystichum aculeatum, Cirsium wallichii, Rhododendron lepidotum, Cotonester microphllyus, Jurinea dolomiaea, Impatiens sulcata, Rumex nepalensis, Potentilla atrosanguinea, Dryopteris barbigera,* and *Morina longifolia.* Of these, only one species i.e., *Danthonia cachemyriana* is moderately grazed by sheep and goats throughout the summer months.

Table 4.5.1a: A comparision of mean above ground phytomass during summer and autumn seasons and number of contributing species at various sites in parts of Kedarnath WS, Garhwal Himalaya.

SN	Altitude	Deg of Slope	AG Biomass (g m^{-2}) (Summer) ±SD	No. of Species	AG Biomass (g m^{-2}) (Autumn)±SD	No. of Species
1	3220	30°	210.81 ±40.41	16	133.28±48.49	8
2	3270	40°	223.09±45.43	16	55.52±38.35	11
3	3300	25°	138.47±11.78	8	42.68±9.27	6
4	3400	30°	171.69±51.04	17	137.2±29.64	10
5	3400	40°	211.58±65.93	17	27.88±25.63	12
6	3400	10°	191.87±38.17	16	119.42±7.61	11
7	3410	10°	232.2±46.11	14	149.26±44.88	9
8	3450	10°	85.84±22.40	12	28.88±7.27	10
9	3450	30°	283.69±64.17	10	172.96±21.07	8
10	3550	40°	256.65±43.18	12	106.18±36.00	8
11	3700	40°	153.63±30.46	11	73.16±13.42	10
12	3770	50°	145.95±53.83	7	81.58±32.38	7

As expected, the mean above ground standing biomass in the Trans-Himalaya is lower (81.51±8.51 g m^{-2}) compared to the similar altitudes in the Greater Himalaya. A comparision of biomass distribution across forbs (dicots), graminoids, ferns and woody species in the Greater and Trans-Himalaya (Table 4.5b) reveals that graminoids contribute a significant proportion of biomass in the Trans-Himalaya and Ferns are virtually absent in the latter region.

(10 x 10 x 2 m) were erected at various sites covering an altitudinal zone of 3400 to 3800 m and uniform vegetation communities which are grazed by livestock during spring and summer. Above ground (standing) phytomass was clipped within quadrats of 50 x 50 cm within and outside the exclosures after a period of one year. It was found that there was no significant difference in the biomass of dicots within and outside exclosures. However there were significant differences in the phytomass of graminoids ($p = 0.031$, *paired t test*) and total above ground phytomass ($p = 0.036$). The reason for little difference in the phytomass of dicots could be a large proportion of unpalatable dicots in the study area. On the other hand graminoids form a significant proportion of forage in the area and heavily grazed throughout the summer season. One year protection resulted in a considerable increase in the biomass of graminoids (Fig. 4.5 a). The prominent herbaceous species within and outside exclosures were *Lindelofia stylosa, L. anchusoides, Rosularia alpestris, Dracocephalum heterophyllum, Cousinia thomsonii, Nepeta podostachys, Plantago tibetica, Taraxacum offinale* and *Aster flaccidus*. The graminoids include *Carex atrata, C. atrofusca, C. infuscata* (=*C. alpina*), *Oryzopsis munroi, Melica persica, Elymus nutans, Calamogrostis emodensis, Festuca kashmiriana* and *Poa* species. *Ephedra gerardiana, Cotoneaster duthieanus, Artemisia santolinifolia* and *A. brevifolia* were the major woody species.

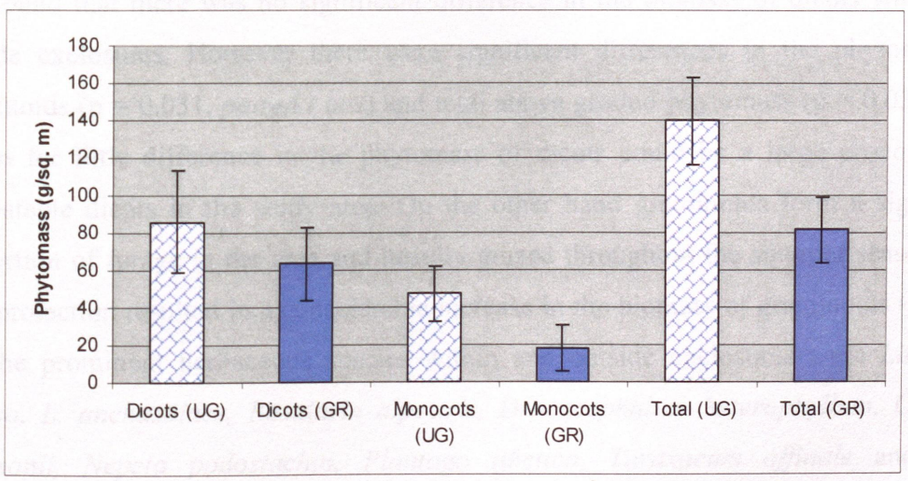


Fig 4.5 a: A Comparision of Above Ground Standing Phytomass Between Grazed (GR) and Protected (UG) Sites in Pin Valley NP, Himachal Pradesh.

The Changthang plateau in Eastern Ladakh is characterized by extensive scrub steppe, desert steppe and a few marsh meadows. The standing phytomass during peak growing season in this

Table 4.5 b: A comparision of standing above ground phytomass at four sites in the Greater (GH) and Trans-Himalaya (TH) [LS = Livestock; AG = Above Ground]

Locality	Altitude (m asl)	AG Biomass during peak summer (g m^{-2})				
		Forbs (Dicots)	Graminoids (Monocots)	Ferns	Woody Species	Total
Sokh Kharak - GH Grazed by LS	3450	110.57±22.18	44.26±8.14	9.66	4.15	168.65±18.54
Rudranath - GH (Ungrazed by LS)	4100	106.66±18.67	66.14±7.88	3.1	0	175.9±11.35
Pin Valley - TH (Grazed by LS)	3560	40.77±7.73	18.12±2.12	-	22.75±7.32	81.51±8.51
Pin Valley - TH (Ungrazed/Exclosed)	3600	48.69±5.64	47.33±7.10	-	37.35±8.24	139.63±9.67

A data set is available on the effect of exclosure on above ground biomass in Pin Valley National Park, Himachal Pradesh. The study was initiated by the author in collaboration with the Himachal Pradesh Forest Department during 1997-99. Six cattle and wildlife proof exclosures (10 x 10 x 2 m) were erected at various sites covering an altitudinal zone of 3400 to 3800 m and uniform vegetation communities which are grazed by livestock during spring and summer. Above ground (standing) phytomass was clipped within quadrats of 50 x 50 cm within and outside the exclosures after a period of one year. It was found that there was no significant difference in the biomass of dicots within and outside exclosures. However there were significant differences in the phytomass of graminoids ($p = 0.031$, *paired t test*) and total above ground phytomass ($p = 0.036$). The reason for little difference in the phytomass of dicots could be a large proportion of unpalatable dicots in the study area. On the other hand graminoids form a significant proportion of forage in the area and heavily grazed throughout the summer season. One year protection resulted in a considerable increase in the biomass of graminoids (Fig. 4.5 a). The prominent herbaceous species within and outside exclosures were *Lindelofia stylosa, L. anchusoides, Rosularia alpestris, Dracocephalum heterophyllum, Cousinia thomsonii, Nepeta podostachys, Plantago tibetica, Taraxacum offinale* and *Aster flaccidus*. The graminoids include *Carex atrata, C. atrofusca, C. infuscata* (=*C. alpina*), *Oryzopsis munroi, Melica persica, Elymus nutans, Calamogrostis emodensis, Festuca kashmiriana* and *Poa* species. *Ephedra gerardiana, Cotoneaster duthieanus, Artemisia santolinifolia* and *A. brevifolia* were the major woody species.

winter and of wild herbivores animals during summer. This may be due to rapid turnover of biomass in this community. The desert steppe is usually characterized by a low vegetation cover (about 24%). Mean above ground biomass during peak growing season was 37 g m^{-2}. Spatially this category forms largest proportion in the eastern Ladakh.

Table 4.5 c: Mean cover of Vegetation, Stem Density and Above Ground Phytomass Across Various Physiognomic Units and Communities in Tso Kar Basin, Eastern Ladakh.

Physiognomic Unit	Mean Cover (%)	Density (Indiv m^{-2})	AG Phytomass (g m^{-2})	Major Plant Communities/ Characteristic Species
Moist / Marsh Meadows	92±5.6	544±300.5	31.99	*Blysmus compressus* *Carex sagaensis* *Kobresia pygmaea* *Kobresia schoenoides*
Desert Steppe / Sandy Plains	24.45±08	80±110.1	37.47	*Stipa – Alyssum – Oxytropis* *Leymus secalinus* *Carex melanantha*
Scrub Steppe (Alpine Dry Scrub)	31±9.5	23±4.0	215.68	*Caragana-Eurotia* *Artemisia – Tanacetum* *Artemisia-Carex*
High Alpine Mixed-Forbs	20±12.5	59±13.8	39.95	*Delphinium brunonianum* *Saussurea gnaphaloides* *Arenaria bryophylla*
Fell-Fields	38±10.4	38±5.2	6.50	*Androsace spp.* *Thylacospermum caespitosum*
Livestock Camps	22±12.5	83±79.8	-	*Chenopodium spp.,* *Physochlaina praealta*

The areas around and above 5000 m, especially on the moist and gently undulating slopes adjacent to snow banks, harbour mixed herbaceous vegetation. This category is rather limited in extent in the basin and confined to north-western slopes. Overall ground cover (20%) and above ground biomass (39 g m^{-2}) are rather low. Major species of herbaceous formation in terms of above ground biomass are *Arenaria bryophylla, Delphinium brunonianum, Dracocephalum heterophyllum, Oxytropis humifusa* and *Potentilla bifurca.*

4.6 Life Form Structue

An analysis of Raunkaier's life-forms across the Greater and Trans-Himalayan ranges (Table 4.6) reveals that in the moist alpine areas of Greater Himalaya (3500 – 5000 m asl) proportion of phanerophytes is much higher (6.85%) as compared to the Trans-Himalaya (3.5%). The proportion of phanerophytes is much lower (0.93) in Changthang plateau (Tso Kar basin) as compared to other parts of Ladakh. Rawat & Adhikari (2001) have found that the flora of cold deserts in eastern Ladakh is dominated by hemi-cryptophytic (graminoids) and chamaephytic (dwarf herbs with perennial rhizome/ root stock) life forms having approximately 57 and 23% species respectively.

Table 4.6: A comparision of various Life-forms (%) in different alpine areas of NW Himalaya

Life-forms*	Valley of Flowers NP[1] N = 525	Tso-kar Basin[2] N = 251	Trans-Himalaya [3] N = 404	Normal [4]
Phanerophytes	6.85	0.93	3.5	43
Chamaephytes	6.09	23.47	5.4	9
Hemicryptophytes	68.38	56.52	62.1	26
Geophytes	11.80	4.78	4.2	4
Hydrphytes	0.38	2. 17	1.7	2
Therophytes	4.95	11.73	22.3	13

1= Rawat (unpublished) ; 2 = Rawat & Adhikari 2001; 3 = Klimes 2003; 4 = Raunkaier 1934. Valley of Flowers data includes parasites / saprophytes (0.95%) and lianas (0.57%).

** Phanerophytes = Trees > 2 m high; Nannophanerophytes = small trees < 2 m high; Chamaephytes = Woody or herbaceous perennials with buds close to the ground; Hemicryptophytes = Rosette or tussock forming plants in which above ground parts die back during unfavourable period e.g., graminoids; Geophytes = Plants with sub-terranean bulbs, tubers or thick rhizomes; Hydrphytes = Aquatic plants; Therophytes = Annual herbs which survive the unfavorable period as seeds. See Kent & Coker (1992) for more details.*

Klimes (2003) studied the distribution of life-forms among the vascular plants in the eastern Ladakh covering an area of 10,227 km^2 and found that among the 404 species recorded in the area, hemicryptophytes prevailed strongly representing 251 species

(62.1%), followed by therophytes with 90 species (22.3%). Chamaephytes comprised 22 species (5.4%) and geophytes 17 species (4.2%). Phanerophytes (14 species, 3.5%) and hydrophytes (7 species, 1.7%) were rare. This life-form spectrum reflects prevailing desert-steppe and steppe vegetation in the study area.

Klimes (2003) has further analyzed the abundance of clonal plants among the vascular plants recorded from the eastern Ladakh. It was observed that about 30% of plant species in the area were clonal from the lowest altitudes up to 5000 m a.s.l., from where the proportion of clonal plants gradually declined down to zero at the highest altitudes. Different factors are likely to be responsible for the relatively low proportion of clonal plants and their decline at higher altitudes. At the highest altitudes clonal plants with persisting inter-connections between widely spaced ramets are usually damaged by repeated freezing and thawing of the soil, breaking their integrated systems. In large screes at intermediate altitudes most types of clonal plants are injured by their mobility and at the lower altitudes tough soil texture prevents horizontal growth in the below-ground. Therefore, diversity of clonal plant types is small in prevailing habitats of the study area and most clonal plants are restricted to small patches of wetlands at intermediate and lower altitudes.

4.7 Discussion

The plant communities are considered sub-divisions of a vegetation cover and wherever the cover showes obvious spatial changes, one may distinguish a different community (Shimwell *et al.* 1971, Mueller-Dombois & Ellenberg 1974, Gauch 1982). The ultimate aim of classifying the vegetation data is to find the 'natural' or near natural groupings so as to make ecological sense. This study attempts at identifying and describing the physiognomic as well community level organization of alpine vegetation across a large geographical region. It was realized that across such a wide environmental gradient plant species may exhibit extreme forms of clustering as well as loose aggregations. An attempt has been made to combine traditional European methods of phytosociology, which mostly use the tabular approach, with the more modern statistical, which rely more

on multivariate analysis. Both these approaches are possible in software for vegetation data analysis namely TURBOVEG and JUICE (Figure 4.2a). In order to give a holistic picture of vegetation in the region, the communities classified within the Greater and Trans-Himalaya based on the above technique has been complemented by qualitative information based on spacing pattern of vegetation and floristic structure.

Communites at local and regional scales

Among the various physiognomic units of alpine region in the Greater Himalaya, the MHF is most prominent. Depending upon the altitude and mean height of herbaceous plants this category is further divisible into two broad sub-types viz., tall forbs (TF) i.e., mean height >30 cm and usually below 4000 m and short forbs (SF) i.e., mean height of plants (< 20 cm) and generally above 4000 m. A preliminary analysis yielded 15 clusters within SF (Table 4.3b). These groups also include some intermediate forms and intermingling of a few species which might form TF at lower altitudes and get stunted growth forms at higher altitudes e.g., *Persicaria polystachya* and *Selinum coniifolium*. When all the plots from the MHF were subjected to cluster analysis 29 communities were obtained. These communities have been given tentative names based on the dominance and consistency of species. In an earlier attempt at classifying the alpine plant communties based on Two Way Indicator Species Analysis (TWINSPAN) in Valley of Flowers NP, Kala et al. (1998) segregated as many as 10 communities between 3300 - 3800 m and 7 communities above 3800 m. Similarly, Singh (1999) classified MHF of Great Himalayan NP into 23 communities, of which 11 were typical of lower areas (<4200 m) and 12 were found at higher (>4200 m) alpine zones (Figure 4.7a). In the core area of Nandadevi National Park, Samant & Joshi (2004) visually identified as many as 49 plant associations along the altitudinal gradient of 3500 – 4500 m.

Rawat & Adhikari (2005) segregated sixteen plant communities in the Tso Kar basin (Changthang) using TWINSPAN. In terms of areal coverage *Stipa-Alyssum-Oxytropis* and *Caragana scrub* are most extensive. Six communities, viz., *Scirpus-Carex, Scirpus-Carex-Ranunculus, Scirpus-Kobresia-Ranunculus, Pucciniella-Polygonum-Carex,*

Polygonum-Minuarta-Carex, and *Carex-Polygonum-Elymus* are confined to wet meadows along the gradients of moisture in the valley bottom and stream courses. Relative position of these communties along the gradients of moisture, altitude and landscape heterogeneity are shown in Figure 4.7b. Unlike the TWINSPAN output for the Tso Kar basin, present analysis for the entire Trans-Himalaya generated only 11 major clusters and for marsh meadows of lake basins primarily three communities have been segregated. These are: *Carex moorcroftiana - Blysmus compressus - Pucciniella himalaica, Kobresia schoenoides- Carex sagaensis-Kobresia royleana* and *Carex parva-Pedicularis longiflora Halerpestes tricuspis.*

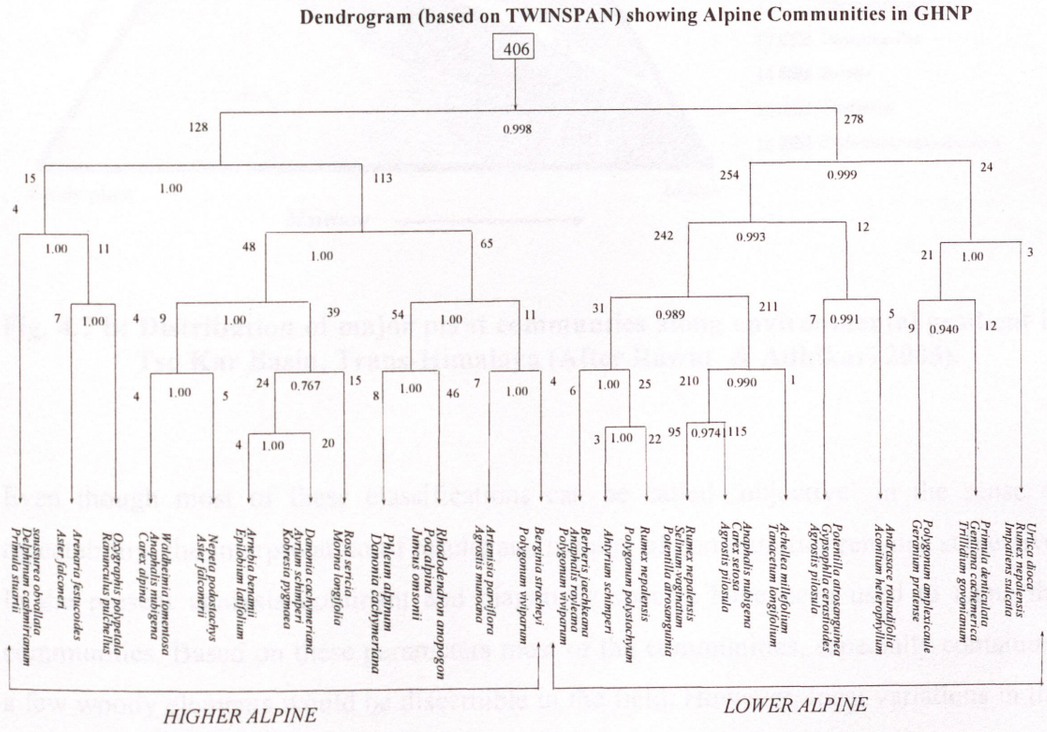


Fig. 4.7a: Alpine plant communties as separated based on TWINSPAN in GHNP (Numbers in the central box and at the corners of each line indicate the no. of sites and smaller numbers indicate eigen values. Source: Singh 1999)

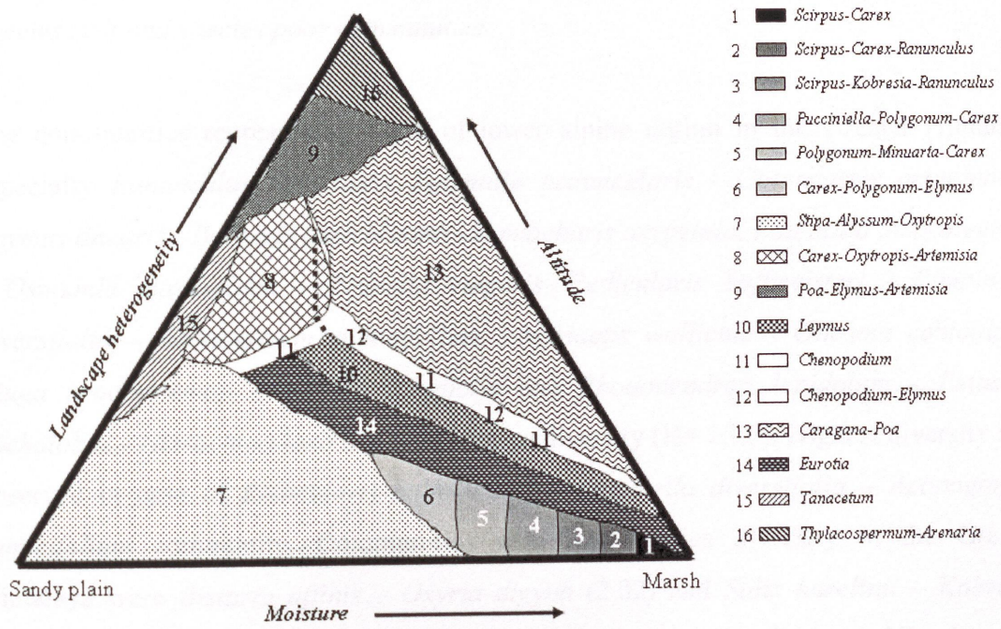


Fig. 4.7 b: Distribution of major plant communties along environmental gradient in Tso Kar Basin, Trans-Himalaya (After Rawat & Adhikari 2005).

Even though most of these classifications can be called 'objective' in the sense of repeatability, the interpretation of results and naming of communities remains subjective. In the present analysis dominant and diagnostic species have been used to name the communities. Based on these parameters most of the communities, especially containing a few woody elements would be discernible in the field. However, local variations in the abundance of constant species, particularly at the lower alpine zones and the MHFs derived from varying degree of anthropogenic pressures are likely to obliterate the identity of such communities in the field. Thus, it can be stated that attempts at classification of plant communities in the areas of intermediate seral stages such as lower alpine zone may result in artificial groupings. Therefore, the plant ecologists working in the higher Himalaya need to focus more on the patterns and processes of community

development especially in the transition zones and MHF and less on mechanically generating such artificial groups.

Species rich and species poor communities

The communities representing MHF of lower alpine region in the Greater Himalaya especially *Ranunculus hirtellus - Potentilla peduncularis - Cotoneaster acuminatus, Thymus linearis - Berberis jaeschkeana - Nomocharis oxypetala, Potentilla atrisanguinea - Osmunda claytoniana - Prunella vulgaris, Pedicularis hoffmeisteri - Pimpinella diversifolia – Aconogonum rumicifolium, Myriactis wallichii – Onosma echioides - Ajuga brachystemon - Morina longifolia* and *Rhododendron lepidotum - Petasites tricholobus - Hierochloa laxa* had high species diversity (H= >3.0). Highest diversity was observed in case of *Pedicularis hoffmeisteri - Pimpinella diversifolia – Aconogonum rumicifolium* community. Communities with low species diversity in the Greater Himalaya were *Bistorta affinis – Oxyria digyna* (2.02) and *Salix karelinii – Kobresia nepalensis* (2.17). Similar results have been reported from Garhwal Himalaya by Nautiyal *et al.* (1997).

The communities representing lowest species diversity were *Phragmites australis- Lycium ruthenicum- Hippophae rhamnoides- Haloxylon thomsonii* (H= 1.12), *Eurotia ceratoides - Caragana versicolor* (H= 1.34) and *Stipa orientalis- Alyssum canescens - Oxytropis microphylla* (H= 1.34) in the Trans-Himalaya. The first community among these exhibited high heterogeneity (or low evenness) largely due to sharp gradient of moisture along the sandy river banks in Nubra Valley. Within Trans-Himalaya community with highest species diversity was *Thalictrum alpinum- Saussurea gnaphalodes – Trisetum aenium* (H=2.37) representing high alpine herbaceous formation, equivalent to MHF (SF) of Greater Himalaya.

Biomass Production in Different Communities

Although the growing season is very short (May to September) in the alpine zone, all species do not attain their maximum biomass at the same time. Most of the species complete their growth cycle rapidly within 3-5 months in order to ensure their survival. Kala *et al.*. (1998), while conducting biomass study, separated a total of 69 plant species including one dwarf woody shrub, 4 grasses, 2 sedges, 3 ferns, 50 herbaceous dicots, and 9 other monocotyledons from a grazed alpine site in Garhwal Himalaya. They found that above ground biomass varied considerably among the camping sites (CS), steep slopes (SS) and undulating landmass (ULM). The live shoot biomass increased continuously from onset of monsoon (June), attained a peak in the first week of September, and declined thereafter. *Danthonia cachemyriana* contributed highest (356 g m^{-2}) on SS, while on ULM highest biomass was contributed by *Geranium wallichianum* (232 g m^{-2}) and by *Polygonum polystachyum* (189 g m^{-2}) in CS. Of the total above ground biomass production in the sampled area, the loss due to trampling and grazing by the livestock was 26%, 23% and 22% on ULM, CS, and SS respectively. Ram (1991), Ram & Arya (1991) and Ram & Singh (1994) have shown that most of the communities in the alpine region of Garhwal Himalaya accumulate more than 60% biomass below ground which is perhaps lower as compared to higher latitudes and arctic regions. Kaul & Sarin (1971), Joshi *et al.* (1988), Nautiyal et al. (1997, 2004), Seth (1996), and Dhaulakhandi *et al.* (2000) have also found very high spatio-temporal variation in the biomass production of moist alpine meadows of Greater Himalaya. In Garhwal Himalaya, Rikhari *et al.*, (1992) found that above ground community phytomass values ranges from 112-390 g m^{-2} while below ground net primary production was 59-250 g m^{-2}. These authors have underlined the importance of interactions between growth forms and grazing in community development in alpine meadows of Greater Himalaya.

There are obvious reasons for low standing phytomass in the Trans-Himalaya as compared to that of Greater Himalaya (low precipitation, poorer soil and higher mean elevation). However, at a few comparable altitudes the Trans-Himalaya may have higher standing phytomass. For example, the sub-nival zone (5200 – 5500 m) in the Greater Himalaya may support very sparse vegetation and low phytomass while moist places in the Changthang plateau may have higher vegetation cover and phytomass. In Tso Kar basin (mean elevation 4800 m) estimate of mean above ground biomass (319-2156 kg ha

^{1}) was higher compared to estimates reported by Jian (2002) from Western Tibet (117-307kg ha^{-1}). Similarly biomass estimates (27.7 g m^{-2}) of Schaller (1998) for *Stipa-Oxytropis* community in North-west Tibet were lower than the estimates in Tso Kar (37.47 g m^{-2}).

Functional Aspects of Plant Communities

How do a multitude of plant communities co-exist in resource poor alpine environments? Despite a great deal of morphological convergence the alpine plants may exhibit physiological as well as phenological divergence in order to co-exist. Although microphylly and dwarfism seem to be general rules in alpine regions, certain species defy this. For example, three species of *Rheum* viz., *R. australe, R. moorcroftianum* and *R. webbianum,* all growing above 3500 m asl, the leaf size often goes over 40 cm x 30 cm and the latter two grow among dwarf *saxifraga* and *sedum.* What strategies these species might have which makes them successful at such environment? According to Ch. Kroener (*personal communication*), these species may occupy sheltered locations free from wind and have long lived massive below ground storage organs and may accumulate substantial heat in their early season growth near the ground and than expand into very water rich tissue without proportional structural investment. They may also trap heat by compact (dense) leaf display. Further, they must not be very tasty for herbivores. In Alps, there is *Rumex alpinus* which is 70 cm tall with leaves of 30 cm length. But this plant is found only in nutrient rich locations (cattle resting areas), so nitrogen availability must play a key role. A large number of species in the alpine areas are said to be stress tolerant which remain in certain environment in a state of delicate equilibrium (Gering *et al.* 2003, Christopher *et al.* 2004).

Common examples of co-existence among several communities is exhibited by *Danthonia cachemyriana – Trachydium roylei* and other mixed forbs in the moist meadows in the Greater Himalaya which support a considerable diversity despite heavy seasonal grazing. Grasses and sedges are well adapted to alpine heights. They are extremely hardy which can withstand severe winds (due to narrow leaves and stems) as

well as a considerable amount of herbivory. *Danthonia* tussocks provide numerous micro-habitats and gaps to a number of associated palatable as well as non-palatable species. A few authors have demonstrated that plant species in resource poor habitats, such as alpine areas, play the role of facilitation while species in productive or resource rich habitats may compete with each other (e.g., Choler *et al.* 2001). Furthermore, across all high and low sites positive interactions are more important at sites with low temperatures in the early summer, but competition prevails at warmer sites. In an experimental study, Callaway *et al.* (2002) demonstrated that biomass, growth and reproduction of alpine plant species are higher when other plants are nearby and competition is generally more intense at lower elevations where conditions are less physically stressful. Singh *et al.* (2005), in study carried out in the Valley of Flowers NP, have also demonstrated that diverse communities adjacent to each other play a role of facilitation and contribute to greater biomass production. These authors have further stated that loss of species from such communities may lead to degradation of ecosystem stability. An extreme case of community coexistence can be seen in high alpine fellfields of Himalaya where large hemispherical cushions of *Thylacospermum caespitosum* often supports species of *Androsace*, *Saussurea gnaphalodes* and *Oxytropis lapponica*.

2.8 Conclusion

Community classification for the alpine vegetation has been attempted using recently developed computer softwares viz., TURBOVEG and JUICE (Hennekens & Schaminée 2001, Lubomír 2002) which were found handy in analyzing the voluminous data. The communities classified using cluster analysis have been compared in terms of their diagnostic, differential and dominant species for Greater as well as Trans-Himalaya. The structure and compostion of various communities have been described under major physiognomic units. Although mean above ground phytomass during peak growing season was higher in the Greater Himalaya as compared to Trans-Himalaya (at comparable altitudes) certain communities in the Trans-Himalaya especially at higher altitudes (4500 m) have much higher standing biomass. A comparision of Life-form structure between Greater and Trans-Himalaya reveals that the former has higher

proportion of phanerophytes while the latter has more of chamaephytes. Several communities at higher altitudes seem to co-exist by facilitation and positive interaction.

* * *

Plate 9: ALPINE PLANT ADAPTATIONS - II



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1. *Koenigia delicatula* (Polygonaceae)- An Annual herb among the mosses



©G.S. Rawat

2. Diverse structural and functional adaptations of Polygonaceae – Leaves of *Rheum moorcrotianum* (shown above) defy rules of microphylly and dwarfism in alpine habitats

5.0 ENVIRONMENTAL CORRELATES AND SUCCESSIONAL TRENDS

"From barren rock to alpine turf requires a mental walk through centuries. Succession in the alpine tundra is painfully slow, but it progresses from infinitesimal lichen hanging by a thread on a weathering bolder to plump clump of grasses and sedges..."

- Zwinger & Willard (1972)

5.1 Introduction

The preceding chapter deals with community classification, structure and composition, biomass structure and certain functional aspects including life-form structure in the alpine region of Western Himalaya. It is realized that not all components of vegetation ecology can be studied and correlated at the community level. Certain aspects are better correlated at the overall physiognomic level and others at the level of individual species.. Use of environmental criteria for characterizing the vegetation and species distribution is a common practice among plant ecologists (Mueller-Dombois & Ellenberg 1974, Kent & Coker 1992). However, scales at which ecologists work vary considerably and often studies carried out at a local scale are insufficient to understand the patterns at a regional scale. Further, the role of various parameters in determining the vegetation dynamics have been discussed. Lastly, trends of primary and secondary succession based on the data collected from a few alpine sites are presented along with suggestions for long term studies at various spatio-temporal scales. It clearly emerges that more coordinated studies are required to address the issue of scale in identifying and understanding vegetation communities. This is particularly pertinent in regions where a study conducted at a local scale forms a sub-set of larger, landcape-level study which aims to understand the vegetation dynamics and causative environmental factors.

5.2 Material and Methods

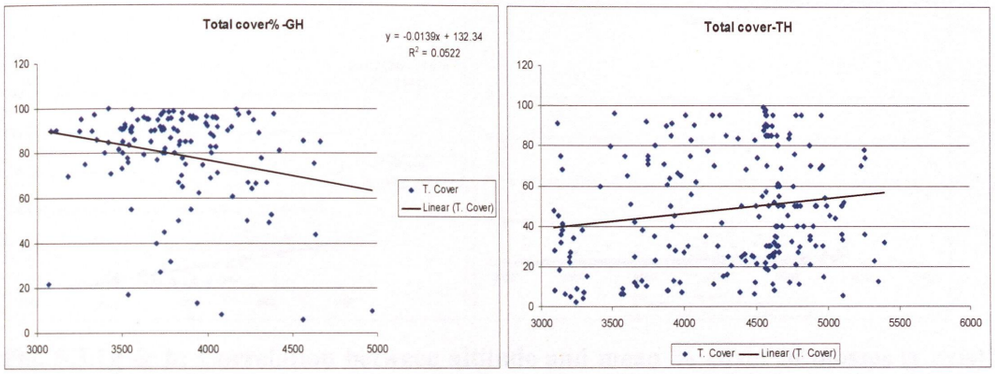
The relationship between altitude and various parameters of vegetation viz., total ground cover, cover of herbaceous plants, graminoids, lichens and mosses have been tested following Spearman's correlation coefficient (Vodnik *et al.* 2006) and using S.P.S.S. (Norussis, 1996). Percent cover of the aforementioned plant forms have been compared in relation to aspect, viz., north, north-east, east, south-east, south, south-west, west, north-west (hereafter

abbreviated as N, NE, E, SE, S, SW, W and NE respectively). Canonical Correspondence Analysis (CCA) using programme CANOCO (ter Braak 1990) has been performed to determine the response of various species and taxonomic groups (such as ferns, members of specialized families e.g., Asteraceae and Polygonaceae) to environmental parameters. CCA uses multiple regression to select the linear combination of environmental variables that explains most of the variation in the species scores on each axis. A few sites such as terminal and lateral moraines representing primary succession have been compared in terms of species composition, ver and density. Patterns of secondary succession were studied in one alpine valleys, Johar in the eastern Kumaon. This valley was extensively cultivated in the past (barely, buckwheat and potato) and much of it is now abandoned. Experienced local people were consulted to ascertain the age of fallow fields. Vegetation sampling protocols for these sites were same as those described in Chapter 3 and as given in Appendix - I. Various sites representing stages of secondary succession have been compared in terms of characteristic species and their cover.

5.3 Environmental Correlates and Vegetation Response

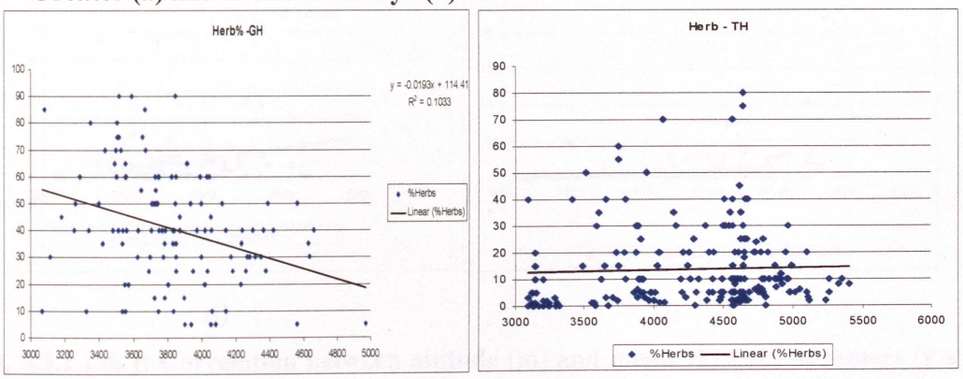
5.3.1 Altitude

Percent cover of vegetation varied considerably within and among the major physiognomic units. In the Greater Himalaya (GH) there was a gradual decline in over all ground cover with increasing altitude (Fig. 5.3.1a). However, the relationship was very weak (R^2 = -0.0509). Interestingly, the trend was reverse in case of Trans-Himalaya (TH) where there was a low positive correlation between the ground cover and increase in altitude up to 5000 m (Fig. 5.3.1b). Likewise, herbaceous species and graminoids showed different trends in the GH and TH. In the GH there was a rapid decline in cover of herbs with increasing altitude but such a trend was not clear in the TH (Fig 5.3.1c and d). In the TH the % cover of graminoids was relatively higher as compared to GH (maximum cover around 4400 – 4800 m) and within the zone of vegetation (3000 – 5500 m) there was a weak but positive correlation between the altitude and graminoid cover (Fig 5.3.1 e, f). Mosses and lichens showed low positive correlations with increase in altitude in the GH but relationship was not clear in the TH (Figs 5.3.1 g, h, i, j).



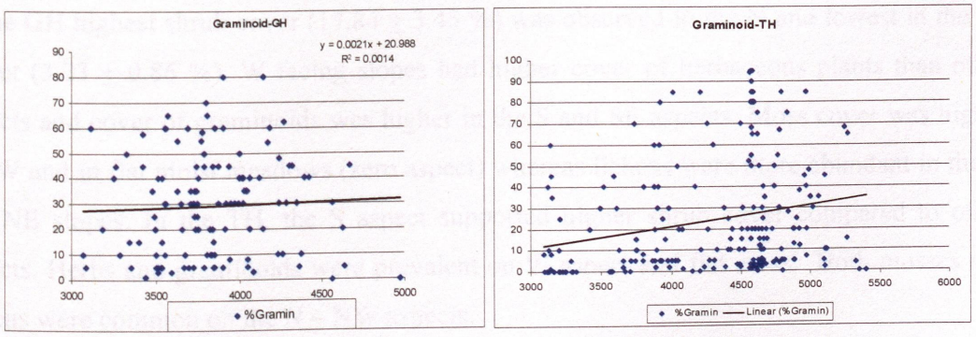
(a) (b)

Fig. 5.3.1a & b: Correlation between altitude (m) and % cover of vegetation (y axis) in the Greater (a) and Trans-Himalaya (b).



(c) (d)

Fig. 5.3.1c & d: Correlation between the altitude (m) and mean % cover of herbaceous plants (y axis) in the Greater (c) and Trans-Himalaya (d).



(e) (f)

Fig. 5.3.1e & f: Correlation between altitude (m) and % cover of graminoids (y axis) in Greater (e) and Trans-Himalaya (b).

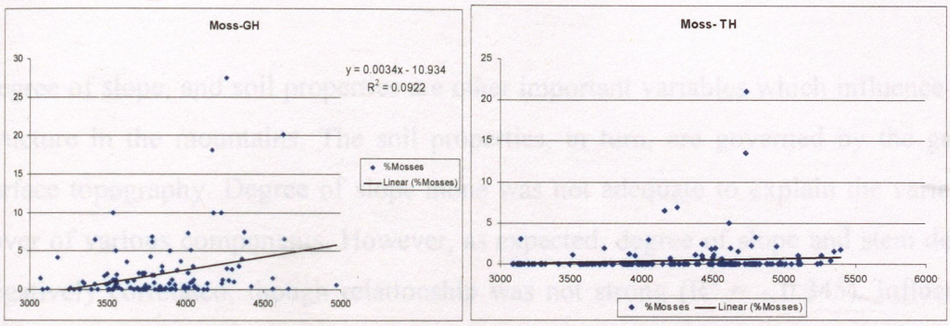
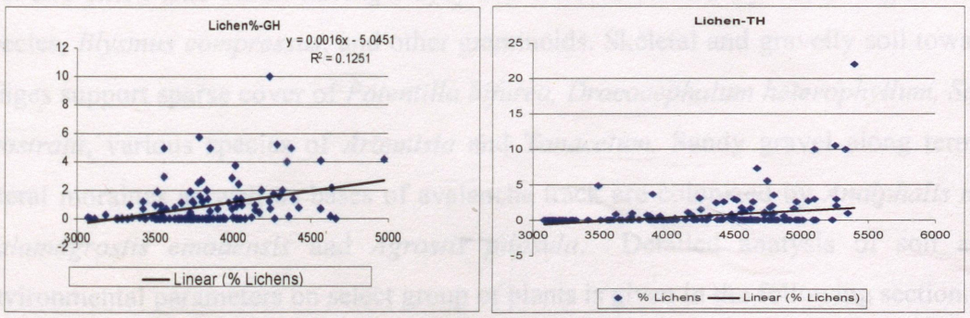


Fig. 5.3.1g & h: Correlation between altitude and mean % cover of mosses (y axis) in the Greater (g) and Trans-Himalaya (h).



(i) **(j)**

Fig. 5.3.1 i & j: Correlation between altitude (m) and mean % cover of mosses (y axis) in the Greater (i) and Trans-Himalaya (j).

5.3.2 Aspect

In the GH highest shrub cover (17.84 ± 3.45 %) was observed in the N and lowest in the SE aspect (3.23 ± 0.86 %). W facing slopes had higher cover of herbaceous plants than other aspects and cover of graminoids was higher in the S and SE aspects. Moss cover was higher in SW and in flat moist meadows (zero aspect) whereas lichens were more abundant in the N and NE slopes. In the TH, the S aspect supported higher shrub cover compared to other aspects. Herbs and graminoids were prevalent on W aspect and flat areas. Both mosses and lichens were common on the N – NW aspects.

5.3.3 Other Variables

Degree of slope, and soil properties are other important variables which influence vegetation structure in the mountains. The soil properties, in turn, are governed by the geology and surface topography. Degree of slope alone was not adequate to explain the variation in the cover of various components. However, as expected, degree of slope and stem density were negatively correlated, though relationship was not strong (R^2 = - 0.345). Influence of soil texture was more pronounced at the level of taxa and certain groups such as moist rock containing skeletal soil had greater cover and frequency of Saxifragaceae and Crassulaceae. Flat and silted lake banks having clayey soil were dominated by *Carex sagaensis, Scirpus* species, *Blysmus compressus*, and other graminoids. Skeletal and gravelly soil towards inner ranges support sparse cover of *Potentilla bifurca, Dracocephalum heterophyllum, Scutellaria prostrata*, various species of *Artemisia* and *Tanacetum.* Sandy gravel along terminal and lateral moraines as well as bases of avalanche track are colonized by *Analphalis nubigena, Calamogrostis emodensis* and *Agrostis pilosula.* Detailed analysis of soil and other environmental parameters on select group of plants is given in the following section.

5.4 Species – Environment Relationships

In the GH, most woody species were confined to lower altitudes especially along productive habitats such as stream courses or areas of deeper soil. The only woody species positively correlated with the altitude and higher moss cover was a prostrate, mat forming shrub, *Salix lindleyana* ssp *microphylla* (Fig 5.3.2a). This also underlines the fact that the riverine scrub at higher altitudes supports very low cover of mosses and lichens.

Unlike the forested habitats of moist temperate and humid sub-tropical zones alpine areas have low abundance of ferns. It was found that a few gregarious species of ferns such as *Osmunda claytoniana* and *Dryopteris barbigera* are strongly correlated with species rich herbaceous formations and negatively correlated with steepness of slope and altitude (Fig 5.3.2 b). CCA for the selected medicinal and aromatic plants (mostly herbaceous) growing in the alpine region revealed that almost all the high value medicinal plants were negatively

correlated with nutrient rich soil (indicated by higher organic Carbon and soil Nitrogen). The sites rich in these factors are mostly confined to lower alpine regions having gentle slopes and frequently grazed and camped by the domestic livestock (Fig 5.3.2 c). Only two species viz., *Allium victorialis* and *Arnebia benthamii* showed positive correlation with the high soil nitrogen indicating nutrient rich soil.

Asteraceae is the largest families of flowering plants in the alpine region of Western Himalaya. CCA for the selected taxa in this family revealed that most of the taxa have strongly correlated with dry habitats poor in mosses (Fig. 5.3.2d). A few species such as *Leontopodium himalayanum* occupy sub-nival habitats showing high Eucledian distance from rest of the species. On the other hand, taxa within Polygonaceae, another typical family in the alpine region of Himalaya, exhibited varied response and occupied a wide range of habitats (Fig. 5.3.2e).

