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Rangeland Vegetation of the Indian Trans-Himalaya: An Ecological Review

Abstract

The Indian Trans-Himalaya (ITH) is characterized by sparse vegetation cover, low primary productivity and short growing season. Much of the area is unsuitable for cultivation but a large number of local and migratory pastoral communities use these areas for livestock grazing. Despite a high density of domestic livestock and low productivity, these rangelands support a rich assemblage of wild ungulates and other faunal groups. Though, several eco-floristic studies have been conducted in different parts of ITH, a comprehensive account on the distribution of major landform units or habitat types, and factors influencing the distribution of major vegetation communities across the larger landscape are needed. This paper gives an overview of vegetation structure and composition in the ITH across major landforms namely scrub steppe, scree slope, plateau/table land, marsh meadow, herbaceous meadow, moraine, dry sub-alpine & temperate forests and riverbed across the elevational gradients in ITH with their predominant species. We then provide an overview of vegetation structure and composition including patterns of species richness and diversity across various sub-regions, community composition, habitat use by wild ungulates and livestock, factors influencing the rangeland vegetation including topography and anthropogenic pressures. Major conservation issues such as degradation of pastures, need for eco-restoration and long term monitoring of rangeland vegetation are discussed.

Key words: Grazing, Ladakh, Landforms, North-West Himalaya, Wild ungulates

Introduction

Rangelands include natural grasslands, savannas, scrublands, steppes and wetlands dominated by grasses and grass-like plants predominantly used for livestock grazing. Spread over more than one third of the global land surface (Everitt et al. 1992), rangelands provide diverse ecosystem services and functions (Busby and Cox, 1994). They serve as main feed resource for traditional pastoral production system in many parts of the world and include about 70 percent of the feed for domestic ruminants. Other key ecosystem services from the rangelands include atmospheric carbon storage, watershed functions and critical habitat for a variety of flora and fauna.

The Indian Trans-Himalaya (ITH), located in the rain shadow zone beyond Greater Himalaya, has been used by a large number of local and migratory pastoral communities for livestock grazing since several centuries. This region is characterized by sparse treeless vegetation, often dominated by scrub, desert steppe or mixed herbaceous vegetation. Owing to extensive use of these areas for livestock grazing, they are often referred as rangelands. This region is also home to a large number of threatened species of flora and fauna. It is spread across three biogeographic provinces viz., 1A i.e., Ladakh Mountains in the north-west; 1B i.e., Tibetan plateau comprising of Eastern Ladakh, adjacent parts of Spiti, small pockets of Uttarakhand along northern frontiers and 1C i.e., Sikkim Plateau (Rodgers et al., 2000; WII, 2015; unpublished). These provinces are usually located above 4000 m above mean sea level and represent characteristic ecology and biogeography. The Trans-Himalayan rangelands are least influenced by summer monsoon and characterized by low productivity, extreme climatic conditions, high diurnal fluctuation in temperatures, scanty and erratic rainfall (<50mm), heavy winds and snowfall during winter. The region is generally considered floristically impoverished as compared to adjacent high altitude areas of Greater Himalaya (Mani, 1978; Schweinfurth, 1984). The vegetation of this region has been described by various authors as *Caragana-Lonicera-Artemisia* formation (Osmaston, 1922), Alpine steppe (Schweinfurth, 1959), Dry alpine scrub (Champion and Seth, 1968) and Alpine stony deserts (Puri et al., 1989).

The ITH has a unique physical, biological, hydrological and anthropological setting that is markedly different from that of the adjoining areas in the Greater Himalaya. This area is of considerable ecological and conservation significance which is crucial for pastoral production for the local herders as well as other ecosystem functions. The area forms upper catchment of several rivers such as Indus, Chenab, Satluj, Jahnavi or Jad Ganga, Alaknanda, Gori Ganga, Lasser Yangti, Kutti Yangti, and Teesta. These areas are quite distinct from the moist meadows of the Greater Himalaya in terms of

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physiognomy, plant community composition, primary productivity and patterns of seasonal use by the wild as well as domestic ungulates. This paper gives an overview of the rangeland vegetation in ITH including major landform units or habitat types across the elevational gradients, their ability to support populations of wild ungulates and domestic livestock and the factors determining the vegetation structure and composition.

