Alpine Vegetation of Northwestern India: An Ecological Review

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Abstract

The alpine zone occupies nearly one third of the geographical area of the Himalayas and represents one of the most interesting biomes in the region. This is a zone of treeless vegetation consisting of dwarf and matted shrubs, herbaceous meadows, bogs, and fell-fields paved with mosses and lichens. Other vegetation types include arid pasture and steppe formations of the Trans-Himalayas. Large numbers of resident and migratory pastoral communities use the alpine areas for livestock grazing and others earn their livelihood by extracting various plants of medicinal value. Ecologists in recent years have raised concern over degradation and over use of alpine areas.

This paper presents a review of the major ecological work pertaining to the alpine vegetation of the Greater and Trans-Himalayas within northwestern India. The major physiognomic and community types, floristic structure, successional trends, and biomass productivity and associated conservation issues are discussed. A few management options pertaining to human and livestock use are given, including more quantitative, management-oriented studies and long-term ecological monitoring of these fragile areas.

Introduction

The alpine zone represents one of the most fascinating biomes in the Himalayas. It forms nearly 33% of the geographical area in the region; *ca.* 80% of the area is vegetated and the remaining 20% is under perpetual snow (GOI 1989). The alpine vegetation comprises closely woven and matted strands of shrubs, herbaceous meadows, bogs, and fellfields paved with mosses and lichens and is limited by a distinct timberline at around 3,300±200m in the northwest to 3800±200m in the northeast. The diversity of life forms, structure, and composition of alpine vegetation have always attracted a large number of naturalists, phytogeographers and ecologists (e.g., Mani 1978, Rau 1975). It is believed that most of the forest vegetation below the natural treeline was derived from tropical forests of peninsular and Indo-Malayan origin, but the alpine vegetation originated only after the final phase of Himalayan upliftment with the subsequent increase in cold-arid climate (particularly in the north-western Himalayas), and the migration of flora from the adjoining regions (Whyte 1976, Vishnu -Mittre, 1984). A closer look at the present day alpine vegetation reveals interesting facts related to both past geo-climatic changes and the ecology and history of human use in the region.

The alpine zone in northwestern India (NWI) is spread over four biogeographic provinces (Rodgers and Panwar 1991), viz., the Ladakh mountains; the Eastern Plains, adjacent to the Tibetan plateau; the North-western Himalayas; and the Western Himalayas. It constitutes nearly 48% of the total geographical area in the region and about 91% of the total alpine area within Indian territory (Table 3). This is largely the result of the wider latitudinal variation and harsher cold-arid climate. Of all the alpine landscapes in the region, the meadows have been the particular subject of interest among naturalists and ecologists on account of their plant species' richness and patterns of adaptation to extreme environmental conditions (Smythe 1938, Rau 1975, Hajra 1983, Wadhwa *et al.* 1987). The meadow areas are commonly termed alpine (moist or arid) pastures and are used as summer grazing grounds by several migratory and local pastoral communities. Other uses of alpine areas include adventure tourism, pilgrimage, commercial exploitation of wild medicinal herbs, and recreation. In addition, this region forms the upper catchment of most of the Himalayan rivers which support millions of people in the lower hills as well as the plains of north India. Thus, the health of the alpine ecosystem is closely linked with the environmental stability and human welfare in the whole region.

Table 3. **Extent of alpine vegetation and livestock populations in North-western India**

State	Geographical Area (sq.km)	Alpine Vegetation (sq.km)	Permanent Snow (sq.km)	No. of Livestock (in '000)
UP hills	51,103	8,524	4,376	840
HP	55,670	17,296	4,934	4800
J&K	222,240	131,851	39,097	4660
Total	**329,013**	**157,671**	**48,407**	**10,300**

(Source: Lal *et al.* 1991)

In recent years several authors have voiced concern about degradation and over- exploitation of alpine areas (Singh and Kaur 1980, Shah 1988). Despite a large number of ecological studies, no comprehensive guidelines have been developed for the conservation and management of these areas. In this paper, I review the major ecological works pertaining to the alpine vegetation of the Greater and Trans-Himalayas within NWI, which covers the states of Jammu & Kashmir (J&K) and Himachal Pradesh (HP) and the hills of Uttar Pradesh (UP). The vegetation characteristics in terms of major physiognomic and community types, factors influencing the species' richness, and biomass production are discussed along with major conservation issues and the implications of various research findings for the conservation and management of the alpine ecosystem.