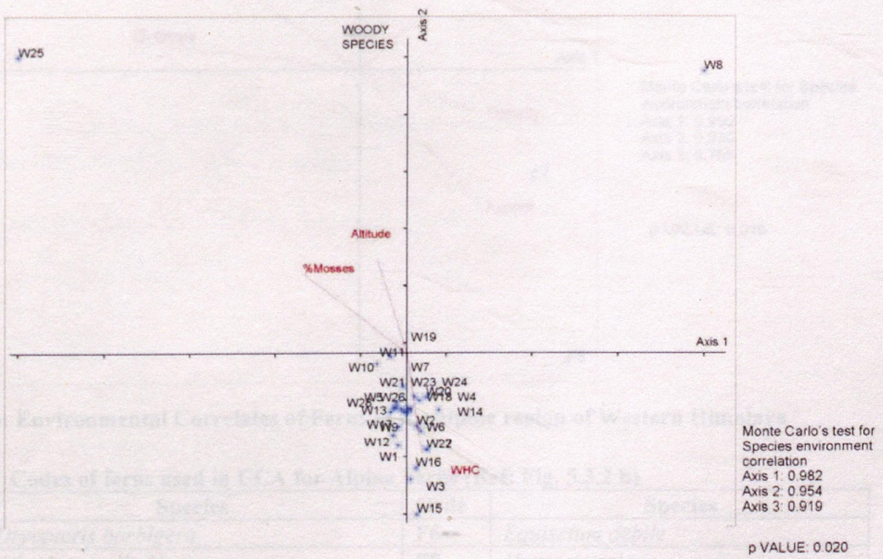


Fig 5.3.2a: Woody species and their environmental correlates in the Greater Himalaya

Codes of woody species used in CCA for alpine region of GH (Ref: Fig 5.3.2a)

Code	Species	Code	Species
W1	*Artemisia santolinifolia*	**W15**	*Juniperus squammata*
W2	*Astragalus candolleanus*	**W16**	*Lonicera myrtillus*
W3	*Astragalus chlorostachys*	**W17**	*Lonicera obovata*

W4	*Astragalus zanskarensis*	**W18**	*Lonicera semenovi*
W5	*Berberis jaeschkeana*	**W19**	*Rhododendron anthopogon*
W6	*Betula utilis*	**W20**	*Rhododendron lepidotum*
W7	*Cassiope fastigiata*	**W21**	*Rosa macrophylla*
W8	*Chesneya nubigena*	**W22**	*Rosa sericea*
W9	*Ephedra gerardiana*	**W23**	*Salix karelinii*
W10	*Ephedra saxatilis*	**W24**	*Salix lindleyana*
W11	*Gaultheria trichophylla*	**W25**	*Salix lindleyana* ssp. *microphylla*
W12	*Hippophae tibetana*	**W26**	*Spiraea arcuata*
W13	*Juniperus communis*	**W27**	*Spiraea bella*
W14	*Juniperus indica*	**W28**	*Stellara chamaejasme*

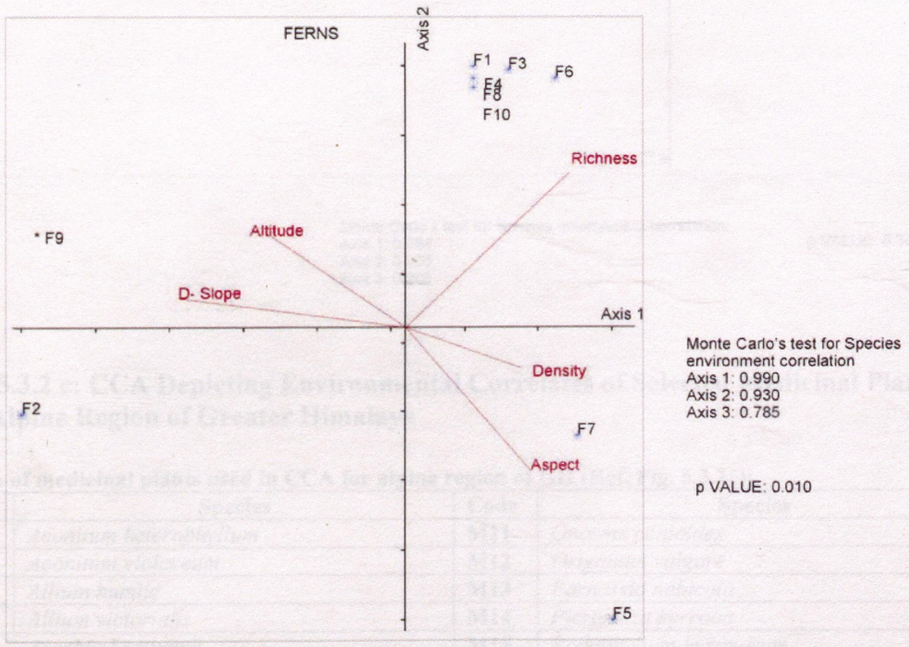


Fig 5.3.2 b: Environmental Correlates of Ferns in the alpine region of Western Himalaya

Codes of ferns used in CCA for Alpine Ferns (Ref: Fig. 5.3.2 b)

Code	Species	Code	Species
F1	*Dryopteris barbigera*	**F6**	*Equisetum debile*
F2	*Athyrium wallichianum*	**F7**	*Huperzia selago*
F3	*Botrychium lunularia*	**F8**	*Polystichum bakerianum*
F4	*Dryopteris chrysocoma*	**F9**	*Cystopteris fragilis*
F5	*Equisetum arvense*	**F10**	*Osmunda claytoniana*

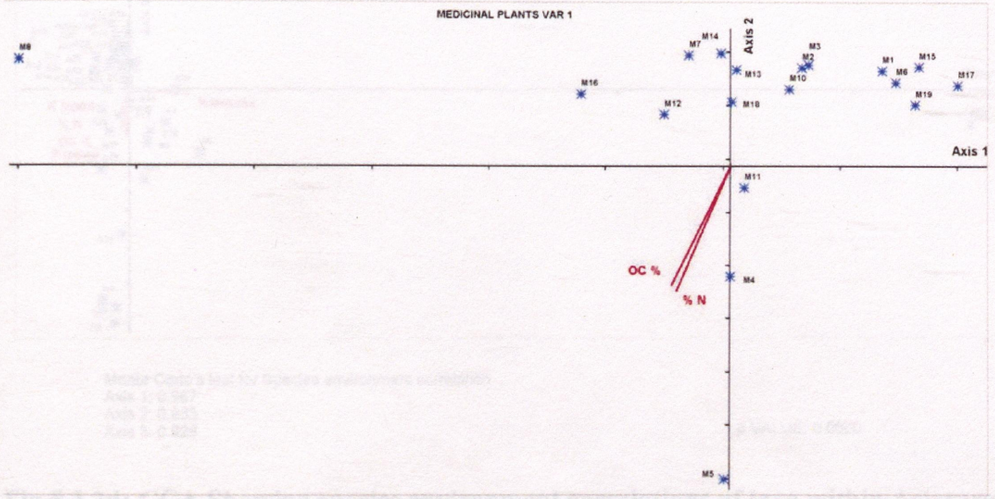
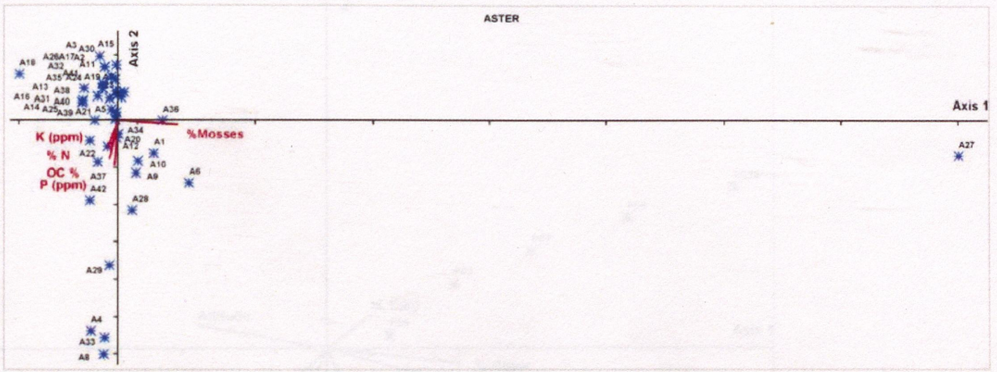


Fig. 5.3.2 c: CCA Depicting Environmental Correlates of Selected Medicinal Plants in the Alpine Region of Greater Himalaya

Codes of medicinal plants used in CCA for alpine region of GH (Ref. Fig. 5.3.2c):

Code	Species	Code	Species
M1	*Aconitum heterophyllum*	**M11**	*Onosma echioides*
M2	*Aconitum violaceum*	**M12**	*Origanum vulgare*
M3	*Allium humile*	**M13**	*Parnassia nubicola*
M4	*Allium victorialis*	**M14**	*Picrorhiza kurrooa*
M5	*Arnebia benthamii*	**M15**	*Podophyllum hexandrum*
M6	*Corydalis govaniana*	**M16**	*Polygonatum verticillatum*
M7	*Dactylorhiza hatagirea*	**M17**	*Rheum australe*
M8	*Ephedra gerardiana*	**M18**	*Swertia ciliata*
M9	*Fritillaria roylei*	**M19**	*Viola serpens*
M10	*Fritillaria stracheyi*	**M20**	*Microstylis muscifera*



Monte Carlo's test for Species environment correlation
Axis 1: 0.967
Axis 2: 0.933
Axis 3: 0.928

p VALUE: 0.0600

Fig 5.3.2d: CCA Showing species environment correlations of taxa within Asteraceae Family in the Greater Himalaya

Codes of Asteraceae used in CCA for alpine region of GH (Ref. Fig 5.3.2d):

Code	Species	Code	Species
A1	*Achillea millefolium*	A22	*Erigeron multiradiatus*
A2	*Anaphalis cuneifolia*	A23	*Gerbera nivea*
A3	*Anaphalis nepalensis*	A24	*Jurinea dolomiaea*
A4	*Anaphalis royleana*	A25	*Lactuca decipiens*
A5	*Anaphalis triplinervis*	A26	*Leibnitzia nepalensis*
A6	*Artemisia demissa*	A27	*Leontopodium himalayanum*
A7	*Artemisia brevifolia*	A28	*Ligularia arnicoides*
A8	*Artemisia myriantha*	A29	*Myriactis wallichii*
A9	*Artemisia santolinifolia*	A30	*Petasites tricholobus*
A10	*Artemisia scoparia*	A31	*Prenanthus violaefolia*
A11	*Aster falconeri*	A32	*Saussurea atkinsonii*
A12	*Aster flaccidus*	A33	*Saussurea auriculata*
A13	*Cicerbita lessertiana*	A34	*Saussurea graminifolia*
A14	*Cicerbita macrorhiza*	A35	*Saussurea leontodontoides*
A15	*Cicerbita cyanea*	A36	*Saussurea obvallata*
A16	*Cirsium verutum*	A37	*Saussurea piptathera*
A17	*Cremanthodium decaisnei*	A38	*Saussurea taraxacifolia*
A18	*Cremanthodium reniforme*	A39	*Tanacetum dolichophyllum*
A19	*Doronicum roylei*	A40	*Tanacetum nubigenum*
A20	*Dubaea hispida*	A41	*Taraxacum officinale*
A21	*Erigeron acer*	A42	*Youngia glauca*

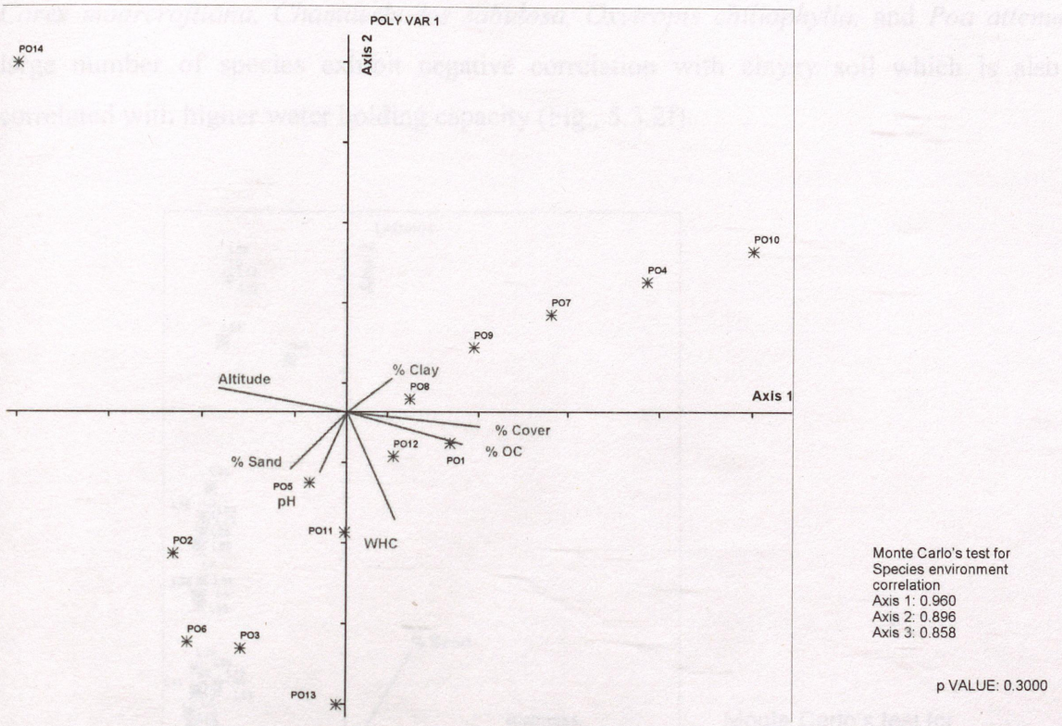


Fig. 5.3.2 e: Environmental Correlates of select taxa within family Polygonaceae in the Greater Himalaya

Codes of Polygonaceae used in CCA for alpine region of GH (Ref. Fig. 5.3.2e):

Code	Species	Code	Species
PO1	*Aconogonum rumicifolium*	**PO8**	*Polygonum emodi*
PO2	*Aconogonum tortuosum*	**PO9**	*Polygonum macrophyllum*
PO3	*Bistorta affinis*	**PO10**	*Polygonum plebeium*
PO4	*Bistorta amplexicaulis*	**PO11**	*Oxyria digyna*
PO5	*Bistorta vivipara*	**PO12**	*Rumex acetosa*
PO6	*Koenigia nepalensis*	**PO13**	*Rheum australe*
PO7	*Persicaria polystachya*	**PO14**	*Rheum moorcroftianum*

The CCA output from the Trans-Himalaya showed an interesting trend. Several species showed strong correlation with high soil moisture, % OC and % N e.g., *Halerpestes tricuspis, Knorringia pamirica, Oxytropis hypoglottoides, Pedicularis longiflora*, *Halerpestes sarmentosa, Scirpus pumilus* and several species of *Carex.* Other species such as *Glaux maritima, Triglochin maritima* and *Blysmus compressus* showed strong correlation with marsh meadows and high soil pH. Third group of species showed stronger correlation with the silt and clayey soil. These are

Carex moorcroftiana, Chamaerhodos sabulosa, Oxytropis chiliophylla, and *Poa attenuata*. A large number of species exhibit negative correlation with clayey soil which is also auto-correlated with higher water holding capacity (Fig., 5.3.2f).

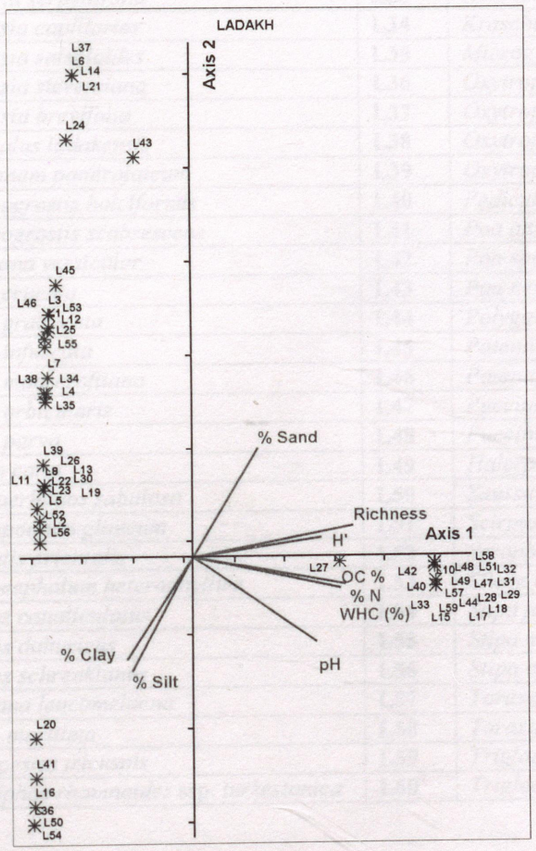


Fig. 5.3.2 f: CCA output showing species – environment correlations in the Trans-Himalaya.

Codes used in CCA for selected species of Trans-Himalaya (Ref: Fig. 5.3.2 f)

Code	Species	Code	Species
L1	*Elymus longiaristatus*	L31	*Knorringia pamirica*
L2	*Alyssum canescens*	L32	*Kobresia capillifolia*
L3	*Arenaria serpyllifolia*	L33	*Kobresia schoenoides*
L4	*Artemisia capillaries*	L34	*Krascheninnikovia ceratoides*
L5	*Artemisia salsoloides*	L35	*Microgynaecum tibeticum*
L6	*Artemisia sieversiana*	L36	*Oxytropis chiliophylla*
L7	*Artemisia brevifolia*	L37	*Oxytropis hypoglottoides*
L8	*Astragalus ladakensis*	L38	*Oxytropis microphylla*
L9	*Polygonum pamirolaicum*	L39	*Oxytropis tatarica*
L10	*Calamogrostis holciformis*	L40	*Pedicularis longiflora*
L11	*Calamogrostis scabrescens*	L41	*Poa attenuata*
L12	*Caragana versicolor*	L42	*Poa species1*
L13	*Carex cruenta*	L43	*Poa nemoralis*
L14	*Carex gracilenta*	L44	*Polygonum sibiricum*
L15	*Carex infuscata*	L45	*Potentilla bifurca*
L16	*Carex moorcroftiana*	L46	*Potentilla nivea*
L17	*Carex orbicularis*	L47	*Pucciniella distans*
L18	*Carex parva*	L48	*Pucciniella himalaica*
L19	*Carum carvi*	L49	*Halerpestes sarmentosa*
L20	*Chamaerhodos sabulosa*	L50	*Saussurea glanduligera*
L21	*Chenopodium glaucum*	L51	*Scirpus pumilus*
L22	*Clematis orientalis*	L52	*Scrophularia dentata*
L23	*Dracocephalum heterophyllum*	L53	*Silene caespitella*
L24	*Elymus canaliculatus*	L54	*Stipa jacquemontii*
L25	*Elymus dahuricus*	L55	*Stipa mongholica*
L26	*Elymus schrenkianus*	L56	*Stipa orientalis*
L27	*Gentiana leucomelaena*	L57	*Taraxacum armerifolium*
L28	*Glaux maritima*	L58	*Taraxacum officinale*
L29	*Halerpestes tricuspis*	L59	*Triglochin maritima*
L30	*Hippophae rhamnoides* ssp. *turkestanica*	L60	*Triglochin palustris*

5.4. Vegetation Dynamics and Successional Trends

Along the gradient of geo-morphological evolution in the higher Himalaya, various factors operate at different spatio-temporal scales. At the micro-topographic scale, change in the position of a sliding rock or addition of another boulder due to gravity induced erosion could make a big change. Likewise, snow deposition pattern, the daily freeze – thaw cycle, disturbances due to herbivory and inter-annual climate variation could alter the course of vegetation development. At larger spatial scales avalanches, debris flow and retreating glaciers provide larger substrates for colonization by specialized plants. At a landscape level at a larger temporal scale the events such as climate change and glaciations make big differences. Causative factors leading to dynamics of vegetation and alpine landscape are

shown in Fig. 5.4.

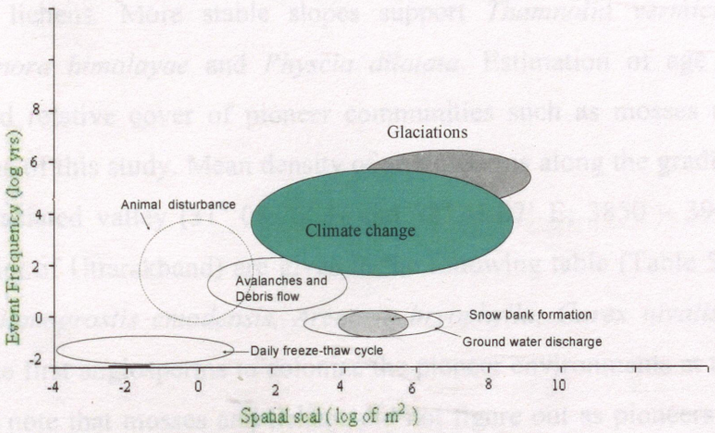


Fig. 5.4. Spatial and temporal domains causing landscape and vegetation dynamics in the alpine areas (after Walker *et al.* 1993).

The above framework gives an idea how vegetation and landscape dynamics in the alpine region could be studied using a hierachical Geographic Information System (HGIS) at various alpine sites in the long run. A few long term studies on such aspects are available from the western countries (e.g., Evans 1989, Weisberg *et al.* 1995, Hart 2001, Einar 2002, and Jones 2003). Even though vegetation changes in the alpine areas are extremely slow, certain changes especially around the treeline, snowline and terminal moraines could be detected within a few decades. Invasion of woody elements at lower alpine slopes in the Valley of Flowers, and Nandadevi NPs, subsequent to protection from livestock grazing (since 1982), show that changes induced climatically and by human activities are inevitable and they need to be studied much more rigorously. The vegetation in the Trans-Himalaya is strongly influenced by climate and livestock grazing. Examples of recent natural changes in the vegetation of this region are lacking.

Along the gradient of pioneer habitats and well established landscapes e.g., terminal and lateral moraines and at freshly formed landscape units closer to main central thrust (MCT),

one can trace a few trajectories of primary succession. The only organisms known to colonize the primary habitats are the lichens. The common lichens on stable moist rocky or pebbly substrate at these altitude are *Lecanora muralis, Rhizoplaca peltata, Phaeophyscia constipate, Umblicaria virginis* and *Xanthoria elegans*. Maximum lichen cover at these altitudes are seen on relatively flat and moist, stable slopes. Scree and morainic slopes had least cover of lichens. More stable slopes support *Thamnolia vermicularis, Cetraria potaninii, Lecanora himalayae* and *Physcia dilatata*. Estimation of age of any pioneer environment and relative cover of pioneer communities such as mosses and lichens was beyond the scope of this study. Mean density of angiosperms along the gradient of landscape stability in a glaciated valley (31° 08.76' N and 78° 41.07' E; 3850 – 3900 m; Kyarkoti, Uttarkashi district of Uttarakhand) are given in the following table (Table 5.4 a). The study reveals that *Calamogrostis emodensis, Arenaria bryophylla, Carex nivalis* and *Epilobium latifolium* are the first angiosperms to colonize the pioneer environments at these altitudes. It is interesting to note that mosses and lichens did not figure out as pioneers on the morainic slopes. Slightly older and stable sites had *Anaphalis nubigena, Oxyria digyna, Myricaria prostrata* and *Festuca valesiaca*. More stable and old moraines had higher density of *Persicaria polystachya, Aconogonum tortuosum, Carex nubigena* and *Potentilla argyrophylla*. More advanced or stable landscape units represented a mosaic of primary and secondary seral trajectories. Such sites, presumably more than 100 years have mixed herbaceous as well as woody formations depending upon the soil thickness. The woody species away from the terminal moraine were *Betula utilis, Lonicera myrtillus* and *Juniperus indica*.

Proportions of organic carbon and C/N ratio in the soil along the gradient of landscape stability can also be used as surrogates for relative age of vegetation. Pioneer environments are largely characterized by inorganic substrate. OC and C/N ratio from a few sites representing different species and communities have been compared in Table 5.4b. It reveals that sites dominated by *Leontopodium himalayanum, Juncus leucomelas, Calamogrostis emodensis* and *Saxifraga pulvinaria* had least % OC (<0.9 %) and relatively low C/N ratio (<3.00). Among the herbaceous and graminoid communities highest % OC were seen under *Danthonia cachemyriana* (5.82 – 8.29), *Kobresia nepalensis – Cassiope fastigiata* (9.37 –

11.44) and *Rumex nepalensis – Impatiens sulcata* (9.62 – 21.56) communities. Range of C/N ratios for these communities were 7.29 – 12.23, 7.29 – 12.23, and 4.89 – 7.35 respectively. Considering both the parameters, *Kobresia nepalensis – Cassiope fastigiata* formations qualify to be closer to climax community in the GH meadows.

Table 5.4a. Mean density (individuals m^{-2}) of herbaceous species across the gradient of landscape stability in a glaciated valley (Kyarkoti), Western Himalaya

Site History--> / Species	Terminal Moraine	Stable lateral moraine	Old Moraine	Old, stable moraine	Intermediate slope	Stable slope	Stable slope-II	Stable slope-III
Arenaria bryophylla	0.5	0	0	0	0	0	0	0
Calamogrostis emodensis	3	9.2	0	0.5	0	0	0	0
Carex nivalis	1.2	0	0	0	0	1.9	0	0.6
Epilobium latifolium	5	4	0	0	0	0	0	0
Anaphalis nubigena	0	1.2	2..5	0	0	0	0	1.7
Anaphalis royleana	0	2.6	0	0	0	0	0	1.1
Festuca valesiaca	0	1.9	0	1.7	0.4	0	0	0
Myricaria prostrate	0	2.8	0	0	0	0	0	0
Oxyria digyna	0	0.2	0	0	0	0	0	0
Persicaria polystachya	0	0.6	0	0	0	0.8	0.2	2.1
Aconogonum tortuosum	0	0	0.4	0.8	0	0	0	0
Aster flaccidus	0	0	3	0	0	0	0	0
Cicerbita lessertioides	0	0	0.2	0	0	0	0	0
Carex nubigena	0	0	11.1	10.5	0	0	0	0
Prenanthus violaefolia	0	0	0.4	0	1.2	2.5	0.8	0
Arenaria festucoides	0	0	0	0.2	0	0	0	0
Potentilla argyrophylla	0	0	9.8	7.7	0	0	0	0
Sibbaldia cuneata	0	0	0	24	0	0	0	0
Anemone polyanthes	0	0	0	0	4	0	0	1.4
Bupleurum longicaule	0	0	0	0	0.1	0	1.6	0
Corydalis cashmeriana	0	0	0	0	0.8	0	0	0
Cyananthus lobatus	0	0	0	0	15	0	0	0
Dactylorhiza hatagirea	0	0	0	0	0.3	0.5	0.3	0.2
Dryopteris barbigera	0	0	0	0	1.4	0	0	0
Epilobium royleanum	0	0	0	0	0.3	0.1	1.8	0
Fritillaria roylei	0	0	0	0	0.8	0.4	3.9	0
Gagea lutea	0	0	0	0	0.1	0.2	0	0
Geranium wallichianum	0	0	0	0	8	16.4	0.3	1.3
Iris kumaonensis	0	0	0	0	1.6	0	0	9.6
Morina longifolia	0	0	0	0	1.8	0	0	0
Nomocharis oxypetala	0	0	0	0	2.8	0	0.1	0
Phlomis bracteosa	0	0	0	0	1.6	0.2	0	0.8
Potentilla atrisanguinea	0	0	0	0	2.8	6.7	0	0.5
Saussurea piptathera	0	0	0	0	0.3	0	1.6	0
Selinum vaginatum	0	0	0	0	3	6.4	4	0
Codonopsis rotundifolia	0	0	0	0	0	0.4	0	0
Osmunda claytoniana	0	0	0	0	0	0	8.6	0
Saussurea auriculata	0	0	0	0	0	0	2.5	0
Selinum wallichianum	0	0	0	0	0	5.9	0	0.4
Bistorta vivipara	0	0	0	0	0	0	0	2.2
Cassiope fastigiata	0	0	0	0	0	0	0	0.3
Kobresia nepalensis	0	2.3	0	0	0	0	0	5.1
Lonicera myrtillus	0	0	0	0	0	0	0	2
Betula utilis	0	0	0	0	0	0	0	1
Juniperus indica	0	0	0	0	0	0	0	5
Total % Ground Cover	**10**	**45**	**80**	**75**	**90**	**95**	**96**	**85**

Table 5.4 b: % organic carbon and C/N Ratio in the alpine soil representing various species and communities in the Greater Himalaya

SN	Commuity / Species	% Organic Carbon	C/N Ratio*
1.	*Leontopodium himalayanum*	0.20	1.67
2.	*Juncus leucomelas*	0.64	2.03
3.	*Calamogrostis emodensis*	0.84	2.40
4.	*Saxifraga pulvinaria*	0.95	2.88
5.	*Epilobium latifolium – Poa alpina*	1.03	5.15
6.	*Circaea alpina – Kobresia duthiei*	1.35	5.87
7.	*Calamogrostis emodensis – Bistorta affinis*	2.86	6.81
8.	*Agrostis pilosula – Poa alpina*	3.43	5.91
9.	*Fragaria nubicola – Galium acutum – Viola biflora*	3.90	8.30
10.	*Cortia depressa – Poa alpina*	4.66	3.50
11.	*Senecio laetus - Ranunculus hirtellus*	6.85	6.80
12.	*Persicaria polystachya*	6.89 – 10.66	6.50 - 7.10
13.	*Danthonia cachemyriana*	5.82 – 8.29	7.29 – 12.23
14.	*Kobresia nepalensis – Cassiope fastigiata*	9.37 – 11.44	11.84 – 13.75
15.	*Rumex nepalensis – Impatiens sulcata*	9.62 – 21.56	4.89 – 7.35

* Range of % OC and C/N ratio for communities 12 – 15 based on 4 sites each.

Per cent cover of common species at various sites representing old field succession in Johar Valley, Uttarakhand is presented in Table 5.4c. First year fallows were dominated by *Capsella bursa-pastoris, Chaerophyllum villosum, Arenaria serpyllifolia, Taraxacum officinale, Trigonella emodi, Typhonium sagittatum, Plantago depressa, Nepeta laevigata* and *Rumex nepalensis*. Most of these species are annual or biennial and ruderal in nature. *Capsella bursa-pastoris* had highest cover at such sites (36.1 %). The intermediate age classes (4-10 year fallows) had a large number of ruderal as well as perennial species such as *Calamintha umbrosa* (6.5 – 22 %), *Anaphalis royleana* (5-7 %), *Potentilla cuneifolia* (0.1 – 0.2 %) and *Astragalus candolleanus* (0.2 – 1.8 %). The older fallows (20 – 50 years) have *Thymus linearis*, *Iris kemaonensis*, *Danthonia cachemyriana* and a few woody elements e.g., *Artemisia santalinifolia*. The late seral stages or natural meadows had preponderance of other

shrubs e.g., Cotoneaster microphyllus, Juniperus indica, *Berberis jaeschkeana* or herbs such as *Thalictrum alpinum, Jurinea dolomiaea*, and *Ranunculus hirtellus* depending upon the inherent properties of soil, exposure, grazing pressure and moisture regimes.

Table 5.4c: % Cover of major species with respect to various alpine sites representing gradient of old field succession in Johar Valley, Uttarakhand

Site History--> / Species	1 yr. Fallow	4 yr. Fallow	10 yr. Fallow	20 yr. Fallow	20 yr. Fallow-II	~ 50 yr. Fallow	~ 50 yr. Fallow-II	~50 yr. Fallow-III	80 yr. Fallow	80 yr. Fallow-II	Natural Meadow	Natural Meadow-II
Anemone rivularis	0.1	0.2	0.4	0.7	0	0	0	1.5	0	0	1.2	0
Arenaria serpyllifolia	3.4	3.8	3.8	2.5	0	0	0	0	0	0	0	0
Capsella bursa-pastoris	36.1	0	0	0	0	0	0	0	0	0	0	0
Chaerophyllum villosum	0.5	2	1.3	4.1	5.6	0	0	0	0	0	0	0
Equisetum arvense	4.2	1.9	7.1	0	3.3	0	0	2.2	0	0	0	0
Artemisia scoparia	6.1	0.3	0	0	2.6	0	0	0	0	0	0	0
Taraxacum officinale	6.9	5.7	2.8	1.8	3.5	0.7	1.6	2.1	0.3	0	0	16.1
Trigonella emodi	3.2	8.4	1.2	0	0.4	0.7	0	4.6	0	0	0	0
Typhonium sagittatum	8.9	0.6	3.8	0	0	0	0	0	0	0	0	0
Nepeta laevigata	0.3	1.3	13.1	5.7	5.6	6.2	7.5	0	4.2	0	0	0
Rumex nepalensis	0.5	0	0.2	0	0.2	0	0	0	0	0	0	0
Plantago depressa	0.4	0	2.9	0	0	0	0	0	0	0	0	0
Anaphalis royleana	0	5.9	7.6	2.5	0	0	0	0	4.2	5.4	0	0
Astragalus candolleanus	0	0.2	1.8	3.8	1	1	6.7	0	6.5	0	0	0
Bupleurum longicaule	0	0.4	0.1	1.1	0	0.5	0	0	0	0	0	0
Calamintha umbrosa	0	6.5	22.9	13.4	1.1	0	0	0	0	0	0	0
Dactylis glomerata	0	2.5	2.3	1.2	0	0	0	0	0	0	0	0
Euphrasia himalayica	0	70.2	175	15.6	0	0	0	20.6	0	0	0	0
Festuca valesiaca	0	9.9	0.6	5.6	34.3	6.6	16	0	9	11.1	4.4	0
Potentilla cuneifolia	0	0.1	0.2	18.2	0	0	0	0	0	0	0	0
Cynoglossum wallichii	0	0	1.8	1.5	0	0	0	0	0	0	0	0
Berberis jaeschkeanus	0	0	0	0.4	0	0	0	0	0	2.4	1.6	0
Juniperus communis	0	0	0	0.2	0	0	0	0	0	0	0	0.3
Thymus linearis	0	0	0	9	1.1	0.8	9.9	0	11.4	4.5	1.8	0
Artemisia santolinifolia	0	0	0	0	0.5	4.2	0	0	0	0	0	0
Danthonia cachemyriana	0	0	0	0	0	0	3.4	0	7	1.2	1.1	0
Allium wallichii	0	0	0	0	0	0	0	0	0	1.7	0	0
Androsace globifera	0	0	0	0	0	0	0	0	0.3	0	0	0
Bistorta vivipara	0	0	0	0	0	0	0	0	0	0	23.1	10.7
Cotoneaster microphyllus	0	0	0	0	0	0	0	0	0	0	1	0
Cyananthus lobatus	0	0	0	0	0	0	0	0	0	0	0	0.6
Cyananthus microphyllus	0	0	0	0	0	0	0	0	0	4.1	0	0
Euphorbia stracheyi	0	0	0	0	0	0	0	0	0	0	3.2	0
Iris kumaonensis	0	0	0	0	0	0	0	0	0	7.4	17.3	42.6
Jurinea dolomiaea	0	0	0	0	0	0	0	0	0	0	4.3	8.9
Ranunculus hirtellus	0	0	0	0	0	0	0	0	0	1.3	2	4.8
Thalictrum alpinum	0	0	0	0	0	0	0	0	0	2.2	8	0

5.6 Discussion

Studies at global scale have shown that there are linear and curvilinear correlative links among temperature, precipitation, productivity, plant interactions, spatial pattern and richness

in alpine ecosystems (Kikvidze *et al.* 2005). Zimmermann & Felix (1999) have opined indicator species within the communities are better for mapping alpine grasslands in Newzealand than communities as a whole. Given that the Greater and Trans-Himalaya represent two distinct climatic zones, the species distribution pattern, structure and composition of major growth forms viz., woody, herbaceous, graminoids and lower plants are expected to be different. Of the two zones, the GH alpine areas are relatively mild and receive higher precipitation but exhibit much sharper altitudinal gradients within short distances. Micro-topographic variations and the sharp altitudinal gradient add to the complexity making it difficult to single out variables defining the relationship between environmental parameters and species response. Importance of soil nutrients, soil Nitrogen, snow and site history have been established in several alpine regions outside Himalaya (Addleman & Ward 1984, Atkin & Collier 1992, Bauer 1990, Bowman 1992, Walker & Walker 1991 and May & Webber 1982).

Overall cover of ground vegetation showed an expected trend in the GH. However, in the TH, a slight increase in the ground cover with increase in altitude till the beginning of nival zone underlines the significance of precipitation and soil moisture rather than altitude alone. Similarly, herbs and graminoids showed different responses with increasing altitude in GH and TH. These responses relate to different adaptive strategies as well as evolutionary history with grazing ungulates (Rawat & Adhikari 2006). When compared with perennial herbs, graminoids are better adapted to grow in shallow and nutrient poor soils, especially in semi-arid environments as they have fibrous roots which can easily absorb moisture from the surface. Bock *et al.* (1995) have established similar relationships among the graminoids and other growth forms in central Caucassus.

The alpine habitats are the most heterogeneous and dynamic and they exhibit a complex mosaic of primary and secondary succession. While meadows and several scrub communities can be regarded as climatic climaxes, a large number of intermediate and edaphic types can be recognized at landscape level. Therefore, it is often difficult to trace the path of Clementsian succession everywhere. Several communities are sensitive to micro-topographic changes (Kikuchi & Ohba 1988) making the successional studies more difficult. Based on various stages

of landscape stability Kala *et al.*, (1998), have suggested two parallel courses of succession for the alpine meadows of the VOF near treeline (3500±200 m asl). These are: (a) Meadow succession on the south facing slope beginning from the moss - lichen (pioneer) stage to herbaceous formations e.g., *Cyananthus - Kobresia - Anaphalis* association and *Danthonia cachemyriana* patches form the climatic climax on such slopes, (b) Forest succession on the north and north eastern (moist) slopes, leading to growth of perennial shrubs and species which thrive well under heavy snow i.e. snow-bed communities. Some of these shrubby intermediate communities eventually give way to birch - rhododendron (*Betula utilis - Rhododendron campanulatum*) community on more stable slopes with deeper soil.

Secondary succession after the abandonment of agriculture may differ in its trend when compared with the abandonment of livestock camping in alpine areas. Rikhari et al. (1993) identified two seres in Baidini-Ali meadows of Garhwal Himalaya after the shifting of livestock camps: (i) *Trachydium* forb seres, (ii) Forb-*Danthonia* seres. In both the seres, the relative importance of tall forbs decreased from younger to older sites. In the latter seres graminoids increased along the age gradient. Decline of tall, opportunistic herbs and increase in short growth forms with advancing succession explain the decrease in biomass and increase in stem density along the gradient of secondary succession at the sites studied by these authors. In two high altitude protected areas of Uttarakhand viz., Valley of Flowers and Nanda Devi NP, where livestock grazing (and camping) has been banned since 1982, the camping sites and tall forb communities (<3500 m asl) exhibit steady decline of nitrophilous species such as *Rumex nepalensis, Persicaria polystachya, Impatiens sulcata* and *Urtica dioica* and better regeneration of woody species such as *Lonicera myrtillus, Ribes glaciale* and *Betula utilis*. Short forbs and *Danthonia* communities in the Valley of Flowers and Nandadevi NP are confined to steeper south facing slopes and it is unlikely that tall forbs around 3500 m would be replaced by short forbs and tussock forming graminoids such as *Korbresia* over the course of secondary succession.

Mosses and lichens are regarded as pioneers of primary succession in the alpine habitats. These life forms, however, do not colonize the all barren surfaces with equal vigor and abundance. Depending upon the availability of moisture and stability of the surface, these

groups may occupy primary as well as secondary substrates. Adhikari (2003), in a survey of alpine vegetation in core area of Nanda Devi NP, found that mosses were completely absent in flat meadows and in eroded and morainic slopes (Table 5.5a):

Table 5.5a: Moss and lichen cover at various habitat types in the core area of Nanda Devi NP (After Adhikari 2004).

SN.	Habitat Type & Altitude (m)	% Mosses	% Lichen
1	Flat Meadow (4323)	0.0	1.0
2	Stable Slope (4316)	1.0	21.0
3	Marsh Meadow (4367)	0.0	0.0
4	Eroded slope (4401)	0.0	12.0
5	Plateau (4403)	7.5	15.0
6	Higher Slope (4480)	1.7	16.3
7	Morainic slope (4501)	0.0	10.0

Contrary to the Clementsian model suggested by a few authors for the Himalayan alpines, Mishra (1998) has proposed catastrophic model to study the dynamics of vegetation and predict the changes in the vegetation communities for the trans-Himalayan rangelands. An experimental study dealing with this aspect is underway in Kibber Wildlife Sanctuary (C. Mishra, *personal communication*). Jacquz & Patten (1996) have reported that on a dry moraine in the northern parts of Nepal Himalaya *Chesneya nubigena,* a stunted legumionous shrub forms a climax formation and several other herbs grow in its association. Further studies on succession in alpine areas should address mechanisms and processes of species replacement at specific locales. Aspects of facilitation and competition along the gradients of landscape stabilization in various communities merit investigation.

5.7 Conclusion

The cover of various growth forms (shrubs, herbs, graminoids, mosses and lichens) varies considerably in the alpine areas of GH and TH. With increase in altitude there was a steady decline in overall vegetation cover in the GH but there was a reverse trend in the TH within the zone of alpine vegetation. The graminoids had higher cover in the TH as compared to GH which is attributed to the evolutionary history of grazing by native ungulates and the

adaptability of graminoids to poorer soil and semi-arid conditions. In the GH, shrubs, herbs, graminoids, mosses and lichens had highest cover in the N, W, S/SE and NW aspects respectively. Based on Canonical Correspondence Analysis for species – environment relationships, it emerged that most woody species are strongly correlated with the deeper soil at lower altitudes. Most ferns occupy the mixed herbaceous formations (moist meadows). Further, except *Allium victorialis* and *Arnebia benthamii* most high value medicinal and aromatic plants showed a negative correlation with high soil Nitrogen and organic carbon indicating that nutrient rich soil may not favour such species and may be out competed at such sites. Members of Asteraceae showed more convergence of habitat types as compared to Polygonaceae, which occurred in a wide range of environmental conditions.

The landscape units and habitats in the alpine areas are distinctly more dynamic due to fragile nature of the mountains and receding glaciers. However rate of vegetation change here is slower as compared to temperate and tropical regions. Long term studies following a hierarchical Geographical Information System at various spatio-temporal scales would be essential to understand the vegetation dynamics in this area. Trajectories of primary and secondary succession within certain gradients of environment are traceable but most alpine areas exhibit a complex mosaic of successional stages influenced by biotic and abiotic factors. Per cent organic carbon and C/N ratios in the soil are reliable indicators of early and late seral stages.

* * *

Plate 10: ALPINE PLANT ADAPTATIONS -III



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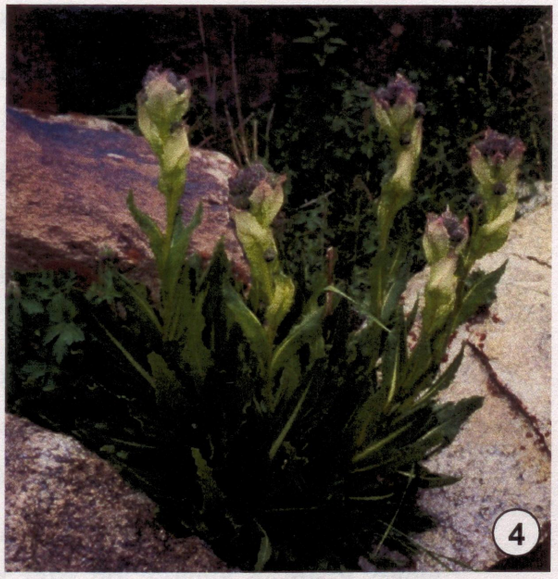
1. ***Thamnolia vermicularis*, a terricolous lichen around sub-nival zone**
2. ***Thylacospermum caespitosum*, *Saussurea gnaphalodes and Carex* species growing together – a case of facilitation**
3. **A Hemispheric Cushion of *Androsace globifera*, Greater Himalaya**
4. **Specialized growth form with waxy needle leaves – *Sassurea graminifolia***

PLATE 10: THREATENED, RARE AND ENDEMIC PLANTS - i









1. ***Dactylorhiza hatagirea*** **(Palm orchid) threatened due to over exploitation for medicine**

2. ***Falconeria himalaica*** **– endemic to Western Himalaya**

3. ***Inula rhizocephala*** **– Restricted Distribution, narrow habitat**

4. ***Saussurea schultzii*** **– Endemic to Western Himalaya - *All Photos – G.S. Rawat***

6.0 PATTERNS OF RARITY AND ENDEMISM

"Rarity is one of those concepts that suffuses our culture; it defies precise definition and when used by the scientists it is often given a spurious accuracy to satisfy our need for precision.."

... V.H. Heywood (1988)

6.1 Introduction

Contemporary literature on the Himalayan Botany is frequented by new reports and extended distribution ranges, especially from floristically under-explored areas (e.g., Ghildiyal 1956, Singh & Gohil 1972, Semwal *et al.* 1981, Semwal 1982, Negi 1983, Farille 1984, Seybold & Kull 1985, Rawat & Pangtey 1987b, c, Wadhwa *et al.* 1987, Balodi & Singh 1988, Naithani 1988, Punetha 1989, Singh & Hajra 1991, Punetha & Kholia 1998). The floristic accounts often give index of abundance for various species such as rare, uncommon, frequent and common. However, in the absence of population estimation, micro-habitat specificity and extent of habitat especially in case of rare species it is difficult to ascertain the status at a regional scale. Some species may be rare in certain parts of their geographic range but common in others (diffusively rare) and others may be rare everywhere i.e., suffusively rare (Schoener 1987). Habitat specificity, taxonomic distinctness and persistence through ecological or evolutionary time are the additional variables which determine the rarity (Reveal 1981, Gaston 1994, Oostermeijer 1999). IUCN (1994) used 'Rare' as one of the categories for red listed plant species which were defined as *'taxa with small world populations that are not at present endangered or vulnerable but are at risk...these taxa are usually localized within restricted geographical areas or habitats or are thinly scattered over a more extensive range'*. This definition was used by Nayar & Sastry (1990) to assess the threat categories of Indian plants. However, the 'Rare' category was subsequently dropped from the new IUCN threat categories.

At a large scale, the concept of rarity is closely allied to that of endemism. Species are endemic to an area if they occur within it and nowhere else. They tend to have small range size and abundance than those species which are not endemic. Narrow endemism

refers to occurrence of a taxon in one or a few small populations confined to a few localities (Krukeberg & Rabinowitz 1985). Depending upon the ways by which the species gets confined to a single or a few localities several forms of endemism are recognized. The major types are 'Neoendemic' or youthful species and 'Palaeoendemic' or relict species (Stebbins & Major 1965). A high degree of endemism is usually correlated with age and isolation of an area and with the diversification of its habitats as these factors influence both evolution (formation of new endemics) and survival or production of relic endemics. Endemics with more than one disjunctive populations are most likely relict while endemics confined to a single population can be either paleao- or neoendemics. In groups of related species, diploids are considered older (schizoendemics) than derivative low polyploids, while both high polyploids and diploids could be palaeoendemics (Stebbins & Major 1965). However, neither genetics, ecology nor history alone would be sufficient to explain the origin of endemic taxa.

Insufficient field records and taxonomic biases pose major problems in ascertaining the status of rare and endemic plants. The taxa described based on a single collection without definite locality and information on population size remains ambiguous in terms of their status on rarity and endemism for a long period. This is particularly true for the taxa which have been collected closer to international border beyond which physical accessibility to area and botanical literature may be difficult. A large number of alpine plants in the Himalaya exhibit micro-habitat specificity e.g., boulder and rock crevices, talus, caves, marsh meadows, moist rocks and riverine scrub. Species with specialized habitats known from small geographic locations without clear endemicity have also been referred as microarealophytes (Dickore & Nusser 2000). Samant *et al.* (2005) analysed diversity and endemism within Himalayan Papaveraceae and Fumariaceae and concluded that Trans- and North-west Himalaya have the highest diversity of endemic species within these families and the altitudinal zone of 3001 – 4500 m as major areas for their occurrence. As the mountains taper at higher altitudes, there is a decrease in the availability of habitats. Hence altitude and rare plant habitats tend to be auto-correlated in the Greater Himalaya. On the other hand, extensive plateaus and gently undulating terrain of Trans-Himalaya e.g., Kibber, Sarchu plains, and Changthang plateaus represent

uniform habitats. Here, soil moisture, rather than altitude may be more confounding factor to determine the micro-habitats and distribution of specialized plants. Dickore & Miehe (2002) analyzed the endemism in the flora of Nanga Parbat and found that there are around 51 species in this area which are endemic to Western Himalaya and most of these species are evenly distributed along the entire altitudinal gradient (1100 – 5100 m). These authors concluded that endemic species confined to the low altitudes of Indus gorge may have faced higher degree of taxonomic isolation as compared to those found at higher altitudes.

This chapter deals with the patterns of rarity among alpine plants across the Greater and Trans-Himalaya based on recent surveys and secondary information. The anthropogenic factors causing rarity is beyond the scope this study. Various floristic sub-regions within the region have been compared in terms of total endemics and narrow (local) endemics. The endemic species have also been classified in terms of their habitat specificity. The results have been discussed in the ecological and evolutionary context.

6.2 Material and Methods

Presently, there is hardly any theory or framework for the study of rarity and endemism among plants. For the present study a catalogue of 'rare' species was prepared from the secondary sources (Nayar & Sastry 1990, Aswal & Mehrotra 1994, Hajra *et al.* 1995, Murti 2001, and Singh *et al.* 2002) prior to field surveys. During the field investigation special attention was paid to locate these species, their abundance and habitat characteristics. In addition, data on the species frequency and abundance from different land forms / micro-habitats across the Greater (n=125) and Trans-Himalaya (n= 213) were pooled to check patterns of species distribution (not necessarily rarity). Total Frequency and number of species in each category were plotted across Greater and Trans-Himalaya. All species which had frequency < 1% were compared with the existing list of rare species. Such species have further been grouped into various categories based on the geographical range, habitat specificity and local population size following

Rabinowitz (1981). Remarks on the selected species representing various categories have been given.

Based on a thorough review of literature, a list of species endemic to Western Himalaya has been prepared. This includes narrow (single locality) as well as broad endemics i.e., found in a larger geographical region irrespective of political boundaries. It is pertinent to note that the erstwhile Western Himalaya includes Pakistan part of Kashmir. In addition, literature available on the alpine regions of adjacent phytogeographic regions were consulted (e.g., Yamazaki 1988, Ohba 1989, Xiao 1995, Woods 1999). For each endemic species, known localities, distribution in other sectors of Western Himalaya and threat status as given by Nayar & Sastry (1990) have been given. Number of endemic taxa within selected families in the Himalayan region and alpine areas of Western Himalaya have been compared. This analysis is largely literature based with some information on abundance collected from the field during present investigation.

6.3 Patterns of Rarity among Vascular Plants

A total of 514 species were recorded at 125 sampling sites in the Greater Himalaya. Of these, 220 species were found only at one sampling site each (Frequency = 1). Likewise, in the Trans-Himalaya 270 species were encountered within 213 plots of which, 65 species occurred only at one sampling site each. Frequency distribution of all species within Greater and Trans-Himalaya are shown in Fig. 6.3a.

