Temperate and alpine grasslands of the Himalaya: ecology and conservation

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The ecology and conservation of grasslands within the Himalayan region are reviewed. Five grassland types are defined and described: warm temperate grasslands; cool temperate grassy slopes; sub-alpine meadows; alpine meadows; and steppe formations of the trans-Himalaya. The floral structure, successional trends in meadow and forest regions, and biomass productivity are examined. Mammalian and bird species are listed as an indicator of biodiversity. The human effects of pastoralism, collection of medicinal herbs, and collection of fuel wood are then described. The paper concludes by looking at aspects of conservation and management, touching on the sustainability of different land-use.

THE HIMALAYAN region, one of the most astounding physical features on the surface of the earth, is well known for its diverse landscapes and aesthetic, cultural, biological and hydrological values. It has witnessed a series of changes in its geomorphology, climate and biota since its origin during Cretaceous-Oligocene periods (Vishnu-Mittre 1984). These changes, coupled with more recent human activities, have given rise to present day vegetation which ranges from lower montane, wet, evergreen forests to cold, arid, steppe communities and several secondary formations (Singh and Singh 1988, Mani 1974). Of these, the natural and semi-natural grasslands are of particular interest due to their relatively recent origin, dynamics and close co-evolution with grazing ungulates.

The grassland vegetation in the Indian Himalaya occupies nearly 35% of the geographical area and includes the warm temperate grasslands, sub-alpine and cool temperate grassy slopes, alpine meadows of the greater Himalaya and the steppe formations of cold arid regions or alpine dry scrub. These grasslands form distinct categories of their own and differ from one another in terms of origin, structure and composition. However, like all other grasslands of the world, these formations support a large number of wild herbivores, domestic livestock and several agro-pastoral cultures.

The temperate and alpine grasslands of the Himalaya have been studied by a large number of ecologists, e.g. Patil and Pathak (1978), Gupta (1990), Numata (1986), Ram *et al.* (1989), Rikhari *et al.* (1992), Sundriyal (1989, 1995), Bawa (1995), Bhat and Kaul 1989, and Kala *et al.* (1998) to name a few. Most of these authors have focused on the flora, use as grazing for domestic livestock and biomass production in the alpine meadows of the western and central Himalaya. But the trans-Himalayan steppe formations and grasslands of cool temperate and sub-alpine regions, which support a considerable number of wild herbivores and birds, have not been studied in detail. Thus, there is a need to collate the available information on the various grasslands in the Himalaya and identify the gaps in information which would be pertinent for further research and conservation efforts.

This paper is an overview of the ecology and aspects of the conservation of various grasslands within the Himalayan region based on the available literature

and the author's own experience of the vegetation and wildlife in the Himalaya.

Origin and classification

The history of grasses and grasslands in the temperate belt of Asia begins with the progressive uplift of the Himalaya which increased aridity in north-west India. The cyclic shifts in climate since the Pleistocene and the aridity and warmth of the Neothermal period permitted diversification and spread of grasses and herbaceous flora (Blow and Hamilton 1975). Subsequent introduction of cattle, fire and the widespread impact of humans over the last 5,000 years has reduced the forest cover and resulted in a spread of grass cover. According to Whyte (1976), and Yadava and Singh (1977) most of the grasses of western monsoon Asia are of recent origin derived through immigration of ancestral species from other areas such as semi-arid Africa, the Mediterranean and continental Asia. Clearing and opening the forests for various land-use practices and frequent burning of steeper south facing slopes for the production of hay and intensive livestock grazing have converted a considerable area under herbaceous vegetation. Such areas include forested blanks in humid areas, mid-elevation hay fields, fallow lands and village grazing grounds. Such areas are frequently termed 'rangelands' or pastures. In fact, the Himalayan rangelands and natural grasslands, including the cold arid pastures of the trans-Himalaya, cover as much as 50% of the geographical area of the Himalaya (Table 1).

Cattle camp; sub-alpine meadows and the alpine pastures of the western Himalaya. Photo: G. S. Rawat.