Physiognomy and Community Structure

The alpine vegetation of NWI has been described and classified by various authors such as Schweinfurth (1957), Mani (1978), Puri *et al.* (1989). The stunted nature of alpine plants as an adaptation to cold climate and exposure to strong winds, blizzards, snow storms, and various other factors have been well documented. Studies on the Raunkiaer's Life Form spectra (Kachroo *et al.* 1977, Rawat and Pangtey 1987, Ram and Arya 1991) have revealed a preponderance of chamaephytes and geophytes in the alpine areas exhibiting typical perrenial- annual growth habits.

The broad physiognomic and community classes of vegetation in the region are given below.

Alpine Vegetation of the Greater Himalayas[17]
The alpine zone within the western and northwestern Himalayas is generally separated by a distinct treeline characterised by birch-rhododendron (*Betula utilis-Rhododendron campanulatum*), fir (*Abies pindrow*), or brown oak (*Quercus semecarpifolia*) forests. The major vegetation types in the alpine zone include the following.

Alpine Scrub
The area immediately above the 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 river banks), *Rosa-Lonicera* scrub, and pure patches of *Rhododendron anthopogon, Cassiope fastigiata,* and *Salix lindleyana.* The latter forms matted snow-bed communities in association with various perennial herbs.

Alpine Meadows
Locally known as '*bugyal*' in the Garhwal and Kumaon regions, '*dhar*'or '*thach*' in HP and '*marg*' in J&K, the alpine meadows are the natural herbaceous formations located above the alpine scrub, or immediately above the treeline in the absence of the latter. The meadows comprise a large number of herbaceous communities with varying proportions of tussock forming grasses and sedges. Dabadghao and Shankarnarayan (1973) categorised the alpine meadows under *Deyeuxia — Deschampsia* type of cover. Generally grasses are low in abundance and herbaceous plants belonging to various dicot families predominate. Such formations are locally recognised as distinct '*bugyal*' types in the UP hills (Rawat and Rodgers 1988). Several tall forb communities also exist in areas of deep soil and camping sites of livestock. Recently attempts have been made to develop a quantitative classification of meadow communities in the Himalayan alpine areas (Kala *et al.* 1998; and Singh 1999).

Scree Slopes and Moraines
The morainic environs and areas generally lie above 4,500 masl, they represent pioneer environments, and include 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 and Pangtey (1987) studied the floristic structure of the snowline vegetation in the Kumaon Himalayas and found that Brassicaceae, Asteraceae, and Ranunculaceae were the dominant families in terms of species number above 5,000m. These areas are similar to the cold deserts of the Trans-Himalayas.

Timberline ecotone and sub-alpine (anthropogenic) herbaceous formations, which gradually merge with the alpine communities, are also included under high altitude vegetation. The blanks within the cool temperate and sub-alpine forests created by migratory graziers are termed '*thaches*' in HP.

[17] The Greater Himalaya in India is synonymous with the High Himalaya Physiographic Zone in Nepal.

Vegetation of the Trans-Himalayan Regions

Almost all the areas in the Trans-Himalayas are devoid of forest vegetation. Hence, it is difficult to find a clear ecotone of treeline, unlike the main Himalayas. However, sporadic patches of *Juniperus macropoda* and *Salix* woodlands can be seen in parts of the Lahul Valley (Aswal and Mehrotra 1994). The Trans-Himalayan vegetation is otherwise distinguishable from those of Himalayan alpine areas by the virtual absence of both *krummholz* formations and extensive moist meadows. The major formations in this area include the following.

Steppe Formations

The majority of the plateau and gentle slopes in the Trans-Himalayas exhibit a Mediterranean type of climate and steppe vegetation, i.e., scattered low shrubs with sparse grasses and forbs. Several communities have been reported in the cold arid regions of Ladakh and Spiti regions, e.g., *Artemisia-Caragana, Ephedra-Juniperus, Salix-Myricaria,* and *Lonicera-Rosa* (Chundawat and Rawat 1994).

Herbaceous and Grassy Meadows

A few patches close to the valley bottoms with moist clayey soil are dominated by herbaceous communities similar to those of the main Himalayan meadows. These communities are often called alpine arid pastures (*cf.* the alpine moist meadows of the main Himalayas) and include *Potentilla-Geranium* type, *Festuca-Stipa* grass communities, and *Carex* dominated meadows. 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 (1987), and Manjrekar (1997).