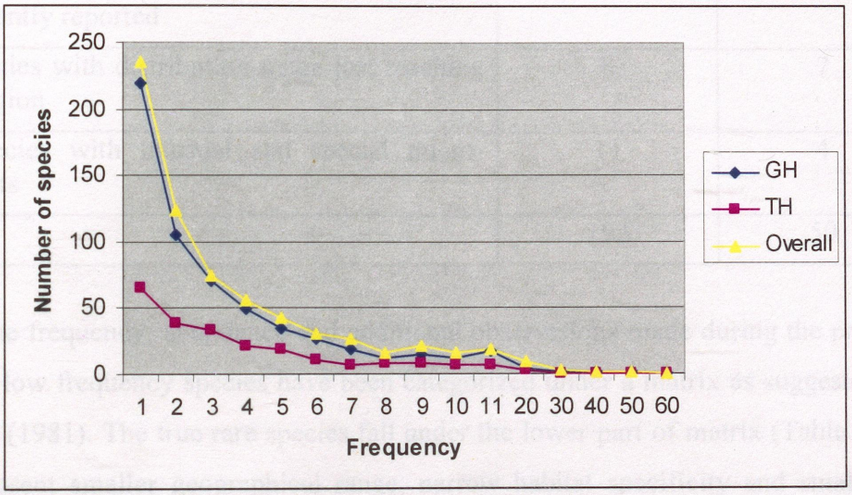


Fig. 6.3a. Frequency distribution of species in alpine region of Greater and Trans-Himalaya [GH = Greater Himalaya; TH = Trans-Himalaya].

Further analysis of the species having low frequency (1%) revealed that at least 8 species (four each in the Greater and Trans-Himalaya) have been identified as red listed species by Nayar & Sastry (1990). These species include *Allium consanguineum, Carex borii, Cyananthus integer, Eremurus himalaicus, Euphorbia sharmae, Hedysarum microcalyx, Pulsatilla wallichiana,* and *Saussurea bracteata*. Five species under the category of low frequency have been reported from the region either during last 10 years or for the first time in this study (e.g., *Duthiea nepalensis, Duthiea bromoides, Astragalus kongrensis, Herminium josephii* and *Huperigia selago*). Other species fall either in the category of micro-habitat specialists or species with distribution range barely reaching the limits of Western Himalaya (Table 6.3a). It is noteworthy that of about 1810 species of vascular plants recorded from the alpine region of Western Himalaya 45 species are listed under the existing Red list of Indian plants (Indeterminate - 18, Vulnerable 5, Endangered – 8, Rare – 11 and Critically Endangered – 3).

Table 6.3a. General break up of low frequency (<1 %) alpine species in the Greater and Trans-Himalaya based on the recent surveys.

SN	Category	Greater Himalaya	Trans-Himalaya
1	# species listed in RDB of Indian Plants	4	4

2	# Species not recorded so far from the region or recently reported	5	-
3	# Species with distribution range just reaching the region	8	7
4	# Species with unusual and special micro-habitats	11	4
5	Other	192	50

Based on the frequency, abundance and additional observations made during the present survey, the low frequency species have been categorized under a matrix as suggested by Rabinowitz (1981). The true rare species fall under the lower part of matrix (Table 6.3b) which represent smaller geographical range, narrow habitat specificity and small-non dominant population size. By this criteria *Allium fedschenkoanum, Cyananthus integer, Inula rhizocephala, Lalldhwojia cooperi, Cryptothladia polyphylla, Lagotis globosa, Scorzonera virgata, Adoxa moschatellina* and *Schultzia dissecta* fall under rare species.

Table 6.3b: Patterns of Rarity among alpine plants of Western Himalaya as per the classification by Rabinowitz 1981).

Geographical Range	Habitat Specificity	Local Population size	# Species	Examples
Large	Wide	Large, dominant at place	43	*Juniperus squamata, Rubia cordifolia var., Saussurea aitkinsonii*
		Small, non-dominant	62	*Ajuga brachystemon, Duthiea bromoides, Duthiea nepalensis*
	Narrow	Large, dominant at place	17	*Eremurus himalaicus Meconopsis aculeata Podophyllum hexandrum*
		Small, non-dominant	47	*Christolea himalayensis Dactylorhiza hatagirea Drosera peltata*
Small	Wide	Large, dominant at place	0	-
		Small, non-dominant	5	*Lactuca decipiens, Lactuca graciliflora Saussurea schultzi*
	Narrow	Large, dominant at place	1	*Megacarpaea polyandra*
		Small, non-dominant	13	*Allium fedschenkoanum Cyananthus integer Inula rhizocephala*

6.4 Status of Endemism

A taxonomic and phyto-geographic update on the vascular plants of Western Himalaya reveals that there are about 135 species of vascular plants endemic to the region which forms about 7.45% of total species recorded in the region (Appendix – V). Of these, 20 species are monocots and the remaining are dicots. The endemic species fall under various threat categories as per earlier evaluation i.e., Rare – 7, Vulnerable- 5, Endangered – 3, Indeterminate – 5). 34 species are recently described based on a single collection without much information on the population size. Around 40 species are based on 2-3 collections each from remote localities closer to international borders including parts of undivided Kashmir. The remaining 55% species are based on multiple collections. All the species need population studies and threat assessment as per the latest IUCN criteria. Taxonomically, *Asplenium khullarii*, *Deparia acuta*, *Circaeaster agrestis*, *Berberis kashmiriana, B. petiolaris* and *B. ulicina* and members Ranunculaceae may be treated as Palaeoendemic and most of the other species may fall under neoendemic or microarealophytes. The families with highest number of endemic species in the alpine zone of WH are Scrophulariaceae (19), Asteraceae (14), Fabaceae (13), Poaceae (12), Ranunculaceae (10), and Brassicaceae (9). A comparison of proportionate endemism within the Himalaya and alpine region (Table 6.4a) shows that the alpine areas actually harbour low proportion of endemic species. Fabaceae (37.14%), Asteraceae (21.53%), and Scrophulariaceae (10.91%) showed relatively high per cent endemism in the alpine zone. However, other families such as Berberidaceae and Caryophyllaceae which have 97.46 and 65.28% endemism in the Himalaya reflect very low proportion within alpine region (< 6%). Chloranthaceae and Selaginaceae are the exclusively alpine families.

The total number of endemic species recorded from various floristic sub-regions are shown in Fig. 6.4a. It reveals that Nanda Devi Biosphere Reserve (NDBR) in Uttarakhand and undivided Kashmir have highest number of endemic species (>16 species). Byans valley, Johar – Ralam, Kedarnath WS in Chamoli, Lahaul and western Zanskar have 11 – 15 endemic species each. The total number of broad endemics (West Himalayan) and proportions of narrow endemic species in various floristic sub-regions

are shown in fig 6.4b.

Table 6.4a. Prominent alpine plant families, approximate number of endemic species in the Himalayan region and proportionate endemism within the alpine region of Western Himalaya:

Family	Total Species in India	Approx. no of endemic spp in Himalaya	Endemic spp >3300 m in WH	% endemism in the alpine area
Apiaceae	209	144	3	2.08
Asteraceae	900	65	14	21.53
Berberidaceae	79	77	3	3.89
Caryophyllaceae	121	79	5	6.32
Fabaceae	818	35	13	37.14
Gentianaceae	147	84	4	4.76
Primulaceae	165	80	6	7.5
Ranunculaceae	180	131	10	7.63
Rosaceae	250	176	8	4.54
Saxifragaceae	117	108	1	0.92
Scrophulariaceae	280	174	19	10.91

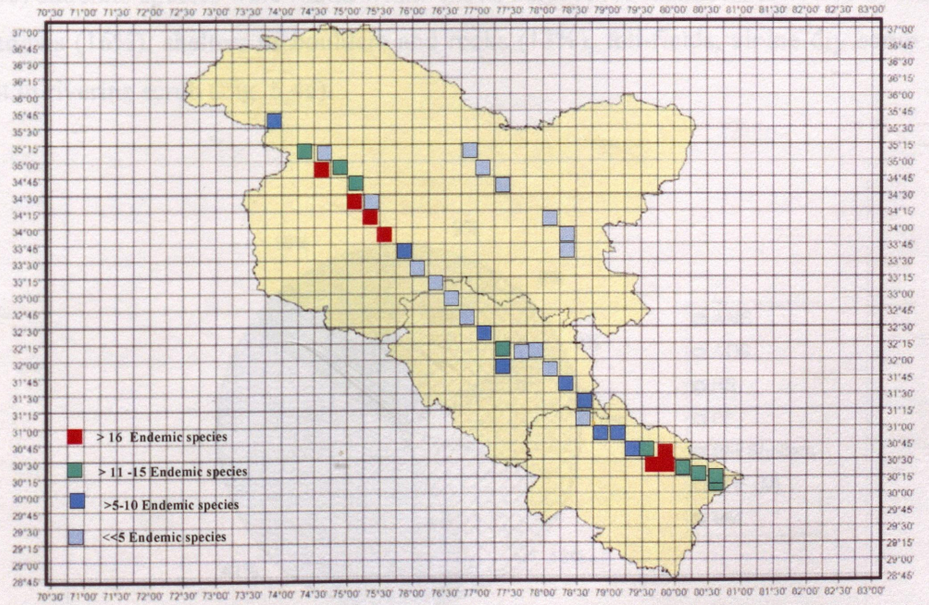


Fig. 6.4a: The number of endemic species reported from different alpine areas of Western Himalaya

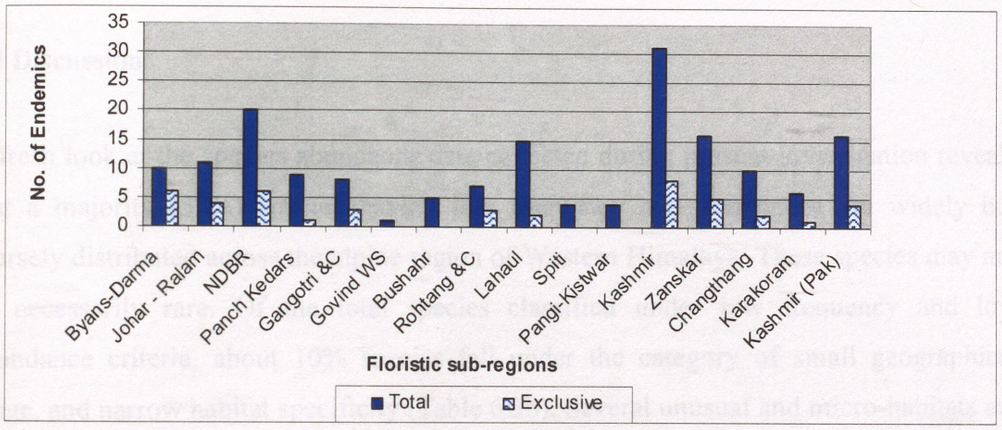


Fig. 6.4b. Total number of endemic species and proportion of narrow (exclusive or local) endemics within various floristic sub-regions of Western Himalaya

A closer look at the reported habitat preference by the endemic species shows that most (41%) endemic species were found within moist herbaceous meadows followed by marsh meadows (16%), shelters of boulders and rocks (13%), fell-fields, alpine dry scrub and least in riverine scrub (Fig. 6.4c).

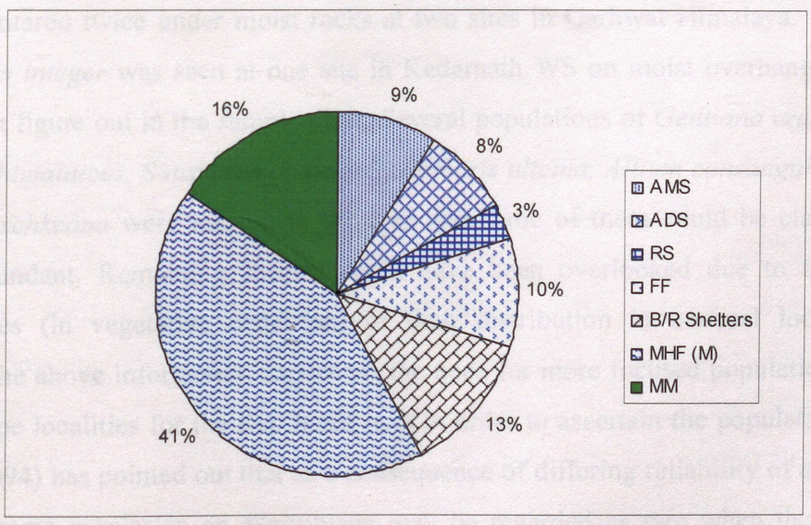


Fig 6.4c. Habitat Characteristics of endemic species [AMS = Alpine Moist Scrub; ADS = Alpine Dry Scrub; RS = Riverine Scrub; FF = Fell Fields with mosses and

lichens; B/R Shelters: boulder and Rock Shelters; MHF = Mixed Herbaceous Formations (Moist); MM = Marsh Meadows].

6.5 Discussion

A fresh look at the species abundance data collected during present investigation reveals that a majority (55%) species having low frequency and abundance are widely but sparsely distributed across the alpine region of Western Himalaya. These species may not be necessarily rare. Of the total species classified under low frequency and low abundance criteria, about 10% species fall under the category of small geographical range, and narrow habitat specificity (Table 6.3b). Several unusual and micro-habitats are likely to have been underrepresented during the present investigation because of extremely large geographical area. Species with smaller geographical range and small-non dominant populations merit further investigations covering micro-habitat requirements and reproductive biology.

Of the 135 endemic species reported in the alpine region of Western Himalaya only 33 species could be located in the field during present investigation. *Circaeaster agrestis* was encountered twice under moist rocks at two sites in Garhwal Himalaya. Similarly, *Cyananthus integer* was seen at one site in Kedarnath WS on moist overhanging rocks and did not figure out in the sample plots. Several populations of *Gentiana crassuloides, Eremurus himalaicus, Saussurea atkinsonii, Berberis ulicina, Allium consanguineum* and *Ferula jaeschkeana* were located in the area and some of them could be classified as locally abundant. Remaining species could have been overlooked due to taxonomic uncertainties (in vegetative condition) or their distribution in unusual localities or habitats. The above information underlines the need for more focused population studies around Type localities for the Red listed taxa in order to ascertain the population status. Gaston (1994) has pointed out that as a consequence of differing reliability of abundance estimates some species in an assemblage may be regarded as rare when they are not (pseudo-rarity) and others may not be regarded as rare when in fact they are (non-apparent rarity).

Chatterjee (1940) estimated that there are 3160 endemic species of vascular plants in the Himalayan region. This number is likely to have changed since then because a large number of species have been added to the flora of the region and several taxonomic groups have been revised. Some of the families representing high level of endemism in the Himalaya are Berberidaceae (98.7%), Saxifragaceae (92%), Ranunculaceae (72%), Rosaceae (74%) and Apiaceae (68.8%). Compared to these figures, the proportions of endemic species within alpine region of WH are very small (Table 6.4a) especially when the proportionate geographical area is quite large. Agakhanyanz & Brekle (1995) and Korner (1999) have opined that high mountain summits may reach greater abundance in the alpine species but they have usually less endemic species. Extreme high altitudes are commonly dominated by otherwise widespread species. Samant & Joshi (2005), while comparing diversity and conservation status of plant species in three highland National Parks (NPs) of WH viz., Nandadevi, Valley of Flowers and Great Himalayan NP have shown that though 73% of the flora in three protected areas were native (Sino-Himalayan) but only about 2% species were endemic.

Studies conducted by Hodgson (1986a, b) in Sheffield, Central Britain, have shown that common species are frequent at sites of high fertility and disturbance and rare species are restricted to less fertile sites, particularly those with calcareous soils. In other words, the common species occupied common, and rare species less common habitats such as islands caused due to presence of certain features or anthropogenic factors (Jacobson *et al.* 1991, Holtmeier & Broll 1992). The author has further stated that though the flora of Sheffield region was initially shaped by climate and edaphic forces, presently the land use appears to be by far the most significant determinant of the commonness and rarity of individual species. Even though, very small proportion of the alpine region in the Western Himalaya has been brought under cultivation, there are other land use practices (see Chapter 7) which have strongly influenced the vegetation and abundance of various species. The seven categories of rare plants identified in the alpine region (Table 6.3b) will have differential response to anthropogenic pressures.

Present analysis reveals that most of the endemic plants (70%) in the alpine area occupy

mesic sites. Even within the dry Trans-Himalayan region the endemic species are mostly confined to moist pockets, fell-fields or in association with woody species which might provide shelter to such plants. This is contrary to earlier observations made by Dhar (2002), who stated that endemic species in the alpine areas occupy drier habitats. Dickore & Nusser (2000) in their account on the flora of Nanga Parbat recorded about 36 endemic species in the alpine zone, of which a majority (72%) species represented mesic or water surplus micro-habitats.

Nandadevi Biosphere Reserve and undivided Kashmir hold special significance in the phytogeography of Western Himalaya. A large number of species have been described from these areas during recent decades. Wide altitudinal and topographic variations coupled with geographical isolation of a few pockets (e.g., Rishiganga gorge) may be attributed to the occurrence of relatively large number of locally endemic species. The narrow endemics remain at one place for one reason or another as they cannot migrate elsewhere. Many species are sedentary in nature as they primarily reproduce by underground rhizomes and may not produce many viable seeds which can be carried by wind, water or animals. They may also be prevented from migrating by barriers of temperature or dryness (Zwinger & Willard 1972).

The Western Himalaya is considered as centre of diversification for a number of genera such as *Carex* (45 species), *Astragalus* (42 species), *Potentilla* (37 species), *Saussurea* (36 species), *Saxifraga* (33 species), *Poa* (32 species), *Pedicularis* (29 species) and *Corydalis* (25 species). Of these, highest degree of endemism is shown by genus *Astragalus* (19%) followed by *Poa* (12%), *Saussurea* (11%), *Potentilla* (8%) and *Carex* (6.66%). *Saxifraga,* a true alpine genus, showed rather low (3%) degree of endemism. Some of the genera such as *Taraxacum* and *Euphrasia* exhibit high ecotypic variation and a large number of species have been described under these genera by van Soest (1963) and Pennell (1943) respectively. It is plausible that such taxa show the insipient stages of speciation and at degree of endemism can be much higher at the level of sub-species and variety. However, biosystematic studies on these taxa would be essential before the nature of their origin is ascertained. In this context, Gentry (1992) states that unless a genus or a family has been

recently monographed, many of its apparently endemic species often turn out to represent taxonomic artifacts resulting from careless or parochial taxonomy rather than true endemics.

6.6 Conclusion

Species with low frequency (1%) and low abundance (<10 individuals in all sites) based on the present survey were categorized as per the matrix of rarity (Rabinowitz 1981). Of the total 188 (20%) such species a majority (>55%) had wide geographical range and wider habitat specificity. Only about 7% species represented small geographical range, narrow habitat specificity and small non-dominant population size. Examples of these species are *Allium fedschenkoanum, Cyananthus integer, Inula rhizocephala, Lalldhwojia cooperi, Cryptothladia polyphylla, Lagotis globosa, Scorzonera virgata, Adoxa moschatellina* and *Schultzia dissecta.*

A detailed phytogeographic analysis of the alpine flora of Western Himalaya reveals that this region has only about 135 (7.45%) endemic vascular plants which turns out to be much less than expected. Undivided Kashmir and Nanda Devi Biosphere Reserve have highest number of narrow endemics, most of which are likely to fall under the category of neoendemic species. Highest endemism was found in the genus *Astragalus* (19%) followed by *Poa* (12%), *Saussurea* (11%), *Potentilla* (8%) and *Carex* (6.66%). *Saxifraga,* a true alpine genus, showed rather low (3%) degree of endemism. It was found that the number of endemic species decreased with increasing altitude. Most (70%) of the endemic species in the alpine areas occupied mesic and water surplus habitats and even within the Trans-Himalayan region the majority of endemic species were confined to sheltered and protected habitats unlike earlier reports. Critical monographic studies on several groups and biosystematic studies on most of the endemic species would be necessary to ascertain the nature of their endemism.

Plate 12: THREATENED, RARE AND ENDEMIC SPECIES – II



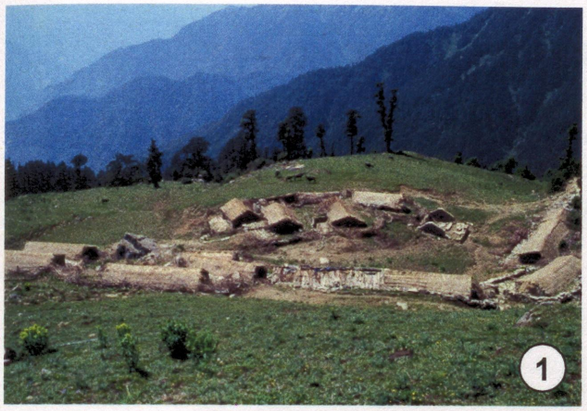






1. ***Megacarpaea polyandra*** **(Brassicaceae) – Narrow habitat range and localized distribution**
2. ***Dictamnus albus*** **(Rutaceae) – Single population of <100 individuals were seen in Gangotri NP**
3. ***Ponerorchis nana*** **(Orchidaceae) – Disjunct distribution and small populations**
4. ***Pinguicula alpine*** **(Lentibulariaceae) – An insectivorous, rare species – *All Photos G.S. Rawat***

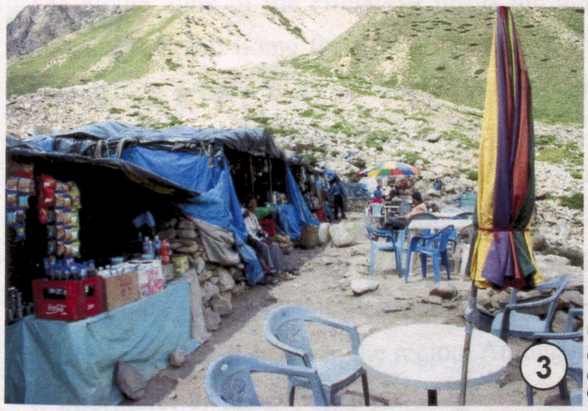
Plate – 13: ANTHROPOGENIC PRESSURES



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1. A seasonal cattle camp near treline in the Greater Himalaya
2. Effect of heavy grazing on alpine meadows– opportunistic, unpalatable herbs and soil erosion

3 & 4: Unregulated tourism and garbage

5. Over harvesting of medicinal plants

7.0 CONSERVATION AND MANAGEMENT

"When forests degrade they convert into secondary scrub, when scrub vegetation degrades it becomes sparsely vegetated herbaceous or grassy formation. But if alpine herbaceous formations degrade they become sparser and dust bowls and man seldom notices the degraded alpine habitats..."

- Unknown Author

7.1 Introduction

The alpine zone of the Himalaya forms the upper catchment for a majority of the north Indian rivers and home for a large number of specialized plants, animals and microbes all nested in a great variety of microhabitats. This region is well known for its aesthetic, ecological, cultural and socio-economic values. The ecosystem services derived from this region are numerous and humans have just begun to appreciate them. The key component of alpine ecosystems is the vegetation cover which controls the functional integrity of high altitudes in terms of stabilizing the mountain slopes, prevention of soil erosion and source of primary production for all the trophic levels. Health of these ecosystems has direct bearing on the human well-being in the region. Among the globally recognized biodiversity hotspots (Mittermeier *et al.* 2004), alpine region of the Himalaya is most fragile and vulnerable demanding adequate attention of conservation community.

The intensity of human use in the alpine region of Western Himalaya has increased significantly in recent years. This, coupled with regional climate change due to global warming has posed serious threat to the alpine ecosystem throughout the world (Holtmeier & Broll 1992, Grabherr & Pauli 1994, Hallwy & Mark 2003, Ni 2006). The diverse socio-economic and political situations in the region have led to complexity of environmental problems and resource use patterns. One of the debatable issues of the alpine zone of the Western Himalaya is sustainability of pastoral practices (Saberwal 1995, Mishra & Rawat 1998). It is estimated that about 1.12 million goats and sheep graze in the alpine pastures of the three West Himalayan states (Lal *et al.* 1991), and each year bare sites of 0.5-1.0 ha are created within the alpine meadows as a result of camping by livestock and trampling (Ram & Singh 1994). Increasing tourism, pilgrimage and medicinal plant collection also pose a continuous threat to the alpine areas in the Himalaya. Further, the biotic pressures which lead to erosion and landslides, avalanches and floods pose a grave threat to the ecological stability of the area.

Conservation and management of alpine ecosystem in the Himalaya suffers due to difficult terrain, remoteness, hostile climatic conditions, lack of funds, low manpower, poor infrastructure, and lack of motivation among the management agencies and political will of the governments. Though, a biogeographic classification and plan for establishment of additional protected areas (PAs) exists for the region (Rodgers & Panwar1988), the state governments are constrained by the lack of financial and human resources to declare and effectively manage the PAs. Moreover, declaring PAs alone would be inadequate to conserve the entire range of alpine ecosystem.

This chapter deals with the review of current conservation status of alpine habitats in and around PAs, land use practices, major conservation issues and strategies in the alpine zone of Western Himalaya. The data on the land use practices including densities of livestock and quantum of medicinal plants extracted from different localities within the Greater and Trans-Himalaya are pooled together from primary as well as secondary sources.

7.2 Conservation Status of Alpine Habitats within Protected Areas

i. The Greater Himalaya: The alpine zone of the Greater Himalaya along with the sub-alpine and temperate belts have been categorized under Biogeographic Zone 2 (Rodgers & Panwar 1988). Of the total 2,03,912 km² covered by Zone 2 the alpine zones constitute 17,642 km² (Rodgers & Panwar 1988; Lal *et al.* 1991), which is *ca.* 9% of the total area. The area under present investigation falls within two biogeographic provinces *viz.*, North West Himalaya (2A) covering Kashmir to Sutlej in Himachal Pradesh, characterised by Mediterranean climate with western Himalaya taxa such as ibex, and Western Himalaya (2B) from Sutlej to Sharada river in eastern Kumaon with a mixture of western and eastern Himalaya species. Within these two biogeographic provinces there are 25 PAs that encompass alpine areas. Excepting a few PAs such as Nanda Devi NP and Valley of Flowers NP, where alpine areas are inviolate, all other alpine areas are extensively used by local villagers and migratory pastoral communities for various purposes often leading to degradation of habitat (Rawat & Satyakumar 2002). Some of the mammalian fauna threatened due to degradation of habitat in the Greater Himalaya include Himalayan musk deer (*Moschus chrysogaster*), Himalayan tahr (*Hemitragus hyalocrius*) and hangul (*Cervus elaphus hanglu*).

ii. The Trans-Himalaya: The rain shadow region lying immediately north of the Great Himalayan ranges, frequently termed as high altitude Cold Deserts constitute Biogeographic Zone 1 or Indian Trans-Himalaya (Rodgers & Panwar 1988). Presently there are two NPs and five WSs covering a total of 10,022 km² (Rodgers & Panwar 1988), which is *ca.* 5.4% of the total area. Owing to the harsh environment, specialized plants and animals occur in relatively low densities, often in geographically isolated populations, which are vulnerable to local extinction (Fox et al. 1994, Mishra 2001). Of the 26 mammalian species found in the Trans-Himalaya, 17 (65%) are included in the Schedule I & II of the Indian Wildlife (Protection) Act 1972 and 15 are listed in the Appendix-I of the CITES. The IUCN recognizes two species viz., snow leopard (*Uncia uncia*) and wild yak (*Bos grunniens*) as endangered, and three species viz., Tibetan wolf (*Canis lupes chanco*), brown bear (*Ursus arctos*) and smooth Indian otter *Lutra perspicillata*) as Vulnerable. Apart from these mammals, the region is home to many endangered birds and lower vertebraes e.g., black necked crane *Grus nigricollis*, bearded vulture or lammergeier *Gyps barbatus*), herpetofauna (*Cyrtodactylus lawderanus*, *Sincella ladacensis tragbulense*) and a number of rare and endemic plants.

Due to low primary productivity, large mammal species need to range over vast areas and many of them have distinct seasonal ranges. Owing to this and the overall vulnerability of the region, large protected areas are needed to maintain viable populations of most species (Chundawat & Rawat 1994). As in the case of Greater Himalaya, most of the Trans-Himalayan PAs are also facing problems largely due to lack of livelihood options with the local communities and intensification of land use such as tremendous growth of tourism.

A review of current status of high altitude PAs covering alpine habitats (Table 7.2) reveals that most of the PAs do not have a management plan and for many PAs final notification and boundary verification has not been done.

Table 7.2: Protected areas of Western Himalaya covering sub-alpine and alpine zones and their conservation status (NP= National Park, WS=Wildlife Sanctuary, GH = Greater Himalaya, TH = Trans=Himalaya)

SN	PA and State	Location	Area (km^2)	Mgmt Plan Y /N	Remarks
1	Karakoram WS, J&K	TH	3000	N	Upper catchment of Nubra and Shyok rivers; Candidate for Trans-frontier peace park

2	Changthang WS, J&K	TH	5000	N	Representative of Tibetan Plateau
3	Hemis NP, J&K	TH	3350	Y	Proposed Biosphere Reserve
4	Rangdum WS, J&K	TH	550	N	High Altitude Wetland
5	Bodh Karbu WS, J&K	TH	80	N	Rich in Medicinal Plants and biota of Western Ladakh
6	Sabu Chukar, J&K	TH	40	N	Representative of Alpine Dry Scurb
7	Gya-Miru WS, J&K	TH	70	N	Forms corridor between Hemis NP and Changthang WS
8	Kibber WS, HP	TH	1400	Y	S-W extension of Tibetan Plateau Ecosystem
9	Pin Valley NP, HP	TH	675	N	Closer to GH; Good populations of *Eremurus himalaicus*, Asiatic ibex and snow leopard
10	Gangotri NP, UA	TH	2390	Y	Well known for cultural, geological and biological values – transition from GH to TH
11	Dachigam NP, J&K	GH	141	N	Alpine habitats crucial for endangered hangul and brown bear
12	Kistwar NP, J&K	GH	400	Y	Representative of Pir Panjal Range
13	Gulmarg WS, J&K	GH	180	N	Rich in floristic diversity
14	Overa WS, J&K	GH	32	N	Rich in alpine flora
15	Limber WS, J&K	GH	26	N	Status unknown
16	Lachipora WS, J&K	GH	80	N	Status unknown
17	Hirapora WS, J&K	GH	110	N	Status unknown
18	Kanawar WS, HP	GH	54	N	Rich in alpine flora and fauna but excessive biotic pressure
19	Manali WS, HP	GH	32	N	Rich in alpine flora and fauna but excessive biotic pressure
20	Kugti WS, HP	GH	379	N	Transition between GH and TH
21	Nargu WS, HP	GH	279	N	Status unknown
22	Tundah WS, HP	GH	64	N	Status unknown
23	Gamgul Siahbehi WS, HP	GH	109	N	Status unknown
24	Sechu Tuan Nala WS, HP	GH	103	N	Status unknown
25	Great Himalayan NP, HP	GH	765	Y	Upper catchments of Tirthan, Sainj and Jiwanal rivers, Rich in Medicinal Plants and best site for Western Tragopan
26	Rupi Bhaba WS, HP	GH	125	N	Rich in alpine flora and fauna but excessive biotic pressure
27	Lipa Asrang WS, HP	GH	31	N	Rich in alpine flora and fauna but excessive biotic pressure
28	Darangati WS, HP	GH	42	N	Status unknown
29	Sangla WS, HP	GH	650	N	Transition between GH and TH
30	Churdhar WS, HP	GH	56	N	Rich in alpine flora and fauna but excessive biotic pressure and religious tourism
31	Nanda Devi NP, UA	GH	650	Y	World Heritage site; Best Protected
32	Valley of Flowers NP, UA	GH	88	Y	World Heritage site; Best Protected
33	Govind NP & WS, UA	GH	730	N	Rich in alpine flora and fauna but excessive livestock grazing

34	Kedarnath WS, UA	GH	830	N	Rich in alpine flora and fauna but high biotic pressure and religious tourism
35	Askot WS, UA	GH	600	N	Transition between GH and TH; Rich in alpine flora and fauna but boundaries of the PA await final demarcation.

7.3 Current Land Use Practices

7.3.1 Pastoral Practices

Five distinct pastoral practices are prevalent across the alpine landscape in the WH: nomadic, semi-nomadic, nuclear transhumance, Trans-migration and sedentary (resident). True nomadic pastoralism is practiced mainly by the *Changpa* herders in the Changthang plateau of Ladakh. *Gujjars,* the buffalo herders in the southern slopes of Greater Himalaya and Shivaliks, have over the years shifted from nomadic to semi-nomadic life style. *Gaddis* and *Bakarwals* of HP and J&K follow semi-nomadic life style where only few members of a family move long distances with their livestock. Nuclear transhumance is practiced in many agro-pastoral communities in UA and HP. In this system, a part of the family moves to higher altitudes closer to treeline along with surplus cattle. Trans-migration (seasonal altitudinal movement by the entire family along with the livestock) is practiced mainly by the local communities in inner ranges of UA such as Byans, Darma, Johar, upper basins of Alanknanda and Bhagirathi. At present only 20-30 per cent of the original house holds and only few members in each family migrate to the distant alpine valleys. In the process, several alpine pastures are now available for other communities belonging to the lower parts of the state and *Gaddi* herders from HP. In the high altitude villages of Kinnaur, Spiti, Lahul, Pangi and Zanskar there is round the year grazing by the resident livestock in addition to migratory livestock. In Chamoli, Tehri, Uttarkashi and Kinnaur districts several families drive their scrub cattle to sub-alpine and alpine areas for free grazing during snow free period (June – October). Such a practice leads to faster degradation of meadows and will need immediate reversal if conservation has to succeed in and around the nearby PAs.

Densities of livestock in the alpine meadows of three states have been compared in Table 7.3.1. Official records suggest that among the three states HP has the highest density of livestock (277 per km^2) followed by UA (168 per km^2) and JK (36 per km^2). However,

livestock densities in the alpine areas of UA during present survey were found much higher (33.92±10.01 per km^2) compared to HP (17.55±9.25 per km^2) and JK (10.45±12.33 per km^2). It is to be noted that the herders from Chamba, Kangra and other parts of HP take their sheep and goats either towards Sarchu Plains in J&K or to various alpine valleys of UA. The herders in various parts of HP opined that pastures in many parts of HP have badly degraded and there is a shortage of forage. Densities of bovids and equids in the alpine region of UA were also found slightly higher. Highest densities of sheep and goats were observed in the alpine areas of Govind WS (50 sheep and goats and 10 bovids and equids per km^2) followed by Thajwas WS (31 sheep and goats and 20 mules per km^2) and Rupi-Bhaba WS (23 sheep and goats and 3-4 bovids per km^2). Except core areas of Nanda Devi NP, Valley of Flowers and parts of Gangotri NP all other PAs had high grazing pressure (mean density of sheep and goats 28.23±17.90 per $km^2$and bovids and equids 2.15±2.87 per km^2). Interestingly, mean livestock densities during peak summer months outside the PAs (22.21±19.16 sheep and goats per km^2 and 1.97±1.81 bovids per km^2) were lower compared to densities within PAs, though the differences are not significant (Table 7.3.1b).

Table 7.3.1a: Density of livestock in alpine meadows of Western Himalaya

SN	Parameters	Uttarakhand	Himachal Pradesh	Jammu & Kashmir
1.	Geographical Area (km^2)	53,485	55,670	222,240
2.	Livestock density in the state (no. / km^2) *	168	277	36
3.	Area under Alpine Vegetation (km^2)**	8,524	17,296	131,851
4.	Density of sheep & goats in alpine areas (no. / km^2)	33.92 ± 19.01	17.55 ± 9.25	10.45 ± 12.33
5.	Density of bovids & equids in alpine areas*	2.48 ± 2.65	1.62 ± 2.46	1.42 ± 1.27

(Source: * State Animal Husbandry Departments, ** Lal *et al.*, 1991):

Table7.3.1b: A comparison of livestock densities within PAs and outside PAs in the alpine region of Western Himalaya*:

SN	Parameters	Protected Areas (N=14)	Outside Protected Areas (N=13)
1.	Approx. area surveyed (km^2)	3205.00	3685.00
2.	Density of sheep & goats±SD (no. Per km^2)	28.23±17.90	22.21±19.16
3.	Density of bovids and equides±SD (no. Per km^2)	2.15 ±2.87	2.06 ±2.38

* Note: Independent samples test: No significant differences in the densities of sheep and goats (t=0.842; df = 24.487, 95 % conf. interval) and bovids and equids (t=0.200; df = 22.130, 95 % conf. int.)

Empirical evidences from Greater Himalaya indicates that light or moderate level of grazing can lead to increase in plant diversity locally (Rawat & Rodgers 1988). However, intensive and heavy grazing often leads to loss of palatable species, abundance of weedy, unpalatable species, vegetation collapse and creation of bare patches. Studies have shown that alpine meadows of Greater Himalaya once degraded, take upto 40 years to recover after protection from livestock camping (Rikhari *et al.* 1993). The rates of recovery in the Trans-Himalaya are yet to be established. The problems associated with changing pastoral practices, overstocking and sedentarization of herds in the cold arid region and much of the Tibetan plateau have been highlighted by a number of authors (e.g., Chang 1981, Brower 1990, Miller 1990, Miller & Schaller 1996, Schaller 1998, Miehe & Miehe 2000, Mishra *et al.* 2001, Miehe *et al.* 2002).

7.3.2 Extraction of Medicinal and Aromatic Plants

Most of the high value medicinal and aromatic plants (MAPs) found in the Himalayan region come from the alpine areas. Traditionally the people in the higher altitudes of Himalaya used the wild medicinal herbs for their own use or for a limited barter system in exchange of commodities from the lower altitudes. With the change in socio-economic conditions and demand for cash income coupled with high demand of certain medicinal herbs in herbal industries the rural people in the high altitudes have shifted their attention towards commercial harvest. Declining population of MAPs in the wild due to overexploitation has raised concern during recent years (Jacobson *et al.* 1991, Katariya

1998, Samant *et al.* 2001, Uniyal *et al.* 2002, Awasthi *et al.* 2003). Unsustainable harvest in the form of uprooting the entire plant, extraction before the seeds are shed and extraction of immature parts not only cause decline of populations but also leads to local extinction of threatened species (Sheldon *et al.* 1998). Other harmful effects of over harvest are soil erosion and habitat degradation. There are cases where faulty or improper harvesting has either restricted the distribution of species or it has completely resulted in its depletion in a particular locality. Of the many factors involved in the depletion of a species from wild, the most important is the small population size (Oostermeijer 1999). In some cases the population size of a species can inherently be low or it might have become low due to its overexploitation and habitat degradation. Some times low habitat diversity results in low population of species and at other times anthropogenic pressures in the form of grazing, trampling and extraction result in the decline of their population. Increased growth of unpalatable/weedy species also limits their growth and consequently results in their low population (Rawat 1998).

Data on the recent levels of trade in MAPs are available only from a few localities of Western Himalaya. Major hotspots of wild medicinal plants in the region are alpine areas of Pithoragarh, Chamoli, Uttarkashi, Kullu, Kangra, Lahaul-Spiti, Kishtwar and Anantnag districts. The herbal healers of Ladakh (*Amchis*) collect medicinal plants mostly from moist valleys of Zanskar and partly from parts of Great Himalayan range in Himachal Pradesh or Kashmir. Among the highly traded MAPs from the region are Atis or Ativisha (*Aconitum heterophyllum*), Colchicum (*Colchicum lueteum*), Maida (*Polygonatum verticellatum*), Jatamansi (*Nardostachys jatamansi*), Pushkarmool (*Inula racemosa*), Kutki (*Picrorhiza kurooa*), Dhup (*Jurinea dolomiaea*), Kuth (*Saussurea costus*) and Salampanja (*Dactylorhiza hatagirea*). Except Kuth and Pushkarmul, all of these species are harvested from the wild and traded to various pharmaceutical companies.

A rapid survey of market and local villages in and around Great Himalayan National Park (GHNP) conducted by the author and co-workers revealed that nearly a decade ago the eco-development zone of GHNP generated revenue to the tune of Rs. 2.04 crore from wild medicinal plants, which were collected mainly from the alpine areas (Table 7.3.2).

In terms of quantity collected, lichens ranked highest i.e., up to 105 tons followed by *Jurinea macrocephala* (82 tons) and *Dioscorea* (45 tons). Lichens, morel mushroom and *Viola serpens* have relatively low biomass per plant and hence, more individuals are collected for per unit weight of these species. There, the highest price of medicinal plant in the local market was for morel mushroom (Rs. 2500/- per kg), followed by *Dactylorhiza hatagirea* (Rs. 850/- per kg) and *Aconitum heterophyllum* (Rs. 800/- per kg). Even though *J. macrocephala* was relatively cheaper in the local market (Rs. 75/- per kg), the maximum number of people engaged in the extraction of this species was more after morel mushroom.

Extraction of MAPs in parts of GHNP was being carried out till its final notification on the basis of 'rights' given to the local people as per the Anderson's Settlement Report (Singh 1999). And, most of the herb collectors of the area claimed to be the 'Right holders'. The studies on the impact of herb collection on the habitat or on the ecological status of herbs showed that there was enormous stress on some habitats and pressure on some species (Singh & Rawat 2000). Interviews with the herb collectors also indicate a progressive decline in the quality and quantity of herbs. For example, Dhoop (*Jurinea dolomiaea*) roots according to the local people used to be as thick as a person's forearm some 10 years ago and today it is difficult to get a root even as thick as a finger of a person. Under the original settlement plan by Anderson in 1886 the collection of medicinal plants was permitted only for 2 months in a year from 15th August. By the beginning of 1960s there was a significant expansion of commercial market for the MAPs giving local people a major new source of income. Steady increase in market forces led to uncontrolled extraction through out the summer months (April to November) and the original system of rights established in Anderson's Settlement were restricted to a collecting season of only two months, 15 August to 15 October. But under the irresistible pull of the booming market, collectors expanded their work to the entire season, from April to November. Extraction in the past has been the major reason for the decline of herbs in this area.

Table 7.3.2: Income generated from medicinal plant trade (selected species) in the buffer zone of GHNP during 1997 -98 (Data collected through village surveys by Singh & Rawat).

SN	Name of the Species	No. of Collectors / Yr	Amount collected (kg/yr)	Rate(Rs. / kg)	* Total Income / Yr (In lakh Rs)
1	*Aconitum heterophyllum*	345	1050	800	8.40
2	*Aconitum violaceum*	842	5100	750	38.25
3	*Acorus calamus*	65	158	50	0.07
4	*Ainsliea aptera*	95	252	60	0.15
5	*Angelica glauca*	368	4675	45	2.1
6	*Dactylorhiza hatagirea*	462	1285	850	10.92
7	*Diplazium maximum*	38	1085	5	0.05
8	*Dioscorea deltoidea*	583	45000	30	13.50
9	*Hypericum patulum*	15	500	75	0.37
10	*Jurinea dolomiaea*	880	82800	75	62.10
11	*Morchella esculenta*	1224	1092	2500	25.12
12	*Nardostachys grandiflora*	125	320	100	0.32
13	*Parmelia* spp.	658	105280	24	25.27
14	*Picrorhiza kurrooa*	355	8350	85	7.09
15	*Podophyllum hexandrum*	215	450	65	0.30
16	*Polygonum amplexicaule*	335	4800	22	1.05
17	*Taxus wallichiana*	35	9750	12	1.17
18	*Thymus linearis*	15	25	40	0.001
19	*Valeriana hardwickii*	125	3055	100	3.05
20	*Valeriana jatamansi*	448	4652	90	4.18
21	*Viola serpens*	336	1170	120	1.40
	Total Income from the MAPs: Rs. 204.91 lakhs				

* Approximate revenue earned from the sale of each species in the local market

The latest figures on the trade of MAPs and revenue earned from different alpine zones of WH are not available owing to secretive nature of the market. However, depending upon the collection pressure, the species can be grouped under high, medium and low pressure. This, coupled with availability in the wild provides an useful matrix of

conservation that can be used for prioritization of species. Using the above criteria the alpine MAPs of Uttarakhand have been categorized under the following eight categories:

i. Restricted distribution heavy pressure (RDHP): Species with sparse population in few areas and in high demand, e.g., *Aconitum heterophyllum, Dactylorhiza hatagirea, Arnebia benthamii, Nardostachys grandiflora* and *Pleurospermum angelicoides.*

ii. Restricted distribution low pressure (RDLP): Species with sparse population but at present low demand, e.g., *Rheum moorcroftianum, Podophyllum hexandrum, Meconopsis aculeata, Waldhemia tomentosa, Angelica archangelica, Biebersteinia odora.*

iii. Locally common heavy pressure (LCHP): Species with gregarious populations in several localities but having heavy demand, e.g., *Jurinea dolomiaea, Picrorhiza kurrooa, Trillidium govanianum, Chaerophyllum villosum* and *Rheum australe.*

iv. Locally common low pressure (LCLP): Species which can withstand disturbances such as trampling and grazing and having low demand at present, e.g., *Achillea millefolium, Tanacetum dolichophyllum,* and *Bistorta macrophylla.*

v. Wide distribution high pressure (WDHP): Species widely distributed throughout the sub-alpine and alpine zone of Uttaranchal and also heavily exploited at present, e.g., *Berginia ciliata* and *Juniperus indica.*

vi. Wide distribution low pressure (WDLP): Widely occurring species and at present low or no demand, e.g., *Taraxacum officinale, Bistorta vivipara, Polygonum amplexicaule, Arisaema jacquemontii* and *Berberis jaeschkeana.*

viii. Under cultivation low pressure (UCLP): Examples: *Carum carvii, Saussurea costus, Allium auriculatum* and *Allium stracheyii.*

7.3.3 Other Practices

The agro-pastoral communities, tourists, pilgrims and other visitors to alpine areas consume a large amount of fuel wood. Consumption of firewood is particularly high around treeline and sub-alpine zone of the greater Himalaya and thickly populated areas of trans-Himalaya. There are clear indications that the natural treeline in many parts of the Himalaya has lowered considerably as a result of regular camping and removal of woody vegetation (Rawat & Uniyal 1993). Selective removal of highly preferred woody species such as *Juniperus semi-globosa* and *J. communis* can also lead to local extinction of such species. Extraction of fuel wood particularly from the low productive areas of trans-Himalaya is one of the burning issues in the conservation of steppe communities. In the absence of larger trees and shrubs local people dig out low shrubs and undershrubs in large quantities in order to warm the houses and for cooking during the long and severe winter months (Manjrekar 1997, Uniyal *et al.* 2003). In addition, collection of livestock dung from the higher pastures for fuel is a common practice in the trans-Himalaya. Ecological implications of such practices have, however, not been investigated so far.

Uncontrolled tourism and developmental projects have caused severe degradation and destruction of wildlife habitat in many alpine areas. Most of the pilgrim centres are located at the river sources or at the upper catchment areas, which are visited by thousands of pilgrims during the season. In order to cater to this growing demand of tourism and pilgrimage, substantial amount of fuel wood, fodder and other non timber forest produces are collected from the sub-alpine forests and alpine scrub year after year. Associated impacts include construction and maintenance of roads, bridges, grazing by mules, horses and garbage accumulation. The possibility of making Hindu temples and the pilgrims playing a major role in the conservation of these areas like in the Buddhist religious places and as monks do in certain regions in the Himalaya should be explored and advocated (Rawat *et al.* 1996).

There exists a strong case for planning and executing conservation efforts in the alpine region of Western Himalaya at a landscape level in which the local communities, PA managers and various line departments are given due responsibilities and partnership. Evolving a policy for conservation of this sacred, ecologically fragile and culturally rich landscape should be accorded highest priority. The conservation plan for the region should

aim at minimising people-park conflict through rationalization of park boundaries, managing the human dominated landscape and PAs in the lines of Biosphere Reserves, creating enterprise based livelihood opportunities for the local people who are highly dependent on the biomass resources of the alpine areas.