Vegetation Structure and Composition

Phyto-diversity and Species Richness

The Indian Trans-Himalaya has been extensively surveyed in terms of eco-floristics by several workers. According to Srivastava (2010), the cold deserts of Western Himalaya are represented by ca. 1405 species, 490 genera under 98 families of flowering plants. Murti (2001) has reported about 347 species, belonging to 103 genera under 16 families of monocotyledons from the same region (Murti, 2001). Other workers, based on extensive floristic studies conducted in different areas have documented the richness of vascular plants e.g., Kachroo et al. (1977), Klimes (2003) and Klimes and Dickore (2005, 2006). Rawat and Adhikari (2005) recorded 232 species of vascular plants in ca. 300 sq. km area and identified several plant communities such as *Caragana-Artemisia, Artemisia- Kraschenennikovia* and *Artemisia-Tanacetum* in Changthang area of Ladakh. Rawat (2007a) estimated that a total of over 1800 species of flowering plants occur within the alpine region of Western Himalaya in an area of ca. 157,671 sq. km. Joshi et al. (2006) recorded 414 species of vascular plants from Nubra Valley, Ladakh. The patterns of plant species distribution in eight landscape types in Ladakh has been studied by Kala and Mathur (2002). In Trans-Himalayan region of Himachal Pradesh, Aswal and Mehrotra (1994) recorded 985 species from the Lahaul-Spiti. In recent floristic surveys of the cold arid regions of the state, Sekhar (2009) recorded 513 plant species belonging to 243 genera under 64 families from Pin Valley National Park while Chawla et al. (2012) reported 911 species of vascular plants in Kinnaur, Himachal Pradesh. The cold arid regions of Uttarakhand include Nilang, Mana and Niti valleys in Garhwal and Johar, inner Darma and Byans valleys in Kumaun. Very few studies have been done on the eco-floristics of these valleys. Naithani (1988) reported ca. 170 species of flowering plants from Nilang valley. However, Chandola (2009) recorded 441 species of vascular plants distributed under 229 genera and 72 families from the same valley. Efforts on ecological assessments of habitat types or landscape units in the alpine arid areas have not been carried out, except in Niti valley, which forms the buffer zone and cold arid region of Nanda Devi Biosphere Reserve. Kumar and Mitra (2015) recorded a total of 469 species belonging to 75 genera under 261 families of vascular plants. A perusal of literature on floristics of the ITH by various workers has been provided in Table 2.1.

Table 2.1. Details of floristic studies carried out in the Indian Trans-Himalaya.

Eco-floristic region & State	Area (sq. km)	Family	Genera	Species	Elevation range (m)	Author (s)
Cold deserts, Western Himalaya; J&K, H.P., UK	98,980	98	490	1405	4500-6000	Srivastava (2010)
Western Himalaya; J&K, H.P., UK	157,671	--	--	1810	3300-5600	Rawat (2007a)
Ladakh, J&K	97,782	51	190	611	2900-5900	Kachroo et al. (1977)
Ladakh, J&K	100,000	--	--	1180	3000-6000	Klimes and Dickore (2006)
Lower Ladakh, J&K	400	--	--	355	2750-4100	Klimes and Dickore (2005)
Western Ladakh, J&K	6523	51	159	301	2700-5300	Angmo (2013)
Eastern Ladakh, J&K	10,227	--	--	404	4180-6000	Klimes (2003)
Eastern Ladakh, J&K	6,912	43	127	272	4180-6670	Dvorsky et al. (2011)
Nubra Valley, J&K	22,656	56	202	414	2800-5400	Joshi et al. (2006)
Tso Kar Basin, Changthang, J&K	300	38	101	232	4400- 5500	Rawat and Adhikari (2005)
Lahaul and Spiti, H.P.	12,210	79	353	985	2000-6600	Aswal and Mehrotra (1994)
Pin Valley National Park, H.P.	1825	64	243	513	3300-6600	Sekhar (2009)
Kinnaur, H.P.	6400	114	450	911	--	Chawla et al. (2012)
Sangla Valley, H.P.	--	99	321	639	1800-4600	Devi et al. (2014)
Nilang Valley, UK	1,360	72	229	441	3000->6000	Chandola (2009)
Niti Valley, UK	726	75	261	469	3000->6000	Kumar and Mitra (2015)
Khangchendzonga National Park, SK	1784	67	243	585	4000-5000	Tambe (2007)