Cold Deserts

A considerable area in the Trans-Himalayas falls under cold desert, which supports less than 5% vegetation cover. Such areas include scree slopes, very high altitude (>4,800m) pioneer environments, and other rocky slopes dotted with a few hardy grasses and herbs, e.g., species of *Stipa, Melica, Christolea, Sedum, Draba,* and *Saussurea.*

Floristic Composition and Species' Diversity

Geographically, NWI has been categorised under the 'Western Himalayas' which was recognised as a distinct floristic zone by earlier phytogeographers. Many workers have described the floristic composition of alpine meadows in the region, e.g., Ghildiyal 1956, Dhar and Kachroo 1983, Hajra 1983, Rawat 1984, and Agarwal 1990. Over 4,500 species of vascular plants have been reported from this region. Of these, nearly 1,500-1,600 species are thought to occur exclusively in the alpine zone (Rau 1975). There is a great deal of variation in the species richness within various geographical areas depending upon various factors such as landscape diversity, stability of land forms, soil moisture, soil depth, and proximity to glaciers or to human settlements (Puri *et al.* 1989). Generally, the alpine vegetation in the main Himalayas is very rich in terms of plant species compared to similar geographical areas in the Trans-Himalayas. For example, Kala *et al.* (1998) reported over 520 species of vascular plants from an area of 87.5 sq.km of the Valley of Flowers (VOF) in the Garwhal

Himalayas, whereas < 500 species have been recorded in the nearly 89,000 sq.km area of Ladakh at a similar altitudinal range (Kachroo *et al.* 1977). Kala *et al.* (1998) observed that overall species' diversity decreases with increase in altitude, but diversity of sites within each zone varies considerably (Table 4). Plant species' richness and composition in alpine meadows are known to be governed by several factors such as the action of glaciers and avalanches, snow melt and deposition, and soil depth and richness, and the resultant variation in landscape diversity (Billings and Bliss 1959, Semwal *et al.* 1981, Kala *et al.* 1998).

Table 4. **Plant species' richness across various landscape units in the Valley of Flowers National Park, Garhwal Himalayas**

Landscape Unit	Altitude (m)	Mean no of Spp / quadrat ± SD	Total spp in 25 quadrat
Sub-alpine meadow	3,000	15 ± 5	38
Eroded slope	3,300	9 ± 3	37
Stable slope	3,350	14 ± 4	51
Treeline gap	3,300	18 ± 6	67
Valley bottom	3,400	17 ± 4	62
River bed	3,300	10 ± 2	50
Moraine	3,400	9 ± 3	42
Lower slope	3,500	12 ± 2	38
Plateau	3,550	15 ± 3	47
Stable meadow on higher slopes	3,700	13 ± 3	45
Scrubby slope	3,600	7 ± 2	12

(Source: Kala *et al.* 1998)

Successional Trends

The alpine habitats are, perhaps, the most heterogeneous and fragile. The vegetation in these areas exhibits a complex mosaic of succession. While meadows and several scrub communities can be regarded as climatic climaxes, a large number of intermediate and edaphic types can be recognised at the landscape level. Therefore, it is often difficult to trace the path of Clementsian succession. Several communities are sensitive to micro-topographic changes (Kikuchi and Ohba 1988), making the successional studies more difficult. Kala *et al.* (1998), based on various stages of landscape stability, have suggested two parallel courses of succession for the alpine meadows of the VOF near the treeline (3,500±200 masl). These are as follow.

Meadow Succession

The moss-lichen (pioneer) community in a glaciated valley on the terminal and south facing lateral moraines give rise to several broadleaved herbaceous formations, e.g., *Cyananthus-Kobresia-Anaphalis* association. *Danthonia cachemyriana* patches form a climatic climax on such slopes. *Kobresia* sedge meadows at such altitudes are considered as a climax community.

Forest succession

The north and north-eastern aspects have a higher moisture regime and less exposure to sun and wind, which promotes the growth of shrubby species that thrive well under heavy snow, the snow-bed communities. Some of these shrubby intermediate communities eventually give way to birch-rhododendron (*Betula utilis* - *Rhododendron campanulatum*) communities on more stable slopes with deeper soil.

Contrary to the Clementsian model suggested by a few authors for the Himalayan alpine areas, Mishra (1998) has proposed a 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 (Mishra, C. personal communication).