Several authors have made attempts to classify Himalayan grasslands based on cover and composition of species (Agarwal and Tiwari 1988, Dabadghao and Shankarnayan 1973, Singh and Saxena 1980). While community-based classification holds true for prominent species and associations representing certain edaphic and climatic climaxes, many intermediate seral stages and loose associations are too dynamic to be classified. For conservation and management purposes a broad level

Table 1. *Land cover (km^2) under the natural/semi-natural grasslands in the Himalaya. (J & K: Jammu & Kashmir, HP: Himachal Pradesh, UP: Uttar Pradesh, AP: Arunachal Pradesh. Source: Kawosa, 1988 and Lal* et al. *1989).*

country/ state	geographical area (km^2)	temperate grassland/ pastures	cultivable waste	alpine pastures & blanks
J & K	222,240	1,240	1,490	131,587
HP	55,670	10,240	1,360	17,296
UP	51,103	91	68	8,524
Nepal	140,800	52,110	23,050	32,616
Sikkim	7,300	1,030	10	1,626
Bhutan	46,500	200	2,540	15,500
AP	83,585	500	850	12,335

classification of Himalayan grasslands is being suggested based on their origin and geographical distribution. Various associations and community types identified by earlier workers can be grouped under these types:

- Warm temperate grasslands;
- Cool temperate grassy slopes;
- Sub-alpine meadows;
- Alpine meadows; and
- Steppe formations of trans-Himalaya.

Warm temperate grasslands

The warm temperate belt (1,500–2,500 m) in north-western, western and central Himalaya, especially on the south and south-eastern slopes, are characterised by extensive grassy slopes dotted with scattered trees and shrubs. Most of these grasslands or 'hill savannas' have been derived as a result of frequent burning and livestock grazing on gentler slopes. According to Dabadghao and Shankarnarayanan (1973) the grass cover in these areas fall under the *Themeda-Arundinella* type. This category also includes the hay fields intensively managed for grass production by local people. Such grasslands are locally known as 'ghasnis' in Himachal Pradesh (HP) and the hills of Uttar Pradesh (UP). Quite a few slopes with abandoned agriculture are dominated by more fire-hardy species such as *Imperata cylindrica* and *Cymbopogon distans*, and can be termed semi-natural or secondary grasslands.

Cool temperate grassy slopes

The steeper (>45°) slopes with thin soil in the cool temperate and sub-alpine zone (2,600–3,300 m) do not favour the tree growth and generally support herbaceous or grassland vegetation. The common species of grasses in such areas in the west are *Chrysopogon gryllus*, *Dactylis glomerata*, *Koeleria cristata*, *Andropogon munroii*, *Danthonia jacquemontii* and *Themeda triandra*. These areas also burn during winter, either accidentally or intentionally.

Sub-alpine meadows and 'thaches'

Forest blanks within the cool temperate and sub-alpine forests have been created by migratory graziers, and in HP are frequently termed 'thaches'. Unlike the above category, these areas are dominated by a large number of herbaceous plants such as *Origanum vulgare, Taraxacum officinale, Ranunculus hirtellus, Rumex nepalensis, Anemone rivularis, Senecio chrysanthemoides* and *Anaphalis cuneifolia*, many of which are unpalatable and weedy. Only a few grasses (e.g. *Poa alpina, Phleum alpinum* and *Stipa* sp.) are found in these areas.

Alpine meadows

These are the natural herbaceous formations located above the natural limit of forest and scrub vegetation, covering an area of approximately 171,646 km^2 or 25% of the Indian Himalaya area (Lal *et al.* 1991). The meadow vegetation typically comprises a large number of herbaceous plants with varying proportions of tussock forming grasses, sedges and matted shrubs. Although grasses form a large proportion in the flora in the alpine region, many herbaceous plants belonging to other families, e.g. Rosaceae, Leguminosae, Asteraceae, Lamiaceae and Scrophulariaceae, dominate the meadows in terms of cover and abundance (Rawat and Rodgers 1988). The following

communities and associations of grasses have been reported from the alpine regions of the western Himalaya: *Deyuxia-Deschampsia*, *Danthonia cachemyriana* patches, species of *Festuca* and *Poa*. Kala *et al*. (1998) have reported as many as 22 herbaceous communities from the alpine meadows of the Valley of Flowers National Park in the western Himalaya.

Steppe formations of trans-Himalaya

The cold arid regions in the trans-Himalaya are characterised by the Mediterranean type of vegetation, i.e. scattered low shrubs with sparse grasses and forbs. Several communities are reported from the cold arid regions of Ladakh and Spiti regions of north-west Himalaya, e.g. *Artemisia-Caragana*, *Ephedra-Juniperus*, *Salix-Myricaria* and *Lonicera-Rosa*. Manjrekar (1998) reported nine associations of herbaceous and shrubby species from Pin Valley National Park in HP which represents typical steppe vegetation of trans-Himalaya.