7.4 Conservation and Management

Across the larger landscape, there are examples of wise and sustainable as well as unsustainable land use practices among the local communities. At state and regional level a few conservation and management plans have been evolved in recent years (Humbert-Droz & Dawa 2004, National Biodiversity Strategy and Action Plan 2004) which are based on a wide consultative process. The existing wise and sustainable land use practices among the local people need to be replicated in other areas and priority activities suggested in the above mentioned plans need to be implemented. The following strategies and actions would go a long way in conserving the alpine ecosystems, habitats and threatened species in the alpine region of Western Himalaya:

i. Management of domestic livestock:

Livestock grazing is the mainstay economy for several agro-pastoral communities in the alpine region. Presently, no policy guidelines are available for the optimal use of grazing resources in this area. Management authorities are faced with the conflicting situations particularly with respect to livestock depredation by the wild carnivores and habitat degradation by large flocks of migratory graziers. Rotational grazing of degraded pastures and limiting the numbers of livestock are the best options for management in this region. Mishra (1997) has suggested a self-financing compensation scheme, and modification of existing livestock pens to reduce the livestock – wild carnivore conflict in selected areas of trans-Himalaya. Settlement of grazing rights in the Himalayan Parks often leads to conflicts and controversies. It must be accepted that complete ban on livestock grazing in all the Himalayan PAs is not achievable. Hence, demarcation of grazing and non-grazing areas or other forms of zonation (e.g., core and buffer) will have to be practised so that livestock grazing can be managed within buffer zones.

ii. Regulated and rotational harvest of MAPs

Data from various pockets of alpine region shows that several MAP species could be effectively conserved by the local communities provided they are empowered and given the responsibility of protecting and sharing some benefits from a regulated and sustainable harvest of such species. In the state of UA, a concept of Conservation, Development and Harvest (CDH) plan has been initiated recently for the public land lying outside the protected areas (Rawat & Chandola 2006). This concept visualizes valley or range specific plans for the conservation of MAPs based on detailed quantification of availability and setting aside various management zones in consultation with the local communities. The focus of conservation and regulated harvest is particularly needed for RDHP species such as *Aconitum heterophyllum, Dactylorhiza hatagirea, Arnebia benthamii, Nardostachys grandiflora* and *Pleurospermum angelicoides.* Period of rotation for these species will have to be longer as compared to other species which are locally common and regenerate faster e.g., *Jurinea dolomiaea, Picrorhiza kurrooa, Trillidium govanianum, Chaerophyllum villosum* and *Rheum australe.* This concept needs to be implemented and replicated in more alpine areas of Western Himalaya.

iii. Management of degraded areas:

Heavily eroded and degraded alpine sites need to be protected on temporary basis in order to allow recovery. Some of the native herbs which are fast growing and opportunistic, such as *Persicaria polystachya* (Polygonaceae), should not be viewed as `weeds' and uprooted. Kala *et al.* (1998) have highlighted the role of such herbs and opined that they play an important role in the stabilization of alpine environment such as soil formation, stabilization of slopes, role in the forest succession near treeline and soil enrichment. In Greater Himalaya, many rare and endangered plant species populations have shown recovery after cessation of livestock grazing. In the trans-Himalaya, especially in eastern Ladakh the moist sedge meadows (*Kobresia pygmaea* turfs) are highly threatened due to excessive grazing, and at times due to diversion of water and camping. Such meadows are crucial for sustenance of

wild as well as domestic ungulates especially during winter. Therefore, utmost care would be needed to conserve such patches of vegetation.

iv. Rare plants and their habitats:

Plant species may be rare due to restricted habitats, small population size, narrow range of distribution and over exploitation in the recent past. Management authorities of conservation areas should develop site specific or species specific conservation plans depending upon their sensitivity to various practices. Relict patches of riverine vegetation, forest and scrub in the Trans-Himalaya are to be accorded top priority and declared as 'botanical hotspots'. Such hot spots should include patches of *Juniperus macropoda* (= *J. semiglobosa*) and *Betula utilis,* which are considered sacred among Buddhists and Hindus. Some of the botanical hotspots and important sites for plant conservation are given in table 7.4. Rawat (1994) and Johnsingh et al. (1998) have suggested several critical habitats and vegetation types in alpine areas of Himalaya for priority conservation action.

Table 7.4 : Botanical hotspots and sites of high conservation significance (outside the Protected Areas in WH:

SN	Name of the Bugyal	Altitude (m)	Latitude (N) / Longitude (E) of central point	Characteristic features
1	Chhiyalekh (Byans)	3350 - 3400	30° 06'31.7" N 80° 50'04.7" E	Type locality for 2 endemic orchids viz., *Herminium kumaonensis* and *Ponerorchis renzii*; religious site, rich in floral diversity and MAPs
2	Barjikang (Ralam)	4700 - 4800	30°18'04.7" N 80° 15'15.0" E	Rich in very high altitude MAPs, 20 species of *Saxifraga* (out of 32 in WH) are reported from this pass and adjacent slopes in Ralam
3	Laspa /Sirti (Johar)	4200 - 4400	30° 16'35.0" N 80° 10' 03" E	Rich in MAPs especially Jatamansi, Mitha, Atis, Hathpanja and Laser / Gokul Dhoop
4	Lang Payar (Niti)	4000 – 4200	30° 46'58.5" N 80° 49'08.2" E	Species rich Bugyal protected by the villagers. High abundance of *Rheum australe, Picrorhiza kurooa* and *Aconitum violaceum.*
5	Bagi / Khatling	3700 - 3800	30° 46'08.1" N 78° 53'36.3" E	Ideal site for Atis MPCA , good populations of Mitha, Barmoul and Salam Panja.
6	Gidara	3900 -	30° 55'53.2" N	One of the ideal sites for MPCA. Best

		4500	78° 37'02.1" E	populations of Barmoul, Kutki and Atis are found in Gidara
7	Kiarki	3800 - 4000	30° 44'01.7" N 78° 44'11.2" E	Most extensive and picturesque Bugyal in Garhwal. Site for endemic species *Circaeaster agrestis.*
8	Changshil	3600 - 3700	31° 11'09.07" N 77° 58'49" E	A low alpine ridge at interstate border between HP and UA. Heavily grazed by livestock yet extremely rich in alpine flora.
9	Moral Danda	4000 - 4500	31° 20'09.46" N 77° 57'54.67 E	Upper catchment of Pabar river in eastern HP. Floristically rich with a number of Allium and Primula species*.
8	Bhrigu Lake	4260	32° 17'35.2" N 77° 14'44.7" E	A high altitude lake surrounded by extremely rich moist meadows and a variety of medicinal plants.
9	Suraj Tal - Baralacha La	4500 - 4850	32° 50'27.62" N 77° 16'57.88" E	Rich in high alpine flora - Brassicaceae, Saxifragaceae, Crassulaceae and Primulaceae
10	Upper Sural Valley	3900 - 4200	33° 09'35.4" N 76° 32'37.7" E	Several medicinal plants including *Aconitum heterophyllum, A. violaceum* and *Allium fedschenkoanum.* Floristically rich
11	Nun Base	4000 - 4250	34° 02'13.1" N 75° 57'03.2" E	Rich in grasses and a number of herbs including *Inula rhizocephala* and *Anemone pulsatilla* and *Arnebia euchroma*
12	Nuruchan, Tso Kar basin in Changthag	4500 - 4600	33° 14'14" N 77° 14'44.7" E	Typical *Carex – Kobresia* sedge meadow rich in herbs and graminoids
13	Khardung, North Slope (North Polu)	4770 - 4800	34° 19'36.9" N 77° 59'34" E	A site for exceptionally high vegetation cover, over 20 species within 10 m^2 area, key species *Carex borii, Saussurea schultzii,* and *Primula nutans*
14	Chumurphu, Karakoram	4500 - 4600	34° 39'04.4" N 77° 41'21.7" E	Gradient of wet meadow, mixed herbaceous formation and alpine dry scrub, representative of Karakoram range.

* *Personal Communication*, Dr. G.S. Goraya, Joint Director, FRLHT, Bangalore

The south-western flank of Ladakh close to Zoji La on the Leh - Srinagar highway represents one of the botanical hotspots in the region. This area being close to the Great Himalayan range is relatively moist and rich in the alpine flora. Some of the important genera of flowering plants in the region *include Primula, Androsace, Corydalis, Saxifraga, Potentilla, Saussurea, Polygonum* and a variety of other species including valuable medicinal and aromatic plants. Humbert-Droz & Dawa (2004) have suggested

establishment of a botanical sanctuary by setting aside about 100 sq. km area of alpine vegetation in this part. Similarly, , Joshi *et al.* (2005), ,

iv. Research and monitoring:

There are a number of research and development agencies working in the Himalaya. However, there seems to be a lack of focus and concerted effort towards intensive research and monitoring of alpine ecosystem. For example, effect of climate change on sensitive taxa, long term changes in the vegetation structure and composition due to anthropogenic pressures, status of rare and endemic species, sustainability of various land use practices have not been investigated in detail. Similarly, no initiatives have been taken to restore the heavily degraded alpine habitats. Long term studies on ecological as well as socio-economic aspects would go a long way in understanding the alpine ecosystems and formulating the management strategies.

7.5 Conclusion

Across the larger landscape in the Western Himalaya there are examples of sustainable as well as non-sustainable land use practices. Traditional grazing by sheep and goats in the alpine zones of Greater Himalaya which involved long distance migration and rotational grazing has now been modified and replaced by more sedentary grazing by heavy animals particularly cattle and buffaloes. This form of grazing is more damaging to the fragile alpine habitats. Similarly, pastoral practices in the Trans-Himalaya are at cross roads. Demands of development including need for higher cash income coupled with recent influx of Tibetan refugee herders in to Changthang plateau of eastern Ladakh has led to a vicious circle of destruction. The natural decrease of carrying capacity and climatic desiccation are likely reducing the overall productivity on one hand, and the other rapidly changing lifestyle especially increasing sedentarism and supplementary feed expect more from the land.

In order to conserve the alpine ecosystem more effectively the management authorities, ecologists and local communities need to initiate dialogues for (i) better livestock management, (ii) sustainable harvest of high value medicinal and aromatic plants, (iii) improved watershed management and protection of degraded alpine areas, (iv) protection of botanical hotspots and sites of rare endemic plants lying outside the existing protected areas.

The research and development agencies need to revamp a well coordinated long term research and monitoring of fragile alpine landscape.

* * *

REFERENCES

Addelman, L. E. and R.T. Ward. 1984. Phyto-edaphic relationships in alpine tundra of north-central Colorado, USA. *Arct. Alp. Res.* 16:343-359.

Adhikari, B.S. 2004. Ecological Attributes of vegetation in and around Nanda Devi National Park. In UAFD. 2004. In: Anonymous. *Biodiversity Monitoring Expedition Nanda Devi 2003*. A Report to the Ministry of Environment & Forests, Government of India. Uttaranchal State Forest Department, Dehra Dun. Pp. 15-38.

Agakhanyantz, O.E. and S.W. Breckle. 1995. Origin and evolution of the mountain flora in middle Asia and neighboring mountain regions. In: Chapin, F.S. & C. Korner (eds) *Arctic and alpine biodiversity: Patterns, causes and ecosystem consequences*. Ecological studies, Vol. 113. Springer, Berlin Heidelberg New York. Pp 63-80.

Agakhanyantz, O. E. and I. K. Lopatin 1987. Main characteristics of the ecosystems of the Pamirs, USSR. *Arct. Ant. Alp. Res.* 10:397-407.

Amano, K. and A. Taira. 1992. Two-phase uplift of Higher Himalayas since 17 Ma. *GEOLOGY* V (20): 391 – 394.

Anonymous, 1989. *The State of Forest Report 1989*. Forest Survey of India, Government of India, Dehra Dun.

Anonymous, 1997. *Statistical package and software solutions. SPSS for windows, version 8.0.0.* SPSS.

Anonymous. 2001. Conserving Biodiversity in the India Trans-Himalaya: New Initiatives of Field Conservation in Ladakh. First Annual Technical Report (1999 – 2000), Wildlife Institute of India, International Snow Leopard Trust and US Fish & Wildlife Service.

Al-Shehbaz, I. A. 2002. New Species of *Alyssum, Aphragmus, Arabis*, and *Sinosophiopsis* (Brassicaceae) from China and India. *Novon* 12 (3): 309 – 313.

Amen, R. D. 1966. The extent and role of seed dormancy in alpine plants. *Quart. Rev. Biol.* 41:271-281.

Aswal, B.S. and B.N. Mehrotra. 1994. *Flora of Lahaul & Spiti: A Cold Desert in North West Himalaya.* Bishen Singh Mahendra Pal Singh, Dehra Dun.

Atkin, O.K. and D.E. Collier. 1992. Relationship between soil nitrogen and floristic variation in late snow areas of the Kosciusko alpine region. *Aust. J. Bot.* 40:139-149.

Austin, C. and M.P. Heylingers. 1989. Vegetation Survey Design for Conservation: Gradsect sampling of forests in North-eastern New South Wales. *Biological Conservation* 50: 13 – 32.

Awasthi, A., S.K. Uniyal and G.S. Rawat. 2003. Status and extraction patterns of *Jurinea dolomiaea* Boiss (Dhoop) in an Alpine Meadow of Kumaon Himalaya (Uttaranchal). *The Indian Forester* 129 (5): 589 – 595.

Balodi, B. and S. Singh. 1988. A New Species of *Androsace* L. (Primulaceae) from Hemkund in Garhwal Himalaya. *Bull. Bot. Surv. India* 30 (1-4): 176-177.

Barbour, M. G., N.H. Berg, T.G.F. Kittel and M.E. Kunz. 1991. Snowpack and the distribution of a major vegetation ecotone in the Sierra Nevada of California. *J. Biogeogr.* 19:141-149.

Bauer, J.J. 1990. The Analysis of plant-herbivore interactions between ungulates and vegetation on alpine grasslands in the Himalayan region of Nepal. *Vegetatio* 90: 15-34. 1990.

Bhatnagar, Y.V. 1997. *Habitat Utilization by Asiatic Ibex in Pin Valley National Park, Himachal Pradesh.* Ph. D. Thesis (unpublished). Saurashtra University, Rajkot.

Billings, W.D. 1973. Arctic and alpine vegetations: similarities, differences, and susceptibility to disturbance. *Bioscience* 23: 697-704.

Billings, W.D. 1974. Adaptations and origins of alpine plants. *Arct. Alp. Res.* 6: 129 – 142.

Billings, W.D. 1978. Alpine phytogeography across the great basin. *Great Basin Nat.* 2:105-117.

Billings, W. D. 1988. Alpine Vegetation. In : M. G. Barbour and W.D. Billings (eds) *North American Terrestrial Vegetation.* Pp. 392-421.

Bliss, L.C. 1966. Plant productivity in alpine microenvironments on Mt. Washington, New Hampshire. *Ecological Monographs* 36: 125-155.

Bliss, L.C. 1971. Arctic and Alpine Plant Life Cycles. *Ann. Rev. Ecol. & Syst.* 2: 405-438.

Bliss, L.C. 1985. The physiological ecology of alpine plants. In: Chabot, B.F. & HA Mooney (eds) *Physiological Ecology of North American Plant Communities.* London Chapman and Hall. Pp. 41-65.

Bock, J.H., C. L. Jolls, and A. C. Lewis. 1995. The effects of grazing on alpine vegetation: A Comparison of the Central Caucasus, Republic of Georgia, with Colorado Rocky Mountains, U.S.A. *Arct. Alp. Res.* 27 (2): 130-136.

Borgen, L. and B. Joshell. 1997. Variation and evolution in Arctic and Alpine Plants. *Opera Bot.* 132: 1-239.

Bowman W.D. 1992. Inputs and storage of nitrogen in inter snow pack in an alpine ecosystem. *Arct. Alp. Res.* 24: 211-215.

Bronger, A., R.K. Pant and A.K. Singhvi. 1987. Pleistocene Climatic Changes and Landscape Evolution in the Kashmir Basin, India: Palaeopedologic and Chronostratigraphic Studies. *Quaternary Research* 27: 167 – 181.

Brower, B. 1990. Range Conservation and Sherpa Livestock Management in Khumbu, Nepal. *Mountain Res. Dev.* 10 (1): 34-42.

Burga C.A. 1988. Swiss vegetation history during the last 18000 years. *New Phytol.* 110:581-602.

Caine N. 1974. The Geomorphic processes of alpine environments. In: Ives J.D. & R.G. Barry (eds) *Arctic and Alpine Environments.* Methuen, London. Pp 721-748.

Callaway, R. M., R. W. Brooker, P. Choler, Z. Kikvidze, C. J. Lortie, R. Michalet, L. Paolini, F. I. Pugnaire, B. Newingham, E. T. Aschehoug, C. Armas, D. Kikodze and B. J. Cook. 2002. Positive interactions among alpine plants increase with stress. *Nature* 417: 844 – 848.

Carter, R.N. and Prince, S.D. 1985. Distribution limits from a demographic viewpoint. In: Davy, A.J. *et al.* (eds) *Plant Population Ecology*. Blackwell Scientific, Oxford. Pp. 165 – 184.

Chambers J.C. 1995. Relationship between seed fates and seedling establishment in an alpine ecosystem. *Ecology* 76:2124-2133.

Champion, H.G. and S. K. Seth. 1968. *A Revised Survey of Forest Types of India.* Manager of Publications, Government of India Press.

Chang, D.H.S. 1981. The Vegetation Zonation of the Tibetan Plateau. *Mountain Res. Dev.* 1 (1): 29-48.

Chapin, F.S, and Ch. Korner (eds) 1995. *Arctic and Alpine Biodiversity: Patterns, causes and ecosystem consequences. Ecological studies*, Vol 113. Springer, Berlin Heidelberg, New York.

Chatterjee, D. 1940. Studies on the endemic flora of India and Burma. *J. Asiat. Soc. Bengal Sci.* 5 (1): 19-68.

Chaudhary, L.B. and R.R. Rao. 2002. A conspectus of the genus *Astragalus* L. (Leguminosae – Papilionideae) in India. In: Rao, R.R. (ed) *Advances in Legume Research in India* Bishen Singh Mahendra Pal Singh, Dehra Dun. Pp. 59 -72.

Chauhan, M.S. 2006. Late Holocene vegetation and climate change in the alpine belt of Himachal Pradesh. *Current Science* 91 (11): 1562 – 1567.

Choler, P., R. Michalet, and R.M. Callaway. 2001. Facilitation and competition on gradients in alpine plant communities. *Ecology* 82:9295 – 3308.

Christopher, J., R.W. Brooker, Z. Kikvidze and R.M. Callaway. 2004. The value of stress and limitation in an imperfect world: a reply to Korner. *J. Veg. Sci.* 15: 577 – 580.

Chundawat, R.S. and G.S. Rawat. 1994. *Indian Cold Desert: A Status Report on Biodiversity*. Wildlife Institute of India, Dehradun.

Dahl, E. 1990. History of the Scandinavian alpine flora. In: Gjaerevoll, O. (ed) *Alpine Plants*. The Royal Norwegian Society of Science and Tapir Publishers, Trondheim. Pp 16-21.

Dar, G.H. and K. I. Christensen. 2003. Gymnosperms of the Western Himalaya - 1. The Genus *Juniperus* (Cupressaceae). *Pak. J. Bot.* 35 (3): 283 – 311, 2003.

DeAngelis, D.L. and J.C. Waterhouse. 1987. Equilibrium and non-equilibrium concepts in ecological models. *Ecological Monographs* 57: 1-21.

Deva, S. and H.B. Naithani. 1986. *The Orchid Flora of North-west Himalaya*. Print & Media Associates. New Delhi.

Dhar, U. and P. Kachroo, 1983. *Alpine flora of Kashmir Himalaya*. Scientific publishers, Jodhpur, India.

Dhar, U. 2002. Conservation implications of plant endemism in high – altitude Himalaya. Current *Science* 82 (2): 141 – 148.

Dhaulakhandi, M., G. S. Rajwar and P. Kumar, 2000. Primary productivity and system transfer functions in an alpine grassland of Western Garhwal Himalaya. *Tropical Ecology* 41 (1): 99-101.

Dickoré, W. B. 1991. Zonation of Flora and Vegetation of fhe Northern Declinity of the Karakoram / Kunlun Mountains (SW Xinjiang China). *GeoJournal* 25: 265-284

Dickore, W.B. 1995. Flora Karakorumensis : Angiospermae, Monocotyledonae. *Stapfia* 39: 1-298.
University of Gottingen, Germany.

Dickore, W.B. and M. Nusser, 2000. *Flora of Nanga Parbat,* NW Himalaya, Pakistan. Botanic Garden and Botanical Museum Berlin – Dahlem.

Dickoré, W. B. and G. Miehe, 2002. Cold spots in the highest mountains of the world - Diversity patterns and gradients in the flora of the Karakorum. In: Körner, Ch. & E.M. Spehn (eds) *Mountain Biodiversity: A global assessment*.

London (Parthenon Publishing) pp. 129-147.

Diggle P.K, S.S. Lower and T.A. Ranker, 1994. Clonal diversity and phenotypic plasticity in three alpine populations of *Polygonum viviparum* (Polygonacae). *Am. J. Bot. (Suppl)* 81:22.

Dikshit, B.K. and Panigrahi, G. 1998. *The Family Rosaceae in India*. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Einar, H. 2002. A model of alpine species distribution in relation to snowmelt time and altitude. *J. Veg. Sci.* 13: 493 – 504.

Evans, B.M., D. A. Walker, C. S. Benson, E.A. Nordstrand and G. W. Peterson. 1989. Spatial interrelationships between terrain, snow distribution and vegetation patterns at an arctic foothills site in Alaska. *Holarctic Ecology* 12: 270-278.

Everett, K.R., P. J. Webber, D.A. Walker, R.J. Parkinson, and J. Brown. 1978. A Geospatial Mapping Scheme for Alaskan Coastal Tundra. *Proc. III International Conference on Permafrost*. National Research Council of Canada. 359-365.

Farille, M. A. 1984. Apiaceae himalayenses. 2 : *Lalldhwojia* gen. nov. *Rev. Gen Bot.* 91: 27 – 34.

Ferrari, C. and G. Rossi. 1995. Relationships between plant communities and late snow melting on Mount Prado (Northern Apennines, Italy. *Vegetatio* 120: 49-58.

Forbes, B.C., J.J. Ebersole, and B. Strandberg, 2001. Anthropogenic Disturbance and Patch Dynamics in Circumpolar Arctic Ecosystems. *Conservation Biology* 15 (4): 954-969.

Fort, M., D.W. Burbank and P. Freytet. 1989. Lacustrine Sedimentation in a Semiarid Alpine Setting: An Example from Ladakh, Northwestern Himalaya. *Quaternary Research* 31: 332 – 350.

Fosberg, F.R. 1961. A Classification of vegetation for general purposes. *Tropical Ecology* 2: 1-28.

Fox, J.L., C. Nurbu, S. Bhatt, and A. Chandola. 1994. Wildlife conservation and land-use changes in the trans Himalayan region of Ladakh, India. *Mountain Res. Dev.* 14: *39-60.*

Freitag, S. and A.S.V. Jaarsveld. 1997. Relative occupancy, endemism, taxonomic distinctiveness and vulnerability: Prioritizing regional conservation actions. *Biodiversity & Conservation* 6: 211-232.

Garg, S. 1987. *Gentianaceae of the North West Himalaya*: *A Revision.* Today and Tomorrow's Printers & Publishers. New Delhi.

Garnier, B.J. and A. Ohmura. 1968. A method of calculating the direct short wave radiation income of slopes. *J. Appl. Meteorol* 7: 796 – 800.

Gaston, K.J. 1994. Rarity: Population and community biology series. 13. Chapman & Hall.

Gauch, H.G. 1982. *Multivariate Analysis in Community Ecology.* Cambridge University Press, Cambridge.

Gaur, U.N., G.P. Raturi, and A.B. Bhatt, 2003. Quantitative Response of Vegetation in Glacial Moraine of Central Himalaya. *The Environmentalist* 23: 237 – 247.

Gaur, U.N., G. P. Raturi, and A.B. Bhatt. 2005. Current Vegetation Pattern along glacial landscape in Central (Garhwal) Himalaya, India. *J. Mountain Science* 2 (3): 255 – 264.

Gentry, A.H. 1992. Tropical Forest Biodiversity: Distributional Patterns and their conservation significance. *Oikos*: 63: 19 – 28.

Gering, J.C., T.O. Crist and J.A. Veech. 2003. Additive Partitioning of species diversity across multiple spatial scales: Implications for regional conservation of biodiversity. *Conservation Biology* 17: 488 – 499.

Ghildiyal, B.N. 1956. A Botanical trip to the Valley of Flowers. *J. Bombay Nat. His. Soc*. 54: 365-386.

Gillison, A.N. and K.R.W. Brewer. 1985. The Use of Gradient Directed Transects or Gradsects in Natural Resource Surveys. *J. Env. Management*. 20: 103-127.

Grabherr, G. and M.G.H. Pauli. 1994. Climate effects on mountain plants. *Nature* 369:448.

Grabherr G. M., A.G. Gottfried and H. Pauli. 1995. Patterns and current changes in alpine plant diversity. In: Chapin FS & Ch Korner (eds) *Arctic and alpine biodiversity: patterns, causes and ecosystem consequences.* Ecological studies, vol 113. Springer, Berlin Heidelberg New York. Pp 167-181.

Grier, C.C. and T.M. Ballard, 1981. Biomass nutrient distribution, and net production in alpine communities of the Kluana Mountains, Yukon Territory, Canada. *Canadian J. Botany*, 59: 2635-2649.

Grime J.P. 1979. *Plant Strategies and Vegetation Processes*. Wiley, Chichester.

Grytnes, J.A. and O.L. Vetaas. 2002. Species richness and altitude: a comparison between null models and interpolated plant species richness along the Himalayan Altitudinal Gradient, Nepal. *The American Naturalist* 159: 294 – 304.

Gupta, R.K. 1983. *The Living Himalayas: Aspects of Environment and Resource*

Ecology of Garhwal. Vol. I & II. Today and Tomorrow's Printers and Publishers, New Delhi.

Hajra, P.K. and Balodi, B. 1995. *Plant Wealth of Nanda Devi Biosphere Reserve.* Botanical Survey of India. 458 pp.

Hajra, P.K., R.R. Rao, D.K. Singh and B.P. Uniyal. 1995. *Flora of India*: Vol. 12 -13. Asteraceae. Botanical Survey of India. Calcutta.

Halloy, S.R.P. and A. F. Mark, 2003. Climate–Change Effects on Alpine Plant Biodiversity: A New Zealand Perspective on Quantifying the Threat. *Arct. Ant. Alp. Res.* Vol. 35 (2): 248-254.

Hart, R.H. 2001. Plant Biodiversity on shortgrass steppe after 55 years of zero, light, moderate or heavy cattle grazing. *Plant Ecology* 155: 111-118.

Hartmann, H. 1984. New and poorly known flowering plants from Ladakh with a supplement to the flora of the Karakoram. *Candollea* 39: 507-537.

Hartmann, H. 1987. Xerophytic sub-alpine and alpine plant communities in the southern and eastern part of Ladakh. *Candollea* 42: 277-326.

Hartmann, H 1995. Contribution to the study of the subalpine desert vegetation in the Indus catchment area in Ladakh, India. [German] *Candollea.* 50 (2) 367-410.

Hartmann, H. 1999. Studies on the flora and vegetation in eastern Trans-Himalaya of Ladakh (India). [German]] *Candollea* 54 (1): 171-230.

Henneknes, S.M. and J.H.J. Schaminee. 2001. TURBOVEG, a comprehensive database management system for vegetation data. *J. Veg. Sci.* 12: 589 – 591.

Hedberg I and O. Hedberg, 1979. Tropical-alpine life-forms of vascular plants. *Oikos* 33: 297 - 307.

Heegard, E. 2002. A model of alpine species distribution in relation to snowmelt time and altitude. *J. Veg. Sci.* 13: 493-504.

Hewitt, J.E., S. F. Thrush, J. Halliday and C. Duffy. 2005. The importance of small-scale habitat structure for maintaining Beta Diversity. *Ecology* 86 (6): 1619 – 1626.

Heywood, V.H. 1988. Rarity: a privilege and a threat. In: Greuter, W. & B. Zimmer (eds) *Proc. XIV International Congress.* Koeltz, Konigstein, Taunus. Pp. 277 - 290.

Hill, M. O. 1979. TWINSPAN. *A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes.* Cornell University, Ithaca, New York.

Hodgson, J.G. 1986a. Commonness and Rarity in Plants with Special Reference to the Sheffield Flora. Part I: The Identity, Distribution and Habitat Characteristics of the Common and Rare Species. *Biological Conservation* 36 : 199 – 252.

Hodgson, J.G. 1986b. Commonness and Rarity in Plants with Special Reference to the Sheffield Flora. Part II: The Relative Importance of Climate, Soils and Land Use. *Biological Conservation* 36 : 253 - 274.

Holtmeier F.K. and G. Broll. 1992. The influence of tree islands and microtopography on pedoecological conditions in the forest-alpine tundra ecotone on Niwot Ridge, Colorado Front Range, U.S.A. *Arct. Alp. Res.* 24:216-228.

Holzner, W. and M. Kriechbaum. 1998. Man's impact on the vegetation and landscape in the inner Himalaya and Tibet. In: Elvin, M & L. Tsui-Jung (eds) *Sediments of Time: Environment and Society in Chinese History*, Cambridge university press, USA. Pp. 53-106.

Hooker, J.D. 1872-97. *The Flora of British India.* Vols 1-7. London.

Hooker, J.D. 1906. *A sketch of the Flora of British India.* Clarendon, Oxford. Bishen Singh Mahendra Pal Singh, Dehra Dun. Reprint 1973.

Humbert-Droz B. and S. Dawa, 2004. *Biodiversity of Ladakh. Strategy and action plan.* LEDeG, Sampark, 243 pp.

Huston, 1979. A general hypothesis of species diversity. *American Naturalist.* 113: 81-101.

IUCN. 1994. IUCN Red List Categories. Gland, Switzerland.

IUCN. 2006. IUCN red list of threatened species. <www.iucnredlist.org>. Downloaded on 03 March 2007.

Jacobson, Jr. G. L., H.A. Jacobson and J.C. Winne. 1991. Conservation of rare plant habitat: Insights from the recent history of vegetation and fire at Crystal Fen, Northern Maine, USA. *Biological Conservation* 57: 287-314.

Jacquz, G.M. and D.T. Patten. 1996. *Chesneya nubigena* on a Himalayan glacial moraine: A case of facilitation in primary succession? *Mountain Res Dev* 16 (3): 265-273.

Jennings, M., O. Loucks, D. Glenn-Lewin, R. Peet, D. Faber-Langendoen, D. Grossman, A. Damman, M. Barbour, R. Pfister, M. Walker, S. Talbot, J.Walker, G. Hartshorn, G. Waggoner, M. Abrams, A. Hill, D. Roberts, and D. Tart. 2002. *Standards for associations and alliances of the U.S. national vegetation classification.* The Ecological Society of America, Vegetation Classification Panel, Version 1.0, USA.

Jian, N., 2002. Carbon storage in grasslands of China. *J. Arid Environment* 50: 205-

218.

Johnsingh, A.J.T., G. S. Rawat, S. Sathyakumar, P.V. Karunakaran and J. Kaur. 1998. Prioritization of Areas for Biodiversity Conservation of Alpine Zone in the Trans-and Greater Himalaya in India. In: Singh, S. *et al.*, (eds) *Setting Biodiversity Conservation Priorities for India*. Vol. 1: WWF. Pp. 212-225.

Joshi, P.K., G.S. Rawat, H. Padalia and P.S. Roy. 2005. Land use / Land Cover Identification in an alpine and arid region (Nubra Valley, Ladakh) using satellite remote sensing. *J. Ind. Society of Remote Sensing* 33 (3): 371-380.

Jones H.G. 1992. *Plants and microclimate*. Cambridge University Press, Cambridge.

Jones, G.A. and G.H.R. Henry. 2003. Primary plant succession on recently deglaciated terrain in the Canadian High Arctic. *J. Biogeography* 30: 277-296.

Joshi, S.P., A. Raizada and M. M. Srivastava. 1988. Net primary productivity of a high altitude grassland in Garhwal Himalaya. *Tropical Ecology* 29: 15-20.

Kachroo, P. , B. L. Sapru, and U. Dhar. 1977. *Flora of Ladakh*. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Kadereit, J. W. and H.P. Comes. 2005. The temporal course of alpine plant diversification in Quaternary. In: Bakker, F. T. & L.W. Chatrou (eds) *Plant Species Level Systematics*. Pp. 117 – 130.

Kala, C.P. and V. B. Mathur. 2002. Patterns of plant species distribution in the Trans-Himalayan region of Ladakh, India. *J. Veg. Sci.* 13: 751-754.

Kala, C.P., G. S. Rawat and V. K. Uniyal, 1998. *Ecology and conservation of the Valley of Flowers National Park, Garhwal Himalaya.* RR-98/003. Wildlife Institute of India, Dehra Dun, 99 pp.

Katariya, V. 1998. Vanishing herbs. *Down to Earth* 6(23): 21.

Kaul , M. K. 1983. Vegetation of Tsokar Lake and Puga Valley, Trans-Himalaya. *Folia Geobot. Phytotax*. 18: 301-308.

Kaul, V. and Y. K. Sarin. 1971. Phytosociology of some alpine meadows in N.W. Himalayas. *Vegetatio* 23 (5-6): 361-368.

Kawosa, M.A. 1988. *Remote Sensing of the Himalaya*. Natraj Publishers, Dehra Dun.

Kent, M. and P. Coker. 1992. *Vegetation Description and Analysis. A Practical Approach.* Belhaven Press London.

Khullar, S.P. 1994 and 2000. An Illustrated Fern Flora of Western Himalaya – Vol. I & II. International Book Distributors. Dehra Dun.

Kikuchi, T. and H. Ohba. 1988. Preliminary study of alpine vegetation of the Himalayas with special reference to the small-scale distribution patterns of plant communities. In: Ohba, H. (ed) *The Himalayan Plants.* Vol. I. University of Tokyo Press. Pp. 47-70.

Kikvidje, Z., F. .I. Pugnaire, R.W. Brooker and P. Choler. 2005. Linking patterns and processes in alpine plant communities: a global study. *Ecology* 86(6): 1395 – 1400.

Kirschner, J., J. Stepanek, and L. Klimes. 2006. Dandelions in Central Asia: A taxonomic revision of *Taraxacum* section *Leucantha. Preslia* 78: 27 – 65.

Klimes, L. 2003. Life-forms and clonality of vascular plants along an altitudinal gradient in E Ladakh, NW Himalaya. *Basic and Applied Ecology* 4 (4): 317-328.

Klimes, L. and W. B. Dickore. 2005. A Contribution to the vascular plant flora of Lower Ladakh, Jammu & Kashmir, India. *Willdenowia* 35: 125-153.

Klimes, L. and B. Dickore. 2006. *Flora of Ladakh (NW Himalaya)- A preliminary checklist*. www.butbn.cas.cz/klimes/desert.html

Korner, C. 1989. The nutritional status of plants from high altitudes: A worldwide comparison. *Oecologia* 81: 379-391.

Korner, C. 1999. *Alpine Plant Life : Functional Plant Ecology of High Mountain Ecosystems*. Srpinger.

Korner, C. 2003. Limitation and stress – always or never ? Invited Perspective. *J. Veg. Sci.* 14: 141 – 143.

Korner, C., 2004. Mountain Biodiversity: Its Causes and Function. *Ambio* Special Report 13: 11 – 17.

Korner, C. and W. Larcher. 1988. Plant Life in Cold Climates. In: Long, S.F. & F.I. Woodward (eds) *Plants and Temperature*, Symp. Soc. Exp. Biol. Vol. 42: 25-57.

Korner, C, M. Neumayer, S.P. Menendez-Riedl. and A. Smeets-Scheel. 1989. Functional Morphology of mountain plants. *Flora* 182: 353- 383.

Krebs, C.J. 2001. *Ecology.* (V Edition). Benjamin Cummings.

Krukeberg, A.R. and D. Rabinowitz. 1985. Biological Aspects of Endemism in Higher Plants. *Ann. Rev. Ecol. Syst.* 16: 447 – 79.

Lal, J.B., A. K. Gulati, and M. S. Bist. 1991. Satellite mapping of alpine pastures in the Himalayas. *Int. J. Remote Sensing,* 12 (3): 435-443.

Leuschner, C. 1996. Timberline and alpine vegetation on the tropical and warm-temperate oceanic islands of the world: elevation, structure and floristics.

Vegetatio 123:193-206

Love, D. 1970. Sub-arctic and subalpine: where and what? *Arct. Alp. Res.* 2: 63 – 73.

Lubomir, T. 2002. JUICE, software for vegetation classification. *J. Veg. Sci.* 13: 451 – 453.

Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. Groom Helm Limited, London.

Mani, M.S. 1978. *Ecology and Phytogeography of the High Altitude Plants of the Northwest Himalaya.* Oxford & IBH Publishing Co., New Delhi.

Mani, M.S. 1994. The Himalaya, its ecology and biogeography - A review. In: Pangtey, Y.P.S. & R.S. Rawal (eds) *High altitudes of the Himalaya*. Gyanodaya Prakashan, Nainital. Pp 1- 10.

Manjrekar, N. 1997. *Feeding Ecology of Asiatic Ibex in Pin Valley National Park, Himachal Pradesh*. Ph. D. Thesis (Unpublished). Saurashtra University, Rajkot.

Mark, A.F. and Bliss, L.C. 1970. The high alpine vegetation of Central Otago, New Zealand. *New Zealand J. Bot*. 8: 67-75.

May, D.E. and P. J. Webber. 1982. Spatial and temporal variation of the vegetation and its productivity, Niwot Ridge Colorado. In: Halfpenny, J.C. (ed) *Ecological Studies in the Colorado Alpine*, University of Colorado, Institute of Arctic and Alpine Research. 37: 35-62.

McCune, B. and M. J. Mefford, 1999. PC-ORD. *Multivariate analysis of ecological data*. Version 4.41, MjM Software, Gleneden beach, Oregon, U.S.A.

Menon, V. 2003. *A Field Guide to Indian Mammals*. Penguin Book India (P) Ltd. & Dorling Kindersley. New Delhi.

Miehe, G. 1989. Vegetation patterns on Mount Everest as influenced by monsoon and fohn. *Vegetatio* 79:21-32.

Miehe, G. 1997. Alpine vegetation types of the Central Himalaya. In: Wielgolaski F.E. (ed) *Polar and alpine tundra Ecosystems of the world.* Vol. 3: 161-184.

Miehe, G. and S. Miehe. 2000. Environmental Changes in the Pastures of Xizang. In: Miehe, G & Z. Yili (eds) *Environmental Changes in High Asia* (Eds.). Proc. International Symp. at the University of Marburg, Faculty of Geography. M.G.S. Pp. 282-311.

Miehe, G., S. Miehe, and W. B. Dickore. 2002. Alpine Deserts in High Asia. In: Xiaoping, Y. (ed) *Desert and Alpine Environments: Advances in Geomorphology and Palaeoclimatology*. China Ocean Press. Pp. 59-79.

Miehe, G., M. Winiger, J. Bohner, and Z. Yili. 2001. The Climatic Diagram Map of High Asia: Purpose and Concepts. *Erdkunde Band* 55: 94-98.

Miehe, S., T. Cramer, J. P. Jacobsen, and M. Winiger. 1996. Humidity conditions in the western Karakoram as indicated by climatic data and corresponding distribution patterns of the montane and alpine vegetation. *Erdkunde Band* 50: 190 – 204.

Miller, D. J. 1990. Grasslands of the Tibetan Plateau. *Rangelands* 12(3): 159-163.

Miller, D. J. and G.B. Schaller. 1996. Rangelands of the Chang Thang Wildlife Reserve in Tibet. *Rangelands* 18 (3): 91-96.

Mishra, C. 1997. Livestock depredation by large carnivores in the Indian trans-Himalaya: conflict perceptions and conservation proposals. *Env. Cons.* 24 (4): 338-343.

Mishra, C. 2001. *High altitude survival: conflicts between pastoralism and wildlife in the Trans-Himalaya.* Ph. D. dissertation. Wageningen University, Wageningen, The Netherlands.

Mishra, C. and G. S. Rawat, 1998. Livestock grazing and biodiversity conservation: comments on Saberwal. *Cons. Biol.* 12 (3): 712-714.

Mishra, C., H. H. T. Prins, and S. E. Van Wieren. 2001. Overstocking in the Trans-Himalayan rangelands of India. *Environmental Conservation* 28: 279–283.

Misra, R., 1968. *Ecology workbook*, New Delhi.

Mittermeier, R.A., P. R. Gils, M. Hoffman, J. Pilgrim, T. Brooks, C. G. Mittermeier, J. Lamoreaux, and G.A.B. da-Fonseca (eds) 2004. *Hotspots Revisited. Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. CEMEX. USA.

Molnar, P. 1989. The Geologic Evolution of the Tibetan Plateau. *Am. Scientist* 77: 350 – 360.

Mueller-Dumbois, D. and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. John Wiley and sons, New York.

Mukherjee, P.K. and L. Constance. 1986. Two new genera of Indian Umbelliferae / Apiaceae. *Brittonia* 38 (2): 145 – 149.

Murty, S.K. 2001. *Flora of Cold Deserts of Western Himalaya.* Vol. 1 (Monocotyledons). Botanical Survey of India. Dehra Dun.

Myers, N., R. A. Mittermier, C. G. Mittermier, G. A. B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 40: 853-858.

Naithani, B.D. 1984. *Flora of Chamoli.* Botanical Survey of India, Howrah. Vols 1-2..

Naithani, B.D. 1988. Botanising the Jadh Ganga Valley in Uttarkashi, Garhwal, U.P. *J. Econ. Tax. Bot.* Vol. 19 (1): 63-74.

Naithani, H.B. 1990. *Flowering Plants of India, Nepal and Bhutan (Not included in Sir J.D. Hooker's Flora of British India).* Surya Publications.

Naithani, H.B., J.D.S. Negi, R. C. Thapliyal and T.C. Pokhriyal. 1992. Valley of Flowers: Need for Conservation or Preservation. *Indian Forester* 118 (5): 371 – 378.

Nasir, E. and S. Ali. 1972. *Flora of (West) Pakistan.* Karanchi.

Nautiyal, B.P., N. Pandey and A. B. Bhatt 1997. Analysis of Vegetation Pattern in an Alpine Zone in Northwest Himalaya: A Case Study of Garhwal Himalaya with Reference to Diversity and Distribution Patterns. *International J. Ecol. Env. Sci.* 23: 49-65.

Nautiyal, A. R., M.C. Nautiyal and A.N. Purohit. 2000. *Harvesting Herbs: 2000. Medicinal and Aromatic Plants – An Action Plan for Uttarakhand.* Bishen Singh Mahendra Pal Singh, Dehra Dun.

Nautiyal, B.P., V. Prakash and M. C. Nautiyal. 2000. Structure and diversity pattern along an altitudinal gradient in an alpine meadow of Madhyamaheshwar, Garhwal Himalaya. *International J. Ecol. and Env. Sci.* 4 (1): 39 – 48.

Nautiyal, B.P., N. Pandey and A. B. Bhatt 1997. Biomass, Production Potential, Dynamics and Turnover Rate in an Alpine Meadow of North-West Himalaya. *J. Hill Research* 10 (2): 95 – 102.

Nautiyal, M. C., B. P. Nautiyal, and V. Prakash. 2004. Effect of grazing and climatic changes on alpine vegetation of Tungnath, Garhwal Himalaya. *The Environmentalist* 24: 125 – 134.

Nayar, M.P and A.R.K. Sastry. 1990. Red Data Book of Indian Plants. Botanical Survey of India, Calcutta.

Negi, G.C.S., H. C. Rikhari, J. Ram, and S. P. Singh. 1993. Foraging niche characteristics of horses, sheep and goats in an alpine meadow of the Indian Central Himalaya. *J. Applied Ecology* 30: 383-394.

Negi, G.C.S., H. C. Rikhari, and S. P. Singh 1992. Phenological features in relation to growth forms and biomass accumulation in an alpine meadow of the Central Himalaya. *Vegetatio* 101: 161 – 170.

Negi, K.S., J. K. Tiwari, and R. D. Gaur. 1983. A Contribution to the flora of Dodital – A High Altitude Lake in the Garhwal Himalaya, Uttarkashi, U.P. *J.*

Bombay Nat. Hist. Soc. 82: 258- 270.

Ni, J. 2006. A simulation of biomes on the Tibetan Plateau and their responses to global climate change. *Mountain Res. Dev.* 20 (1): 80 – 89.

Norussis, M. J. 1996. Advanced Statistics SPSS-PC for the IBM Pc. Inc, Chicago, 1986.

Ohba, H. 1989. The Alpine Flora of the Nepal Himalayas: An Introductory Note. In: Ohba, H. (ed.) *The Himalayan Plants* Vol. 1. Pp. 19-46. Univ. of Tokyo Press.

Oostermeijer, G. 1999. Rare plants in the Netherlands. The problems of small populations. *Plant Talk* April: 26-28.

Packer, J.G. 1974. Differentiation and dispersal in alpine floras. *Arct. Alp. Res* 6:117-128.

Pande, H.C. and Pande, P.C. 2003. *An illustrated fern flora of the Kumaon Himalaya*. 2 Vols. Bishen Singh Mahendra Pal Singh.

Pant, R.K., N.R. Phadtare, L.S. Chamyal and N. Juyal. 2005. Quaternary deposits in Ladakh and Karakoram Himalaya: A treasure trove of the palaeoclimate records. *Current Science* 88 (11): 1789 – 1798.

Partel, M. 2002. Local plant diversity patterns and evolutionary history at the regional scale. *Ecology* 83 (9): 2361 – 2366.

Pennell, F.W. 1943. *Scrophulariaceae of the Western Himalayas*. Rep. 1997. Bishen Singh Mahendra Pal Singh. Dehra Dun.

Philip, G. and R. K. Mazari. 2000. Shrinking lake basins in the proximity of the Indus suture zone of northwestern Himalaya: a case study of Tso Kar and Startsapuk Tso using IRS – 1C data. *Int. J. Remote Sensing* 2000, 21 (16): 2973 – 2984.

Polunin, O and A. Stainton. 1984: *Flowers of Himalaya*. Oxford Press, New Delhi India, 580 pp.

Punetha, N. 1989. Ecological and phytogeographical observations on the fern flora of Pithoragarh district (north-west Himalaya). *Proc. of Indian Academy of Sciences*: Plant Sciences 98 (4): 327-333.

Punetha, N. and B. S. Kholia. 1998. Pteridophytic Flora of Kumaon Himalaya: Distribution, Evolution and Status. *Indian Fern J.* 15: 75-79.

Puri, G.S., R. K. Gupta, V.M. Meher-Homji, and S. Puri. 1989. *Forest Ecology.* Oxford and IBH Publication Co. Pvt. Ltd. New Delhi, Vol. II, 582 pp.

Rabinowitz, D. 1981. Seven forms of rarity. In: Synge, H. (ed) *The Biological Aspects of Rare Plant Conservation.* Wiley, New York. Pp. 205-217.

Raina, V.K. 2005. Status of glacier studies in India. *Him. Geol.* 26 (1): 285-293.

Ram, J, S. P. Singh, and J. S. Singh. 1988. Community level phenology of grassland above tree-line in central Himalaya, India. *Arct. Alp. Res.* 20 (3): 325-332.

Ram, J., J. S. Singh, and S. P. Singh. 1989. Plant Biomass, Species Diversity and Net Primary Production in a Central Himalayan High Altitude Grassland. *Journal of Ecology* 77: 456-468.

Ram, J. 1992. Effects of Clipping on Aboveground Plant Biomass and Total Herbage Yields in a Grassland above Treeline in Central Himalaya, India. *Arct. Alp. Res.* 24 (1): 78-81.

Ram, J. and P. Arya. 1991. Plant forms and Vegetation Analysis of an Alpine Meadow of Central Himalaya, India. *Proc. Indian National Science Academy,* 57 (5): 311-318.

Ram, J., S. P. Singh, and J. S. Singh. 1991. Effect of fertilizer on plant biomass distribution and net accumulation rate in an alpine meadow in central Himalaya, India. *J. Range Management* 44 (2): 140 – 143.

Ram, J. and S.P. Singh. 1994. Ecology and Conservation of Alpine Meadows in Central Himalaya, India. In: Pangtey, Y.P.S. & R.S. Rawal (eds) *The High Altitudes of the Himalaya.* Gyanodaya Prakashan. Pp. 33 - 55.