Seasonality and Biomass Production

Although the growing season (May to September) is very short in the alpine zone, not all species 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 survival. Kala *et al.* (1998), while conducting a 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 the Garhwal Himalayas. They found that above ground biomass varied considerably between the camping sites (CS), steep slopes (SS) and undulating landmass (ULM) areas. The live shoot biomass increased continuously from the onset of the monsoon (June), attained a peak in the first week of September, and declined thereafter. *Danthonia cachemyriana* contributed the highest biomass on SS (356 g m^{-2}), *Geranium wallichianum* on ULM (232 g m^{-2}), and *Polygonum polystachyum* on CS (189 g m^{-2}). Of the total above ground biomass production in the sampled area, the loss due to trampling and grazing by livestock was 26%, 23%, and 22% on ULM, CS, and SS, respectively. In a community level study at an alpine site in the Garhwal Himalayas, Rikhari *et al.* (1992) found that the above ground community phytomass values ranged from 112 to 398 g m^{-2}, while the below ground net primary production ranged from 59 to 250 g m^{-2}.

Conservation Issues

Livestock grazing

The history of livestock grazing in the alpine meadows of the northwestern Himalayas dates back several centuries (Tucker 1986). It is estimated that this region now supports nearly 1.2 million livestock, which includes sheep, goats, cattle, yak, cattle–yak hybrids, horses, and donkeys (Kawosa 1988). Since the lower altitude grazing lands are limited in extent, summer migration to higher altitudes and alpine meadows has become a common practice as a means to sustain the number of livestock.

Several authors have studied the production potential and biomass uptake by livestock in the alpine areas of the UP hills (e.g., Ram *et al.* 1989; Negi *et al.* 1993; Kala *et al.* 1998). Sundriyal (1995) has observed that agro-pastoralists in the western and central Himalayas generally keep more cattle than really needed, mainly because of easy access to free grazing areas and their inability to dispose of or cull the population as a result of religious sentiments. While some authors believe that livestock grazing is essential to maintain species' diversity in these areas (Naithani *et al.* 1992; Negi *et al.* 1993; Saberwal 1996), others advocate alternative grazing practices and policies (Sundriyal and Joshi 1990, Rawat & Uniyal 1993, Mishra & Rawat 1998). Although the alpine pastures play an important role in relieving the grazing pressure on forests and grazing lands at lower altitudes, the increased number of livestock and overuse of certain pastures can, potentially, lead to degradation of the high altitude grasslands and the habitats for wild herbivores.

Based on the intermediate disturbance hypothesis, a few authors, such as Rawat and Rodgers (1988), have opined that a moderate level of grazing may enhance herbaceous species' diversity in alpine meadows. However, in the absence of quantitative studies it becomes difficult to decide what level is 'moderate', and to choose graziers in terms of whom to allow and whom not. Grazing animals affect plant communities in several interrelated ways, including plant defoliation, nutrient removal, redistribution of nutrients through excreta, and mechanical impacts on soil and plant material through trampling. Nevertheless, some flowering plants such as *Iris kumaonensis, Anemone rivularis, Primula denticulata, Taraxacum officinale, Plantago major, Inula grandiflora, Rumex nepalensis, Polygonum polystachyum,* and *Urtica dioica* show a tendency to increase under grazed conditions. This may be mainly due to their non-palatability and ability to withstand grazing. Thus, livestock grazing has a differential impact on different plant species, and the practice cannot be seen as completely negative.

Collection of Medicinal Plants

A large number of medicinal plants has been found in the alpine zone of NWI (Dhar & Kachroo 1983, Rawat 1984, Kala 1997, Singh 1999). Several local communities depend on these herbs for their own consumption as well as commercial extraction. As a result, many species are reported to have become rare and others are in danger of local extinction causing concern among conservationists (Rawat 1994). Most of the medicinal plants growing in the alpine meadows have tuberous or rhizomatous roots. Digging of fragile alpine soil to collect such herbs, and subsequent trampling and grazing by livestock, leads to spread of weeds and soil erosion. In the Western Himalayan meadows, exploitation pressure is particularly high on *Dactylorhiza hatagirea, Picrorhiza kurrooa, Jurinea macrocephala,* and *Aconitum heterophyllum*. At present, there are only a few protected areas in the western Himalayas where extraction of medicinal plants is prohibited. Kala *et al.* (1998) compared the density and abundance of various medicinal herbs in and around the Valley of Flowers National Park and found that some of the rare and threatened medicinal plants were completely absent from the grazed and unprotected alpine meadows.