Structure and function

Flora

Grass families (Graminae or Poaceae) occupy the top positions in the flora of western Himalaya in terms of species number (Uniyal *et al*. 1994). Based on the published literature on the Himalayan flora, Singh and Saxena (1980) listed 73 prevalent grass species at 350–1,800 m, 51 species at 2,200–2,500 m and 2,550–3,000 m belts with 62 species above 3,000 m. Uniyal *et al*. (1994) enumerated 450 species of grasses from UP, of which more than half are from the Himalayan region which covers only 18% of the state. A closer look at the morphology of various species reveals that most of the grasses in the warm temperate region are rhizomatous and with the increase in the altitude proportion of tussock-forming grasses increases.

Based on the floristic composition and species dominance Tsuchida and Numata (1983) have identified four zones of grasslands in Nepal. These are:

- Zone I (<1,100 m): *Cynodon dactylon*, *Chrysopogon aciculatus*, *Desmodium triflorum*.
- Zone II (1,100–2,600 m): *Paspalum scorbiculatum*, *Pycreus sanguinolentus*, *Fimbristylis* spp. *Setaria* spp.
- Zone III (2,600–3,800 m): *Carex* spp. *Poa* spp.
- Zone IV (>3,800 m): species of *Carex*, *Calamogrostis*, *Festuca* and *Agrostis*.

Successional trends

The grasslands on the steeper south facing slopes in the temperate and sub-alpine regions of the Himalaya have not been investigated in terms of community dynamics and succession. According to Dabadghao and Shankarnarayan (1973) *Themeda anathera* represents the higher seral stage in the *Themeda-Arundinella* type of cover. As grazing pressure increases, the *Themeda* community is replaced by *Arundinella nepalensis* and *A. bengalensis*. On heavily grazed areas *Cynodon dactylon* replaces all other communities. Towards higher altitudes the *Poa annua*, *Koeleria-Chrysopogon gryllus* and *Agrostis munroana* communities occupy the frequently grazed sites (Singh and Saxena 1980). Sundriyal (1995) has given the floristic composition of grasses within various climatic zones and traced climax species (trees and shrubs) for each zone assuming that all the grasslands below the natural treeline are seral in

nature and would be changed to forest vegetation if kept free from human interference.

The alpine meadows exhibit a complex mosaic of plant succession. The species which occur on frequently grazed sites include *Danthonia cachemyriana*, *Calamogrostis* sp., *Stipa* spp. and *Agrostis munroana*. Kala *et al*., (1998) have suggested two parallel courses of succession for the alpine meadows near the treeline (3,500+200 m) in the Valley of Flowers National Park, western Himalaya:

- *Meadow succession*: The moss-lichen (pioneer) community in a glaciated valley on the terminal and south-facing lateral moraines give rise to several annual herbaceous formations. The *Cyananthus-Kobresia-Anaphalis* association and *Danthonia cachemyriana* patches form the climatic plant community on such slopes; and
- *Forest succession*: The north and north-eastern aspects, due to higher moisture regime and less exposure to sun and wind, promote the growth of shrubby species which thrive well under heavy snow, i.e. snow-bed communities. Some of these shrubby intermediate communities will eventually give way to a birch-rhododendron (*Betula utilis-Rhododendron campanulatum*) community on more stable slopes with deeper soil.

Biomass productivity

The above-ground biomass in these grasslands varies from 1,000 kg/ha to 10,000 kg/ha for warm temperate grassland and 400–5,000 kg/ha for high altitude grasslands (Gupta 1990, Sundriyal 1995). It has been estimated that due to increase in the cover of unpalatable species the herbage production in the Himalayan grasslands has decreased by 20–50% in terms of quantity and 10–15% in terms of quality compared with their potential (Patil and Pathak 1978). In parts of Garhwal and Kumaon Himalaya the standing biomass of grasses was found to increase with increasing altitude up to about 3,750 m (Dabadghao and Shankarnarayan 1973). However, no detailed studies on the productivity are available along the entire gradient. The dry matter yields (in kg/ha) of certain indigenous fodder grasses (within pure stands) are reported to be up to 7,440 for *Andropogon pumilus*, 11,040 for *Apluda mutica*, 6,986 for *Arundinella nepalensis*, 6,951 for *Bothriochloa intermedia*, 4,975 for *Chrysopogon fulvus*, 6,941 for *Chrysopogon gryllus*, 6,925 for *Heteropogon contortus*, 9,918 for *Pennisetum orientale* and 4,836 for *Themeda anathera*. In terms of nutrient value, i.e. crude protein content, *Apluda mutica*, *Bothriochloa intermedia* and *Chrysopogon fulvus* are considered to be the best grazing (Singh and Saxena 1980).