Rao, R.R., T. Hussain, B. Dutt and A. Garg. 1998. Revision of the Family Berberidaceae of India I & II. *Rheedia* 8(1): 1-66 and 8 (2): 109 -143.

Rau, M.A. 1975. *High altitude flowering plants of west Himalaya.* BSI, Howrah, India 214pp.

Raunkaier, C. 1934. *The Life Forms of Plants and Statistical Plant Geography.* Clarrendon Press, Oxford.

Rawat, D.S., L. R. Dangwal, and R. D. Gaur. 1995. A new species of *Dilophila* Thoms. (Brassicaceae) from Garhwal Himalaya (India). *J. Bombay Nat. Hist. Soc.* 93: 262 – 264.

Rawat, G.S. 1984. *Studies on the high Altitude Flowering Plants of Kumaun Himalaya.* Ph. D. Thesis (Unpubl.), Kumaun University Naini Tal.

Rawat, G.S. 1987. On the occurrence of *Lalldhwojia cooperii* Farille (Apiaceae) in India. *J. Bomb. Nat. Hist. Soc.* 84(3): 725-727.

Rawat, G.S. 1994. Protected Areas and Conservation of Rare endemic Plants in the Himalaya. In: Pangtey, Y.P.S. & R.S. Rawal (eds) *The High Altitudes of the Himalaya.* Gyanodaya Prakashan. Pp. 88 – 101.

Rawat, G.S. 1998. Temperate and alpine grasslands of the Himalaya: Ecology and Conservation. *Parks*: 8 (3): 27-36.

Rawat, G.S. 2000. Alpine Vegetation of North Western India: An Ecological Review. In: Richard, C. *et al.* (eds) *Grassland Ecology and Management in Protected Areas of Nepal.* Vol. III. Pp. 32-44. ICIMOD, Kathmandu, Nepal.

Rawat, G.S. 2005. *Alpine Meadows of Uttaranchal: Ecology, Landuse and Status of Medicinal and Aromatic Plants*. Bishen Singh Mahendrapal Singh, Dehra Dun.

Rawat, G.S. and Y.P.S. Pangtey. 1987a. Floristic Structure of Snowline Vegetation in Central Himalaya, India. *Arct Alp Res* 19 (2): 195-201.

Rawat, G.S. and Y.P.S. Pangtey. 1987b. A note on *Rosa osmastonii* Rawat et Pangtey *Nom. nov.* from Kumaun Himalaya: *The Indian Forester* 113(12): 823-824.

Rawat, G.S. and Y.P.S. Pangtey. 1987c. On the occurrence of *Morina betonicoides* Benth. (Dipsacaceae) in Western Himalaya. *Ind. Journ. of Forestry* 10(4): 118.

Rawat, G.S. and V.K. Uniyal. 1993. Pastoralism and Plant Conservation: The Valley of Flowers Dilemma. *Environmental Conservation* 20 (2): 164-168.

Rawat, G.S., R.S. Chundawat and S. Sathyakumar. 1996. Conservation planning and management of Protected Areas in the Himalaya. In: Ramakrishnan, P.S. *et al.* (eds) *Conservation and management of biological resources in the Himalaya.* G.B.Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora. Pp 69-84.

Rawat, G.S. and B. S. Adhikari. 2001. Vegetation characteristics and patterns of livestock grazing in Chang Thang plateau, Eastern Ladakh. Wildlife Institute of India & ICIMOD, Kathmandu, Nepal.

Rawat, G.S. and B.S. Adhikari. 2005. Floristics and Distribution of Plant Communities across Moisture and Topographic Gradients in Tso Kar Basin, Changthang Plateau, Eastern Ladakh. *Arct. Ant. Alp. Res.* 37 (4): 539-544.

Rawat, G.S. and W. A. Rodgers. 1988. The alpine meadows of Uttar Pradesh: An ecological review. In: Singh, P. and P.S. Pathak (eds) *Rangeland Resource and Management.* Range Management Society of India. Jhansi, India. 119-137.

Rawat, G.S. and S. Satyakumar. 2002. Conservation issues in the Himalayan region of India. *Envis Bulletin*, Wildlife and Protected Areas, 2002. 1(1): 50-56.

Rawat, G.S. and S. Chandola. 2006. Rapid Mapping Exercise for Quantification of Medicinal Plants: Lessons from Uttaranchal. In: Kumar, S. (ed) *Plant Science Research in India: Challenges and Prospects.* Botanical Survey of India. Pp. 69 - 99.

Reveal, J.L. 1981. The concepts of rarity and population threats in plant communities. In: Morse, L.E. and M.S. Henefin (eds) *Rare Plant Conservation*. The New York Botanical Garden, Bronx. Pp. 41 – 6.

Rikhari, H.C. G. C. S. Negi, G. B. Pant, B. S. Rana, and S. P. Singh. 1992. Phytomass and primary productivity in several communities of a Central Himalayan alpine meadow, India. *Arct. Alp. Res.* 24(4): 344-351.

Rikhari, H.C., G. C. S. Negi, J. Ram, and S. P. Singh. 1993. Human induced secondary succession in an Alpine Meadow of Central Himalaya, India. *Arct. Alp. Res.* 25 (1): 8-14.

Rodgers, W.A. and H. S. Panwar. 1988. *Planning a Wildlife Protected Area Network in India*. 2 Vols. Wildlife Institute of India, Dehra Dun.

Rosenzweig, M.L. 1995. *Species diversity in space and time*. Cambridge University Press. Cambridge University Press. Cambridge, UK.

Saberwal, V.K. 1995. Pastoral Politics, Gaddi Grazing, Degradation and Biodiversity Conservation in Himachal Pradesh, India. *Conservation Biology* 10 (3): 741-749.

Sahni, K.C. 1990. Gymnosperms of India and adjacent countries. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Samant, S.S., U. Dhar and L.M.S. Palni. 1998. Medicinal Plants of Indian Himalaya: Diversity, Distribution and Potential Values. G.B. Pant Insitute of Himalayan Environment & Development. Almora.

Samant, S.S., U. Dhar and L.M.S. Palni. 2001. *Himalayan Medicinal Plants: Potential and Prospects.* G.B. Pant Insitute of Himalayan Environment & Development. Almora.

Samant, S. S. and H. C. Joshi. 2004. Floristic Diversity, Community Patterns and Changes in Vegetation of Nanda Devi National Park. In: Anonymous. 2004. *Biodiversity Monitoring Expedition Nanda Devi 2003*. A Report to the Ministry of Environment & Forests, Government of India. Uttaranchal State Forest Department, Dehra Dun. Pp. 139 -54.

Samant, S. S. and H. C. Joshi. 2005. Plant diversity and conservation status of Nanda Devi National Park and comparison with highland National Parks of the Indian Himalayan Region. *International J. of Biod. Sci. & Management* 1: 65-73.

Samant, S.S., U. Dhar and R.S. Rawal. 2005. Diversity, Endemism and Socio-economic values of the Indian Himalayan Papaveraceae and Fumariaceae. *J. Ind. Boc. Soc.* 84: 33 – 40.

Schaller, G.B., 1998. *Wildlife of the Tibetan Steppe,* University of Chicago, USA

Schoener, T.W. 1987. The geographical distribution of rarity. *Oecologia* (Berl.), 74: 161 – 73.

Schweinfurth, U. 1957. Die horizontale und vertikale Verbreintung der Vegetation im Himalaya (Mit Veg. 1:2,000,000). *Bonner Geogr. Abh. H.* 20.

Schweinfurth, U. 1984. The Himalaya: Complexity of a mountain system manifested by its vegetation. *Mountain Res. Dev.* 4(4): 339 – 344.

Semwal, J.K. 1982. Flowering Plants Around the Holy Shrine of Kedarnath, Uttar Pradesh. *J Bombay Nat. Hist. Society* 81: 71-85.

Semwal, J.K., R. D. Gaur, and A. N. Purohit. 1981. Floristic pattern of Tungnath, an alpine zone in Garhwal Himalaya. *Acta Botanica Indica* 9: 110-114.

Seth, C. M. 1996. Biomass Fluctuation in Alpine Pastures of Kashmir Himalaya. Annals of Arid Zone 35 (1): 65-67.

Seybold S. And U. Kull 1985. A contribution to the floristics and vegetation of Zanskar (Kashmir). *Bot. Jahrb. Syst.* 105: 263-277.

Shannon, C. E. and W. Weaver. 1949. *The mathematical theory of communication.* Urbana; University of Illinois Press.

Sharma, B. M. and P. S. Jamwal 1998. Flora of Upper Liddar Valleys of Kashmir Himalaya. Vol. I & II. Scientific Publishers. Jodhpur.

Sheldon, J. W., M. Balick and S. Laird. 1998. Is using medicinal plants compatible with conservation? *Plant Talk April:* 29-31.

Shimwell, D.W. 1971. *Description and Classification of Vegetation.* Sidgwick and Jackson, London.

Singh, G. and R. N. Gohil. 1972. Some new records to the flora of Ladakh. *J. Bombay Nat. Hist. Society.* 73: 487-490.

Singh, J.S. and S.P. Singh. 1992. Forests of Himalaya. Gyanodaya, Naini Tal.

Singh, N.P., D.K. Singh and B.P. Uniyal (eds.). 2002. *Flora of Jammu & Kashmir.* Vol. I. Botanical Survey of India. Calcutta.

Singh, R.P., N. Bahar, and P. Chand. 1992. Autecology of *Capparis spinosa* L. in Cold Desert of Spiti Valley in Himachal Pradesh. *Annals of Arid Zone* 31 (4): 291-293.

Singh, S. and P. K. Hajra 1991. *Pimpinella hookeri* Clarke (Apiaceae) in Chamoli District (Uttar Pradesh). *Indian Journal of Forestry* 14 (2): 157.

Singh, S.K. 1999. *A Study on the Plant Community Composition and Species Diversity*

in Great Himalayan National Park, Western Himalaya. Ph. D. Thesis (Unpublished). Kumaun Univeristy, Naini Tal.

Singh, S.K. and G.S. Rawat. 2000. *Flora of Great Himalayan National Park, Himachal Pradesh*. Bishen Singh Mahendra Pal Singh. Dehra Dun. 304 pp.

Singh, S.P., P. Sah, V. Tyagi and B.S. Jina. 2005. Species diversity contributes to productivity- evidence from natural grassland communities of the Himalaya. *Current Science* 89(3): 548 – 552.

Sinha, A.K. 1989. *Geology of the Higher Central Himalaya*. John Wiley & Sons.

Smith, A.P. 1994. Introduction to tropical alpine vegetation. In: Rundel P.W. *et al.* (eds) *Tropical Alpine Environments*. Cambridge University Press, Cambridge, pp 1-19.

Smith, A.P. and T.P. Young. 1987. Tropical alpine plant ecology. *Ann. Rev. Ecol. Syst* 18:137-158.

Smythe, F.S. 1939. *The Valley of Flowers*. London.

Stebbins, G.L. and J. Major. 1965. Endemism and Speciation in Californian Flora. *Ecol. Monograph* 35: 1-35.

Sundriyal, R.C. 1992. Structure, productivity and energy flow in an alpine grassland in the Garhwal Himalaya. *J. Veg. Sci.* 3:15-20.

Sundriyal, R.C and A. P. Joshi. 1992. Annual nutrient budget for an alpine grassland in the Garhwal Himalaya. *J. Veg. Sci.* 3:21-26.

Sundriyal, R. C. 1989. Assessment of the grazing ability of an alpine pasture in the Garhwal Himalaya, India. *Environment and Ecology* 7 (1): 247-249.

Sundriyal, R. C. 1995. Grassland forage production and management in the Himalaya: a review. *J Hill Research* 8 (2): 135-150.

Sundriyal, R. C. and A. P. Joshi. 1990. Effect of grazing on standing crop, productivity and efficiency of energy capture in an alpine grassland ecosystem at Tungnath (Garhwal Himalaya), India. *Tropical Ecology,* 31 (2): 84-97.

Swan, L.W. 1992. The Aeolian Biome. Ecosystems of the earth's extremes. *Bioscience* 42: 262 – 270.

Tambe, S. 2007. *Ecology and Management of alpine landscape in Khangchendzonga National Park, Sikkim Himalaya*. Ph. D. Thesis (Unpublished), FRI University, Dehra Dun.

ter Braak, C.J. F. 1990. Updated Notes on CANOCO ver. 3.10. Wageningen: Agricultural Mathematics Group. 35.

Thakur, V.C. and B.S. Rawat. *Geological Map of Western Himalaya*. Wadia Institute of Himalayan Geology.

Thomson T. 1849. Successful journey to the Karakorum Pass, in Central Asia. *J. Royal Geogr. Soc. London* 19: 25-29.

Tucker, R. P. 1986. The evolution of transhumant grazing in the Punjab Himalaya. *Mountain Res. Dev* 6 (1): 17-28.

Uniyal, S., A. Awasthi and G.S. Rawat. 2002. Current status and distribution of commercially exploited medicinal and aromatic plants in upper Gori Valley, Kumaon Himalaya, Uttaranchal. *Current Science* 82 (10): 1246-1252.

Uniyal, S. K., A. Awasthi, and G. S. Rawat. 2003. Is the future of *Eurotia ceratoides* safe in Changthang? *Current Science.* 85, 1395.

Valdiya, K. S. 2001. *Himalaya: Emergence and Evolution*. University Press (India) Limited.

van Soest, J.L. 1963. *Taraxacum* species from India, Pakistan and neighbouring countries. *Wentia* 10: 1-91.

Vishnu-Mittre, V. 1972. *The glacial succession in the Kashmir valley. A summary and discussion of recent research.* Geological Survey of India. Miscellaneous Publication 15: 89-96.

Vishnu-Mittre, V. 1984. Floristic changes in the Himalaya (southern slopes) and Siwaliks from Mid-Tertiary to Recent times. In: Whyte, R.O. (ed) *The evolution of the east Asian Environment*. Vol. II. Centre of Asian Studies, University of Hongkong Press. Pp. 483 – 503.

Vodnik, D., D. Kastelec, H. Pfanz, I. Maček and B. Turk. 2006. Small-scale spatial variation in soil CO_2 concentration in a natural carbon dioxide spring and some related plant responses. *Geoderma* 133 (3-4): 309-319.

Wadhwa, B. M., R. R. Rao, and P. K. Hajra. 1987. Botany of the Valley of Flowers National Park and its environs. *Bull. Bot. Surv. India.* 29 (1-4): 129-75.

Wadia, D. 1967. Geology of India. London, MacMillan.

Walker, D.A. and M. D. Walker. 1991. History and Pattern of Disturbance in Alaskan Arctic Terrestrial Ecosystems: A Hierarchical approach to Analysing Landscape Change. *J Applied Ecology* 28: 244 – 276.

Walker, D.A., E. Binnian, B. M. Evans, N. D. Lederer, E. Nordstrand, and P. J. Weber. 1989. Terrain, Vegetation and Landscape evolution of the R4D Research Site, Brooks Range Foothills, Alaska. *Holarctic Ecology* 12: 238-261.

Walker, D.A., J.C. Halfpenny, M.D. Walker, and C.A. Wessman. 1993. Long-term Studies of Snow-Vegetation Interactions. *Bioscience* 43 (5): 287 – 301.

Wang, J. 1981. On the fundamental characteristic of the steppe vegetation in Xizang Plateau. In: Liu, D. (ed) *Geological and Ecological Studies of Quinghai-Xizang Plateau*. Science Press, Beijing. Pp. 1929-1936.

Wardle, P. 1974. Alpine Timberlines. In: Ives, J.D. & R. G. Barry (eds) *Arctic and Alpine Environments*. Methuen. Pp. 371-401.

Weber, W.A. 2003. The Middle Asian Elements in the Rocky Mountain Flora of the W USA: a critical biogeographic review. *J. Biogegraphy* 30: 649-685.

Weisberg, P.J. and W. L. Baker. 1995. Spatial Variation in Tree Seedling and Krummholz Growth in the Forest – Tundra Ecotone of Rocky Mountain National Park, Colorado, USA. *Arc. Alp. Res.* 27 (2): 116-129.

Whittaker, R.H. 1975. *Communities and Ecosystems*. Macmillan, New York.

Whittaker, R.H. 1977. Evolution of species diversity in land communities. In: Hecht, M.K. et al. (eds) *Evolutionary Biology,* Vol. 10. Plenum, New York. Pp. 1-67.

Woods, C.A., C. W. Kilpatrick and W. Khan. 1999. Biodiversity of the Deosai Plateau, NW Pakistan. In: Mufti, S.A. *et al.* (eds), *Biodiversity of Pakistan*. Pp. 33- 61.

Xiao, X., D. S. Ojima, W. J. Parton, Z. Chen and D. Chen. 1995. Sensitivity of Inner Mongolia Grasslands to Climate Change. *J Biogeography* 22: 643 – 648.

Yamazaki, T. 1988. A Revision of the Genus Pedicularis in Nepal. In: Ohba, H. (ed) *The Himalayan Plants* Vol. 1. University of Tokyo Press. Pp. 91-159.

Yu, G., L. Tang, X. Yang, X. Ke, and S. P. Harrison. 2001. Modern Pollen samples from alpine vegetation on the Tibetan Plateau. *Global Ecology & Biogeography* 10: 503-519.

Zaal, K. 1993. Plant species association in alpine-subnival vegetation patches in the Central Caucasus. *J. Veg. Sci.* 4: 297-302.

Zheng, H., C. M. Powell, Z. A. Zhou and G. Dong. 2000. Pliocene uplift of the northern Tibetan Plateau. *Geology*: 28 (8): 715 –718.

Zhu, L., T. J. Owens, and G. E. Randall. 1995. Lateral variations in crustal structure of the NW Tibet. *Bull Seismological Society of America* 85 (6): 1531- 1540.

Zimmermann, N.E. and K. Felix. 1999. Predictive mapping of alpine grasslands in Switzerland: Species versus community approach. *J. Veg. Sci.* 10: 469-482.

Zwinger, A.H. and B.E. Willard. 1972. *Land above the trees: A Guide to American Alpine Tundra*. The University of Arizona Press, Tucson.

Appendix – I: Data Sheet Used for the Survey of Alpine Vegetation in the Western Himalaya

Locality **Date…..**

Sampling Point # Geog. Coordinates

Altitude

Topography (Land form):

Aspect Slope (°)

Soil (Type and thickness of A1 horizon):

Vegetation Type (Formation):

% Shrubs …. ….% Herbs… … % Graminoids… …% Mosses … …

% Lichens .. .. ….Total Ground Cover (Occular):. . . . . .

Notes: (Grazing pressure, MAP collection, signs of wild ungulates etc):

Species enumeration: 5 m radius area for shrubs; 10 x 1m^2 random quadrates for Herbaceous plants:

Species	Abundance / Cover in 10 Quadrates										
	1	2	3	4	5	6	7	8	9	10	Remarks
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											

Appendix - II: An Annotated List of Vascular Plants Recorded from the Alpine Region of Western Himalaya

Index:

New Record for India	***
New Record for W Himalaya	**
Doubtful occurrence	?
Endemic to W Himalaya	@
Collected after >century	#

Reference: Collection Nos refer to specimens deposited at WII Herbarium, SR = Site Record, P = Photographed .

Group / Family & Species	Locality	Reference
1. Ferns & Fern Allies		
Adiantum venustum D. Don	Dhaman Payar	14637
Araiostegia pulchra (D.Don) Copel	Rishiganga	BSD
Araiostegia hookeri (Moore ex Bedd.) Ching	Latakharak	BSD
Asplenium aitchisonii Fraser-Jenkins	Byans	Duthie DD
Asplenium ensiforme Wall. Ex Hk. & Grev.	Roopkund	BSD
Asplenium khullarii Viane	Sunderdhunga	BSD @
Asplenium nesii Christ.	Dhaman Payar	14627
Asplenium ramosum L.	Martoli, Pachoo	GSR SR
Asplenium ruta-muraria L.	Martoli	GSR SR
Asplenium septentrionale (L.) Hoffm.	Shellang Gwar	14339
Asplenium trichomanes L.	Above Kalapani	14076
Athyrium atkinsonii Bedd.	Kalamuni, Kumaon	DD
Athyrium attenuatum (Cl.) Tagawa	Above Martoli	14353
Athyrium davidii	Dhanu, Niti	GSR SR
Athyrium fimbriatum Moore	Dhakuri	BSD
Athyrium rupicola (Hope) C. Chr.	Namik	BSD
Athyrium wallichianum Ching	Phatab Panchachuli Base	14231
Botrychium lunularia (L.) Sw.	Napalchu nala	14110
Cheilanthes duthiei Baker	Kuari Pass	BSD
Cryptogramma brunoniana Wall. ex Hk. & Grev.	Above Martoli	14357
Cryptogramma stelleri (Gmel.) Prantl.	Surru Valley	15101
Cystopteris dickieana R. Sim	Pindari	BSD
Cystopteris fragilis (L.) Bernh. f.	Above Martoli	14354
Cystopteris montana (Lam.) Bernh.	Pindari	BSD
Deparia acuta (Ching) Fras.-Jenk.	Pahalgam, Kolahoi	Khullar @
Deparia allantodioides (Bedd.) Kato	Dhaman Payar	14632
Dryopteris acutodentata Ching	Tragpal Pass, Kashmir	Khullar
Dryopteris barbigera (T. Moore ex Hk.) Kze	Pindari	BSD
Dryopteris blanfordii (Hope) C. Chr.	Kaphni	BSD
Dryopteris chrysocoma (Christ) C. Chr.	Kashmir	Khullar
Dryopteris filix-mas (L.) Schott.	Valley of Flowers	GSR SR
Dryopteris juxtaposita	Changshil	14819
Dryopteris komarovii Kossin.	Garbyang, 3400 m	BSD
Dryopteris redatopennata	Kyarki	14801

Dryopteris serratodentata (Bedd.) Hayata	Namik	BSD
Dryopteris xanthomelas (Christ) C. Chr.	Gulmarg	Khullar
Equisetum arvense L.	Hemis	GSR SR
Equisetum debile Roxb. ex Vauch.	Milam	GSR SR
Equisetum ramosissimum Desf.	Domkhar Yogma, Ladakh	Klimes 38
Huperzia selago (L.) Bernh. ex Schr. & Mart.	Rohtang	15003
Lepisorus clathratus (Cl.) Ching	Sonamarg	DD
Lepisorus sesquipedalis (J. Sm.) Fras.-Jenk.	Garbyang way to Gunji	14031
Lycopodium clavatum L.	Phatab Panchachuli Base	14228
Notholaena delavayi var. *intermedia*	Garbyang	BSD
Notholaena lanuginosa (Desv.) Desv. ex Poiret.	Kashmir sl	DD
Notholaena marantae (L.) Desv.	Maitoli Glacier 3700 m	BSD
Ophioglossum reticulatum L.	Tungnath	BSD
Osmunda claytoniana L.	Valley of Flowers	BSD
Phymatopteris ebenipes (Hk.) Pichi Sermolli	Kyarki	BSD
Phymatopteris malacodon (Hk.) Pichi Sermolli	Tungnath	BSD
Phymatopteris oxyloba (Wall ex Kze) Pichi-Sermolli	Khaliya	BSD
Phymatopteris stracheyi	Valley of Flowers	BSD
Polystichum bakerianum (Atkins. ex Cl.) Diels	Ghangaria, Chamoli	BSD
Polystichum lachenense (Hk.) Bedd.	Liddar Valley	DD
Polystichum lonchitis (L.) Roth	Sonamarg	DD
Polystichum manmiense	Dhaman, Gamsali	14638
Polystichum prescottianum (Wall. ex Mett.) T. Moore	Dras	DD
Polystichum shensiense Christ	Kashmir, SL	Khullar
Polystichum stimulans (Kunz ex Mett.) Bedd.	Kashmir, SL	BSD
Polystichum wilsonii Christ	Dagwan	BSD
Selaginella aitchisonii Hieron.	Baltal, Kashmir	GSR SR
Woodsia alpina (Bolton) Gray	Tso Kar	GSR SR
Woodsia cycloloba Hand.-Maz.	Kutti Yagti	DD
Woodsia hancockii Baker	Kashmir, SL	DD
Woodsia lanosa Hk.	Sunderdhunga	KU
2. GYMNOSPERMS		
Abies spectabilis (D. Don) Mirb.	Rupi-Bhaba	GSR SR
Ephedra gerardiana Wall. ex Stapf.	Tola (Johar)	14316
Ephedra intermedia Shrenk et Mey	Dras - Kargil Road	BSD
Ephedra pachyclada Boiss.	Minu Pureng, Ladakh	BSD
Juniperus communis L.	Byans, Darma	GSR SR
Juniperus indica Bertol.	Tungnath	GSR SR
Juniperus semiglobosa Regel	Johlma upper slope	15048
Juniperus recurva Buch.-Ham. ex D. Don	Panch Chuli Basin	Sahni – DD 20462 ?
Juniperus squamata Buch.-Ham. ex D. Don	Churdhar	15149
Pinus gerardiana Wall. ex Lamb.	Kinnaur	GSR SR
Pinus wallichiana A.B. Jackson	Darma	GSR SR
Taxus wallichiana Zucc.	Kedarnath WS	GSR SR
Tsuga dumosa (D. Don) Eichler	Chhipla, Askot WS	GSR SR
3. ANGIOSPERMS: DICOTYLEDONS		

RANUNCULACEAE		
Aconitum atrox (Bruhl.) Mukherjee	Valley of Flowers	@
Aconitum chasmanthum Stapf. ex Holmes	Kashmir	
Aconitum deinorhizum Stapf.	Kashmir	BSD
Aconitum falconeri Stapf.	Kedarkantha	DD @
Aconitum heterophyllum Wall. ex Royle	Amarnath	15124
Aconitum kashmiricum Stapf ex Coventry	Kashmir, sl	Rau @
Aconitum laeve Royle	Mandal	GSR *P*
Aconitum ferox ssp *moschatum* Bruhl. ex Duthie	Ganghar pasture	14435 @
Aconitum violaceum Jacq. ex Stapf.	Kingkru Thach	14883
Actaea acuminata Wall. ex Royle	Burphu Gwar	14412
Adonis aestivalis L.	Lahul <3000 m	DD
Adonis chrysocyathus Hk. f. & T.	Lipu Lekh	DD
Anemone demissa Hk.f. & T.	Lang Payar, 3600 m	14607 **
Anemone elongata Don	Above Dugtu, Darma	14241
Anemone obtusiloba D. Don	Bhrigu Lake	14955
Anemone polyanthes D. Don	Valley of Flowers	GSR SR
Anemone rivularis Buch.-Ham.	Chhiyalekh	GSR SR
Anemone rupestris Hk.f. & T.	Nabedhang	14042 **
Anemone rupicola Camb.	Napalchu	14034
Anemone tetrasepala Royle	Khaliya	GSR SR @
Anemone trulifolia Hk.f. &T.	Topidhunga	339 **
Aquilegia fragrans Benth.	Sural Valley	GSR SR
Aquilegia moorcroftiana Wall. ex Royle	Hemis NP	BSD
Aquilegia nivalis Falc. ex Baker	Kunawar	GSR SR @
Aquilegia pubiflora Wall. ex Royle	Nelong	GSR SR
Callianthemum pimpenelloides Hk.f. & T.	Opp. Kutti	14151
Caltha palustris L.	Marhi	GSR SR
Cimicifuga foetida L.	Chhiyalekh	GSR SR
Clematis barbellta Edgew.	Ganghar pasture	14424
Clematis montana Buch. – Ham. ex DC.	Panch Chuli	GSR SR
Clematis ladakhiana Grey-Wilson	Hemis NP	Chauhan & Singh @
Clematis orientalis L. var. *acutifolia*	Milam on way to Dung	14440
Delphinium brunonianum Royle	Barjikang	GSR SR
Delphinium caeruleum Jacq. ex Camb.	Topidhunga	14498
Delphinium *cashmirianum* Royle	Amarnath	15122 @
Delphinium densiflorum Duthie ex Maxim	Kakbhusandi	GSR SR
Delphinium kumaonense Huth	Garbyang slope	14023
Delphinium pyramidale Royle	Ralam	
Delphinium roylei Munz.	Liddar Valley	
Delphinium vestitum Wall. ex Royle	Rohtang pass	
Delphinium viscosum Hk.f. & T.	Topidhunga	336
Halerpestes sarmentosa (Adams) Kom. & Klob	Tso Kar	
Halerpestes tricuspis (Maxim.) Hand.- Mazz.	Tso Kar	5394
Oxygraphis endlicheri (Walp.) Bennet et Chandra	Kyarki	GSR SR
Oxygraphis glacialis (Fisch. ex DC.) Bunge	Jeolingkong	
Paraquilegia anemonoides (Willd.) Ulbr.	Chhiyalekh	14009
Paraquilegia microphylla (Royle) Drumm. & Hutch.	Topidhunga	14499

Paraquilegia uniflora (Aitch. & Hemsl.) Drumm. & Hutch.	s.l.	?
Pulsatilla wallichiana (Royle) Ulbri.	Nunkun	GSR P
Ranunculus adoxifolius Hand.-Mazz.	Baralacha La	Aswal
Ranunculus bikramii Aswal & Meh.	Rohtang pass	15012 ?
Ranunculus brotherusi Freyn	Hemis NP	
Ranunculus diffusus DC.	Rohtang	DD
Ranunculus falcatus L.	Keylong	DD
Ranunculus flavidus (Hand.-Mazz.) Cook	Kashmir, sl	Rau
Ranunculus gaurii Dangwal & Rawat	Tapovan, Gaumukh	GUH
Ranunculus hirtellus Royle	Barjikang	
Ranunculus longicaulis Mey	Stot (Nia Phu), Ladakh	Klimes 6197
Ranunculus munroanus Drumm. ex Dunn.	Liddar Valley	Dickore & Nusser @
Ranunculus natans C.A .Mey	Phatab Panchachuli Base	14226
Ranunculus pulchellus C.A. Mey	Lapthal, Korzok	14540
Ranunculus radicans C.A. Mey	Lapthal	
Ranunculus trichophyllus Chaix.	Hemis NP	
Ranunculus trivedii Aswal et Mehrotra	Rohtang pass	CDRI @
Thalictrum alpinum L.	Pindari	
Thalictrum chelidonii DC.	Ralam	
Thalictrum cultratum Wall.	Nabedhang way to lipulekh	14041
Thalictrum elegans Wall. ex Royle	Liddar Valley	
Thalictrum foetidum L.	Nilang	
Thalictrum minus L. var. *majus*	Hemis NP	
Thalictrum reniforme Wall.	Liddar Valley	
Thalictrum secundum Edgew.	Gamsali	15025
Thalictrum rutifolium Hk.f. & T.	Pang, Sarchu	DD
Trollius acaulis Lindl.	Barjikang	14302
Trollius pumilus D. Don	Topidhunga	
BERBERIDACEAE		
Berberis angulosa Wall ex Hk. f. & T.	Kugti	GSR SR **
Berberis jaeschkeana Schneid.	Ralam	14263
Berberis kashmirana Ahrendt.	Muntnar Valley	@
Berberis kumaonensis Schneid.	Garbyang, Chopta	14016
Berberis kunawurensis Royle	Mundali, Jaunsar	?
Berberis macrantha Schrander	Tungnath, On way	Rao et al. ?
Berberis orthobotrys Bier. Ex Aitch.	Nelang	Rao et al.
Berberis pachycantha Koehne	Shansha	15031
Berberis petiolaris Wall. ex G.Don var. garhwalana Ahrendt.	Yamunotri	Rao et al. @
Berberis ulicina Hk. f. & T.	Nubra	@
PODOPHYLLACEAE		
Podophyllum hexandrum Royle	Kedarnath	GSR SR
CIRCAEASTERACEAE		
Circaeaster agrestis Maxim	Kyarki, Valley of Flowers	14795 @
PAPAVERACEAE		

Dicranostigma lactucoides Hk. f. & T.	Sipu Mahadev Khola	14220
Meconopsis aculeata Royle	Rohtang	
Meconopsis bikramii Aswal & Meh.	Rohtang	@
Meconopsis latifolia Prain	Kashmir	@
Meconopsis paniculata (D. Don) Prain	Sunderdhunga	GSR SR
Meconopsis robusta Hk. f. & T.	Namik 3000 m	
Papaver nudicaule L.	Nubra	GSR SR
FUMARIACEAE		
Corydalis adiantifolia Hk. f. & T.	Sumna (NDBR)	14583
Corydalis alpestris C.A. Mey	Kashmir	?
Corydalis boweri Hemsl.	Bomras	14475
Corydalis cashmeriana Royle	Jeolingkong	14189
Corydalis casimiriana Duthie & Prain	Darma	
Corydalis clarkei Prain	Rimkhim, Tso Kar	5501 @
Corydalis crassifolia Royle	Hemis	
Corydalis crithmifolia Royle	Near Kalapani	14078
Corydalis diphylla Wall.	Khaliya	
Corydalis elegans Wall. ex Hk. f. & T.	Barjikang	
Corydalis falconeri Hk. f. & T.	Tungnath	
Corydalis flabellata Edgew.	Niti, Hemis	
Corydalis govaniana Wall.	Ralam, Kushkalyani	15146
Corydalis gortschakovii Schrenk.	Kashmir, sl	FWP ?
Corydalis hendersonii Hemsl.	Khingru Dhura	
Corydalis lathyroides Prain.	Ralam, Rambara	GUH
Corydalis longipes DC.	Ralam	
Corydalis meifolia Wall.	Satopanth	14679
Corydalis nana Royle	Barjikang	
Corydalis pseudo-juncea Ludlow	Kuari Pass	GUH
Corydalis sikkimensis (Prain) Fedde	Liddar Valley	FWP ?
Corydalis stricta Steph. ex DC.	Kashmir Valley	FWP
Corydalis stracheyi Duthie ex Prain	Pindari	DD
Corydalis thyrsiflora Prain	Kyogar	DD
Corydalis tibetica Hk. f. &T.	Lanjar Pass	DD
Corydalis vaginans Royle	Hemis	DD
Fumaria indica (Haussk.) Pugsley	Kutti village	14143
Hypecoum leptocarpum Hk. f. & T.	Garbyang	GSR SR
BRASSICACEAE		
Alyssum canescens DC.	Tso Kar	
Alyssum klimesii Al-Shehbaz	Tso Moriri, Rupshu	
Aphragmus ladakiana Al-Shehbaz	Parang Valley, Rupshu	Klimes 5317023 @
Aphragmus obscurus (Dunn) Schulz.	s.l.	Dickore & Nusser @
Aphragmus oxycarpus (Hk. f. & T.) Jafri	Liddar Valley	DD
Arabidopsis himalaica (Edgew.) Schulz.	Johar	
Arabidopsis lasiocarpa Schulz.	Kashmir, s.l.	DD
Arabidopsis mollissima (C.A. Mey) Schulz .	Gulmarg, Sonamarg	

Arabidopsis thaliana (L.) Heynh.	Johar	
Arabis amplexicaulis Edgew.	Madhari Pass	
Arabis nova Vill.	Garbyang	
Arabis pterosperma Edgew.	Liddar Valley	
Arabis saxicola Edgew	Kashmir, s.l.	Dickore & Nusser @
Arabis tenuirostris Schulz.	Sonamarg	BSD @
Arabis tibetica Hk. f. & T.	Nelang	
Arcyosperma primulifolium (Toms.) Schulz	Tungnath	
Barbaraea intermedia Boreau	Byans	
Barbaraea vulgaris R. Br.	Ralam	
Braya rosea (Turcz.) Bunge	Tso Kar	SKU 445
Braya thomsonii Hk. f.	Kashmir, s.l.	FWP
Braya tibetica Hk. f. & T.	Chhitkul	
Capsella bursa-pastoris (L.) Medik.	Milam	
Cardamine flexuosa With.	Kushkalyani	14785
Cardamine impatiens L.	Harkidoon	
Cardamine loxostemonoides Schultz.	Jeolingkong	
Cardamine macrophylla Willd.	s.l.	?
Cardamine yunnanensis Franch.	s.l.	
Chorispora sabulosa Camb.	Rimkhim	
Chorispora sibirica DC.	Kashmir, s.l.	DD
Chorispora tenella (Pallas) DC.	Rangdum	BSD
Christolea albiflora (T. Anders.) Jafri	Rupshu	FWP
Christolea crassifolia Camb.	Tso Kar	5542
Christolea himalayensis Camb.	Untadhura	14522
Christolea lanuginosa (Hk. f. & T.) Jafri	Rupshu	
Christolea parkeri (Schulz) Jafri	Zanskar	
Christolea scaposa Jafri	s.l.	
Christolea stewartii (T. Anders.) Jafri	Rupshu	
Cochlearia scapiflora Hk. f. & T.	Guge'	
Cornigia planisiliqua Fisch. & Mey	Da - Hanu	
Crambe cordifolia Stev.	Sumna	14584
Descuraina sophia (L.) Webb. ex Prantl.	L. Rimkhim	14582
Dilophila salsa Thoms.	Chang Chenmo	
Dilophila purii Rawat et al.	Roopkund, 4850	GU @
Dontostemon glandulosus (Kar. & Kir.) Schulz.	Da - Hanu	
Draba altaica (C. A. Meyer) Bunge	Karakoram	AP 67
Draba amoena Schulz	Baralacha La	
Draba cachemirica Gandoger	Jangdang, Darma Valley	Dickore & Nusser @
Draba glomerata Royle	Stot, Rulung River	Klimes 6294
Draba falconeri Schulz.		
Draba glomerata Royle	Kibber	
Draba gracillima Hk. f. & T.	Ralam	
Draba korshiniskyi (Fedt.) Pole	Kyo Gar	
Draba lasiophylla Royle -	Milam	
Draba lanceolata Royle		
Draba ludlowiana Jafri		@

Draba olgae Regel & Schmalh		
Draba oreades Schrenk	Tso Kar	
Draba radicans Royle		
Draba setosa Royle		
Draba stenobotrys Gilg. & Schulz.		
Draba stenocarpa Hk. f. & T.		
Draba tibetica Hk. f. & T.	Rupshu	
Draba trinervis Schulz.		
Erophila verna (L.) Mey		
Erysimum hieracifolium L.	Way to Kalapani	14061
Erysimum melicentae	Darma Valley	
Erysimum pachycarpum Hk. f. & T.		
Euclidium syriacum (L.) R. B.r.		
Eutrema edwardsii R.Br.	Stot, Nia Phu	Klimes 6205
Hedinia tibetica (Thoms.) Ostenf.	Tso Kar	
Hymenolobus procumbens (L.) Nutt. Torrey & Grey		
Isatis tinctoria L.		
Leiospora pamirica Botsch. & Pach.	Chang Chenmo	
Lepidium apetalum Willd.	Dung	14456
Lepidium capitatum Hk. f. & T.	Topidhunga	
Lepidium latifolium L.	Upshi, Ladakh	
Lignariella duthiei Naqshi	Mt. Kolahoi, Kashmir	Lit. @
Lignariella obscura (Dunn) Jafri	Sangam Valley, Kashmir	Lit., DD @
Malcomia africana R. Br.	Nubra	
Matthiola chorassanica	Pin Valley, Hemis	
Megacarpaea polyandra Benth.	Ralam, Gidara	
Microsisymbrium axillare (Hk. f. & T.) Schulz.		@
Microsisymbrium minutiflorum (Hk. f. & T.) Schulz.		
Parrya nudicaulis (L.) Regel.	Tso Kar	5548
Pegaeophyton scapiflorum (Hk. f. e& T.) Marq. et Shaw	Tso Kar	
Phaeonychium parryoides (Kurz. ex Hk.f. &T) Schulz.		
Pycnoplinthopsis bhutanica (Hara) Jafri	Roopkund	GUH
Rorippa indica (L.) Riern.	Pin Valley	
Sisymbrium bracissiforme C.A. Mey	Nelang	
Sisymbrium irio L.		
Tauscheria lasiocarpa DC.	Kibber	GSR SR
Tetracme pamirica (Stephan) Bunge		
Thlaspi andersonii (Hk. f. & T.) O. E. Schulz	Kuari Pass	GUH
Thlaspi arvense L.	Ralam	
Thlaspi cochlearioides Hk. f. & T.	Burphu	
Thlaspi montanum L.		
Torularia humilis (C. A. Mey) Schulz		
Turritis glabra L.	Burphu (Bhadel Gwar)	14381
CAPPARACEAE		
Capparis himalayensis Jafri	Leh	
VIOLACEAE		

Viola betonicifolia	above Garbyang	14021
Viola biflora L.	Tungnath	
Viola kunawarensis Royle	Nabedhang	14053
Viola pilosa Bl.	Tirthan Valley	
Viola rupestris F.W. Schum.	Shesh Nag, Liddar Vy	BSD
CARYOPHYLLACEAE		
Arenaria bryophylla Fernald	Bomras	14484
Arenaria ciliolata Edgew.		
Arenaria curvifolia Majumdar	Garhwal s.l.	BSD @
Arenaria depauperata (Edgew.) Hara		
Arenaria ferruginea Duthie ex Williams		
Arenaria festucoides Benth.	Shellang Gwar	14343
Arenaria glanduligera Edgew.		
Arenaria kansuensis Maxim.		
Arenaria orbiculata Royle ex Edgew.	Valley of Flowers	
Arenaria perlevis (Will.) Hand.-Mazz.		
Arenaria serpyllifolia L.	Mapa (Johar)	14375
Arenaria stracheyi Edgew.		
Cerastium cerastoides (L.) Britton	Da Hanu	
Cerastium dahuricum Fisch.	Jalandhri Gad	
Cerastium fontanum	Raksham - Chitkul	
Cerastium thomsonii Hk. f.		
Dianthus anatolicus Boiss.	Sural nala	15065
Dianthus angulatus Royle	Pin Valley	
Gypsophila cerastioides D. Don	Shellang Gwar	14342
Gypsophila sedifolia Kurz.		
Holosteum umbellatum L.	Raksham - Chitkul	
Lepyrodiclis holosteoides (Meyer) Frenzl	Burphu Gwar	14384
Minuartia biflora (L.) Sch. & T.	Da Hanu	
Minuartia ebracteolata Majumd. & Giri	Pissu Ghati, Kashmir	Lit @
Minuartia kashmirica (Edgew.) Mattf.	Kalapani	14077
Sagina saginoides (L.) Karsten	Rohtang	
Silene amoena L.		
Silene caespitella Williams		
Silene edeordi Bocquet	Chhatru	Lit @
Silene edgeworthii Bocquet		
Silene himalayensis	Tso Kar	5511
Silene griffithii Boiss	Nelang	
Silene indica Roxb. ex Otth	Ralam	
Silene kumaonensis Williams	Kutti, Byans	Lit @
Silene kunawarensis Royle		Lit @
Silene laxantha Majumd.	Tungnath	
Silene madens Majumd.	Ralam	
Silene moorcroftiana Wall. ex Benth.	Chhyudhang	14514
Silene nigrescens (Edgew.) Majumd.	Tso Kar	
Silene rechingeri Bocquet		
Silene songarica Bocq.	Lapthal	

Silene stewartii (Edgew.) Majumd.		
Silene vulgaris (Moench) Garcke	Burphu (Bhadel Gwar)	14395
Spergularia diandra (Guss.)Helder. & Sart.	Pin Valley	
Stellaria decumbens Edgew.	Nabedhang	14083
Stellaria himalayensis Majumd.	Ralam	
Stellaria irrigua Bunge	Stot, Indus Valley	Klimes 6200
Stellaria media (L.) Vill.		
Stellaria monosperma Buch.- Ham. ex D. Don		
Stellaria monosperma (Edgew) Majumd.		
Stellaria palustris Retz.	Ralam	
Stellaria patens D. Don		
Stellaria subumbellata Edgew. ex Hk.f.		
Stellaria tibetica Kurz.		
Stellaria uliginosa Edgew. & Hk. f. non L.	Barjikang	
Thylacospermum caespitosum (Camb.) Schischk.	Barahoti	
TAMARICACEAE		
Myrtamma elegans (Royle) Ovc. & Kinz.	Kalapani	14068
Myricaria germainca Dsev. (Schrenk.) Kitam.	Niti	
Myricaria prostrata Hk. f. & T.	Dugtu, Darma	
Tamarix ramocissima	Nubra Valley	
HYPERICACEAE		
Hypericum choiseanum Wall. ex Robs.	Chuli Bugyal	
Hypericum hookerianum Wt. & Arn.	Gamsali	
Hypericum monanthemum Hk. f. et T. ex Dyer		?
Hypericum wightianum Wall. ex Wt.		?
MALVACEAE		
Lavatra kashmeriana Camb.	Sonamarg	@
Malva neglecta Wall.	Malari	
Malva verticillata L.	Burphu, Sipu	
LINACEAE		
Linum perenne L.	Pin Valley	
ZYGOPHYLLACEAE		
Peganum harmala L.	Leh	
Tribulus terrestris L.	Nubra	
GERANIACEAE		
Biebersteinia odora Steph.	Chhyudhang-Lapthal	14518
Erodium stephanianum Willd.	Malari	14641
Erodium tibetanum Edgew.	Tso Kar	
Geranium donianum Sw.	Lapthal	
Geranium himalayense Klotz.		
Geranium rubifolium		
Geranium sibiricum L.		