Collection of Fuelwood

Agro-pastoral communities, tourists, pilgrims, and other visitors to alpine areas consume a large amount of fuelwood. Consumption of fuelwood is particularly high around the treeline and sub-alpine zone of the greater Himalayas and the thickly populated areas of the Trans-Himalayas. There are clear indications that the natural treeline in many parts of the Himalayas 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 macropoda* and *J. communis* can also lead to local extinction of such species. Extraction of fuelwood, particularly from the low productive areas of the Trans-Himalayas, 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 low shrubs and undershrubs in large quantities in order to warm the houses and cook during long and severe winters (Manjrekar 1997). In addition, collection of livestock dung from the higher pastures for fuel is a common practice in the Trans-Himalayas. The ecological implications of such practices have not been investigated so far.

Wildlife Use

The alpine habitats support a diverse array of faunal communities. The typical mammalian fauna inhabiting the alpine areas include Himalayan tahr (*Hemitragus jemlahicus*), blue sheep (*Pseudois nayaur*), Himalayan ibex (*Capra ibex sibirica*), Tibetan antelope (*Pantholops hodgsoni*), Tibetan gazelle (*Procapra picticaudata*), Ladakh urial or shapu (*Ovis vignei vignei*), Tibetan argali or nayan (*Ovis ammon hodgsoni*), and Tibetan wild ass (*Equus kiang*), with apex predators such as snow leopard (*Uncia uncia*) and Tibetan wolf (*Canis lupus chanko*). Alpine habitats also harbour some of the highly threatened and vulnerable bird species such as Tibetan sand grouse (*Syrraptes tibetanus*), snow partridge (*Lerwa lerwa*), chukar partridge (*Alectoris chukar*), and snow cocks (*Tetraogallus tibetanus* and *T. Himalayas us*). So far only a few ecological studies have been undertaken on habitat use by wild herbivores in the alpine areas (Green 1985, Chundawat 1992, Sathyakumar *et al.* 1994, Manjrekar 1997, Bhatnagar 1997). Mishra (1997) estimated that the livestock holdings of agro-pastoral communities in Kibber wildlife sanctuary (Trans-Himalayas) have increased by 37.7% in 10 years, potentially resulting in more conflicts with wild carnivores such as snow leopard and wolf.

Management Options

Management of grazing areas and livestock in the Trans-Himalayas—Livestock grazing is the mainstay of the economy for several agro-pastoral communities in the Trans-Himalayas. At present there are no policy guidelines available on the optimal use of grazing resources in this area. Management authorities are faced with conflicting situations, particularly with respect to livestock depradation by wild carnivores and habitat degradation by large flocks of migratory graziers. Rotational grazing of degraded pastures and limiting the number of livestock are some of the 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 the Trans-Himalayas.

Livestock grazing in the PAs—India's Wildlife (Protection) Act 1972 prohibits livestock grazing within the NPs. The settlement of grazing rights in the Himalayas Parks often leads to conflicts and controversies. It must be accepted that it is not possible to achieve a complete ban on livestock grazing in all the

Himalayan protected areas (PAs). 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.

Rare plants and their habitats—Plant species may be rare as a result of restricted habitats, small population size, narrow range of distribution and/or over-exploitation in the recent past. Management authorities for conservation areas should develop site-specific or species-specific conservation plans depending upon the sensitivity of plants to various practices.

Management of degraded areas—Heavily eroded and degraded sites within the PAs should be protected on a temporary basis in order to allow recovery. Some of the native herbs that are fast growing and opportunistic, such as *Polygonum polystachyum* (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 stabilisation of the alpine environment in terms of soil formation, stabilisation of slopes, role in the forest succession near the treeline, and soil enrichment.

Research and monitoring—Further experimental studies and long-term monitoring on various management-related topics will be useful for the sound management of these areas. Some of the topics that have not been covered in terms of research in alpine areas are: (a) competition and dietary overlaps between domestic and wild ungulates; (b) the effect of differential grazing on vegetation cover and species' diversity; and (c) autecological investigations of some valuable plants such as *Dactylorhiza hatazirea, Picrorhiza kurrooa,* and *Aconitum heterophyllum.*

Peoples' participation—Involvement of local people in the ecodevelpment, conservation, and management of alpine sites has been emphasised frequently in most publications and meetings in recent years. Strong initiatives are needed to bring this concept into practice.

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