Unlike the tropical grasslands, the temperate and alpine grasslands exhibit a strong seasonality. While the growing season in the temperate region generally begins in April, the sub-alpine and alpine grasslands start sprouting in June to July. Thus, the biomass production in these grasslands is lower than in tropical grasslands (Misra 1987, Ram *et al.* 1989) due to the shorter growing season.

Wildlife

The Himalayan grasslands support a diverse array of animal communities. The typical mammalian fauna inhabiting grassland habitats in these mountains include wild sheep, goats, goat antelopes and rodents. In addition, a number of avian communities, especially partridges and other members of the phasianidae, depend on the grasslands and meadow vegetation for their survival (Table 2).

Table 2. *Major grassland types in the Himalayan mountains, distribution and characteristic (wild) faunal elements. Grassland types: WTGS: warm temperate (semi-natural) grassy slopes; CTGS: cool temperate grassy slopes; SAM: sub-alpine meadows; AM: alpine meadows and SFTH: steppe formations of the trans-Himalaya.*

SN grassland type	distribution	faunal elements
1. WTGS	Frequently burnt and grazed south facing slopes (<2,500 m) J & K, HP, UP hills, Sikkim.	Goral, Himalayan Y-throated marten, Partridges, cheer pheasant.
2. CTGS	Steep slopes with scattered woody vegetation, less freqently burnt (2,500–3,000 m) Western Himalaya.	Him. tahr, goral, serow, monal Kashmir stag.
3. SAM	Man made openings in the sub-alpine forests, openings near treeline and rocky slopes (30–3,500 m)	Him. musk deer, Pica, monal, wild pigs.
4. AM	Natural herbaceous formations above 3,600 m in the western and >4,000 m in the eastern Himalaya more stable compact soils.	Blue sheep, Himalayan tahr, Pica, Voles, Himalayan marmot, long-tailed marmot, snow cock, snow partridge.
5. SFTH	Scattered, stunted scrubby vegetation with sparse grass cover in the cold arid areas of Ladakh, Lahul & Spiti, northern parts of UP hills Sikkim (>4000 m asl).	Blue sheep, Tibetan wild ass, Tibetan woolly hare, Tibetan antelope, Tibetan gazelle, Nayan, snow leopard, snow cock and wild yak.

Mammals

Goral (*Nemorhaedus goral*), Himalayan tahr (*Hemitragus jemlahicus*), blue sheep (*Pseudois nayaur*), Himalayan ibex (*Capra ibex sibirica*), Tibetan antelope (*Panthalops 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*) are the typical grazing ungulates of the high altitude grasslands and scrubs. Mishra and Johnsingh (1996) studied the habitat use by goral in western Himalaya and found that this species feeds almost entirely on grasses (92.2% in the cold season and 98.3% in the warm season) and prefers open grass-dominated vegetation and avoid shrub-rich patches. Schaller (1977), Chundawat (1992), Sathyakumar (1994), Bhatnagar (1997) and Manjrekar (1997) give some more information on the use of temperate-alpine grasslands by mountain ungulates.

Birds

The bird species diversity in the Himalayan grasslands is relatively low compared to forested habitats. This is evident from the fact that the western Himalaya, with more area under one or other type of grassland, has fewer number of bird species (nearly 405 species in Jammu and Kashmir and 375 species in HP) compared with Arunachal Pradesh (642 species) which is largely forested (Singh 1994). Nevertheless, grasslands support some of the most highly threatened and vulnerable bird species such as Tibetan sandgrouse (*Syrraptes tibetanus*), snow partridge (*Lerwa lerwa*), chukar partridge (*Alectoris chukar*), snow cocks (*Tetraogallus tibetanus* and *T. himalayanus*), cheer pheasant (*Catreus wallichii*) and supposedly-extinct mountain quail (*Ophrysia superciliosa*) (Ali and Ripley 1983). Status surveys and ecological studies are lacking on the habitat use of these birds as well as many associated raptors.

Human use and abuse

Pastoralism

Most of the grasslands in the lower temperate belt of western and central Himalaya are grazed by domestic livestock throughout the year. It is estimated that the Himalayan region supports nearly 12 million sheep and goats, 10 million cattle, 3–4 million buffaloes, 400,000 horses and donkeys, and up to 350,000 pigs (Kawosa 1988). Since the lower altitude grazing lands are limited in area and the livestock population in these areas far exceeds the carrying capacity, the practice of summer migration to the higher altitude alpine meadows has become necessary to sustain the number of livestock. It has been observed that agro-pastoralists in the western and central Himalaya generally keep more cattle than they really need because of easy access to free grazing areas and their inability to dispose or cull the population due to religious sentiments. Uncontrolled grazing on the steeper slopes reduces water holding capacity and compaction reduces the permeability of the soil. Continuous grazing also creates channels or paths on hill slopes which remove huge quantities of soil during rains. Over-grazed areas near mid- and high-elevation villages in Nepal shows a decrease in grasses and an increase in the unpalatable species such as *Rhododendron anthopogon*, *Berberis* spp. *Euphorbia wallichii*, *Euphorbia longifolia* and *Iris kumaonensis* (Numata 1986). However, Brower (1990) has stressed that the migratory lifestyle of Sherpa communities in Nepal was better for the conservation of rangelands than a sedentary lifestyle would have been.