Geranium polyanthes Edgew. & Hk. f.		
Geranium procurrens Yeo	Shusha Valley	14897
Geranium robertianum L.		
Geranium rotundifolium L.		
Geranium wallichianum D. Don ex Sweet	Valley of Flowers	
BALSAMINACEAE		
Impatiens amplexicaulis Edgew.	Rohtang	
Impatiens brachycentra Kar. & Kir.	Nelang	
Impatiens glanduligera Royle	Liddar Valley	
Impatiens racemosa DC.	Karki	
Impatiens sulcata Wall.	Burphu glacier	14386
Impatiens thomsonii Hk. f.	Lambi Dhar	14826
CELASTRACEAE		
Euonymus lacerus Buch.-Ham.	Ralam	
Euonymus pendulus Wall.	Tola (Johar)	14315
RHAMNACEAE		
Berchemia edgeworthi Laws	Darma Valley	
Rhamus prostrata Jacq. ex Parker	Nelang	
LEGUMINOSAE [FABACEAE]		
Astragalus aegacanthoides Parker	Byans	@
Astragalus amherstianus Benth.	Nelang	
Astragalus badrinathensis Sharma et al.	Badrinath	CDRI @
Astragalus candolleanus Royle ex Benth.	Niti	14617
Astragalus chlorostachys Lindl.	Raksham Chitkul	
Astragalus coluteocarpus Boiss.	Nelang	
Astragalus confertus Benth. ex Bunge	DBO	AP 103
Astragalus congrensis	Napalchu nala	14097
Astragalus densiflorus Kar. & Kir.	Dung	14467
Astragalus drasianus Chowdhery et al.	Dras	BSD @
Astragalus emodi Steud.	Byans	
Astragalus frigidus (L.) A. Gray	Darcha	
Astragalus gracilepis Benth. ex Bunge	Zanskar	
Astragalus grahmianus Royle ex Benth	Opp. Marhi	15018 @
Astragalus graveolense Buch. – Ham. ex Benth.	Malari	14640
Astragalus heydei Baker	Changchenmo	AP 12A
Astragalus himalayanus Klotz.	Dhanu Satopanth	14678
Astragalus hoffmeisteri (Klotz.) Ali	Zanskar	@
Astragalus kongrensis Benth. & Baker	Napalchu nala	14097 **
Astragalus ladakhense Rao & Balodi	Ladakh	@
Astragalus lessertioides Benth. ex Bunge	Byans	
Astragalus macropterus DC.	Zanskar	
Astragalus maddenianus Benth. ex Baker	s.l.	FBI **
Astragalus malacophyllus Benth. ex Baker	Khoksar	CDRI
Astragalus maxwellii Royle ex Benth.	Tola (Johar)	14313 @

Astragalus melanostachys Benth. ex Bunge	Rajhoti	14911
Astragalus munroi Benth. ex Bunge	Spiti	
Astragalus oplites Benth. ex Parker	Zingzingbar	
Astragalus oxyodon Baker	Pindari	
Astragalus peduncularis Royle ex Benth.	Darcha	
Astragalus pindreensis (Benth. ex Baker) Ali	Fras Nag, Gilgit	DD @
Astragalus polycanthus Royle ex Benth.	s.l.	
Astragalus prainii Duthie	Sangcha Malla	
Astragalus pycnorhizus Benth.	Garbyang	
Astragalus rhizanthus Royle	Dhanu Satopanth	14680
Astragalus strictus Benth.	Base of Chhota Kailash	14186
Astragalus strobiliferus Royle	Kinnaur	
Astragalus subuliformis DC.	Taklang La	
Astragalus thomsonianus Benth. ex Baker	Spiti	BSD
Astragalus tibetanus Benth. ex Bunge	Milam	
Astragalus tribulifolius Benth. ex Bunge	Tsokar	SKU 438
Astragalus webbianus Grah. ex Bunge	Sonam	14761
Astragalus zanskarensis Benth. ex Bunge	above Garbyang	14029
Caragana gerardiana Royle	Sumna	14590
Caragana versicolor (Wall.) Benth.	Lapthal	
Chesneya cuneata (Benth.) Ali	Kibber	
Chesneya nubigena (D. Don) Ali	Lipulekh	
Cicer microphyllum Benth.	Naga,Nelang	14767
Gueldenstaedtia himalaica Baker	Milam	
Hedysarum astragaloides Benth. ex Baker	s.l.	Rau @
Hedysarum cachemerianum Benth. ex Baker	s.l.	Rau @
Hedysarum kumaonense Benth. ex Baker	above Garbyang	14027 @
Hedysarum laxiflorum Benth. ex Baker	s.l.	
Hedysarum microcalyx Baker	Lahul	@
Lathyrus laevigatus (Walldst.& Kit) Gren.	Panch Chuli	
Lotus corniculatus L.	Chhitkul	14832
Medicago falcata L.	Lahul	
Medicago lupulina L.	Leh	
Melilotus officinalis (L.) Pallas	Spiti	
Oxytropis cahemiriana Camb.	Amarnath	15120
Oxytropis chiliophylla Royle ex Benth.	Tsokar	5362
Oxytropis duthieana Ali	Khingru Dhura	Rau
Oxytropis humifusa Kar. & Kir	Takuli sen, Than Pattan	14558
Oxytropis hypoglottoides (Baker) Ali	Tsokar	5371
Oxytropis lapponica (Wahlb.) Gaud.	Tipani Nelang	14740
Oxytropis microphylla (Pallas) DC.	Way to PDA	14732
Oxytropis mollis Royle	Spiti	
Oxytropis pusilla Bunge	Changchenmo	AP 12A
Oxytropis sericopetala Fische.	Kaza	
Oxytropis tatarica Jacq. ex Baker	Tsokar	5462
Parochetus communis Buch.-Ham. ex D. Don	Sipu	
Piptanthus nepalensis (Hk.) D. Don	Valley of Flowers	
Sophora moorcroftiana Benth. ex Baker	Nubra	

Thermopsis barbata Royle	Above Kutti village	14133
Thermopsis inflata Camb.	Chhota Hoti	14566
Trifolium repens L.	Byans	
Trigonella emodi Benth.	Raksham Chitkul	
Trigonella pubescens Edgew. ex Baker	Nelang	
ROSACEAE		
Acomastylis elata (Wall. ex Royle) Bolle	Changshil	
Alchemilla psilotoma Rothm.	Palang gar	
Alchemilla trolii Rothm.	Pachhoo Gwar	Dickore & Nusser @
Aruncus dioicus (Walter) Fernald	Kyarki	
Chamaerhodos sabulosa Bunge	Tso Kar	
Cotoneaster acuminatus Lindl.	Khaliya	
Cotoneaster cashmiriensis Klotz.	Sintham Pass, Kashmir	
Cotoneaster duthieanus (Schneid) Klotz.	Kutti	
Cotoneaster falconeri Klotz.	Garbyang	14028
Cotoneaster garhwalensis Klotz.	Nelang	@
Cotoneaster gilgitensis Klotz.	Gilgit	@
Cotoneaster microphyllus Wall. ex Lindl.	Ralam	
Cotoneaster nitidus Jacq.	Ralam	
Cotoneaster numularius Fisch. & Mey	Satopanth, Da Hanu	Klimes
Cotoneaster prostratus Baker	s.l.	
Cotoneaster rosea Edgew.	Way to Nabedhang	14037
Cotoneaster rotundifolius Wall. ex Lindl.	Kedarnath	
Cotoneaster species Osmaston	Dhauli Valley (Chorhoti)	@
Filipendula vestita (Wall. ex G.Don) Maxim	Martoli	
Fragaria daltoniana Gay	Palang gar	
Fragaria nubicola Lindl. ex Lacaita	Johar	
Malus baccata (L.) Barkh.	Chhitkul	
Potentilla agrimonioides M. Bieb.	Tso Kar	
Potentilla anserina L.	Barjikang	14310
Potentilla arbuscula D.Don	Jeolingkong	
Potentilla argyrophylla Wall. ex Lehm.	Parvati Tal	14163
Potentilla atrisanguinea Lodd.	Below Phatab	14234
Potentilla biflora Willd. ex Schlecht.	Shellang Gwar	14347
Potentilla bifurca L.	Nelang	
Potentilla breviscissa Bertol.	Ladakh	
Potentilla collettiana Aitch. & Hemsl.	Liddar Valley	?
Potentilla cuneifolia Bertol.	Mana, Ralam	
Potentilla curviseta Hk. f.	Above Ralam village	14257 @
Potentilla desertorum Bunge	Shellang Gwar	14348
Potentilla eriocarpa Wall. ex Lehm.	Milam, Kailu Vinayak	
Potentilla gelida C.A. Mey	Hemkund	
Potentilla grifithii Hk.f.	Khiron Valley	?
Potentilla karakoramica Sojak	Karakoram	@
Potentilla leuconota D. Don	Dawe	
Potentilla lineata Trevier. & Reich.	Garbyang	
Potentilla microphylla D. Don	Upper Gidara	14700

Potentilla monanthes Wall. ex Lehm.	Barjikang	
Potentilla multifida L.	Above Mapa	14370
Potentilla nepalensis Hk.	Opp. Raksham	14913
Potentilla nivea L.	Topidhunga	
Potentilla ornithopoda Tausch.	Khalatse, Ladakh	@
Potentilla pamirica Wolf.	Rupshu	
Potentilla parvifolia Fisch. & Lehm.	s.l.	
Potentilla peduncularis D. Don	Valley of Flowers	
Potentilla polyphylla Wall. ex Lehm.	Kedarnath	
Potentilla pteropoda Royle	s.l.	
Potentilla rigida Wall. ex Leh.	s.l.	
Potentilla salesoviana Steph.	Hemis NP	
Potentilla sino-nivea Hulten	Tso Kar	
Potentilla sericea L.	Near Nabedhang	14069
Potentilla sino-nivea Hulten	s.l.	
Potentilla sojakii Dikshit & Panigrahi	s.l.	
Potentilla soongarica Bunge	s.l.	
Potentilla thomsonii Hand.-Mazz.	Jeolingkong	
Prunus jacquemontii Hk. f.	Malari	
Prunus cornuta (Wall. ex Royle) Steud.	Valley of Flowers	
Rosa anserinaefolia Boiss.	s.l.	
Rosa eglanteria L.	s.l.	
Rosa macrophylla Lindl.	Valley of Flowers	
Rosa osmastonii Rawat & Pangtey	Milam	@
Rosa sericea Lindl.	Burphu	14323
Rosa webbiana Wall. ex Royle	Milam	
Rubus foliolosus D. Don	Valley of Flowers	
Rubus irritans Fockew	s.l.	
Rubus nepalensis (Hk. f.) Kuntz.	Kedarnath	
Rubus niveus Thunb.	s.l.	
Rubus pentagonus Wall. ex Focke	Shansha	15030
Rubus saxatilis L.	s.l.	
Sanguisorba diandra (Wall. ex Hk. f.) Nord.	Ralam	
Sibbaldia cuneata Hornem. ex Ktze	Tungnath	
Sibbaldia micropetala (D. Don) Hand.-Mazz.	Valley of Flowers	
Sibbaldia purpurea Royle	Barjikang	14308
Sibbaldia purpusilla (Hk.f.) Chatt.	s.l.	
Sibbaldia tetrandra Bunge	s.l.	
Sorbus aucuparia L.	Panch Chuli	
Sorbus foliolosa (Wall.) Spach	Napalchu nala	14096
Sorbus lanata (D. don) Schauer		
Sorbus microphylla Wenzig	Valley of Flowers	
Spiraea affinis Parker	s.l.	
Spiraea arcuata Hk. f.	Valley of Flowers	
Spiraea bella Sims	Napalchu nala	14094
SAXIFRAGACEAE		
Bergenia ciliata (Haw.) Sternb.	Tungnath	

Bergenia stracheyi (Hk.f. & T.) Engl.	Tungnath	
Deutzia compacta Craib	Valley of Flowers	
Hydrangea heteromalla D.Don	Valley of Flowers	
Chrysosplenium carnosum Hk. f. & T.	Valley of Flowers	
Chrysosplenium nepalense D. Don	Valley of Flowers	
Chrysosplenium tenellum Hk.f. & T.	s.l.	
Chrysosplenium trichospermum Edgew. ex Hk.f. & T.	s.l.	
Saxifraga andersonii Engl.	s.l.	
Saxifraga androsacea L.		
Saxifraga aristulata Hk. f. & T.		
Saxifraga asarifolia Sternb.	Dhanu Satopanth	14685 @
*Saxifraga brachypoda*Engl. & Irmsch.		
Saxifraga brunonis Wall. ex Ser.	Dung	14465
Saxifraga filicaulis Wall. ex DC.		
Saxifraga flagellaris Wild. ex Sternb.	Sinla Pass	14196
Saxifraga granulifera H. Sm.		
Saxifraga hemisphaerica Hk. f. & T.		
Saxifraga hirculus L.	Valley of Flowers	
Saxifraga hispidula D. Don		
Saxifraga hookeri Engl. & Irmsch.		
Saxifraga jacquemontiana Decne.	Satopanth	14669
Saxifraga kashmeriana Dhar & Kach.		
Saxifraga kumaonensis Engl.	s.l.	
Saxifraga lychnitis Hk. f & T.	Rajthor Ralam	14286
Saxifraga meeboldii Engl. & Irmsch.		
Saxifraga microphylla Royle ex Hk. f. & T.	Vasukital, Kedarnath	GUH
Saxifraga moorcroftiana Wall. ex Sternb.		
Saxifraga nanella Klimes		
Saxifraga oppositifolia L.		
Saxifraga pallida Wall. ex DC	Nabedhang	14071
Saxifraga parnassifolia D.Don	Dhanu Satopanth	14682
Saxifraga pseudopallida Engl. & Irm.	Mhurchu pani (Johar)	14332
Saxifraga pseudo-pallida Engl. & Irm.		
Saxifraga pulvinaria H. Sm.		
Saxifraga saginoides Hk. f. & T.	Barjikang (Ralam)	14285
Saxifraga sibirica L.	Barjikang	14298
Saxifraga stenophylla Royle	Rajtor Barjikang	14287
Saxifraga strigosa Wall.ex DC		
Saxifraga subspathulata Engl. & Irm.		
PARNASSIACEAE		
Parnassia kumaonica W. Nekr.	Napalchu nala	14107
Parnassia nubicola Wall. ex Royle	Dhaman Payar	14639
Parnassia laxmanni Pallas	Ralam	
Parnassia pusilla Hk f. & T.	Above Martoli	14330
GROSSULARIACEAE		
Ribes alpestre Decne	Milam	

Ribes himalense Decne	s.l.	
Ribes nigrum L.	s.l.	
Ribes orientale Desf.	Napalchu nala	14111
Ribes takare D. Don	Sural nala	15063
CRASSULACEAE		
Hylotelephium ewersii (Ledeb) Ohba	Above Kutti village	14141
Rhodiola bouveri (R. Hamet) Ohba		
Rhodiola bupleuroides Wall ex Hk. f. & T.	Ralam	
Rhodiola crenulata (Hk.f. & T.) Ohba		
Rhodiola fastigiata (Hk.f. & T.) Fu	Rupshu	
Rhodiola heterodonta (Hk. f. & T.) A. Boriss.	Napalchu nala	14092
Rhodiola himalense D. Don		
Rhodiola imbricata Edgew		
Rhodiola quadrifida (Pallas) Fisch. & Mey	Dhanu Satopanth	14691
Rhodiola sacra (R. Hamet) Fu		
Rhodiola sinuata (Royle ex Edgew) Fu		
Rhodiola tibetica (Hk. f.&.T) Fu	Changthang	
Rhodiola wallichiana (Hk.) Fu	Nabedhang way to lipulekh	14039
Rosularia alpestris (Kar. & Kir) Boriss.	Chhyudhang	14523
Sedum jaeschkei Kurz.	Ralam, Shellang	
Sedum roseum (L.) Scop.	Johar	
Sedum scabridum Franch.		
Sedum trullipetalum Hk.f. & T.		
Sempervivum mucronatum Edgew.	Malari	
Tillaea pharnaceoides Hochst. ex Britt	Rohtang	15002
DROSERACEAE		
Drosera peltata var. lunata	Garbyang	GSR
HIPPURIDACEAE		
Hippuris vulgaris L.	Bara Hoti	14574
ONAGRACEAE		
Circaea alpina L. 2 ssp.: *imaicola* and *pricei*	Ralam	
Circaea cordata Royle	Khaliya	
Epilobium amurense Hausskn.		
Epilobium angustifolium L.	Dugtu	
Epilobium brevifolium D. Don		
Epilobium chitralense Raven		
Epilobium clarkeanum Hausskn.		
Epilobium cylindricum D. Don	Da-Hanu	
Epilobium glaciale Raven	Da-Hanu	
Epilobium hirsutum L.		
Epilobium latifolium L.	Sipu, Chhitkul	
Epilobium laxum Royle		
Epilobium leiophyllum Hausskn.	Milam	
Epilobium minutiflorum Hausskn.		

Epilobium palustre L.	Lapthal	
Epilobium rhynchospermum Hausskn.		
Epilobium royleanum Hausskn	Garbyang	
Epilobium sikkimense Hausskn.		
Epilobium speciosum Decne	Ganghar pasture	14434
Epilobium stracheyanum Haussk.	Milam	
Epilobium tibetanum Hausskn.	Da-Hanu	
Epilobium trichophyllum Hausskn.		
Epilobium williamsii Raven		
APIACEAE		
Acronema tenera Edgew.	Changshil	
Angelica archangelica L.	Kyarki	
Angelica glauca Edgew.	Gidara	
Anthriscus nemorosa Spreng.		
Bunium cylindricum (Boiss & Hob.) Drude		
Bunium persicum (Boiss.) Fedtsch	Goshal, Lahul	
Bupleurum aitchisonii (Boiss.) Wolff		
Bupleurum candollii Wall. ex DC.		
Bupleurum falcatum L.		
Bupleurum hoffmeisteri Klotz & Cl.		
Bupleurum jucundum Kurz.		
Bupleurum longicaule Wall. ex DC. -	Sipu Mahadev Khola	
Bupleurum marginatum Wall. ex DC.		
Bupleurum thomshonii Cl.		
Carum carvi L.	Milam	
Chaerophyllum aromaticum L.	Changshil	
Chaerophyllum villosum Wall. ex DC.	Ralam, Bampa	
Chamaesciadium garhwalicum (Wolff) Norman.		
Cortia depressa (D. Don) Norman	Lipu Lekh	
Eriocycla caespitosa (Edgew.) Wolff.		
Eriocycla nuda Lindl.		
Eriocycla thomsonii (Cl.) Wolff.	Billing Nala,	Aswal CDRI @
Ferula jaeschkeana Vatke	Bhaironghati	@
Heracleum brunonis (DC) Cl.		
Heracleum lanatum Michx.		
Heracleum pinnatum Cl.	Niti	
Heracleum thomosonii Cl.		
Lalldhwojia cooperi Farille	Tungnath	GSR **
Ligusticum daucoides Franch.	Raksham - Chitkul	
Ligusticum marginatum Cl.		
Ligusticum thomsonii Cl.	Lapthal	
Osmorhiza aristata (Thunb.) Rydb.		
Pimpinella tenera (Wall. ex DC.) Benth. ex Cl.	Changshil	
Pimpinella hookeri Cl.	Chuli Bugyal	14782
Pleurospermum angelicoides (DC.) Cl.	Ralam	
Pleurospermum benthamii Cl.	Dung	14460
Pleurospermum brunonis (DC.) Cl.	Between Dung and Bomras	14468

Pleurospermum candollei (DC.). Cl.	Gidara	14704
Pleurospermum corydalifolium Aitch. & Hemsl.		
Pleurospermum dentatum (DC.) Cl.		
Pleurospermum govanianum (DC.) Cl.	Dung, Topidhunga	
Pleurospermum hookeri Cl.	Tso Kar	5467, 5508
Pleurospermum pulzkyi Kanitz		
Pleurospermum stellatum Cl.	Nelang	
Pleurospermum stylosum Cl.	Billing Nalla	15182
Sanicula elata Buch. ex D. Don		
Schultzia dissecta (Cl.) Norman		
Selinum coniifolium (Wall. ex DC.) Benth. & Hk. f.	Niti	
Selinum elatum (Edgew.) Hiroe		
Selinum papyraceum Cl.		
Selinum vaginatum Cl.	Changshil	
Seseli libanotis (L.) Koch.		
Seseli mucronatum		
Seseli trilobum (Edgew.) Cl.		
Trachydium roylei Lindl.	Kyarki, Kush Kalyani	
Vicatia coniifolia DC.	Sela Yangti Vally	14148
Vicatia millefolia (Klotz) Cl.		
Vicatia wolffiana (Fedde ex Wolff) Norman		
ARALIACEAE		
Aralia cachemirica Decne		
Acanthopanax cissifolius (Griff. ex Seem) Harms.		
Panax pseudo ginseng Wall.	Khaliya (above Betuli)	Pangtey **
Pentapanax leschenaultii (DC.) Seem.		
ADOXACEAE		
Adoxa moschatellina L.	s.l.	
CAPRIFOLIACEAE		
Abelia triflora R.Br. ex Wall.	Gidara	
Lonicera angustifolia Wall. ex DC.	Bedang	
Lonicera asperifolia (Decne) Hk. f. & T.	Rimkhim	
Lonicera discolor Lindl.	Napalchu	14024
Lonicera heterophylla Decne		Klimes
Lonicera hispida Pall.	Jalandhri Gad	
Lonicera hypoleuca Decne.		
Lonicera microphylla Willd. ex Roem.	Da-Hanu	
Lonicera myrtillus Hk. f. & T.	Mitlibai lake above Sipu	14213
Lonicera obovata Royle ex Hk. f. & T.	Jeolinkong	14166
Lonicera purpurascens (Decne.) Hk. f. & T.	Darma	
Lonicera rupicola Hk. f. & T.		
Lonicera semenovii Regel	Bompras, Nelang	
Lonicera spinosa (Decne.) Jacq. ex Hk. f. & T.	Dung	14464
Lonicera webbiana Wall ex DC.		
Triosteum himalayanum Wall.	Palang Gar	

Viburnum cordifolium Wall. ex DC.		
Viburnum cotinifolium D. Don	Way to Nampa\ Kutti	14119
Viburnum nervosum D. Don	Kyarki	
RUBIACEAE		
Asperula brachycantha Boiss	Sumna, Niti	
Asperuola cyananchica L.	Nelang	
Galium acutum Edgew.	Napalchu nala	14117
Galium aparine L.	Malari	14642
Galium asperifolium Wall.	Ramni	
Galium asperuloides Edgew.	Liddar Valley	
Galium boreale L.	Lahul	
Galium exile Hk.f.	Nelang way to PDA	14743
Galium paradoxum Maxim.	Burphu	
Galium serpylloides Royle ex Hk.f.		@
Galium tibeticum Aswal & Mehr.	Zingzingbar	
Galium tricorne With.	Ralam	
Galium verum L.	Lahul	
Leptodermis kumaonensis Parker	Chhiyalekh	
Rubia cordifolia L. var.	New Dung	14445
Rubia tibetica Hk.f.	Nelang way to PDA	14747
VALERIANACEAE		
Nardostachys jatamansi DC.	Kush Kalyan	14793
Valeriana hardwickii Wall.	Above Kutti	14140
Valeriana himalayana Grub.	Dhanu Satopanth	14690
Valeriana jatamansi Jones	Napalchu nala	14103
Valeriana pyrolaefolia Decne.	Above Tola village	14311
Valeriana royeli Klotz.		?
DIPSACACEAE		
Cryptothladia polyphylla (DC.) Cannon	Chhiyalekh	
Dipsacus mitis D. Don		
Morina betonicoides Benth.	Jangdang	GSR **
Morina coulteriana Royle	Kutti, Sipu	
Morina longifolia Wall. ex DC.	Kandara	
Pterocephalus hookeri (Cl) AS & Greene	Kutti	
Scabiosa speciosa Royle	Sural Valley, Pangi	
Triplostegia glandulifera Wall. ex DC.	Gidara	
ASTERACEAE		
Achillea millefolium L.	Changshil	14817
Ainslaea aptera DC.	Changshil	
Anaphalis contorta Hk. f.	Malari	
Anaphalis kashmiriana Pant et al.		
Anaphalis margaritacea (L.) Benth	Valley of Flowers	
Anaphalis nepalensis (Spreng.) Hand.-Mazz.	Barjikang	14307
Anaphalis nepalensis var. cuneifolia	Gidara	

Anaphalis royleana DC.	Churdhar	
Anaphalis staintonii Georg.		
Anaphalis triplinervis (Sims.) Cl. -	Khaliya	
Anaphalis virgata Thoms. -	Da-Hanu	
Anaphalis xylorhiza Sch.-Bip	Bogdyar	Duthie ?
Arctium lappa L.	Garbyang	GSR
Artemisia austro-himalayana (Ling. & Puri) Ling.		
Artemisia biennis Willd.		
Artemisia brevifolia Wall. ex DC	Sumna	14587
Artemisia capillaris Thunb.	Burphu (Bhadel Gwar)	14415
Artemisia demissa Krasch.	Nelang	
Artemisia desertorum Spreng.		
Artemisia dracunculus L.	Gamsali, Nelang	
Artemisia dubia Wall ex Bess -	Garbyang	
Artemisia eriocephala Pamp.		
Artemisia falconeri Cl. ex Hk. f.		
Artemisia filiormilobulata Ling & Puri		
Artemisia laciniata Willd.		
Artemisia macrocephala Jacq. ex Bess.	Tso Kar	5304
Artemisia minor Jacq.	Tso Kar	5347
Artemisia myriantha Besser	Jalandhri Gad	
Artemisia salsoloides Willd.	Nelang way to PDA	14735
Artemisia santolinifolia	Burphu (Bhadel Gwar)	14399
Artemisia sieversiana Willd.	Tso Kar	5507, 5534
Artemisia stracheyi Hk. f. & T. ex Cl.	Tso Kar	5359
Artemisia tournefortiana Reichb.	Tso Kar	5463
Artemisia wallichiana Besser		
Aster albescens (DC.) Hand.-Mazz.	Burphu glacier	14402
Aster altaicus Willd.		
Aster asteroides (DC.) O. Ktze.		
Aster diplostephoides (DC.) Cl.	Ralam	
Aster falconeri (Cl.) Hutch. -	Parvati Tal	14162
Aster flaccidus Bunge	Lapthal	
Aster flaccidus	Gidara	14715
Aster himalaicus Cl.	Byans	
Aster indamellus Griers.	Darma	
Aster laka Cl.		
Aster molliusculus (DC.) Cl.	Way to Balchhi Dhura	
Aster myriantha Besser.		
Aster stracheyi Hk. f.	Pindari, Nipchikang	
Aster thomsonii Cl.		
Brachyactis anomalum (DC.) Kitam	Above Chhitkul	14842
Brachyactis pubescens (DC.) Aitch. & Cl.	Niti	
Brachyactis roylei (DC.) Wendel	Da-Hanu	Klimes
Breea arvensis (L.) Less.	Rangdum	15089
Carduus edelbergii Reichb. f.	Niti, Malari	
Carduus kumaonensis (J. Arenes) Kazmi	SL	
Chrysanthemum pyrethroides (Kar. & Kir.) Fedtsch.	Way to Nun base	15108

Chrysanthemum stoliczkai Cl.	Nun Kun	
Chrysanthemum tibeticum Cl.		
Cicerbita crambifolia (Bunge) Beauv.	Chitral	?
Cicerbita cyanea (D.Don) Beauv		?
Cicerbita macrorhiza (Royle) Beauv.	Niti, Valley of Flowers	
Cichorium intybus L.	Nubra	
Cirsium falconeri (Hk. f.) Petrak	Dawe	
Cirsium verutum (D.Don) Spreng.	Kush Kalyani	
Cirsium wallichii DC.		
Cousinia falconeri Hk. f.		
Cousinia thomsonii Cl.	Burphu	
Cremanthodium arnicoides (DC. ex Royle) R. Good	Barjikang	14297
Cremanthodium decaisnei Cl.		
Cremanthodium ellisii (Hk.f.) Kitam.		
Cremanthodium nanum (Decne.) W.W. Sm.	Stot, Rulung	Klimes
Cremanthodium oblongatum Cl.		
Cremanthodium reniforme (DC.) Benth.	Changshil	
Crepis capillaris (L.) Wallr.		
Crepis kashmirica Babc.	Kashmir s.l.	Dickore & Nusser @
Crepis multicaulis Ledeb.		
Crepis naniforma Babc.		@
Crepis sancta (L.) Babc.		
Doronicum falconeri Cl.ex Hk. f.	Satopanth	
Doronicum pardalianches L.		
Doronicum roylei DC.	Niti	14613
Dubaea hispida (D.Don) DC.	Above Chhitkul	14840
Echinops cornigerus DC.	Leh	GSR, SR
Erigeron acer L. var. multicaulis	Shansha	15037
Erigeron bellidioides Cl.	s.l.	s.n. ?
Erigeron kumaonensis (Vierh.) Wendelb.	s.l.	?
Erigeron monticolus DC.	Kurram Vy, Zanskar	?
Erigeron multiradiatus (DC.) Benth. & Hk.f.	Above Chhitkul	14834
Erigeron patentisquama Cl.ex. Jeff.	Khoksar	Aswal 6540
Erigeron roylei DC.	s.l.	?
Erigeron uniflorus L.	s.l.	?
Gerbera nivea (DC.) Sch.– Bip.	Ralam	
Gnaphalium stewartii Cl. ex Hk. f.		
Gnaphalium thomsonii Hk.f.		
Heterpappus holohermaphroditus Griers.		
Heterpappus semiprostratus Griers.	Tso Kar	5448
Hieracium umbellatum L.		
Hieracium vulgatum Fries.		
Hypochoeris radiata L.		
Inula barbata Wall. ex DC.	Chyang Kutang opp Sangla	14927
Inula obtusifolia Kerner		
Inula racemosa Hk.f	Lahaul	GSR, SR
Inula rhizocephala Schrenk	Surru Valley	15099
Inula royleana DC.		

Jurinea dolomiaea Boiss.	Ralam	
Koelpinia linearis Pall.	Kibber	
Lactuca benthamii Cl.	J&K	@
Lactuca decipiens Cl.		
Lactuca graciliflora DC.		
Lactuca kashmiriana Mamgain & Rao	Kashmir	@
Lactuca lahulensis Mamgain & Rao	Keylong	BSD @
Lactuca lessertiana	Satopanth	14672
Lactuca orientalis (Boiss.) Boiss		
Lactuca rapunculoides (DC.) Cl.		
Lactuca serriola Tourn		
Lactuca tatarica (L.) C.A. Mey		
Lactuca viminea (L.) Jaub		
Leontopodium campestre (Ledeb.) Hand.-Mazz.		
Leontopodium himalayanum DC.		
Leontopodium jacotianum P. Beauv.		
Leontopodium leontopodinum (DC.) Hand.-Mazz.	Surru Valley	15100
Leontopodium monocephalum Edgew.		
Leontopodium nanum (Hk. f & T.) Hand.-Mazz.	Khingru	14509
Leontopodium pusillum (Beauv.) Hand.-Mazz.	Korzok	Klimes 6329
Leontopodium stracheyi Cl. ex Hemsl.		
Leibnitzia nepalensis (Kuntze) Kitam.	Garbyang	
Ligularia amplexicaulis DC.		
Ligularia jacquemontiana (Decne.) Rau.		@
Ligularia sibirica Cass.		
Ligularia thomsonii (Cl.) Kitam.		
Myriactis nepalensis Less.		
Myriactis wallichii Less.	Kutti	
Olgaea thomsonii (Hk.f.) Iljin	Niti	@
Picris heiracioides L.	Jalandhri Gad	
Prenanthus brunoniana Wall. ex DC.	Churdhar	15138
Prenanthus sikkimensis Hk. f.	SL	?
Prenanthus violaefolia Decne	Jalandhri Gad	
Petasites tricholobus Franch.	Kutti, Nipchang	
Psychrogeton andryaloides (DC.) Novop.	Myar Nala, Zanskar	
Saussurea abnormis Lips.	Niti	
Saussurea andryaloides (DC.) Sch. Bip	Stot	Klimes
Saussurea aster Hemsl.	Singo La, Lahul	BSD
Saussurea atkinsonii Cl.	Kyarki	@
Saussurea auriculata (Spreng ex DC.) Sch - Bip.	Valley of Flowers	
Saussurea bracteata Decne.	Nelang	
Saussurea candolleana Wall. ex DC.	Pindari	BSD
Saussurea ceratocarpa Decne	Chandra Tal, Da - Hanu	
Saussurea clarkei Hk. f.	K	@
Saussurea columnaris Hand.-Mazz.		
Saussurea costus (Falc.) Lipsch	Kashmir, Lahaul (cult.)	Dickore & Nusser @
Saussurea deltoidea Cl.		
Saussurea depsangensis Pamp.		

Saussurea fastuosa (Decne.) Sch.-Bip.	Niti, Gamsali	
Saussurea gilesii Hemsl.		
Saussurea glacialis Herd.	Tso Kar	5508
Saussurea glanduligera Sch.-Bip.	Taklang La, Khardung La	
Saussurea gnaphaloides (Royle) Sch.-Bip.	Bomras	14477
Saussurea gossypiphora D. Don	Barjikang	
Saussurea graminifolia Wall. ex. Hk. f.	Upper Gidara	14699
Saussurea hookeri Cl.		?
Saussurea hypsipeta Diels.	Nia Phu (Indus V)	Klimes ?
Saussurea jacea Cl.	Near Kirthing (Lahul)	15024
Saussurea leontodontoides (DC.) Lipsch.	Nelang	
Saussurea nana (Pamp.) Pamp.		
Saussurea obvallata (DC.) Sch.-Bip.	Upper Dhanu	14683
Saussurea ovata Benth.		?
Saussurea piptatera Edgew.	Kinkru Thach	14884
Saussurea roylei (DC.) Sch.-Bip	Jalandhri Gad	
Saussurea simpsoniana (Field & Gardn.) Lipsch.	Kakbhusandi	
Saussurea stoliczakae Cl.	Rulung Valley, Ladakh	Klimes
Saussurea sudhansui Hajra	Dhransi Pass, 4800 m	BSD @
Saussurea taraxacifolia Wall. ex DC.	Kinkru Thach	14885
Saussurea thomsonii Cl.		
Saussurea polystechoides Hk f.	Nubra	K
Saussurea wernerioides Sch.- Bip. ex Hk. F	Hanley, Karakoram	WII
Scorzonera virgata DC.	Zanskar	
Senecio alatus Wall. ex DC	Kedarnath	
Senecio candolleanus Wall. ex DC.		
Senecio chenopodifolius DC.		
Senecio desfontainei Druce	Shel Shel, Chandratal	
Senecio dubitabilis Jeff. & Chen.	Tso Kar	5522, 5525
Senecio duthiei Rau	Kutti	
Senecio krascheninnikovii Sch.		
Senecio kunthianus Wall. ex DC.	Dhanu Satopanth	14692
Senecio ladakhensis Chowdhery et. al.	Ladakh	BSD @
Senecio laetus Edgew.	Above Mapa	14378
Senecio royleanus DC	Valley of Flowers	
Senecio tibeticus Hk. f.	Kashmir, Ladakh (s.l.)	Dickore & Nusser @
Solidago virga-aurea L.	Above Chhitkul	14841
Sonchus asper (L.) Hill.	Nubra	
Sonchus brachyotus DC.		
Soroseris daesyi (Moore) Stebb.		
Soroseris gillii (Moore) Stebb.		
Soroseris glomerata (Decne.) Stebb.		
Tanacetum artemisioides Sch.-Bip. ex Hk.f.		
Tanacetum dolichophyllum (Kitam) Kitam.		
Tanacetum falconeri Hkf.		
Tanacetum gossypinum Hk.f. & T.		
Tanacetum gracile Hk. f.	Tso Kar	5330
Tanacetum nanum Cl.		

Tanacetum nubigenum Wall.	Niti way to Long Payar	14599
Tanacetum robustum Hk. f. & T. ex Cl.		
Tanacetum tomentosum DC.		
Tanacetum tenuifolium Jacq.		
Tanacetum tibeticum Hk. f. & T. ex Cl.		
Taraxacum armeriifolium Soest.	Pangong Tso	Klimes
Taraxacum candidatum Kirsch.	Tso Kar, Tso Moriri	Klimes
Taraxacum forrestii van Soest	PDA	14759
Taraxacum kashmirense van Soest		
Taraxacum luridum Hagl.	Pangtong Tso, Tso Moriri	Klimes
Taraxacum officinale Weber	Rudranath	
Taraxacum virgineum Kischner et al.	Thukje Gompa, Tso Kar	Klimes @
Taraxacum watti Hk. f.		
Tragopogon dubius Scop.		
Tragopogon gracilis D. Don		
Tricholepis tibetica Hk. f. & T. ex Cl.		
Tussilago farfara L.	Burphu	
Waldhemia glabra (Decne.) Regel	Topidhunga	
Waldhemia nivea (Hk. f. & T.) Regel		
Waldhemia stoliczkai (Cl.) Ostenf.	Changchenmo	
Waldhemia tomentosa (Decne.) Regal	Burphu glacier	14383
Waldhemia vestita (Hk. f. & T.) Pamp.	Changchenmo	
Youngia glauca Edgew.	Nelang, Hanle	
Youngia gracilipes (Hk. f.) Babc. & Stebb.	Nelang	
Youngia tenuifolia (Willd.) Babc. & Stebb.	Gamsali	14593
CAMPANULACEAE		
Campanula argyrotricha Wall. ex DC.	Ganghar	14433
Campanula aristata Wall. ex Roxb.	Sangcha	
Campanula cashmiriana Royle	Burphu (Bhadel Gwar)	14387
Campanula lacei Duthie	Ralam way to Dudu dhar	14280
Campanula latifolia L.	Gidara	
Campanula modesta Hk.f.&T.	Nandanvan, Gangotri	GUH
Campanula pallida Wall.		
Codonopsis clematidea (Schrenk.) Cl.		
Codonopsis ovata Benth.		
Codonopsis rotundifolia Benth.	Kyarki	
Cyananthus integer Wall. ex Benth.	Kush Kalyani	
Cyananthus lobatus Wall. ex Benth.	Ralam	
Cyananthus microphyllus Edgew.	Dhaman Payar	14621
ERICACEAE		
Cassiope fastigiata D.Don	Kutti village pasture	14129
Gaultheria nummularioides D. Don	Tungnath	
Gaultheria trichophylla Royle	Valley of Flowers	
Lyonia villosa (Hk. f. ex Cl.) Hand.-Mazz	Tungnath	
Pyrola karakoramica Krisa		
Rhododendron anthopogon D.Don	Above Kalapani	14072

Rhododendron barbatum Wall. ex G. Don	Panch Chuli	
Rhododendron campanulatum D.Don	Valley of Flowers	
Rhododendron lepidotum Wall. ex G.Don	Valley of Flowers	
PLUMBAGINACEAE		
Acantholimon lycopodioides Boiss	Khardung La	
Dictylimon macrorhabdos (Boiss.) Rech. f.	Rumbak Valley, Hemis	
MONOTROPACEAE		
Hypopitys lanuginosa Nutt	Chhiyalekh	
PRIMULACEAE		
Androsace aizoon Duby	Kashmir, PoK	Dickore & Nusser @
Androsace chamaejasme Host.	Milam	
Androsace delavayi Franch.		
Androsace garhwalicum Balodi & Singh	Hemkund	BSD @
Androsace globifera Duby	Upper Gidara	14705
Androsace mucronifolia Watt.		
Androsace muscoidea Duby	Kishenganga Vy	Dickore & Nusser @
Androsace poissonii Kunth		
Androsace rotundifolia Hardw.	s.l.	
Androsace sarmentosa Wall.	above Garbyang	14022
Androsace sempervivoides Jacq. ex Duby	Hemis NP, Tso Kar, KK	
Androsace septentrionalis L.	Hemis NP, Tso Kar, KK	BSD
Androsace studiosorum Kress.		
Androsace villosa L.		
Cortusa brotheri Pax ex Lipsky	Napalchu nala	14100
Glaux maritima L.	Tso Kar	
Primula atrodentata Sm.		
Primula denticulata Sm.	Chhiyalekh slope	14014
Primula duthieana Balf. f. & Sm.		@
Primula edgeworthii (Hk. f.) Pax		
Primula elliptica Royle		
Primula glandulifera Balf. f. & Sm.		
Primula heydeii Watt.		
Primula involucrata Wall. ex Duby	Above Kalapani	14080
Primula macrophylla D. Don	Nabedhang	14036
Primula moorcroftiana Wall. ex Klatt	Panch Chuli	
Primula minutissima Jacq. ex Duby	Barjikang Ralam	14289
Primula nutans Delav.	Tso Kar	5457
Primula obtusifolia Royle		@
Primula petiolaris Wall. (incl. Var. name)		
Primula primulina (Spreng) Hara	North Polu	
Primula rosea Royle	Rohtang	
Primula reidii Duthie	Tungnath	@
Primula reptans Hk.f. ex Watt		
Primula rotundifolia Wall.		

Primula schlagintweitiana Pax.		
Primula stuartii Wall.	Rohtang	15001
OLEACEAE		
Fraxinus excelsior L.	Malari	
Fraxinus floribunda Wall.		
Jasminum humile L.	Valley of Flowers	
Syringa emodi Wall. ex Royle	Valley of Flowers	
ASCLEPIADACEAE		
Cynanchum auriculatum Royle ex Wight		
Cynanchum heydei Hk. f.		
Cynanchum vincetoxicum (L.) Pers.	Dhaman Payar	14633
GENTIANACEAE		
Gentiana aquatica L. var. *aquatica*	Lossar, Spiti, Ganghar	14416
Gentiana argentea Royle ex D. Don	Nelang	GSR
Gentiana burkillii Sm.	Stot (Nyi), Milam	Klimes
Gentiana cachemirica Decne	Kishenganga vy, Kashmir	DD
Gentiana capitata Buch. - Ham.ex D.Don	Jeolingkong	14184
Gentiana coronata Royle	Sural Vy, Pangi	15060
Gentiana crassuloides Burr. & Fr.	Nampha, Shallang Gwar	14124,
Gentiana infelix Cl.	Kinnaur, Vasukital	BSD
Gentiana leucomelaena Maxim.	Tso Kar	5381
Gentiana nubigena Edgew.	Kutti Vy, Chhota Hoti	14561
Gentiana pedicellata (D.Don) Griseb.	Mapa	14373
Gentiana prostrata Haenke	Bhrigu Tal, Raksham	14907, 14960
Gentiana stipitata Edgew.	Tungnath, Chandrashila	GSR
Gentiana tetrasepala Biswas	Ralam Valley	CAL @
Gentiana tianschaniaca Rupr.	Rimkhim, Chhitkul	14570, 14833
Gentiana tubiflora Wall. ex Griseb	Bhrigu Tal, Hemkund	BSD
Gentiana venusta Wall. ex Griseb.	Dhanu Satopanth	14686
Gentiana veitchiorum Hemsl.	Bedini Bugyal, NDBR	BSD ?
Gentianella aurea (L) H. Sm.	Burji La, Zoji La	DD
Gentianella maddenii (Cl.) Airy Shaw	Mapa (Johar), Kirthing	15017
Gentianella moorcroftiana (Wall ex Griseb) Airy Shaw	Dras, Darcha, Pindari	15076
Gentianella tenella (Rottb.) Borner	Nelang, Ralam	DD
Gentianopsis detonsa (Rottb.) Ma	Pang, Tsokar, Kioto	5486, 5517
Gentianopsis paludosa (Hk.) Ma	Way to Sipu From Tidang	14731
Halenia elliptica D. Don	Mapa (Johar)	14377
Jaeschkea canaliculata (Royle) Knobl.	Sural Valley, Sonamarg	15034
Jaeschkea oligosperma (Griseb) Knobl.	Billing Nala	BSD
Lomatogonium carinthiacum (Wulff) Reichb.	Khardung La, Lahul	14895
Lomatogonium caeruleum (Royle) H. Sm	Kishenganga Vy, Sach P	DD
Lomatogonium thomsonii (Cl.) Fernald.	Tso Kar; Kunzam	5538
Swertia alpina Bhatt. & Sunita	Kedarnath, Kush Kalyani	BSD @
Swertia alternifolia Royle	Rohtang, Kedarnath	BSD @
Swertia ciliata (G. Don) Burtt	Throughout	GSR

Swertia cordata (G.Don) Cl.	Sangla Vy	14925
Swertia cuneata D.Don	Chitkul, Kyarki	14684
Swertia petiolata D. Don	Kyarki	14807
Swertia speciosa D.Don	Changshil	14822
Swertia thomsonii Cl.	Sonamarg [Type Locality]	DD @
POLEMONIACEAE		
Polemonium coeruleum L.	Ganghar	14432
BORAGINACEAE		
Actinocarya acaulis (Sm.) Johnst.		@
Actinocarya tibetica Benth.	Stot, Ladakh	Klimes
Anoplocaryum brandisii Brand.		@
Arnebia benthamii (Wall. ex G. Don) Johnst.	Rama Way to Bedang	14209
Arnebia euchroma (Royle) Johnst.	Rimkhim, Nubra	
Arnebia guttata Bunge	Hemis	
Asperugo procumbens L.	Around Kutti village	14144
Cynoglossum microglochin Berk.	Ralam	
Cynoglossum nervosum Benth. ex Cl.		
Cynoglossum wallichii G. Don	Valley of Flowers	
Eritrichum canum (Benth) Kitam.	Napalchu nala	14108
Eritrichum fruticulosum Klotz.		
Eritrichum nanum Schrad.		
Eritrichum pustulosum Cl.		
Eritrichum rupestre (Pall.) Bunge		
Eritrichum thymifolium (DC.) Lian & Wang.		
Hackelia roylei (Wall. ex DC.) Johnst.		
Hackelia stewartii Johnst		@
Hackelia uncinata (Benth.) Fisch.	Rupi Bhaba	
Lappula barbata (M.Bieb.) Gurke		
Lappula heteracantha (Ledeb.) Gurcke		
Lappula microcarpa (Ledeb.) Gurcke		
Lappula patula (Lehm.) Asch. & Gurcke		
Lappula semi-glabra (Ledeb) Gurcke		
Lindelofia anchusoides (Lindl.) Lehm.	Pin Valley	
Lindelofia longiflora (Benth.) Baill.		
Lindelofia stylosa (Kar. & Kir.) Brand.	Above Kalapani	14079
Mattiastrum himalayense (Klotzsch) Brand		
Mertensia racemosa (Royle) Cl.		
Microparacaryum intermedium (Fresen.) Hilger & Podlech.	Tso Kar	
Lasiocaryum diffusum (Brand) Johnst.		
Lasiocaryum densiflorum (Duthie) Johnston		
Lasiocaryum munroi (Cl.) Johnst.		
Microcaryum pygmaeum (Cl.) Johnst.		
Microula tibetica Maxim.	Tso Kar	
Myosotis arvensis Hoffm.	Ralam	
Myosotis caepitosa Schultz		
Myosotis silvatica Hoffm.	Jeolingkong	

Myosotis stricta Link		
Onosma bracteatum Wall.	Sipu	
Onosma emodi Wall.	Ralam	
Onosma hispidum Wall. ex. D.Don	Tso Kar	
Oreogenia munroi (Cl.) I.M. Johnst.		
Pseudomertensia echioides (Royle ex Benth) Reidl.	Base of Kun	15097
Pseudomertensia lahulensis (Brand.) Aswal	Lahul	@
Pseudomertensia moltkioides		
Rochelia macrocalyx Bunge		
Solenanthus circinnatus Ledeb.		
Trigonotis rotundifolia (DC) Cl.	Jeolingkong	14159
CONVOLVULACEAE		
Convolvulus arvensis L.	Milam, Niti	
CUSCUTACEAE		
Cuscuta approximata Babington		
Cuscuta brevistyla Braun ex Rich		
Cuscuta planiflora Ten.	Nubra	Klimes
Cuscuta europaea L.	Chhitkul	14864
Cuscuta indica (Engl.) Petro.		
SOLANACEAE		
Atropa acuminata Royle	Kinnaur	
Hyoscyamus niger L.	Garbyang	
Physochlaina praealta (Walp.) Hk. f.	Nabedhang	
Lycium ruthenicum Murray ex Dunal.	Nubra	
Scopolia lurida Dunal.	Way to Kutti village	14128
SCROPHULARIACEAE		
Euphrasia alba Pennell	Hemis	Pennell @
Euphrasia flabellata Pennell	POK	Pennell @
Euphrasia foliosa Pennell	Burzil Pass	Pennell @
Euphrasia himalayica Wettst.	Nampa nala	14123 @
Euphrasia jaeschkei Wettst.	Sach Pass, Chamba	DD @
Euphrasia kashmiriana Pugsley	Gya, Ladakh	Pennell @
Euphrasia paucifolia Wettst.	Losar, Spiti	Pennell @
Euphrasia platyplylla Pennell	Billing Nala, Lahul	Pennell @
Euphrasia remota Pennell	Zoji La	Pennell @
Euphrasia schlagintwitii Wettst.	Badrinath, Simla, Kashmir	DD
Falconeria himalaica Hk.f.	Tungnath	@
Hemiphragma heterophyllum Wall.	Dhunkhan, Panch Chuli	
Lancea tibetica Hk. f. & T.	Kalapani, Nabedhang	
Leptorhabdos parviflora Benth.	Nelang	
Limosella aquatica L.	Kunzam La	
Pedicularis albida Pennell	Nubra, Spiti	
Pedicularis bicornuta Klotz.	Mapa (Johar)	14372
Pedicularis brevifolia D. Don	Zanskar, Lahul	