Abbreviations: J &K: Jammu and Kashmir, H.P: Himachal Pradesh, UK: Uttarakhand, SK: Sikkim

Plant community structure and composition

Most of the published studies on the plant community structure and composition pertaining to the ITH are from the Ladakh Mountains of the North-West Himalaya. For example, Dvorsky et al. (2011) identified eight distinct vegetation types and found scree as well as alpine grasslands as the most species-rich and reported altitude, soil moisture and salinity as the most important environmental factors influencing the species composition in Eastern Ladakh. In Ladakh, Rawat (2008) identified eight special habitats, viz., moist meadows, marsh meadows, craggy rock surfaces, scree bases, scrub steppe and sub-nival zones and remnant woodlands which harbours unique plant assemblages including some rare and threatened plants viz. *Colchicum luteum, Inula rhizocephala, Saussurea medusa, Allium przewalskianum,* and *Arnebia euchroma*. In a comprehensive effort covering Trans-Himalayan region of North-West and Western Himalaya, Rawat (2007a) identified eleven major vegetation communities, of which *Lonicera spinosa-Caragana versicolor-Oryzopsis lateralis* and *Thalictrum alpinum-Saussurea gnaphaloides-Trisetum aenium* showed highest diversity (2.27 and 2.37 respectively) and lowest (1.12) by *Phragmites australis-Lycium ruthenicum* community. Among the 16 plant communities observed in Tso-Kar Basin of Changthang Plateau, Eastern Ladakh, Rawat and Adhikari (2005) reported *Stipa-Alyssum-Oxytropis* and *Caragana-Poa* as the most extensive communities with respect to the aerial coverage. Kala and Mathur (2002) identified six communities in western Ladakh, viz., *Ephedra-Artemisia, Poa annua-Ranunculus hirtellus-Pedicularis oederi, Caragana brevifolia-Cotoneaster, Hippophae rahmnoides-Myricaria germanica, Artemisia-Salsola collina-Kraschenennikovia ceratoides* and *Agropyron-Trisetum-Oryzopsis-Carex*. In Nubra valley of Ladakh, Joshi et al. (2006) reported that herbaceous meadows on the gentle slopes had higher species diversity (1.2-2.29) and richness (14-21) followed by fell fields with species diversity (2.08-2.23) and richness (13-18) and least diversity was observed on scree slopes and on lower eroded slopes. The study also revealed that nearly 78-80% of plant species are restricted to the valley bottoms.