A flock of migratory sheep and goats on their way to higher pastures in the Himalaya. Photo: G. S. Rawat.

Despite the fact that domestic animals are an integral part of agro-pastoral ecosystems and that grazing-based animal husbandry is the mainstay of the economy in many parts of the Himalaya, no studies and policy guidelines are available for optimal use of grazing resources. Plantation of agroforestry trees and round the year production of fodder would be the best option for the agro-pastoralists, but excessive use of resources for horticulture (orchards) and heavy use of pesticides to promote fruit production may, as practices in the states of HP, and Jammu and Kashmir (J&K) show, have severe ecological consequences and loss of biodiversity in the long run.

Collection of medicinal herbs

Alpine meadows, besides being popular summer grazing grounds for a large number of migratory livestock, harbour numerous medicinal herbs which are extracted in large quantity by many local communities for their own consumption, as well as for sale. Over-exploitation of some of the herbs from high altitude areas has caused serious concern amongst conservationists (Edwards 1996 and Tandon 1997). Most of the medicinal plants growing in the alpine meadows have tuberous or rhizomatous roots. Digging of fragile alpine soil for such medicinal herbs and subsequent trampling and grazing by livestock spreads weeds and causes soil erosion. In the western Himalayan meadows, exploitation pressure is particularly high on

Dactylorhiza hatagirea, *Picrorhiza kurrooa*, *Jurinea macrocephala* and *Aconitum heterophyllum*. Presently, there are only a few protected areas in the western Himalaya where extraction of medicinal herbs 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 in the grazed and unprotected alpine meadows.

Collection of fuel wood

Collection of brush from the steppes has been a major anthropogenic factor influencing the vegetation in the trans-Himalaya. Photo: G. S. Rawat.

Livestock grazing and extraction of woody plants by the pastoral communities go together. Consumption of firewood is very high around treeline and sub-alpine zones 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 and Uniyal 1993). Selective removal of highly preferred species such as *Juniperus macropoda* 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 the low shrubs and undershrubs in large quantities in order to warm their 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-Himalaya. The ecological implications of such practices have not been fully understood so far.

Conservation and management

The mid-elevation grasslands, particularly the hay fields, or 'ghasnis', are maintained by regulation of livestock grazing and winter season burning. This system has been successful in many parts of western Himalaya through village level cooperatives and personal care of ghasnis which are passed on within families. However, no management system has evolved for the village grazing lands which are considered to be common property. Raina (1960) has pointed out the plight of such grazing lands, locally known as 'charand' in HP, stating that these areas have been "nobody's child". Despite a number of government departments operating in the region, including Revenue, Animal Husbandry, and Agriculture and Forestry, none are responsible for the restoration of grazing lands. Thus it is imperative to develop a better management system for village pastures to increase fodder production and to reduce pressure on the natural grasslands which act as refuges for the wild grazing ungulates.

The sustainability of seasonal grazing by large flocks of migratory sheep and goats in the alpine meadows in summer and the Himalayan foot-hills in winter has been much debated recently (e.g. Saberwal 1996, Mishra and Rawat 1998). Alpine pastures play an important role in relieving the grazing pressure on the forests and grazing lands of the lower altitudes, but the increased number of livestock and overuse of certain

pastures can lead to degradation of high altitude grasslands including habitats for wild herbivores (Bhatnagar 1997). Restriction of grazing by migratory livestock in crucial wildlife areas, especially within the national parks, and limiting the number of livestock in other areas would be the most practical solution. Johnsingh *et al.* (1998) have given more recommendations for the conservation of various species and ecosystems in the trans and alpine areas of the Greater Himalaya.

Ecodevelopment plans to address the problems of fuel wood and non-timber forest products (including medicinal plants) in the high altitude areas are needed, especially for the people living in and around the protected areas in the Himalaya. More concerted efforts in monitoring the health of threatened grassland ecosystems and representative biota will be crucial in achieving the long term conservation goal.

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