Pedicularis brevirostris Pennell	Zoji La, Pensi La	@
Pedicularis brunoniana	Kugti, Chamba	
Pedicularis gracilis Wall ex Benth.	Saba Udiyar, Ralam	DD
Pedicularis heydei Prain	Tso Kar	5550
Pedicularis hoffmeisteri Klotz.	Gidara	
Pedicularis hookeriana Wall. ex Benth.	Ralam	
Pedicularis jainii Aswal ex Mehrotra	Lahul, Zanskar	
Pedicularis kashmiriana Pennell	Kashmir	@
Pedicularis klotzschii	Ralam	
Pedicularis longiflora Rud.	Phatab Panchachuli Base	14223
Pedicularis megalantha D. Don	Ralam	14262
Pedicularis mollis Wall. ex Benth.	Nipchang, Ralam	
Pedicularis nodosa Pennell	Kyogar	
Pedicularis oederi Vahl	Bomras	14471
Pedicularis ophiocephala Maxim.	Barjikang	
Pedicularis pectinata Wall. ex Benth.	Shellang Gwar	14344
Pedicularis porrecta Wall. ex Benth.	Ralam	
Pedicularis punctata Decne.	Rohtang	@
Pedicularis purpurea Pennell	Nelang	
Pedicularis pycnantha Boiss.	Baralacha	
Pedicularis rhinanthoides Schrenk	Lahul, Zanskar	
Pedicularis roylei Maxim.	Rupin Pass	
Pedicularis stewartii Pennell	Sach Pass, Chamba	
Pedicularis svenhedinii Pauls.	Hanle	
Pedicularis tenuirostris Benth.	Nelang	
Pedicularis trichoglossa Hk. f.	Bedang	
Picrorhiza kurrooa Royle ex Benth.	Sela Yangti	14154
Scrophularia calycina Benth.	Palang Gadh	DD
Scrophularia decomposita Royle ex Benth.	Rohtang	DD
Scrophularia dentata Royle ex Benth.	Puga Valley, Pensi La	@
Scrophularia edgeworthii Benth.	Munsiary, Tola	DD
Scrophularia himalayensis Royle ex Benth.	Tungnath	
Scrophularia koelzii Pennell	Dras, Kugti Pass	DD
Scrophularia scabiosaefolia Benth.	Chhyudhang	14503
Scrophularia suffruticosa Pennell	Kibber	Pennell
Verbascum thapsus L.	Bilju, Johar	
Veronica anagallis-aquatica L.	Bedang	14200
Veronica beccabunga L.	Bedang	
Veronica biloba L.	Ralam	
Veronica cachemirica Gaud.	Gulmarg	@
Veronica cana Wall. ex Benth.	Saba	
Veronica capitata Royle ex Benth.	Chhitkul	
Veronica cephaloides Pennell	Jeolingkong, Topidhunga	@
Veronica ciliata Fisch.	Stot, Indus Vy	Klims 6218
Veronica hirta Pennell	Kugti Pass, Rohtang	
Veronica koelzii Pennell	Rupshu	@
Veronica lanosa Royle ex Benth.	Chhitkul	
Veronica lasiocarpa Pennell	Barjikang	

Veronica macrostemon Bunge ex Ledeb.	Timti La, Kharbu	Pennell
Veronica melissaefolia Poiret.	Ralam	
Veronica nana Pennell	Debring, Rupshu	@
Veronica perpusilla Boiss	Sonamarg	Pennell
Veronica salina Schur.	Trilokinath, Dah	
Veronica serpyllifolia L.	Banihal Pass, Burzil Pass	Pennell
Veronica umbelliformis Pennell	Barjikang	Pennell @
Veronica uncinata Pennell	Tog Nallah, Ladakh	Pennell @
ACANTHACEAE		
Pteracanthus alatus (Wall. ex Nees) Brenk.	Dhunkhan	
Strobilanthes atropurpureus Nees	Sokh Kharak	
SELAGINACEAE		
Lagotis cashmeriana (Royle) Rupr.	Rohtang	
Lagotis decumbens	Dauletbeg Oldi, Karakoram	AP
Lagotis globosa (Kurz.) Hk.f.	Rumbak, Hemis	
Lagotis kunawurensis (Royle ex Benth.) Rupr.	Parvati Tal	14177 @
OROBANCHACEAE		
Boschniakia himalaica Hk. f. & T.	Tola (Johar)	
Orobanche alba Steph.	Burphu	
Orobanche amoena Mey		
Orobanche cernua Loeffl.	Tola (Johar)	14320
Orobanche hansii Kerner		
Orobanche kashmirica Cl. ex Hk. f.	Kishen Ganga Vy	@
Orobanche solmsii Cl. ex Hk. f. & T.		
LENTIBULARIACEAE		
Pinguicula alpina L.	Napalchu nala	14105
Utricularia minor L.	Ralam	
Utricularia brachiata Oliver	Rudranath, Tungnath	GUH
LAMIACEAE (LABIATAE)		
Ajuga brachystemon Maxim.	Changshil, Churdhar	
Clinopodium umbrosum (M. Bieb.) Koch	Kutti	
Clinopodium vulgare L.	Churdhar	
Dracocephalum heterophyllum Benth.	Chhyudhang	14510
Dracocephalum nutans L.		
Dracocephalum speciosum Benth.	Kalajowar, Kyarki	
Dracocephalum stamineum Kar. & Kir.	Karakoram	
Elsholtzia densa Benth.	Kutti	14132
Elsholtzia eriostachya Benth. var pusilla	Sonam	14741
Elsholtzia strobilifera Benth.		
Eriophyton wallichianum Benth.		
Glechoma nivalis (Benth.) Press	Khingru Base	14511
Hyssopus decumbens L.	Sumna Above	14591
Lamium amplexicaule L.	Kutti village	14142

Lamium rhomboideum Benth.	Tipani Nelang	14739
Leonurus cardiaca L.		
Marrubium lanatum Benth.	Temasha Valley	15082
Mentha longifolia (L.) Huds.	Gechhang	
Nepeta clarkei Hk.f.		
Nepeta coerulescens Maxim.	Tso Kar	5536
Nepeta connata Royle ex Benth.	Kashmir, PoK	Dickore & Nusser @
Nepeta discolor Royle ex Benth.	Nelang, Tso Kar	5528
Nepeta duthiei Prain & Mukher.		
Nepeta eriostachya Benth.	Nelang	
Nepeta floccosa Benth.	Da - Hanu	
Nepeta glutinosa Benth.	Da - Hanu	
Nepeta govaniana Benth.	Chuli	
Nepeta laevigata (D. Don) Hand.-Mazz.	Burphu	14326
Nepeta leucolaena Benth. ex Hk.f.	Da - Hanu	
Nepeta linearis Royle ex Benth.		
Nepeta longibracteata Benth.	Balch Pass	
Nepeta nervosa Royle ex Benth.		
Nepeta nivalis Benth.		
Nepeta podostachya Benth.		
Nepeta raphanorhiza Benth.	Temasa, Zanskar	
Nepeta salvaefolia Royle ex Benth.		
Nepeta supina Stev.		
Nepeta tibetica Benth.		
Origanum vulgare L.	Opp. Marhi	15016
Perovskia abrotanoides Karel	Nubra	
Phlomis bracteosa Royle ex Benth.	Valley of Flowers	
Phlomis rotata Benth. ex Hk. f.		
Phlomis setigera Falc. ex Benth.		
Prunella vulgaris L.	Mapa (Johar)	14380
Salvia campanulata Wall. ex Benth.		
Salvia hians Royle ex Benth.	Gidara	
Scutellaria heydei Hk. f.		
Scutellaria prostrata Jacq. ex Benth.	Nabedhang	14088
Stachys melissaefolia Benth.		
Stachys tibetica Vatke		
Thymus linearis Benth.		
PLANTAGINACEAE		
Plantago brachyphylla Edgew.		
Plantago depressa Willd.	Gunji, Nelang	
Plantago gentianoides Sibth. & Smith.	Korzok	Klimes 6323
Plantago lanceolata L.	Sural Valley, Pangi	
Plantago major L.	Kush Kalyani	
NYCTAGINACEAE		
Oxybaphus himalaicus Edgew.	Nelang, Jalandhri Gad	

CHENOPODIACEAE		
Atriplex crassifolia Mey	Leh	
Atriplex pamirica Iljin	Samad, Starstsapuk Tso	Klimes
Axyris amaranthoides L.		?
Axyris hybrida L.	Ganghar pasture	14421
Chenopodium album L. subsp. *album*	Chhojan	
Chenopodium botrys L.	Nelang	
Chenopodium foliosum (Moench.) Asch.	Jalandhri	
Chenopodium glaucum L.	Naga,Nelang	14763
Chenopodium himalaicum Klimes	Rupshu	
Chenopodium hybridum L.	Nelang	
Chenopodium tibeticum A.J. Li	Tso Kar	5400
Corispermum tibeticum Iljin	Tso Kar	5341
Halogeton glomeratus (MB) Mey	Tso Kar	
Haloxylong thomsonii Bunge	Da - Hanu	
Kochia dasyphylla Fisch. et Mey	Nubra	
Kochia stellaris Moq.	Da - Hanu	
Kochia prostata (L.) Schrad	Da - Hanu	
Krascheninnikovia ceratoides (L.) Gueldenst.	Tso Kar	
Microgynoecium tibeticum Hk. f.	Bedang	14199
Salsola collina Mey	Nubra	
Salsola jacquemontii Moq.	Tso Kar	5339
Suaeda corniculata (Mey) Hk.f.	Parang, Rupshu	
Suaeda microsperma Ledeb.		
POLYGONACEAE		
Aconogonum kuttiensis Maiti, Dutta & Babu	Kutti	@
Aconogonum rumicifolium (Royle ex Bab.) Hara	Niti way to Long Payar	14605
Aconogonum tortuosum (D. Don) Hara	Sonam	14762
Bistorta affine (D. Don) Greene	Kyarki	
Bistorta amplexicaulis (D. Don) Greene	Chuli	
Bistorta emodi (Meisn.) Hara	Nelang	
Bistorta macrophylla (D. Don) Soj.	Tungnath	
Bistorta vaccinifolia (Wall. ex Meisn.) Greene	Malari	14646
Bistorta vivipara (L.) S. F. Gray	Burphu	14401
Fagopyrum esculentum Moench.	Sipu, Darma	
Fagopyrum tataricum (L.) Gaertn.	Sipu, Darma	
Fallopia dumetorum (L.) Holub.	Malari	BSD
Knorringia pamirica	Chhojan	14552
Koenigia delicatula (Meisn.) Hara	Kyarki	
Koenigia islandica L.	Bomras	14486
Koenigia nepalensis D. Don	Kyarki	14792
Koenigia nummularifolia (Meisn.)	Pahalgam	
Oxyria digyna (L.) Hill	Nelang	14752
Polygonum alpinum All.	Darcha	
Polygonum arinastrum Boreau		
Polygonum avicuare L.	Milam	
Polygonum chinense L.	Badrinath	

Polygonum glaciale Hk. f.		
Polygonum molliaeforme Boisse	Debring, Tso Kar	5489
Polygonum olivieri J. & S.	Zanskar, SL	Klimes
Polygonum pamirolaicum Kom.	Bomras, Da - Hanu	
Polygonum paronychioides C.A. Mey	Surru	Klimes
Polygonum perpusillum Hk. f.	Barjikang	
Polygonum persicaria L.	Valley of Flowers	
Polygonum plebejum R. Br.	Niti	
Polygonum polystachyum Meissn.	Valley of Flowers	
Polygonum tubulosum Boiss.	Niti, Milam	
Rheum australe D. Don	Kutti	
Rheum moorcroftianum Royle	Nabedhang	
Rheum spiciforme Royle	Way to Khingru	14508
Rheum tibeticum Maxim.	Nubra	
Rheum webbianum Royle	Thajwas, Hanle	
Rumex acetosa L.	Valley of Flowers	
Rumex nepalensis Spreng.	Kedarnath	
Rumex patientia L.	Nelang	
THYMELAEACEAE		
Daphne retusa Hemsl.	Napalchu Nala	14098 #
Stellera chamaejasme L.	Above Chhiyalekh	14013
ELAEAGNACEAE		
Hippophae rhamnoides L.	Naina Gahar, Lahul	15046
Hippophae salicifolia	Garbyang	GSR, SR
Hippophae tibetana Schlecht.	Burphu glacier	14403
LORANTHACEAE		
Arceuthobium minutissimum Hk. f.	On way to Kalapani	14060
Arceuthobium oxycedri M. Bieb.	Naina Gahar	15047
SANTALACEAE		
Thesium himalense Royle ex Edgew	Chhiyalekh	14010
Thesium hookeri Hendr.	Broglau, Da - Hanu	Klimes 2503
EUPHORBIACEAE		
Euphorbia hispida Boiss.		
Euphorbia kanaorica Boiss.	Rimkhim	
Euphorbia sharmae Bhatt.	Phatab Panchachuli Base	14222 @
Euphorbia stracheyi Boiss.	Nabedhang	14050
Euphorbia thomsoniana Boiss.		
Euphorbia tibetica Boiss	Tso Kar	
Euphorbia wallichii Hk. f.		
BUXACEAE		
Buxus wallichiana Bail.		

URTICACEAE		
Parietaria micrantha Ledeb.	Ralam	
Urtica dioica L.	Tola (Johar)	14314
Urtica hyperborea Jacquem. ex Weidd.	Kharnak, Rupshu	
BETULACEAE		
Betula utilis D. Don	Rohtang slope	
FAGACEAE		
Quercus semecarpifolia Sm.	Tirthan, Kedarnath WS	GSR, SR
SALICACEAE		
Populus balsamifera L.		
Populus euphratica Oliv.	Nubra Valley	
Populus ciliata Wall. ex Royle	Chitkul	
Salix caesia Vill.	Rimkhim, Lower Lapthal	
Salix calyculata Hk.f. ex Anders.	Napalchu Nala	
Salix daphnoides Vill.	Sela Yangti Vally	14145
Salix divergens Anders.		
Salix elegans Wall. ex Anders.	Niti	14596
Salix flabellaris Anders.	Nelang	
Salix flagellaris Anders.		
Salix furcata Anders.	s.n.	?
Salix karelinii Turcz. ex Stsche.	Martoli	
Salix lindleyana Wall. ex Anderss.	Way to Nabedhang	14065
Salix lindleyana var. microphylla Anders.	Palang Gadh	GSR, SR
Salix oxycarpa Anders.		
Salix pycnostachya Anders.	Korzok, Da-Hanu	
Salix wallichiana Anders.	Ralam	
MONOCOTYLEDONES		
ORCHIDACEAE		
Corallorhiza trifida Chatel.	Martoli	BSD @
Cypripedium cordigerum D. Don	Nagtiba	JS 13823 ?
Cypripedium elegans Rchb.f.	On the way to Ralam	JS 13933
Cypripedium himalaicum Rolfe	Phatab Panchachuli Base	14242
Dactylorhiza hatagirea (D.Don) Soo	Sipu	14211
Epipogium aphyllum (Sm.) Sw.	Gangotri, Ghangarea	DD, BSD
Gymnadenia orchidis Lindl.	Gidara	14709
Herminium josephii Rchb.f.	Tola (Johar)	14319
Herminium kumaunensis Deva et Naithani	Chhiyalekh	Duthie DD @
Herminium monorchis R.Br.	Sipu village moist field	14250
Herminium pugioniforme Lindl.ex Hk.f.	Briggng (Ralam valley)	JS 13942
Listera pinetorum Lindl.	Nampha Gad	DD
Listera tenuis Lindl.	Near Tola (Johar)	JS 13945
Malaxis muscifera (Lindl.) O.Kze.	Ralem Valley	JS 13937

Neottianthe calcicola (Sm.)Schlt.	Chhiyalekh	GSR 1510
Oreorchis foliosa (Lindl.) Lindl.	Sokh Kharak	GSR SR
Peristylis duthiei (Hk. f.) Deva & Naith.	Naher Devi (Johar)	JS 13957
Poneorchis chusua (D.Don) Soo	Napalchu nala	14106
Poneorchis nana (Schltr.) Soo	Chuli Bugyal	14781
Poneorchis renzii Deva & Naithani	Chhiyalekh	GSR 1225 @
Satyrium nepalense Don	Chena Peak	JS 13718
Spiranthes sinensis (Pers.) Ames	Mahesh khan	JS 13727
ZINGIBERACEAE		
Roscoea alpina Royle	Chhiyalekh	GSR, SR
IRIDACEAE		
Iris duthiei Foster	Lapthal	
Iris lactea	Da - Hanu	
Iris *hookeriana* Foster	Lapthal	14528
Iris kumaonensis Wall. ex G. Don	Gunji	14066
MELANTHIACEAE		
Aletris pauciflora (Klotzsch) Hand.-Mazz.	Kutti	
LILIACEAE		
Allium auriculatum Kunth.		
Allium caesoides Wendel.		
Allium carolinianum DC.	Way to Nun base	15109
Allium consanguineum Kunth.	Ralam	GSR P @
Allium fedschenkoanum Regel	Sural Valley, Pangi	GSR P
Allium humile Kunth.	Panch Chuli	
Allium jacquemontii Kunth.	Surru	Klimes
Allium loratum Baker		
Allium oreoprassum Schr.	Hemis	Klimes
Allium przewalskianum Regel.	Rupshu, Da - Hanu	GSR, Klimes
Allium schoenoprasum L.	Rupshu	
Allium spicatum		
Allium stoliczki Regel.	Losar	
Allium tuberosum		
Allium victorialis L.	Napalchu nala	14093
Allium wallichii Kunth	Changshil	
Asparagus racemosus	Gamsali	
Clintonia udensis Trautv.		
Eremurus himalaicus Baker	Pin Valley, Meenamarg	@
Fritillaria cirrhosa D. Don		
Fritillaria roylei Hk.		
Fritillaria stracheyi Hk.f.	Garbyang slope	14020
Gagea lutea (L.) Ker.	Pindari	
Gagea kunawarensis (D. Don) Grent.		
Lilium polyphyllum D. Don	Gangotri	
Lloydia longiscapa Hk.	Byans, Darma	

Lloydia serotina (L.) Reichb.	Chhiyalekh slope	14012
Milula spicata Prain	Da - Hanu, Nyoma	BSD
Nomocharis oxypetala (Royle) Balf. f. ex Evans	Chhiyalekh	14011
Polygonatum cirrhifolium (Wall.) Royle	Kedarnath	
Polygonatum geminiflorum Decne	Keylong	
Polygonatum graminifolium Hk. f.	Barjikang	
Polygonatum hookeri Baker	Sela Yangti	14152
Polygonatum kansuense Maxim. Ex Batal.	Raksham Chitkul	GSR P **
Polygonatum leptophyllum (D. Don) Royle	Valley of Flowers	**
Polygonatum multiflorum (L.) All.	Rupi - Bhaba	
Polygonatum verticillatum (L.) All.	Sela Yangti opp. Kutti	14150
Smilacina purpurea Wall.	Raksham Chitkul	
Smilax vaginata Decne.	Valley of Flowers	
Streptopus simplex D. Don	Changshil	
Trillidium govanianum (D. Don) Kunth	Chyang Kutang opp Sangla	14919
JUNCACEAE		
Juncus articulatus L.	Nubra	
Juncus bracteatus Buchen.	Pin Valley	
Juncus bufonius L.	Tso Kar	5545
Juncus clarkei Buchen.	Gilgit, Kashmir	
Juncus concinnus D. Don	Rohtang	
Juncus grisebachii Buch.		
Juncus himalensis Klotz.		
Juncus leucanthus Royle ex D. Don		
Juncus leucomelas Royle ex D. Don	Rupshu	
Juncus membranaceus Royle ex D. Don	Sapi La, Baltistan	
Juncus puctorius L. f.	Zanskar	
Juncus rohtangensis Goel & Aswal	Rohtang	Aswal & Goel @
Juncus sphacelatus Decne.	Zanskar	
Juncus thomsonii Buchen.	Pangong Tso, Rupshu	
Juncus triglumis L.	Changthang	
Luzula multiflora (Retz.) Lez.	Zanskar	
Luzula spicata DC.	Ralam	
ARACEAE		
Arisaema flavum (Forsk.) Schott.	Byans	GSR, SR
Arisaema jacquemontii Bl.	Ralam	GSR, SR
Arisaema propinquum Schott.	Ralam	
Typhonium diversifolium Wall. ex Schott	Badrinath	
JUNCAGINACEAE		
Triglochin maritima L.	Lapthal	14541
Triglochin palustris L.	Lapthal	
POTAMOGETONACEAE		
Potamogeton crispus L.	Leh	
Potamogeton filiformis Pers.	Tso Kar	5386

Potamogeton natans L.	s.l.	
Potamogeton nodosus Poir.	s.l.	
Potamogeton pectinatus L.	Bara Hoti	14567
ZANICHELIACEAE		
Zannichelia palustris L.	Tso Kar	GSR, SR
CYPERACEAE		
Baeothryon pumilum (Vahl.) Koyama	Nubra	
Blysmus compressus (L.) Panz. ex Link	Mapa (Johar)	14365
Blysmus rufus (Huds) Link.	Tso Kar	Klimes
Carex alexeenkoana Litv.	Baltal, More Plains	Klimes
Carex atrofusca Schkuhr.		
Carex borii Nelmes	Baralacha La	@
Carex cardiolepis Nees		
Carex cruenta Nees	Zanskar	14055
Carex curta Gooden.	Tapovan, Gaumukh	
Carex diluta M. Bieb.	Dras	BSD
Carex dimorpholepis	Lahaul, s.l.	
Carex duthiei Cl.	Lahaul, s.l.	
Carex gelisii Nelmes	Zanskar	
Carex haematostoma Nees	Nubra	
Carex heterostachya Bunge	Dras	
Carex inanis Kunth		
Carex infuscata Nees	Khoksar, Lahaul	
Carex karoi Freyn.	Surru Valley	
Carex kashmiriensis Cl.	s.l.	
Carex lehmannii Drejer	Ralam village pasture	14276
Carex maritima Gunnerus	Baralacha La	
Carex moorcroftii Falc. ex Boott	Way to Wilsia	14169
Carex microglochin Wahlenb.	Tso Kar	
Carex munda Boott	s.l.	
Carex munroi Boott ex Cl.	Kinnaur	FBI @
Carex nandadeviensis Ghildiyal *et al.*	Bhojgara, Nandadevi NP	BSD @
Carex nigerrima Nelmes	Lahaul, s.l.	
Carex nivalis Boott	Nampa nala	14122
Carex notha Kunth.	Lahaul, s.l.	
Carex nubigena D. Don	Ralam	
Carex obscura Nees	Way to Gunji	14025
Carex oligocarya Cl.	Karakoram	
Carex orbicularis Boott	Zoji La, Rupshu	
Carex pamirensis	Dras	
Carex parva Nees	Mapa (Johar)	14362
Carex plectobasis V. Krecz.	Khoksar, Lahaul	
Carex polyphylla Kar. & Kir.	Lahaul, s.l.	
Carex pseudofoetida Kukenth.	Rupshu	
Carex psychrophylla Nees	Zanskar	
Carex sagaensis Yang	Tso Kar	

Carex serotina Merat.	Dras	
Carex setosa Boott	Ralam village pasture	14273
Carex stenophylla Wahlb.	Chhyudhang	14502
Carex stracheyi Boott ex Cl.	s.l.	
Carex supina Willd. ex Wahlb.	s.l.	
Carex stenocarpa Turcz. ex Krecz.	Zanskar	
Elaeocharis atropurpureus (Retz.) Presl.	Sissoo, Lahaul	
Elaeocharis palustris R. Br.	Spiti	
Elaeocharis quinqueflora (Hartm.) Schw.	s.l.	
Elaeocharis uniglumis (Link) Schult.	Rupshu	
Elaeocharis retroflexa (Poir) Urb.	Sissoo, Lahaul	
Eriophorum microstachyum Boeck	s.l.	
Elaeocharis scheuchzeri Hoppe	s.l.	
Kobresia bellardii (All.) Degl.	Martoli, 4200 m	BSD
Kobresia capillifolia Cl.	Above Kutti village	14137
Kobresia duthiei Cl.	Lahaul, s.l.	
Kobresia fissiglumis Cl.	Palangar, E. Kumaon	DD 6092 ?
Kobresia laxa Nees	Ralam Above village	14267
Kobresia macrantha Boeck.	Baralacha La	
Kobresia nepalensis (Nees) Kukenth.	Napalchu nala	14116
Kobresia nitens Cl.	Tso Kar	
Kobresia pamiroalaica Ivan	Karakoram	
Kobresia pygmaea Cl.	Rupshu	
Kobresia royleana Boeck.	Tso Kar	
Kobresia schoenoides Steudel	Lapthal	14531
Kobresia stolonifera Tang ex Li	s.l.	
Kobresia trinervis (Nees) Boeck.	Kush Kalyan	14786
Microshoenus duthiei Cl.	Tehri Garhwal s.l.	FBI
Schoenoplectus lacustris (L.) Palla	s.l.	
Scirpus pauciflorus Ligtf.	s.l.	
Scirpus setaceus L.	Ganghar	14431
POACEAE		
Agrostis filipes Hk.f.	Khoksar	
Agrostis gigantea Roth	Sissu	
Agrostis griffithiana (Hk.f.) Bor	Sissu	
Agrostis munroana Aitch. & Hemsl.	Khoksar	
Agrostis pilosula Trin.	Burphu	14325
Agrostis stolonifera L.	Spiti	
Agrostis tungnathii Bhattacharya et Jain	Tungnath	BSD @
Agrostis vinealis Schreb.	Padam, Khardung	
Alopecurus aequalis Sobol	Nubra	
Alopecurus arundinaceus Poir.	s.l.	
Alopecurus himalaicus Hk.f.	Suru, Dras	
Anthoxanthum odoratum L.	Lahaul	
Avena barbata Pett. ex Link.	Indus Valley	
Avena fatua L.	Lahaul	
Brachypodium sylvaticum (Huds.) P. Beauv	Indus Valley	

Briza media L.	Kinkru Thach	14889
Bromus arvensis L.	s.l.	
Bromus confinis Nees ex Steud.	Bhrphu (Bhadel Gwar)	14382
Bromus danthoniae Trin.	Indus Valley	
Bromus gracillimus Bunge	Rupshu	
Bromus inermis Leyss	Sissu	
Bromus japonicus Thunb.	Khoksar	
Bromus lanceolatus Roth.	Keylong	
Bromus oxyodon Schrenk.	Da Hanu	
Bromus pectinatus Huds.	Darcha	
Bromus ramosus Huds.	Tandi, Lahaul	
Bromus scoparius L.	Dras	
Bromus sericeus Drobow	Korzok	Klimes 6320
Bromus stenostachyus Boiss	s.l.	
Bromus tectorum L.	Burphu	14322
Calamagrostis arundinacea (L.) Beauv.	s.l.	
Calamagrostis decora Hk.	Deosai	@
Calamagrostis emodensis Griseb.	Mapa (Johar)	14369
Calamagrostis epigejos (L.) Roth.	Mapa (Johar)	14364
Calamagrostis garhwalensis Hubb. & Bor.	Matyan, Ladakh	
Calamagrostis holciformis Jaub. & Spach.	Lapthal	14536
Calamagrostis pseudophragmites (Hall. f.) Koel.	Shansha	15040
Calamagrostis pulchella Griseb.	Khoksar	
Calamagrostis scabrescens Griseb.	Leh	
Calamagrostis stoliczkai Hk. f.	Pensi La	
Calamagrostis tianschanica Rupr.	s.l.	
Calamagrostis turkestanica Hack.	s.l.	
Catabrosa aquatica (L.) Beauv.	Tso Kar	
Catabrosa sikkimensis Stapf.	s.l.	
Catabrosella himalaica (Hk. f.) Tzvelev.	Tso Kar	
Colpodium leucolepis Nev.	Zanskar	
Colpodium himalaicum (Hk. f.) Bor	Bomras	14480
Colpodium nutans Griseb.	Kashmir, Ralam	14274 @
Cymbopogon jwarancusa (Jones) Schult.	Kibber	
Dactylis glomerata L.	Ralam	
Danthonia cachemyriana Jaub. & Spach.	Martoli Bugyal	14360
Deschampsia caespitosa (L.) Beauv.	Barjikang	14304
Deschampsia koeleroides Regel.	Skardu	
Duthiea bromoides Hack.	Valley of Flowers	
Duthiea nepalensis Bor	Niti way to Lang Payar	14610 ***
Elymus canaliculatus (Nevski) Tzv.	Burphu (Bhadel Gwar)	14390
Elymus caninus L.	s.l.	
Elymus cognatus (Hack.) Cope	Karakoram	
Elymus dahuricus Turcz.	Suru, Dras	
Elymus dentatus (Hk.f) Cope	Lahaul	
Elymus fedtschenkoi Tzv.	Dras	
Elymus himalayanus (Nevski) Tzv.	s.l.	
Elymus hispidus (Opiz.) Meld.	Zanskar	

Elymus kuramensis (Meld.) Cope	Hemis	
Elymus jacquemontii (Hk.f.) Tzv.	Tso-moriri	
Elymus nutans Griseb.	Way to Wilsia	14170
Elymus repens (L.) Gould.	Zanskar	
Elymus russellii (Meld.) Cope	Gechang, Pin Valley	BSD
Elymus schrenkianus (Fishch.) Tzv.	Tso Kar	
Elymus schuganicus (Nevski) Tzv.	Karakoram	
Elymus semicostatus (Nees ex Steud.) Meld.	Spiti	
Elymus sibiricus L.	Changthang	?
Elymus stewartii (Meld.) Cope	Shyok Valley	
Elymus thomsonii (Hk. f.) Meld.	Spiti	
Eremopoa altaica (Trin.) Rosch.	Zanskar	
Eremopoa persica (Trin.) Roschev	Hemis	
Eremopoa soongarica (Schr.) Roshev	s.l.	
Festuca alaica Drobov.	Changthang	
Festuca alatavica (St.-Yves) Rozhev	Tola (Johar)	14312
Festuca gigantea (L.) Vill.	Pindari	Y
Festuca hartmanii (Markgr.) Alex.	Zanskar	
Festuca kashmiriana Stapf.	Lower Lapthal	14516
Festuca lucida Stapf.	s.l.	
Festuca nandadeviensis Ghildiyal et al.	Deodi, Nandadevi NP	BSD @
Festuca nitidula Stapf	Zanskar	
Festuca olgae (Regel.) Krivot.	Rupshu	
Festuca pamirica Tzv.	Dras	
Festuca polycolea Stapf.	Nabedhang	14073
Festuca rubra L.	Nubra	
Festuca tibetica (Stapf.) Alex.	Above Kutti village	14135
Helictotrichon pratense (L.) Pilger	Tungnath	
Helictotrichon virescens (Nees ex Steudel) Henr.	Opp. Marhi	15015
Hierochloe flexuosa Hk.f.	Ralam village pasture	14275 **
Hierochloe laxa R. Br. ex Hk. f	Ralam	
Kengia mutica (Keng) Packer	Puga Valley	
Koeleria argentea Griseb.	Above Chitkul	14845
K. macrantha (Ledeb) Schult.	s.l.	
Leymus secalinus (Georgi) Tzv.	Tso Kar	
Lolium perenne L.	Kugti	
Melica persica Kunth.	Pin Valley	
Melica secunda Regel	Zoji La	
Milium effusum L.	s.l.	
Orinus thoroldii (Stapf) Bor	Changthang	
Oryzopsis aequiglumis Duthie ex Hk. f.	s.l.	
Oryzopsis lateralis Stapf.	Napalchu nala	14099
Oryzopsis munroi Stapf. ex Hk. f.	Pin Valley	
Oryzopsis wendelboi Bor	Western Ladakh	
Pennisetum flaccidum Griseb.	Tola (Johar)	
Pennisetum lanatum Klotzsch.	s.l.	
Pennisetum orientale L.	Byans	
Phleum alpinum L.	Way to Bedang	14205

Phragmites australis (Vav.) Trin ex Steud.	Nubra	
Phragmites karka (Retz.) Trin ex Steud.	Nubra	
Poa aitchisonii Boiss.	s.l.	
Poa alpina L.	Sela Yangti Vally	14147
Poa annua L.	Byans	
Poa attenuata Trin.	Darma	
Poa bactriana Roshev	s.l.	
Poa bulbosa L. var. vivipara Koeler	Kashmir	
Poa calliopsis Litw. ex Kom	s.l.	
Poa falconeri Hk. f.	s.l.	
Poa glauca Vahl.	s.l.	
Poa himalensis Nees ex Steud.	Rohtang	Dickore'
Poa infirma HBK	s.l.	
Poa jaunsarensis Bor.	s.l.	
Poa koelzii Bor	Baralacha La	@
Poa ladakhensis Hartm.	Rupshu	@
Poa lahulensis Bor	Above Chhitkul	14844
Poa markgrafii Hartm.	s.l.	@
Poa nemoralis L.	Near Napalchu	14035
Poa nepalensis Wall. ex Duthie	Byans	
Poa pagophila Bor	s.l.	
Poa polycolea Stapf.	Kedarnath	
Poa pratensis L. -	Above Kutti village	14134
Poa pseudoamoena Bor	Zanskar	
Poa rhadina Bor	s.l.	
Poa sikkimensis (Stapf) Bor	s.l.	
Poa stapfiana Bor	Darcha	
Poa sterilis M. Bieb.	s.l.	
Poa stewartiana Bor	Tso Kar	
Poa supina Schrad.	Zanskar	
Poa suruana Hartm.	Suru Valley	@
Poa tibetica Munro ex Stapf.	Changthang	
Poa trivialis L.	s.l.	
Poa versicolor Boiss.	s.l.	
Polypogon monspeliensis (L.) Desf.	Lahaul	
Puccinellia distans (L.) Parl.	Tso Kar	
Puccinellia himalaica Tzv.	Tso Kar	@
Pucciniella minuta Bor	Kashmir, Lahul, PoK	Dickore & Nusser @
Pucciniella stapfiana R.R. Stew.	Tso Kar	
Pucciniella tenuiflora (Griseb.) Scribn. & Merr.	s.l.	
Pucciniella thomsonii (Stapf.) R.R. Stew	Zanskar	@
Schismus barbatus (L.) Thell.	s.l.	
Setaria viridis (L.) P. Beauv.	Nubra	
Stipa brandisii Mez.	Da Hanu	
Stipa breviflora Griseb.	Rumtse, Leh	
Stipa capillata L.	Dras	
Stipa caucasica Schmal.	Chang chenmo	
Stipa concinna Hk.f.	Baralacha La	

Stipa consanguinea Trin. et Rupr.	Gya	
Stipa duthiei Hk.f.	Gulmarg	
Stipa himalaica Roshev.	Pangong Tso	
Stipa jacquemontii Jaub. & Spach.	Da Hanu	
Stipa mongholica Turcz. ex Trin.	Rupshu	
Stipa orientalis Trin.	Padam, Spiti	
Stipa pennata L.	Dras	
Stipa purpurea Griseb.	Rupshu	
Stipa regeliana Hack.	Apharwat	
Stipa roylei (Nees) Mez	Chamba	
Stipa splendens Trin.	Rumbak	
Stipa subsessiliflora (Rupr.) Rozhev	Rupshu	
Stipa tianschanica Roshev	Pangong Tso	
Stipa turkistanica Hackel	Kibber	
Stipagrostis plumosa (L.) Munro ex T. Anders.	Liddar Valley	
Tikeraia hookeri (Stapf) Bor	s.l.	
Trisetum aeneum (Hk. f.) R. R. Stew.	Jeolingkong	14194
Trisetum clarkei (Hk.f.) R.R. Stew.	Milam	
Trisetum spicatum (L.) Richt.	Chhyudhang	14512
Vulpia myuros (L.) Gmel	Panamik	

APPENDIX - III: Plant Species Diversity, Richness and Evenness at Selected Sites in Alpine Region of Greater Himalaya [Vegetation Types: AMS = Alpine Moist Scrub, CV = Cushion Forming Vegetation, DG = Danthonia Grassland, KSM = Kobresia meadows, MHF (SF) = Mixed Herbaceous Formation – Short Forbs, MHF (TF) = Mixed Herbaceous Formation – Tall Forbs, MM = Marsh Meadows, PV = Pioneer Vegetation after denudation, TL Gap = Treeline Gap]

SN	Locality/ Sampling Site	Alt. (m)	Latitude-N Longitude-E	Aspect	Veget. Type	Diversity (H')	Rich-ness	Even Ness
1	2	3	4	5	6	7	8	9
1	Churdhar -3	3514	30° 52' 20" 77° 29' 08"	E	AMS	2.23	28	0.67
2	Dronagair, VOF -3	3536	30° 43' 35" 79° 36' 27"	E	AMS	1.97	27	0.60
3	Kedarnath -1	3951	30° 43' 50" 79° 04' 46"	SW	AMS	2.03	25	0.63
4	Kyarkoti - 2	3850	31° 07' 42" 78° 42' 24"	E	AMS	2.91	34	0.83
5	Kyarkoti - 5	3900	31° 08' 32" 78° 41' 27"	NE	AMS	2.13	15	0.79
6	Kyarkoti - 8	3850	31° 08' 49" 78° 40' 52"	O	AMS	1.37	17	0.49
7	Sela-Yangti 1	3835	30° 17' 50.3" 80° 45' 19.5"	N	AMS	1.87	27	0.57
8	Sural Valley, Pangi	3876	33° 09' 33.2" 76° 32' 14.8"	S	AMS	3.06	34	0.87
9	Sewachand, VOF	3553	30° 45' 39.5" 79° 36' 45.3"	O	AMS	1.83	12	0.74
10	Jangdang, Sipu	4970	30° 19' 50.2" 80° 25' 3.7"	E	CV	1.94	15	0.72
11	Kedarnath -2	4294	30° 43' 46" 79° 05' 24"	SW	CV	1.34	14	0.51
12	Brahma Kharak	4090	30° 35' 35" 79° 21' 08"	SE	DG	2.11	19	0.72
13	Chhiyalekh-2	3325	30° 07' 18.8" 80° 50' 45.2"	SE	DG	2.70	30	0.79
14	Chyang Kuttang -1	3538	31° 23' 38.0" 78° 13' 36.5"	SE	DG	3.05	45	0.80
15	Chyang Kuttang -2	3550	31° 23' 28.9" 78° 13' 37.2"	SE	DG	3.18	40	0.86
16	Danga, Lissar -2	3799	30° 21' 19.6" 80° 27' 26.7"	E	DG	2.53	29	0.75
17	Ganghar, Johar	3422	30° 12' 21" 80° 09' 27"	O	DG	2.33	19	0.79
18	Kham -2	3991	30° 41' 59" 79° 05' 58"	SW	DG	1.82	18	0.63
19	Kush Kalyani	3768	30° 42' 23.5" 78° 39' 41.2"	E	DG	3.06	30	0.90
20	Kutti - 1	4015	30° 18' 28.7" 80° 46' 7.4"	SW	DG	2.37	26	0.73
21	Kyarkoti - 3	3900	31° 07' 45" 78° 42' 28"	E	DG	2.89	30	0.85
22	Mandani - 1	3827	30° 41' 45" 79° 09' 06"	SW	DG	2.22	27	0.68
23	Marhi - 1	3116	32° 20' 24" 77° 12' 22"	S	DG	1.90	31	0.55

1	2	3	4	5	6	7	8	9
24	Martoli, Johar	3801	30° 20' 09.5" 80° 11' 14.4"	SE	DG	2.72	37	0.75
25	Nampa, Byans - 1	4051	30° 16' 38.2" 80° 28' 22.7"	N	DG	2.22	14	0.84
26	Nampa, Byans - 2	4238	30° 16' 26.1" 80° 28' 31.2"	NE	DG	2.06	21	0.68
27	Pandavsera-2	3867	30° 37' 31" 79° 18' 52"	S	DG	1.56	19	0.53
28	Ralam - 1	3691	30° 19' 09" 80° 18' 15"	E	DG	2.61	31	0.76
29	Shelpe, Chhitkul	3898	31° 21' 47.9" 78° 26' 14.2"	SE	DG	3.18	39	0.87
30	Tin Chula, Johar	3572	30° 21' 24" 80° 10' 45.6"	SE	DG	2.51	22	0.81
31	Bhrigu Tal -1	4267	32° 17' 52.8" 77° 14' 39.2"	E	KSM	2.15	31	0.63
32	Churdhar - 4	3560	30° 51' 55.3" 77° 28' 40.7"	W	KSM	2.19	27	0.66
33	Danga, Lissar -3	3787	30° 21' 25.2" 80° 27' 25.7"	O	KSM	2.38	29	0.71
34	Karola Top	3850	30° 42' 18.2" 78° 39' 41.3"	W	KSM	2.44	35	0.69
35	Kham -1	3790	30° 42' 56" 79° 05' 55"	S	KSM	1.02	20	0.34
36	Kyarkoti - 6	4180	31° 08' 04" 78° 41' 31"	E	KSM	2.47	28	0.74
37	Rajthor, Ralam - 1	4388	30° 18' 14.3" 80° 15' 51.9"	SE	KSM	2.57	28	0.77
38	Rohtang - 1	3871	32° 21' 52" 77° 14' 22"	SE	KSM	2.42	32	0.70
39	Satopanth	4035	30° 46' 6.6" 79° 28' 12"	NE	KSM	2.40	20	0.80
40	Chitkul - 3	3995	31° 19' 48" 78° 26' 32.7"	S	KSM	2.62	23	0.84
41	Chhiyalekh-1	3340	30° 06' 09.5" 80° 49' 17.8"	O	MHF (SF)	3.01	56	0.75
42	Changshil	3728	31° 10' 45.4" 77° 58' 41.3"	NE	MHF (SF)	2.80	31	0.82
44	Kutti - 2	3723	30° 17' 45" 80° 45' 50"	O	MHF (SF)	2.19	25	0.68
45	Nibchikang	4375	30° 19' 37" 80° 25' 37"	SE	MHF (SF)	2.66	28	0.80
46	Pandavsera -1	3866	30° 37' 34" 79° 18' 57"	W	MHF (SF)	1.98	25	0.62
47	Phatab, Darma	3740	30° 13' 40.8" 80° 30' 22.7"	O	MHF (SF)	1.80	23	0.58
48	SelaYangti - 2	3970	30° 17' 39.6" 80° 44' 28.6'	N	MHF (SF)	2.26	25	0.70
49	Sipu, Darma	3504	30° 18' 35.8" 80° 29' 27.3"	O	MHF (SF)	2.44	36	0.68
50	Thajwas - 1	3068	34° 16 25.7" 75 16' 50"	E	MHF (SF)	2.53	31	0.74
51	Thauli, Chamoli	3995	30° 38' 51" 79° 08' 55"	NE	MHF (SF)	1.95	21	0.64
52	Amarnath - 1	3724	34° 12' 33.4" 75 29' 23"	W	MHF (SF)	2.95	35	0.83

1	2	3	4	5	6	7	8	9
53	Barjikang	4636	30° 18' 04" 80° 15' 08.4"	SW	MHF (SF)	2.38	20	0.80
54	Bhrigu Tal -2	4260	32° 17' 35.2" 77° 14' 44.7"	SW	MHF (SF)	1.49	23	0.48
55	Burphu-1	3253	30° 22' 00" 80° 10' 54"	O	MHF (SF)	2.33	27	0.71
56	Chuli -1	3497	30° 43' 25.6" 78° 39' 14"	NE	MHF (SF)	2.79	33	0.80
57	Chuli - 2	3626	30° 43' 33.1" 78° 38' 55.9"	E	MHF (SF)	2.93	38	0.81
58	Churdhar-1	3552	30° 51' 52.4" 77° 28' 49.7"	NE	MHF (SF)	2.85	33	0.81
59	Dhaman Payar	3870	30° 46' 26.8" 79° 47' 46.8"	O	MHF (SF)	2.60	26	0.80
60	Dudu, Ralam	3913	30°17' 45.6" 80° 16' 09.3"	SE	MHF (SF)	2.77	41	0.75
61	Gidara -1	4028	30°56' 45.3" 78° 36' 01.1"	O	MHF (SF)	1.41	15	0.52
62	Gidara -2	3915	30° 55' 59.9" 80° 37' 11.2"	SE	MHF (SF)	2.93	37	0.51
63	Bhrigu - 3	3557	32° 19' 11.7" 77° 13' 19.2"	W	MHF (SF)	2.74	36	0.76
64	Kyarki - 3	3934	30° 43' 51.6" 78° 43' 43.6"	NE	MHF (SF)	2.47	31	0.72
65	Kyarkoti - 1	3750	31° 08' 01" 78° 42' 23"	SE	MHF (SF)	2.96	31	0.86
66	Kyarkoti - 4	3850	31° 08' 52" 78° 41' 00"	O	MHF (SF)	1.95	15	0.72
67	Manpai Bugyal	3826	30° 35' 12" 79° 21' 48"	NW	MHF (SF)	1.85	29	0.55
68	Marhi - 2	3352	32° 20' 51.7" 77° 13' 26"	W	MHF (SF)	3.08	36	0.86
69	Milam, Johar	3399	30° 25' 43.2" 80° 09' 25.2"	O	MHF (SF)	2.24	17	0.79
70	Ralam - 3	3709	30° 18' 40.7" 80° 17' 9.4"	SE	MHF (SF)	2.51	41	0.68
71	Ranikanda - 2	3750	31° 18' 35.9" 78° 30' 51"	O	MHF (SF)	2.01	20	0.67
72	Ratiya, Sangla Vy - 1	3948	31° 20' 28.8" 78° 21' 10"	O	MHF (SF)	2.07	24	0.65
73	Rohtang Pass	4018	32° 22' 07.8" 77° 15' 06.8"	O	MHF (SF)	2.64	29	0.78
74	Rohtang - 3	3625	32° 21' 41.8" 77° 12' 53.6"	W	MHF (SF)	2.27	45	0.60
75	Shallang Gwar	4234	30° 17' 51.5" 80° 08' 26.6"	N	MHF (SF)	2.73	32	0.79
76	Chitkul - 1	3775	31° 20' 23.6" 78° 26' 24.9"	W	MHF (SF)	1.96	21	0.65
77	Multhat, Changshil	4019	30° 56' 3.0" 78° 36' 54.9"	NW	MHF (SF)	2.31	32	0.67
78	Churdhar -2	3481	30° 51' 56.7" 77° 28' 36.6"	W	MHF (SF)	3.14	47	0.82
79	Bagi, Khatling	3744	30° 46' 08.1" 78° 53' 36.3"	SE	MHF (TF)	2.33	20	0.78
80	Napalchu Nala	3670	30° 10' 13.9" 80° 50' 27.3"	N	MHF (TF)	2.25	35	0.63

1	2	3	4	5	6	7	8	9
81	Patudi - 1	3487	30° 37' 44" 79° 08' 54"	SW	MHF (TF)	2.71	33	0.77
82	Khatling - 1	3732	30° 46' 59.5" 78° 56' 36.3"	S	MHF (TF)	2.81	41	0.76
83	Baminidhaur, VOF	3437	30° 43' 27.8" 79° 35' 24.5"	O	MHF (TF)	2.63	23	0.67
84	Bansinarayan-1	3672	30° 33' 31" 79° 22' 57"	W	MHF (TF)	1.85	28	0.55
85	Bansinarayan-2	3751	30° 32' 46" 79° 23' 58"	NE	MHF (TF)	2.79	24	0.88
86	Danga, Lissar -1	3175	30° 40' 21" 79° 08' 29"	W	MHF (TF)	2.05	32	0.59
87	Dhara Thach	3500	32° 04' 25.6" 77° 21' 11.56"	E	MHF (TF)	2.76	43	0.73
88	Dronagair, VOF -1	3698	30° 43' 51" 79° 36' 34.7"	O	MHF (TF)	2.52	23	0.80
89	Dronagair VOF -2	3669	30° 43' 51" 79° 36' 13"	SE	MHF (TF)	2.64	27	0.80
90	Kachin	3968	30° 38' 27" 79° 15' 46"	S	MHF (TF)	2.82	28	0.85
91	Kandara Bugyal	3591	31° 00' 57.6" 78° 39' 93.1"	SE	MHF (TF)	3.30	52	0.83
92	Khatling - 2	3704	30° 47' 12.6' 78° 57' 4.4"	S	MHF (TF)	2.71	36	0.76
93	Madhmaheshwar	3490	30° 38' 00" 79° 13' 19"	O	MHF (TF)	2.22	23	0.71
94	Mandani - 2	3596	30° 42' 08" 79° 08' 57"	O	MHF (TF)	2.37	30	0.70
95	Ralam - 2	3647	30° 18' 50.3" 80° 17' 33.9"	O	MHF (TF)	3.01	34	0.85
96	Ranikanda - 1	3736	31° 20' 04.4" 78° 30' 36.1"	SW	MHF (TF)	2.29	20	0.76
97	Rohtang - 2	3653	32° 21' 48.8" 77° 12' 51.7"	S	MHF (TF)	2.50	29	0.74
98	Semartoli, VOF	3515	30° 43' 32.8" 79° 36' 08.7"	O	MHF (TF)	2.43	21	0.80
99	Chitkul - 2	3822	31° 20' 14.3" 78° 26' 16.5"	N	MHF (TF)	2.84	33	0.81
100	Kyarki -1	3784	30° 44' 21.7" 78° 44' 13.7"	O	MM	1.32	13	0.52
101	Mapa, Johar	3420	30° 22' 10.0" 80° 10' 08.1"	SE	MM	1.42	20	0.47
102	Ratiya, Sangla Vy - 2	4168	31° 19' 49.8" 78° 20' 44.8"	O	MM	1.49	12	0.60
103	Kyarki -2	3784	30° 44' 20.8" 78° 44' 11.4"	O	PV	2.44	23	0.78
104	Kyarkoti - 7	4230	31° 07.46" 78° 41' 18"	SE	PV	2.27	20	0.76
105	Thajwas - 2	3182	34° 16' 32.5" 75° 16' 34.3"	NE	TL Gap	2.65	32	0.77
106	Sokh Kharak	3083	30° 28' 38.2" 78° 13' 03"	NW	TL Gap	2.26	26	0.69