Of the 14 forest communities recorded from Lahaul valley by Singh and Samant (2010), tree density was found maximum for *Hippophae salicifolia* community (1850 individuals ha^{-1}), followed by *Fraxinus xanthoxyloides* (1000 individuals ha^{-1}), *Juglans regia-Ulmus wallichiana-Acer acuminatum* mixed (760 individuals ha^{-1}), *Abies pindrow-Pinus wallichiana* mixed (640 individuals ha^{-1}), *Juniperus polycarpos-Cedrus deodara* mixed (600 individuals ha^{-1}) while *Cedrus deodara-Acer cappadocicum* mixed community had lowest density (171 individuals ha^{-1}). Further, these authors have prioritized 15 habitats and 14 forest communities distributed between 2490-4000 m in the Lahaul Valley, Cold Desert Biosphere Reserve for conservation. Jisthu and Goraya (2008) identified six unique habitats such as moist meadows, riverine scrub, Juniper woodland and sub-alpine scrub, alpine dry scrub, alpine mixed communities and riverine scrub with respect to taxa of high conservation significance in cold deserts of Lahaul and Spiti valley and part of Pooh sub-division in Kinnaur, Himachal Pradesh.

In Niti and Nilang valleys of Uttarakhand state, the dry and undulating slopes in interior areas exhibit characteristic scrub steppe vegetation dominated by *Caragana versicolor, Lonicera spinosa* and *Potentilla rigida* and at places by *Krascheninnikovia ceratoides*. The unstable scree slopes harbour a distinct community characterized by *Aconogonum tortuosum, Eriophyton rhomboideum, Cicer microphyllum,* and *Cousinia thomsonii* (Chandola et al. 2008; Kumar and Mitra 2015).

In alpine meadows of north Sikkim, Tambe and Rawat (2008) reported the dominance of sedges namely *Kobresia nepalensis* on smooth slopes, *Kobresia duthiei* on broken slopes and *Kobresia pygmaea* and *Kobresia schoenoides* in dry meadows. The study also identified 11 vegetation types in the alpine landscape namely, 'krummholz' thicket, Juniper scrub, *Rhododendron* scrub, morainic scrub, *Salix sikkimensis* riverine thicket, *Myricaria rosea* riverine scrub, *Kobresia nepalensis* moist meadow, *Kobresia duthiei* moist meadow, *Kobresia pygmaea* moist meadow, *Deschampsia caespitosa* marsh meadow and *Anaphalis xylorhiza* dry meadow based on numerical classification.

Habitat use by wild ungulates and livestock in Indian Trans-Himalaya

Several workers have studied habitat use by wild ungulates and their interaction with domestic livestock in the ITH (e.g., Johnsingh et al., 1999; Mishra, 2001; Bagchi et al., 2002; Raghavan, 2003; Namgail et al., 2007; Rawat, 2007b; Chanchani et al., 2008; Hussain, 2009; Kumar and Mitra, 2015). Johnsingh et al. (1999) studied the ecology of the Ibex (*Capra sibirica*) in Pin Valley NP and its interaction with livestock. Mishra (2001) studied pastoralism, human-animal conflict and livestock competition with Blue sheep (*Pseudois nayaur*) in the Spiti valley, Himachal Pradesh and concluded the co-existence between pastoralism and wildlife is far from harmonious and suggested that majority of the rangelands of the valley are overstocked, as they are grazed at intensities much higher than what is biologically optimal. In Spiti, Himachal Pradesh, Bagchi et al. (2002) found that domestic goat and sheep imposed resource limitation on ibex and excluded them spatially. Ibex remained relatively unaffected by other livestock such as yaks, donkeys and cattle. Raghavan (2003) investigated the interaction between Ladakh urial (*Ovis orientalis vignei*) and livestock and opined that Urial may have been pushed to areas with sub-optimal resources, by livestock that used relatively resource rich areas. Namgail et al. (2007) reported a shift in the habitat use by the Tibetan Argali (*Ovis ammon hodgsoni*) in the presence of livestock in the