APPENDIX - IV: Plant Species Diversity, Richness and Evenness of Selected Sites in Indian Trans-Himalaya [Vegetation Types: ADS = Alpine Dry Scrub, CV = Cushion Forming Vegetation, DS = Desert Steppe, FG = Festuca Grassland, KSM = Kobresia meadows, GSM = Grass – Sedge Mixed Meadow, MHF (SF) = Mixed Herbaceous Formation – Short Forbs, MM = Marsh Meadows, PV = Pioneer Vegetation after denudation, RS = Riverine Scrub, PL = Plantation, SM = Sedge Meadow dominated by *Carex* species]

SN	Locality / Sampling Site	Alt. (m)	Latitude-N Longitude-E	Aspect	Veget. Type	Diversity (H')	Rich-ness	Even-ness
1	2	3	4	5	6	7	8	9
1	Turtuk 2	3096	34° 39' 39" 77° 20' 23"	O	ADS	1.2	9	0.55
2	Turtuk 3	3096	34° 38' 28" 77° 24' 24"	O	ADS	0.11	2	0.17
3	Diskit 1	3130	34° 33' 43" 77° 30' 58"	O	ADS	0	1	0
4	Lakzung 4	3167	34° 34' 40.6" 77° 37' 16"	O	ADS	0	1	0
5	Sangra, Surru Valley	3200	34° 12' 57.6" 75° 58' 16.3"	W	ADS	1.382	9	0.629
6	Panamic 3	3244	34° 50' 19" 77° 30' 18"	SE	ADS	0.68	3	0.62
7	Diskit - 5	3248	34° 32' 34" 77° 34' 13"	NE	ADS	1.06	4	0.76
8	Panamic 2	3294	34° 51' 30" 77° 29' 46"	O	ADS	0.23	2	0.33
9	Panamic 1	3300	34° 52' 18" 77° 29' 29"	SE	ADS	0.54	3	0.5
10	Hunder Dok 1	3560	34° 33' 57" 77° 27' 08"	NE	ADS	0.45	2	0.65
11	Hunder Dok 2	3579	34° 32' 54" 77° 26' 32"	NE	ADS	0.51	2	0.74
12	Phadam, Myar Valley	3626	32° 52' 53.4" 76° 52' 47.6"	O	ADS	1.972	14	0.747
13	Kun Base	3653	34° 05' 13.7" 76° 00' 05.6"	W	ADS	1.824	10	0.792
14	Phe', Zanskar	3710	33° 39' 21.1" 76° 38' 22.4"	O	ADS	0.566	3	0.515
15	Khalsar 3 / KV 3	3738	34° 26' 45" 77° 42' 13"	NW	ADS	0.11	2	0.16
16	Phadam, Myar Valley	3750	32° 52' 49.1" 76° 53' 02.8"	NW	ADS	2.079	18	0.719
17	Kun Base	3793	34° 05' 2.7" 75° 59' 53.0"	N	ADS	2.434	16	0.878
18	Sancha Gar, Patan V	3862	32° 39' 29.2" 76° 56' 12.1"	NE	ADS	2.488	23	0.793
19	Nilapani - 1	3914	31° 06' 33.6" 79° 08' 40.2"	E	ADS	2.64	22	0.854
20	Jadung	3924	31° 11' 11.8" 79° 02' 30"	E	ADS	1.842	11	0.768
21	Pensi La - 1	4000	33° 46' 06.3" 76° 27' 51.3"	O	ADS	1.062	8	0.511
22	Rangdum	4024	34° 03' 23.6" 76° 18' 32.1"	SE	ADS	2.016	11	0.841
23	Temasha, Zanskar	4046	33° 21" 03.5" 76° 53' 18.4"	O	ADS	1.282	6	0.715

1	2	3	4	5	6	7	8	9
24	Pensi La - 2	4080	33° 49' 54.2" 76° 25' 22.2"	S	ADS	0.822	6	0.458
25	Unta-Lassar Jn	4201	30° 31' 40.3" 80° 11' 51.5"	O	ADS	1.497	15	0.553
26	Tipani, Nelong	4230	31° 16' 50.8" 79° 06' 65"	N	ADS	2.222	16	0.803
27	Sumur Fu 3	4297	34° 38' 54" 77° 40' 21"	O	ADS	1.141	4	0.82
28	North Polu 7	4384	34° 21' 48" 77° 40' 2"	O	ADS	1.19	8	0.57
29	PDA (Nilang)	4400	31° 17' 50.8" 79° 07' 45.8"	N	ADS	0.995	5	0.618
30	PDA (Nilang)	4400	31° 17' 49.9" 79° 07' 45.3"	W	ADS	1.49	5	0.926
31	Sumur Fu 4	4471	34° 39' 07" 77° 41' 45"	O	ADS	1.35	4	0.97
32	Chhyudhang	4482	30° 41' 48.5" 80° 09' 16.1"	SW	ADS	1.903	15	0.702
33	North Polu 6	4494	34° 21' 40" 77° 39' 51"	SE	ADS	1.02	5	0.63
34	Sumur Fu 12	4562	34° 38' 57" 77° 41' 40"	O	ADS	1.06	5	0.66
35	North Polu 5	4565	34° 20' 59" 77° 39' 30"	SE	ADS	1.22	6	0.68
36	Sumur Fu 6	4615	34° 39' 16" 77° 41' 30"	SE	ADS	1.02	4	0.73
37	Sumur Fu 7	4644	34° 39' 15" 77° 41' 38"	SE	ADS	1.54	7	0.79
38	More Plains	4647	33° 24' 50" 77° 53' 02"	O	ADS	1.014	5	0.630
39	Taklang Base	4651	33° 24' 36" 77° 53' 09"	O	ADS	1.683	10	0.731
40	Shebuk Nala 1	4680	33° 23' 09" 77° 58' 01"	S	ADS	1.569	7	0.806
41	Sumur Fu 10	4749	34° 38' 47 " 77° 41' 52"	NW	ADS	1.75	9	0.79
42	North Polu 4	4775	34° 20' 20" 77° 38' 43"	SE	ADS	2.19	15	0.8
43	Sumur Fu 9	4800	34° 38' 49 " 77° 42' 02"	NW	ADS	1.44	8	0.69
44	Tso Kar	4807	33° 19' 49" 77° 56' 56"	E	ADS	1.574	7	0.809
45	Polokongkha stream	4812	33° 15' 31" 78° 07' 49"	O	ADS	1.657	11	0.719
46	Taklang Valley Bottom	4831	33° 29' 05" 77° 48' 23"	O	ADS	0.703	9	0.320
47	Shebuk Nala 2	4860	33° 24' 06" 77° 27' 06"	S	ADS	1.696	9	0.772
48	Milam - 2	3535	30° 27' 21.8" 80° 07' 18.9"	O	ADS	2.625	24	0.826
49	Sancha Gar, Lahul	3490	32° 38' 09.6" 76° 55' 08.1"	SE	ADS	2.538	25	0.788
50	Burphu-2	3804	30° 22' 48.1" 80° 13' 08.1"	O	ADS	2.383	24	0.749
51	Bhojvasa, Gangotri	3829	30° 57' 8.5" 79° 02' 54.9"	E	ADS	2.29	17	0.808

1	2	3	4	5	6	7	8	9
52	Bedang 2	4058	30° 19' 30.3" 80° 34' 25.8"	NE	ADS	2.411	23	0.768
53	Lipu Lekh	4507	30° 40' 50.9" 80° 58' 56.4"	SE	CV	2.248	28	0.674
54	Bomprass 1	4624	30° 32' 47.8" 80° 11' 10.9"	O	CV	1.272	18	0.44
55	Bomprass 2	4675	30° 32' 59.2" 80° 10' 5.2"	O	CV	2.078	20	0.693
56	Topidhunga	4791	30° 36' 51'.4" 80° 09' 46.6"	N	CV	2.564	25	0.796
57	Gangpani	4876	30° 36' 3.0" 80° 09' 56.8"	O	CV	2.292	17	0.808
58	Tso Kar	4902	33° 24' 06" 78° 01' 48"	EW	CV	2.286	13	0.891
59	Chhojan	4915	30° 47' 9.1" 80° 04' 44.9"	O	CV	1.758	12	0.707
60	Khardung La 6	4970	34° 18' 13" 77° 37' 33"	NE	CV	1.55	11	0.64
61	Tso Kar	5101	33° 22' 36" 78° 02' 53"	NW	CV	2.125	11	0.886
62	Khingru Dhura	5104	30° 39' 36.5" 80° 09' 38.9"	O	CV	1.257	10	0.546
63	Shebuk Nala 4	5160	33° 24'16" 77° 57' 10"	E	CV	2.121	14	0.720
64	Nalbokhar 9	5170	33° 27' 00" 78° 03' 25"	NW	CV	1.086	5	0.675
65	Nalbokhar 8	5190	33° 26' 08" 78° 03' 48"	O	CV	0.612	7	0.315
66	Nalbokhar 4	5245	33° 26' 43" 78° 02' 09"	O	CV	1.265	10	0.549
67	Khardung La 4	5257	34° 17' 26" 77° 36' 02"	O	CV	2.23	18	0.77
68	Khardung La 3	5325	34° 17' 22" 77° 35' 48"	O	CV	2.08	13	0.81
69	Khardung La 2	5349	34° 17' 8" 77° 35' 50"	N	CV	2.13	6	0.83
70	Shebuk Nala 5	5430	33° 24' 28" 77° 56' 07"	O	CV	0.937	8	0.451
71	Startsapuk Tso - 5	4571	33° 15' 46" 78° 02' 36"	O	DS	0.572	4	0.413
72	Tso Kar	4584	33° 17' 43" 77° 58' 10"	O	DS	0.689	2	0.994
73	Tso Kar	4597	33° 16' 47" 78° 00' 17"	O	DS	1.037	6	0.579
74	Tso Kar	4621	33° 22' 00" 77° 57' 53"	O	DS	1.326	6	0.740
75	Chhyudhang	4623	30° 41' 11.7" 80° 09' 26.7"	S	DS	1.903	9	0.866
76	Tso Kar	4626	33° 22' 58" 78° 00' 47"	O	DS	1.091	5	0.678
77	Rale, Tsokar	4629	33° 21' 33" 78° 01' 38"	O	DS	0.993	8	0.477
78	Tso Kar	4645	33° 23' 44" 77° 54' 31"	O	DS	0.737	5	0.458
79	More Plains	4648	33° 25' 00" 77° 52' 59"	O	DS	1.574	6	0.879

1	2	3	4	5	6	7	8	9
80	Tso Kar	4655	33° 20' 59" 77° 57' 19"	O	DS	0.679	4	0.489
81	More Plains	4660	33° 25' 00" 77° 53' 09"	O	DS	1.252	5	0.778
82	Tso Kar	4684	33° 23' 58" 78° 01' 02"	O	DS	0.921	4	0.664
83	Tso Kar	4727	33° 23' 57" 78° 01' 28"	O	DS	0.521	5	0.324
84	Nuruchan	4740	33° 13' 33" 77° 59' 04"	O	DS	1.244	6	0.694
85	Nuruchan	4748	33° 13' 38" 77° 59' 06"	O	DS	0.680	5	0.423
86	Tso Kar	4766	33° 24' 25" 78° 01' 50"	O	DS	0.627	3	0.571
87	Tso Kar	4768	33° 20' 21" 77° 57' 04"	E	DS	1.633	8	0.785
88	Tso Kar	4784	33° 23' 54" 78° 01' 41"	W	DS	1.356	6	0.757
89	Rang	4785	33° 16' 18" 78° 06' 10"	N	DS	1.083	5	0.673
90	Tso Kar	4797	33° 22' 00" 78° 02' 02"	S	DS	0.875	6	0.488
91	Polokongkha stream	4818	33° 16' 35" 78° 08' 10"	O	DS	1.513	7	0.777
92	Polokongkha stream	4832	33° 16' 34" 78° 08' 23"	O	DS	1.469	8	0.706
93	Polokongkha stream	4832	33° 16' 20" 78° 07' 36"	N	DS	1.479	8	0.711
94	Tso Kar	4842	33° 24' 27" 78° 02' 53"	O	DS	0.167	5	0.104
95	Polokongkha stream	4847	33° 15' 58" 78° 06' 57"	N	DS	1.880	11	0.784
96	Tso Kar	4873	33° 19' 21" 77° 56' 42"	O	DS	1.498	7	0.770
97	Tso Kar	4874	33° 19' 32" 77° 56' 42"	O	DS	1.427	9	0.649
98	Rang	4912	33° 15' 02" 78° 05' 58"	N	DS	1.437	7	0.738
99	Taklang La	4915	33° 29' 01" 77° 48' 39"	S	DS	1.271	8	0.611
100	Rang	4921	33° 15' 12" 78° 06' 22"	N	DS	1.548	10	0.672
101	Rang	4950	33° 15' 42" 78° 05' 34"	NE	DS	1.635	9	0.744
102	Tso Kar	4965	33° 18' 39" 77° 56' 31"	NW	DS	1.354	8	0.651
103	Rang 1	4975	33° 13' 54" 78° 05' 54"	O	DS	0.259	4	0.187
104	Rang	5009	33° 15' 04" 78° 05' 38"	NE	DS	1.440	7	0.740
105	Rang	5010	33° 15' 17" 78° 05' 24"	N	DS	1.611	9	0.733
106	Tso Kar	5095	33° 22' 43" 78° 02' 44"	NW	DS	1.695	9	0.771
107	Nalbokhar 1	5132	33° 26' 11" 78° 02' 32"	S	DS	1.58	7	0.812

1	2	3	4	5	6	7	8	9
108	Nalbokhar 2	5160	33° 26' 16" 78° 02' 38"	S	DS	1.515	12	0.61
109	Nalbokhar 3	5225	33° 26' 28" 78° 02' 08"	O	DS	1.834	9	0.834
110	Nun Base	4040	34° 02' 13.1" 75° 57' 03.2"	N	FG	2.058	13	0.802
111	Tso Kar	4573	33° 21' 26" 78° 01' 06"	O	GSM	1.186	7	0.609
112	Tso Kar	4610	33° 21' 55" 77° 57' 26"	O	GSM	2.181	13	0.850
113	Tso Kar	4645	33° 23' 11" 77° 55' 19"	O	GSM	0.279	3	0.254
114	Rongpoche Nala	4293	31° 17' 47.5" 79° 07' 34.7"	O	KSM	1.352	10	0.587
115	Tapovan, Gangotri	4314	30° 55' 25" 79° 04' 36.9"	O	KSM	1.874	14	0.71
116	Gaumukh, Moraine	4346	30° 54' 48.3" 79° 04' 37.8"	O	KSM	1.707	15	0.63
117	Lassar	4375	30° 31' 42.9" 80° 12' 25.6"	N	KSM	1.897	17	0.669
118	Nuruchan	4690	33° 14' 14" 77° 59' 34"	O	KSM	2.157	20	0.708
119	Nuruchan	4735	33° 13' 33" 77° 59' 10"	O	KSM	1.643	14	0.623
120	North Polu 1	4770	34° 19' 37" 77° 39' 04"	NW	KSM	2.29	18	0.79
121	Rachangaru (U. Nuruchan)	4940	33° 09' 09" 78° 02' 56"	O	KSM	0.934	6	0.521
122	Khardung La 7	4948	34° 18' 23" 77° 37' 17"	NE	KSM	1.75	16	0.63
123	Khardung La 5	5051	34° 17' 37" 77° 36' 39"	O	KSM	2.21	21	0.72
124	Polokongkha La	5259	33° 15' 30" 78° 08' 44"	N	KSM	1.211	14	0.459
125	Bedang 1	4057	30° 19' 31.1" 80° 34' 26.7"	N	MHF (SF)	2.544	29	0.755
126	Dawe	4117	30° 21' 34" 80° 32' 45.1"	O	MHF (SF)	1.619	18	0.56
127	Lower Jeolingkong	4281	30° 20' 2.5" 80° 40' 46.8"	N	MHF (SF)	2.039	22	0.659
128	Chodang	3845	30° 18' 11.2" 80° 45' 56.3"	O	MHF (SF)	1.909	17	0.673
129	Tongul Village, Surru	3417	34° 03' 25.6" 75° 55' 40.0"	E	MHF (SF)	1.76	14	0.667
130	Tongul Village, Surru	3514	34° 03' 28.4" 75° 55' 34.3"	N	MHF (SF)	2.485	28	0.746
131	Phadam, Myar Valley	3589	32° 52' 46.7" 76° 52' 29.6"	O	MHF (SF)	1.973	16	0.711
132	Way to Nun Base	3607	34° 02' 53.4" 75° 56' 29.9"	W	MHF (SF)	2.12	12	0.853
133	Kalapani	3750	30° 14' 05.6" 80° 55' 32.4"	SE	MHF (SF)	1.458	16	0.526 1
134	Way to Nun Base	3751	34° 02' 35.7" 75° 56' 33.5"	N	MHF (SF)	1.934	15	0.714
135	Way to Neelkanth	3800	32° 44' 59.9" 76° 52' 58.8"	E	MHF (SF)	1.512	19	0.514

1	2	3	4	5	6	7	8	9
136	Way to Neelkanth	3883	32° 45' 28.3" 76° 53' 20.0"	S	MHF (SF)	2.146	21	0.675
137	Jadung	3883	31° 10' 57.2" 79° 02' 53.9"	O	MHF (SF)	1.042	11	0.434
138	Gompa Thang, Myar Valley	3896	32° 57' 41.7" 76° 52' 20.9"	O	MHF (SF)	2.239	20	0.747
139	New Dung 2	3955	30° 29' 26.7" 80° 11' 4.7"	W	MHF (SF)	2.598	23	0.828
140	New Dung 1	3982	30° 29' 26.8" 80° 11' 06.2"	W	MHF (SF)	2.484	21	0.816
141	Bedang	3998	30° 19' 37.3" 80° 34' 15.4"	O	MHF (SF)	1.911	25	0.594
142	Ellias	4072	32° 46' 19.1" 76° 54' 56.6"	O	MHF (SF)	1.248	8	0.6
143	Nun Base	4259	34° 02' 59.9" 75° 57' 09.7"	E	MHF (SF)	2.339	18	0.809
144	Adi-Kailash Base	4361	30° 20' 37.8" 80° 39' 21.3"	O	MHF (SF)	2.232	16	0.805
145	Jeolingkong	4421	30° 20' 43.6" 80° 39' 32.1"	O	MHF (SF)	1.509	16	0.544
146	Neelkanth	4432	32° 46 05.2" 76° 57' 08.9"	NE	MHF (SF)	2.212	18	0.765
147	Pensi La	4499	33° 51' 50.8" 76° 21' 27.3"	O	MHF (SF)	1.863	12	0.749
148	Neelkanth	4520	32° 45' 34.9" 76° 57' 11.2"	O	MHF (SF)	1.805	17	0.636
149	Sumur Fu 8	4540	34° 39' 04" 77° 41' 21"	O	MHF (SF)	1.2	12	0.48
150	Parvati Tal 1	4561	30° 21' 41.1" 80° 39' 23.3"	N	MHF (SF)	2.344	31	0.683
151	Parvati Tal 2	4561	30° 21' 3.4" 80° 39' 22.9"	S	MHF (SF)	1.991	12	0.6
152	Startsapuk Tso	4569	33° 15' 04" 78° 01' 21"	O	MHF (SF)	1.685	13	0.657
153	Startsapuk Tso 11	4621	33° 15' 41" 78° 01' 36"	O	MHF (SF)	1.334	13	0.505
154	Topidhunga	4625	30° 37' 33.3" 80° 08' 54.7"	N	MHF (SF)	2.635	36	0.735
155	North Polu 3	4728	34° 20' 14" 77° 38' 46"	SE	MHF (SF)	1.49	8	0.71
156	Tso Kar	4896	33° 19' 01" 77° 56' 52"	N	MHF (SF)	1.544	10	0.671
157	Tso Kar	4930	33° 24' 04" 78° 02' 04"	N	MHF (SF)	1.682	10	0.730
158	Tso Kar	4971	33° 23' 58" 78° 02' 12"	S	MHF (SF)	2.162	11	0.870
159	Way to Polokongkha	4977	33° 15' 51" 78° 10' 54"	O	MHF (SF)	1.244	5	0.773
160	Tso Kar	4989	33° 15' 31" 78° 10' 59"	N	MHF (SF)	1.436	7	0.738
161	Shebuk Nala 3	5075	33° 24' 14" 77° 57' 24"	S	MHF (SF)	1.760	24	0.587
162	Nalbokhar 10	5160	33° 27' 17" 78° 03' 04"	N	MHF (SF)	1.488	17	0.573
163	Nalbokhar 6	5195	33° 26' 41" 78° 03' 41"	O	MHF (SF)	1.337	7	0.687

1	2	3	4	5	6	7	8	9
164	Nalbokhar 5	5220	33° 26' 53" 78° 03' 29"	N	MHF (SF)	2.132	16	0.769
165	Nalbokhar 11	5225	33° 27' 03" 78° 02' 16"	S	MHF (SF)	1.891	17	0.667
166	Polokongkha La	5233	33° 15' 47" 78° 08' 43"	N	MHF (SF)	1.202	8	0.578
167	Polokongkha La	5260	33° 15' 40" 78° 08' 39"	N	MHF (SF)	1.566	13	0.610
168	Turtuk 1	3089	34° 41' 38" 77° 41' 59"	O	MM	1.34	12	0.54
169	Diskit 3	3121	34° 33' 55" 77° 31' 04"	O	MM	1.52	9	0.69
170	Lakzung 5	3141	34° 36' 43" 77° 36' 59"	O	MM	0.908	10	0.394
171	Rangmanch Gad	4200	31° 16' 77" 79° 06' 35.4"	O	MM	1.999	19	0.679
172	Nabedhang	4248	30° 14' 02.7" 80° 58' 46.4"	O	MM	1.52	17	0.536
173	Tso Kar	4555	33° 17' 48" 77° 58' 11"	O	MM	1.234	10	0.536
174	Startsapuk Tso 9	4562	33° 16' 15" 78° 01' 38"	O	MM	1.841	9	0.838
175	Starstapuk 1	4565	33° 16' 06" 78° 02' 08"	O	MM	1.785	10	0.775
176	Startsapuk Tso 1	4568	33° 15' 31" 78° 02' 35"	O	MM	1.239	8	0.637
177	Startsapuk Tso 2	4569	33° 15' 28" 78° 02' 38"	O	MM	1.285	7	0.660
178	Startsapuk Tso	4569	33° 15' 27" 78° 02' 48"	O	MM	1.557	5	0.974
179	Startsapuk Tso 6	4569	33° 16' 34" 78° 02' 05"	O	MM	1.706	12	0.687
180	Tso Kar	4569	33° 19' 19" 77° 57' 13"	O	MM	1.590	14	0.602
181	Tso Kar	4572	33° 19' 40" 78° 02' 14"	O	MM	1.443	11	0.602
182	Startsapuk Tso 10	4573	33° 15' 48" 78° 01' 40"	O	MM	1.479	15	0.533
183	Tso Kar	4577	33° 21' 48" 78° 00' 23"	O	MM	1.465	11	0.611
184	Tso Kar (Rale)	4579	33° 21' 20" 78° 01' 20"	O	MM	1.568	14	0.594
185	Tso Kar	4586	33° 21' 51" 78° 00' 24"	O	MM	1.736	10	0.754
186	Tso Kar	4611	33° 21' 37" 77° 57' 31"	O	MM	0.692	13	0.270
187	Lower Wilsia	4626	30° 28' 45.3" 80° 38' 45.4"	O	MM	1.839	14	0.697
188	Chhojan	4728	30° 46' 27.5" 80° 05' 19.8"	O	MM	2.534	17	0.895
189	Jadung	3655	31° 08' 24.5" 79° 04' 41.1"	SE	PV	1.51	7	0.776
190	Jadung	3889	31° 11' 15.2" 79° 02' 32"	E	PV	1.316	8	0.632
191	Gaumukh, Moraine	3939	30° 55' 55.7" 79° 04' 26.5"	N	PV	1.229	5	0.763

1	2	3	4	5	6	7	8	9
192	Gaumukh, Moraine	4080	30° 55' 31.9" 79° 04' 50.7"	W	PV	1.903	12	0.766
193	Rangmanch Gad	4149	31° 17' 11.8" 79° 06' 26.2"	SW	PV	1.788	9	0.813
194	Temasha, Zanskar	4268	33° 18' 28.6" 76° 50' 51.0"	O	PV	1.296	7	0.666
195	Myar Moraine	4325	33° 04' 07.4" 76° 46' 27.9"	SW	PV	1.729	12	0.696
196	Neelkanth	4421	32° 46' 20.7" 76° 57' 05.6"	O	PV	1.694	12	0.682
197	Neelkanth	4424	32° 46' 05.6" 76° 57' 10.7"	O	PV	1.655	9	0.753
198	Sumdo, Zanskar	4487	33° 17' 29.2" 76° 49' 05.7"	O	PV	1.406	8	0.676
199	Neelkanth	4500	32° 45' 42.8" 76° 57' 14.0"	O	PV	1.136	6	0.634
200	Khardung La 1	5398	34° 16' 47" 77° 36' 18"	N	PV	0	8	0
201	Lakzung 3	3147	34° 32' 39" 77° 38' 28"	O	PL-Hippophae	0.59	10	0.86
202	Lakzung 2	3147	34° 34' 04" 77° 37' 08"	O	PL-Willow	0.06	3	0.05
203	Lakzung 1	3140	34° 34' 02" 77° 37' 09"	O	PL-Willow	0.66	4	0.47
204	Abran, Zanskar	3798	33° 42' 23.8" 76° 33' 02.6"	O	PL-Willow	1.871	15	0.691
205	Diskit 4	3118	34° 34' 10.3" 77° 31' 14"	O	RS	0.56	4	0.8
206	Diskit 2	3125	34° 33' 50" 77° 31' 00"	O	RS	0.92	5	0.57
207	Diskit 7	3137	34° 32' 44" 77° 34' 29"	O	RS	0.76	3	0.7
208	Hunder Dok 6	3227	34° 34' 48" 77° 27' 28"	O	RS	0.55	3	0.5
209	Panamic 4	3287	34° 47' 30" 77° 32' 08"	O	RS	1.545	12	0.622
210	Nilapani	3893	31° 06' 33.1" 79° 09' 8.3"	O	RS	2.56	23	0.816
211	Sumur Fu 2	3978	34° 38' 41" 77° 39' 49"	SW	RS	2	14	0.75
212	Surru Valley	4048	33° 57' 39.5" 76° 19' 28.4"	O	RS	1.978	13	0.771
213	Tipani, Nelong	4211	31° 16' 56.1" 79° 06' 67.6"	O	RS	2.029	15	0.749
214	Rimkhim	4304	30° 49' 25.9" 79° 57' 54.4"	O	RS	1.655	15	0.611
215	Lakzung 6	3147	34° 36' 57" 77° 36' 59"	O	SM	0.724	9	0.329
216	Diskit 6	3150	34° 32' 42" 77° 34' 26"	O	SM	1.41	7	0.72
217	Lobathang, Panamic	3206	34° 45' 06" 77° 30' 16"	O	SM	1.009	5	0.627
218	Than Pattan, Myar Valley	3736	32° 53' 50.1" 76° 53' 43.3"	O	SM	1.832	18	0.634
219	Lang Payar	3838	30° 47' 13.3" 79° 39' 14.3"	NE	SM	2.156	19	0.732

1	2	3	4	5	6	7	8	9
220	Sural Valley, Pangi	3874	33° 09' 30.0" 76° 31' 55.0"	O	SM	0.821	10	0.356
221	Gompa Thang, Myar Valley	3904	32° 56' 58.1" 76° 53' 23.5"	O	SM	1.291	7	0.663
222	Sural Valley, Pangi	3908	33° 09' 35.4" 76° 32' 37.7"	SE	SM	1.256	14	0.476
223	Zardong, Myar Valley	3915	32° 58' 51.7" 76° 51' 21.9"	O	SM	1.782	17	0.628
224	Zero point, Myar Valley	3936	33° 00' 46.8" 76° 50' 04.7"	O	SM	0.578	9	0.263
225	Rangdum	4010	34° 03' 16.3" 76° 18' 29.3"	O	SM	1.7597	19	0.597
226	Khalsar 4 / KV 4	4163	34° 22' 30" 77° 39' 43"	N	SM	1.92	15	0.71
227	Pensi La	4489	33° 52' 08.6" 76° 21' 17.0"	O	SM	1.978	16	0.714
228	Sumur Fu 13	4550	34° 39' 03" 77° 41' 32"	O	SM	1.454	16	0.524
229	Startsapuk Tso 4	4560	33° 15' 25" 78° 02' 54"	O	SM	2.017	9	0.918
230	Startsapuk Tso 3	4567	33° 15' 24" 78° 02' 51"	O	SM	2.141	15	0.790
231	Sumur Fu 11	4567	34° 38' 57" 77° 41' 35"	O	SM	1.1	13	0.43
232	Startsapuk Tso 8	4574	33° 16' 17" 78° 01' 38"	O	SM	2.319	13	0.904
233	Tso Kar	4590	33° 20' 02" 78° 02' 03"	O	SM	0.963	9	0.438
234	Tso Kar	4645	33° 23' 11" 77° 55' 20"	O	SM	0.002	2	0.003
235	Lapthal	4653	30° 45' 24.0" 80° 06' 43.6"	SE	SM	2.647	21	0.869
236	More Plains	4653	33° 24' 45" 77° 53' 10"	O	SM	0.009	4	0.062
237	Wilsia	4661	30° 23' 26.6" 80° 38' 13.3"	O	SM	2.017	22	0.653
238	More Plains	4665	33° 22' 49" 77° 56' 23"	O	SM	0.005	4	0.004
239	North Polu 2	4733	34° 19' 43" 77° 39' 06"	NW	SM	1.45	17	0.51
240	Tso Kar	4756	23' 22' 53" 78° 01' 58"	W	SM	0.240	5	0.149
241	Taklang Base	4780	33° 28' 34" 77° 48' 20"	O	SM	0.529	5	0.329
242	Chhota Hoti	4821	30° 49' 40.2" 80° 01' 24.1"	SE	SM	1.851	18	0.64
243	Chhota Hoti	4957	30° 48 38.1" 80° 02' 07.3"	O	SM	1.456	9	0.663
244	Polokongkha La	4964	33° 16' 08" 78° 10' 32"	O	SM	0.970	10	0.421
245	Tso Kar	4568	33° 21' 26" 78° 00' 51"	o	SM	0.006	3	0.005

APPENDIX V: Endemic Vascular Plants in the Alpine Areas of Western Himalaya [RDB Status as per 1990 assessment by Nayar & Sastry (1990) – **R** = Rare, **E** = Endangered, **V** = Vulnerable, **I** = Indeterminate; **Ref**erence: 1 = Khullar 1994; 2= Aswal & Mehrotra 1994; 3 = Mukherjee & Constance 1986; 4= Dickore & Nusser 2000 ; 5 = Hajra et al. 1995; 6 = Kirschner et al. 2006; 7 = Rao et al. 1998; 8 = Nasir & Ali 1972; 9 = Al-Shehbaz 2002; 10 = Singh et al. 2002; 11 = Rawat et al., 1995; 12 = Rau 1975; 13 = Nayar & Sastry 1990; 14 = Murti 2001; 15 = Naithani 1990; 16 = Chaudhary & Rao 2002; 17 = Rawat 1984; 18 = Herbaria and Records of BSI (North Circle) and Garhwal University; 19 = Garg 1987; 20 = Hajra & Balodi 1995; 21 = Dikshit & Panigrahi 1998; 22 = Pennell 1943; 23 = Pande & Pande 2003; Locality: s.l. (sine locale = uncertain locality)]

SN	Group / Family & Species	RDB Status	Known Locality	Distribution*	Ref.
1	2	3	4	5	6
	Ferns				
1	*Asplenium khullarii* Viane	–	Sunderdhunga	Kum	1, 23
2	*Deparia acuta* (Ching) Fras.-Jenk.	–	Gulmarg; Kolahoi	Kash	1, 23
	Apiaceae				
3	*Eriocycla thomsonii* (Cl.) Wolff.	–	Billing Nala	Lah	2
4	*Ferula jaeschkeana* Vatke	–	Spiti, Bhaironghati	Zans, Spiti, Garh	2
5	*Kedarnatha sanctuarii* Mukh. & Const.	–	Kedarnath	Garh	3
	Asteraceae				
6	*Crepis kashmirica* Babc.	–	Kashmir s.l.	Kash	5
7	*Crepis naniforma* Babc.	**R**	Kashmir, s.l.	Kash	5
8	*Lactuca benthamii* Cl.	**E**	Kashmir, s.l.	Kash	5
9	*Lactuca kashmiriana* Mamgain & Rao	–	Kashmir, s.l.	Kash	5
10	*Lactuca lahulensis* Mamgain & Rao	–	Keylong	Lah	5
11	*Ligularia jacquemontiana* (Decne.) Rau	–	Kashmir s.l.	Kash, Lah	5
12	*Olgaea thomsonii* (Hk.f.) Iljin	–	Ladakh, s.l.; Nelang	Lad., Garh	5
13	*Saussurea atkinsonii* Cl.	–	Rohtang; Kyarki	WHP, Garh	5
14	*Saussurea clarkei* Hk. f.	**R**	Tilail, Kashmir	Kash	5
15	*Saussurea costus (Falc.) Lipsc.*	**E**	Kishenganga Vy, Astor	Kash (Pak) – Kum (Cult)	5
16	*Saussurea sudhansui* Hajra	–	Dharansi, NDNP	Garh	5
17	*Senecio ladakhensis* Chowdhery et. al.	–	Dras	Zans.	5
18	*Senecio tibeticus Hk.f.*	–	Chitral, Indus Vy	Kash (Pak); Lad	4
19	*Taraxacum virgineum* Kischner et al.	–	Thukje Gompa, Tso Kar	Chang.	6

1	2	3	4	5	6
	Berberidaceae				
20	*Berberis kashmirana* Ahrendt.	–	Muntnar Valley, Pak	Kash (Pak)	7
21	*Berberis petiolaris* Wall. ex G.Don	–	Malari; Milam	Garh , Kum	7
22	*Berberis ulicina Hk.f. & T.*	–	Nubra, Aksai Chin	KK	7
	Boraginaceae				
23	*Actinocarya acaulis* (Sm.) Johnst.	–	Lachulung La	Chang	8
24	*Anoplocaryum brandisii* Brand.	–	Gilgit, Burzil	Kash (Pak)	8
24	*Eritrichum spathulatum* Cl.	–	Baltistan	Kash (Pak)	8
26	*Hackelia stewartii* Johnst	–	Chitral; Liddar Vy	Kash (Pak)	8
27	*Pseudomertensia lahulensis* (Brand.) Aswal	–	Keylong	Lah	2
	Brassicaceae				
28	*Aphragmus obscurus (Dunn) Schultz.*	–	Sangam Vy	Kash (Pak)	4
29	*Aphragmus ladakiana* Al-Shehbaz	–	Parang La, Rupshu	Chang	9
30	*Arabis tenuirostris* Schulz.	–	Sonamarg	Kash	10
31	*Dilophila purii* Rawat et al.	–	Roopkund	Garh	11
32	*Draba cachemirica* Gandoger	–	Kashmir s.l.	Kash, Kum	10
33	*Draba ludlowiana* Jafri	–	Rupshu	Chang	10
34	*Lignariella duthiei* Naqshi	–	Kolahoi	Kash	10
35	*Lignariella obscura* (Dunn) Jafri	–	Sangam Vy	Kash	10
36	*Microsisymbrium axillare* (Hk. f. & T.) Schulz.	–	Keylong	Lah	2
	Campanulaceae	–			
37	*Cyananthus integer* Wall.ex Benth.	**R**	Kyarki; Tungnath	Garh, Kum	12
	Caryophyllaceae				
38	*Arenaria curvifolia* Majumd.	**E**	Kuari Pass	Garh	10
39	*Minuartia ebracteolata* Majumd. & Giri	–	Pissu Ghati; Batal	Kash, Lah	10
40	*Silene edeordi* Bocquet	–	Chhatru	Lah	2
41	*Silene kumaonensis* Williams	**R**	Kutti, Byans	Kash, Garh, Kum	13
42	*Silene kunawarensis* Royle	**R**	Liddar; Punang	Kash, Bush	13
	Chloranthaceae				
43	*Circaeaster agrestis* Maxim	–	Kyarki; Valley of Flowers	Garh, Kum	13

1	2	3	4	5	6
	Cyperaceae				
44	*Carex borii* Nelmes	**I**	Baralacha La	Lah	14
45	*Carex munroi* Boott ex Cl.	**I**	Kinnaur	E HP	14
46	*Carex nandadeviensis* Ghildiyal *et al.*	–	Bhojgara, Nandadevi NP	Garh	14
47	*Microschoenus duthiei* Cl.	**I**	Uttarkashi s.l.	Garh	14
	Euphorbiaceae				
48	*Euphorbia sharmae* Bhatt.	**I**	Roopkund	Garh	15
	Fabaceae				
49	*Astragalus aegacanthoides* Parker	–	Byans	Kum	15
50	*Astragalus badrinathensis* Sharma et al.	–	Badrinath	Garh	16
51	*Astragalus drasianus* Chowdhery et al.	–	Dras	Zans	16
52	*Astragalus grahmianus* Royle ex Benth	–	Rohtang, Garhwal	W HP; Garh	16
53	*Astragalus hoffmeisteri* (Klotz.) Ali	–	Zanskar	Zans	16
54	*Astragalus ladakhense* Rao & Balodi	–	Rupshu	Chang	16
55	*Astragalus maxwellii* Royle ex Benth.	–	Chitral, Liddarwat; Johar	Kash (Pak), Kum	16
56	*Astragalus pindreensis* (Benth. ex Baker) Ali	–	Fras Nag, Gilgit	Kash (Pak)	16
57	*Hedysarum astragaloides* Benth. ex Baker	–	Chitral; Kishtwar; Billing Nala	Kash (Kash); Lah	8
58	*Hedysarum cachemerianum* Benth. ex Baker	**R**	Kagan; Sheshnag, Nanga Parbat	Kash (Kash)	4
59	*Hedysarum kumaonense* Benth. ex Baker	–	Garbyang	Kum	17
60	*Hedysarum microcalyx* Baker	**V**	Jispa; Nanda Devi	Kash, Lah, Garh	2
61	*Oxytropis rautii* Dangwal & Gaur	–	Nandanvan	Garh	18
	Fumariaceae				
62	*Corydalis clarkei* Prain	–	Hemis NP	Zans, E Lad	4
	Gentianaceae				19
63	*Gentiana tetrasepala* Biswas	**I**	Ralam	Kum	19
64	*Swertia alpina* Bhatt. & Sunita	–	Kedarnath; Kush Kalyani	Garh	19
65	*Swertia alternifolia* Royle	–	Rohtang; Kedarnath	W HP; Garh	19
66	*Swertia thomsonii* Cl.	–	Sonamarg	Kash	19

1	2	3	4	5	6
	Juncaceae				
67	*Juncus rohtangensis* Goel & Aswal	–	Rohtang	W HP	2
	Lamiaceae				
68	*Nepeta connata* Royle ex Benth.	–	Kashmir s.l.	Kash	4
	Liliaceae				
69	*Allium consanguineum* Kunth.	**V**	Kashmir; Ralam	Kash to Kum	14
70	*Eremurus himalaicus* Baker	**R**	Lahaul & Spiti	Kash, Lah, Spiti	2
	Malvaceae				
71	*Lavatra kashmeriana* Camb.	–	Sonamarg	Kash	10
	Orchidaceae	–			
72	*Corallorhiza trifida* Chatel.	–	Martoli, Johar	Kum	17
73	*Herminium kumaunensis* Deva & Naithani	–	Chhiyalekh	Kum	17
74	*Poneorchis renzii* Deva & Naithani	–	Chhiyalekh	Kum	17
	Orobanchaceae				
75	*Orobanche kashmirica* Cl. ex Hk. f.	–	Kishen Ganga Vy	Kash (Pak)	8
	Papaveraceae				
76	*Meconopsis bikramii* Aswal & Meh.	–	Rohtang	W HP	2
77	*Meconopsis latifolia* Prain	**V**	Kishanganga Valley	Kash (Pak)	8
	Poaceae				
78	*Agrostis tungnathii* Bhatt. & Jain	–	Tungnath	Garh	18
79	*Calamagrostis decora* Hk.	–	Gilgit; Pahalgam; Kishenganga Vy	Kash (Pak)	8
80	*Calamogrostis stoliczkae* Hk.f.	–	Indus Valley, Zanskar	Kash (Pak), KK, Zans	4
81	*Colpodium nutans* (Stapf.) Bor	–	Kashmir	Kash, Zans	4
82	*Festuca nandadevica* Hajra	–	Deodi, Nandadevi NP	Garh	20
83	*Poa koelzii* Bor	–	Keylong	Lah	2
84	*Poa ladakhensis* Hartm.	–	Zanskar	Zans	14
85	*Poa markgrafii* Hartm.	–	Suru	Zans	14
86	*Poa suruana* Hartm.	–	Suru	Zans	14
87	*Puccinellia himalaica* Tzv.	–	Tso Kar	Chang	14
88	*Pucciniella minuta* Bor	–	Lahaul s.l.	Kash (Pak), Lah	4
89	*Puccinellia thomsonii* (Stapf.) R.R. Stew	–	Zanskar; Tso Kar	Chang	14

1	2	3	4	5	6
	Polygonaceae				
90	*Aconogonum kuttiensis* Maiti et al.	–	Kutti, Byans	Kum	15
	Primulaceae				
91	*Androsace aizoon* Duby	–	Hemis NP	Kash (Pak), Zans	4
92	*Androsace garhwalicum* Balodi & Singh	–	Hemkund	Garh	18
93	*Androsace muscoidea* Duby	–	Nanga Parbat, Hemis NP	Kash (Pak), Zans	4
94	*Primula duthieana* Balf. f. & Sm.	–	Nanga Parbat Kishenganga Vy	Kash (Pak)	4
95	*Primula obtusifolia* Royle	–	Khardung La	Nubra	8
96	*Primula reidii* Duthie	–	Kishtwar; Churdhar; Tungnath	Kash, E HP, Garh	18
	Ranunculaceae				
97	*Aconitum atrox* (Bruhl.) Mukherjee	**V**	Gangotri NP ; Valley of Flowers	Garh	18
98	*Aconitum falconeri* Stapf.	**V**	HP s.l.; Kedarkantha	HP; Garh	18
99	*Aconitum kashmiricum* Stapf ex Coventry	–	Kashmir s.l.	Kash	8
100	*Aconitum moschatum* (Bruhl.) Stapf.	–	Kashmir s.l.	Kash	10
101	*Anemone tetrasepala* Royle	–	Kedarnath; Khaliya	Kash, Garh, Kum	18
102	*Aquilegia nivalis* Falc. ex Jackson	–	Kunawar WS	Kash (Pak) to W HP	4
103	*Clematis ladakhiana* Grey-Wilson	–	Hemis NP	Zans	10
104	*Delphinium cashmirianum* Royle	–	Amarnath, Harkidoon, Milam	Kash to Kum	10
105	*Ranunculus gaurii* Dangwal & Rawat	–	Tapovan, Gaumukh	Garh	18
106	*Ranunculus trivedii* Aswal & Meh.	–	Rohtang pass	W HP	2
	Rosaceae				
107	*Alchemilla trollii* Rothm.	–	Burzil Pass	Kash, Kum	4
108	*Cotoneaster garhwalensis* Klotz.	–	Nelang	Garh	18
109	*Cotoneaster gilgitensis* Klotz.	–	Gilgit, Lahaul, Garhwal s.l.	Kash (Pak), Lah, Garh	8
110	*Potentilla curviseta* Hk. f.	–	Nanga Parbat; Kishtwar; Chenab; Ralam	Kash, Lah, Kum	4
111	*Potentilla karakoramica* Sojak	–	Karakoram	KK	21
112	*Potentilla ornithopoda* Tausch.	–	Khalatse, Ladakh	Zans	21
113	*Rosa osmastonii* Rawat & Pangtey	–	Milam	Kum	15

1	2	3	4	5	6
114	*Galium serpylloides* Royle ex Hk.f.	–	Rupshu; Pin Valley; Johar	Zans, Spiti, Garh, Kum	2
	Saxifragaceae				
115	*Saxifraga asarifolia* Sternb.	–	Dhanu, Satopanth	Garh	18
	Scrophulariaceae				
116	*Euphrasia alba* Pennell	–	Hemis NP	Zans	22
117	*Euphrasia flabellata* Pennell	–	Shigar, Baltistan	Kash (Pak), W Lad	22
118	*Euphrasia foliosa* Pennell	–	Minimarg to Burzil	Kash (Pak)	22
119	*Euphrasia himalayica* Wettst.	–	Bushahar; Nampa in Byans	E HP, Kum	22
120	*Euphrasia jaeschkei* Wettst.	–	Gadsar; Sach Pass; Keylong	Kash to Lah	22
121	*Euphrasia kashmiriana* Pugsley	–	Gya; Bragnag	Zans	22
122	*Euphrasia paucifolia* Wettst.	–	Pahalgam; Losar	Kash, Spiti	22
123	*Euphrasia platyplylla* Pennell	–	Sonamarg; Billing Nala	Kash, Lah	22
124	*Euphrasia remota* Pennell	–	Zoji La	Kash	22
125	*Falconeria himalaica* Hk.f.	–	Tungnath; Madhari Pass	Garh, Kum	22
126	*Pedicularis brevirostris* Pennell	–	Zoji La; Pensi La	Kash	22
127	*Pedicularis kashmiriana* Pennell	–	Hazara; Gulmarg; Nubra	Kash (Pak), Shyok Vy (KK)	22
128	*Pedicularis punctata* Decne.	–	Chitral; Dras; Sural; Bushahr	Kash (Pak), Zans, E HP	22
129	*Scrophularia dentata* Royle ex Benth.	–	Pensi La; Puga Valley;Giam	Chang, Spiti	22
130	*Veronica cachemirica* Gaud.	–	Gulmarg	Kash	22
131	*Veronica koelzii* Pennell	–	Rupshu	Chang	22
132	*Veronica nana* Pennell	–	Debring; Rupshu	Chang	22
133	*Veronica umbelliformis* Pennell	–	Barjikang	Kum	22
134	*Veronica uncinata* Pennell	–	Tog Nallah, Ladakh	Zans	22
	Selaginaceae				
135	*Lagotis kunawurensis* (Royle ex Benth.) Rupr.	–	Zanskar; Sangla; Rajhoti	Zans, E HP, Garh	2

* Kash = Kashmir; Pak = Pakistan part of Kashmir Himalaya; Chang = Changthang; W Lad = Western Ladakh; KK = Karakoram; Zans = Zanskar; Lah = Lahaul; W HP = Western Himachal Pradesh – Rohtang and West; E HP = Eastern HP – Rupibhaba , Bushahar including ; Garh = Garhwal; Kum = Kumaon

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