Gya-Miru Wildlife Sanctuary, Ladakh. Rawat (2007b) based on a landscape survey in Western Himalaya reported higher densities of livestock in the alpine areas of Uttarakhand compared to those of Himachal Pradesh and Jammu & Kashmir. Chanchani et al. (2010) studied seasonal distribution of four ungulates viz., Tibetan argali, Tibetan gazelle (*Procapra picticaudata*), Southern kiang (*Equus kiang polyodon)* and blue sheep (*Pseudois nayaur*) in Trans-Himalayan region of Sikkim. These authors found that argali was associated with sparsely-vegetated scree hills, gazelles frequently used valleys, basins and plateaus, kiang predominately used plateaus and gentle slopes and blue sheep were mainly seen on rocky or grassy slopes in the transition zone. According to these authors persistence of these ungulates in the small area of Sikkim plateau may be due to non-hunting practices of the local herders and absence of livestock grazing by domestic livestock during summer season. According to Hussain (2009) kiang showed complete separation with livestock (sheep, goat and horse) with respect to habitat preferences in Hanley valley of Changthang Wildlife Sanctuary, Ladakh. However, Kumar and Mitra (2015) in Niti valley of Nanda Devi Biosphere Reserve, Uttarakhand found that scrub steppe is used in high percentage by blue sheep and livestock and suggested that the area is avoided by blue sheep in the presence of domestic livestock.

Factors affecting rangeland vegetation in the Indian Trans-Himalaya

The Indian Trans-Himalaya is characterized by low productivity, high intensity of solar radiation and high degree of seasonality. The plant species in these altitudes exhibit several features such as reduced leaves, stunted growth, deep tap root system, xerophytic nature. Several factors such as climatic, topographical, bio-geographical and anthropogenic play important role in determining the vegetation structure and plant community composition in these areas. The key factors determining the vegetation of the Trans-Himalayan rangelands are summarized below:

Topography and altitude: Topographic features such as terrain, degree of slope and elevational gradients strongly influence the vegetation communities. For example, scrub steppe, one of the dominant physiognomic units in Trans-Himalayan region of Ladakh is found mostly on gentle slopes with adequate drainage (Rawat and Adhikari, 2005). Alpine grasslands and the sub-nival vegetation are common vegetation features of the landscape at the highest elevations (Dvorsky et al., 2011; Rawat and Adhikari, 2005). Table lands and undulating terrain harbour highest diversity of species in Ladakh (Kala and Mathur, 2002). Kumar and Mitra (2015) found that the species richness among various landforms was highest in morainic deposits (99 species) and scrub steppe (97 species) followed by scree slopes in Niti valley, Uttarakhand.

Moisture availability: In cold arid regions, vegetation types with respect to plant cover largely follow moisture and altitudinal gradients (Rawat and Adhikari, 2005; Dvorsky et al., 2011). The presence of typical plant formations along the river beds comprising of the species of *Myricaria, Salix* and *Hippophae* in entire ITH range corroborates the previous statement. Moist meadows having greatest species richness are mostly dominated by sedge such as species of *Carex* and *Kobresia* and moist areas above 5000m are usually dominated by *Thylacospermum-Arenaria* community (Rawat and Adhikari, 2005).

Anthropogenic factors: Alpine rangelands in the ITH have been used by local and migratory pastoral communities for seasonal livestock grazing since several centuries. Despite a harsh climate, poor vegetation cover and relatively low standing biomass, this area sustains a high livestock population (Rawat, 2007b). Alpine grasslands very likely experience the greatest grazing pressure compared to other areas and the prevalence and dominance of a specific group of plants is determined by grazing history of the region. The vegetation in and around animal resting places or camping sites is scattered along the elevation gradient quite haphazardly because its distribution is partly of human origin. Species such as *Rumex nepalensis, Urtica hyperborea, Chenopodium botrys*, mostly dispersed by livestock prefer growing in animal resting places which could be due to nitrogen enrichment of soil by their dung. Poor species richness compared to other habitats is mainly due to limited extent of these habitats and high disturbance regime which possibly reduce diversity by increasing plant mortality.

Phytogeographic affinities of Rangelands: Western Ladakh and adjacent mountain ranges, Eastern Ladakh, Lahaul and Spiti, Cold arid regions of Uttarakhand and Sikkim plateau represent different biogeographic sub-divisions and provinces. Accordingly, there is a gradual transition of species assemblage across the region from west to east. For example, *Haloxylon-Statice; Acantholimon-Thylacospermum* and riverine scrub vegetation especially *Tamarix-Hippophae rhamnoides* are confined to 1A. In the Sikkim plateau the lower fringes of rangelands have moist alpine scrub dominated by *Rhododendron setosum, Juniperus indica, Salix calyculata* and *Myricaria prostrata*. It is noteworthy that grassy meadows of *Danthonia cachemyriana* and tall forb communities in deep soil are more characteristic of the western Himalaya and are virtually absent in Khangchendzonga National Park, Sikkim (Rawat, 2005). Such differences in the vegetation are largely influenced by phytogeographic affinities with the surrounding regions. The sole presence of *Pinus gerardiana* in dry temperate forests of Kinnaur region compliments the above statement.

Distribution of species across major landforms or habitats:

A number of authors have attempted to classify landforms or habitats in the Trans-Himalayan region. These landforms vary in extent according to altitude and geographic locations. The present ecological review suggests eight major landforms or habitats namely herbaceous meadow, dry sub-alpine and temperate forests, moraine, scree slope, tableland, marsh meadow, riverbed and scrub steppe (**Plate 2.1 - 2.12**) across the elevational gradients in ITH with their predominant species (**Table 2.2**). Among various landforms,scrub steppe occupies larger area in all the Trans-Himalayan states followed by herbaceous meadow. The dry sub-alpine forests predominately of *Betula utilis* (remnant patches) and dry temperate forests (*Pinus wallichiana* and *Cedrus deodara*) in lower reaches of the interior valleys in Western Himalaya are relatively absent in North West Himalaya (Ladakh and Lahaul and Spiti). Due to comparatively narrow valleys in cold-arid regions of Uttarakhand and Kinnaur, Himachal Pradesh, the table lands and marshy areas are reasonably absent.

Plate 2.1: Herbaceous meadow

Plate 2.2: Dry Sub-alpine forests

Plate 2.3: Dry temperate forests

Plate 2.4 : Moraine

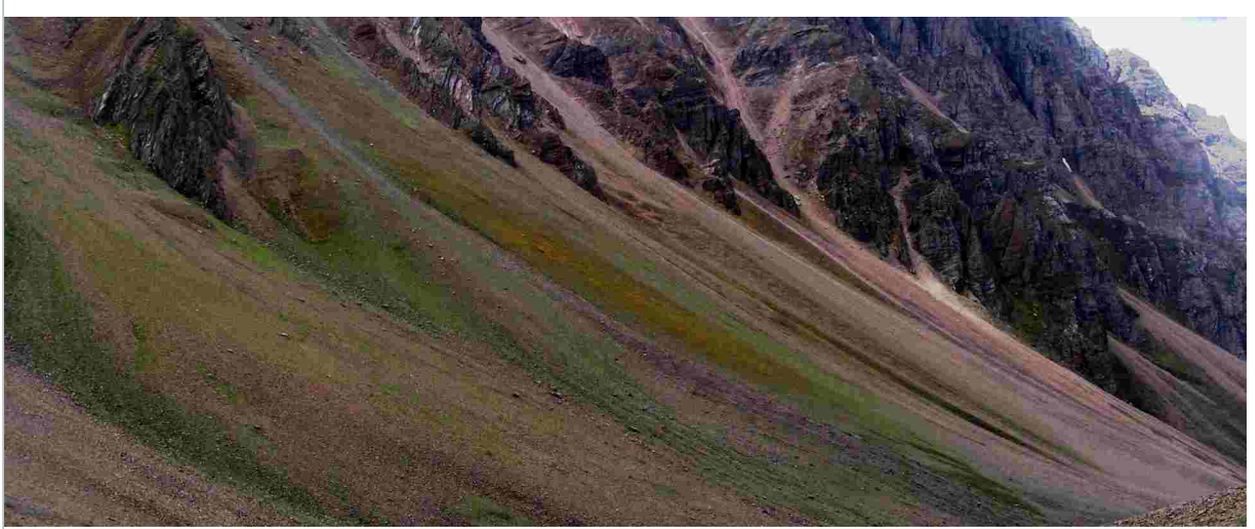

Plate 2.5 : Scree slope

Plate 2.6 : Table land

Plate 2.7 : Marshy area

Plate 2.8 : Riverbed

Plate 2.9: Scrub steppe vegetation comprising *Caragana-Krascheninnikovia* community in Niti valley, Uttarakhand

Plate 2.10: Overview of an alpine arid pasture in Spiti valley, Himachal Pradesh. ©*Yashveer Bhatnagar*

Plate 2.11: Alpine dry scrub (Scrub steppe) dominated by *Krascheninnikovia ceratoides,* a key stone species in Eastern Ladakh.

Table 2.2 Major landforms/habitats with respect to elevational range, characteristic and dominant vegetation in the Indian Trans-Himalaya.

Elevation range (m)	Landforms/ Habitats	Characteristic species	Reference
>5000	Scrub steppe	*Astragalus* spp., *Acantholimon lycopodioides, Thylacospermum caespitosum*	Rawat and Adhikari (2005), Rawat (2007a), Dvorsky et al. (2011)
	Scree slope	*Aconogonum tortuosum, Astragalus* spp., *Cousinia thomsonii, Cicer microphyllum*	Kala and Mathur (2002), Dvorsky et al. (2011), Angmo (2013)
	Plateau/Tableland	*Elymus nutans, Stipa* spp., *Oryzopsis munroi, Carex moorcroftiana, Oxytropis* spp., *Potentilla bifurca*	Kala and Mathur (2002), Angmo (2013)
	River bed	*Hippophae tibetana, Myricaria germanica, Salix flabellaris*	Joshi et al. (2006), Rawat (2007a)
4500-5000	Scrub steppe	*Caragana versicolor, Krascheninnikovia ceratoides, Lonicera spinosa, Astragalus* spp., *Elymus* spp., *Poa* spp.,	Rawat and Adhikari (2005), Tambe (2007), Dvorsky et al. (2011), Kumar and Mitra (2015)
	Scree slope	*Eriophyton rhomboideum*, *Cicer microphyllum, Aconogonum tortuosum, Cousinia thomsonii*	Kala and Mathur (2002), Dvorsky et al. (2011), Angmo (2013)
	Plateau/Tableland	*Agropyron* sp., *Trisetum* sp., *Oryzopsis* sp., *Carex* sp., *Oxytropis* sp., *Potentilla* sp.	Kala and Mathur (2002), Angmo (2013)
	River bed	*Hippophae tibetana*, *Myricaria germanica, Salix flabellaris, S. pycnostachya*	Joshi et al. (2006), Rawat (2007a)
4000-4500	Scrub steppe	*Caragana versicolor, Krascheninnikovia ceratoides, Juniperus* sp., *Lonicera spinosa*, *Astragalus* sp., *Ephedra gerardiana, Elymus* spp., *Poa* spp.,	Rawat and Adhikari (2005), Tambe (2007), Dvorsky et al. (2011), Kumar and Mitra (2015)
	Scree slope	*Eriophyton rhomboideum*, *Aconogonum tortuosum, Astragalus* spp., *Cousinia thomsonii, Cicer microphyllum*	Kala and Mathur (2002), Chandola (2009), Kumar and Mitra (2015)
	Marsh meadow	*Kobresia pygmaea, Carex* spp., *Blysmus compressus, Potentilla anserina, Pedicularis tubiformis*	Joshi et al. (2006), Tambe (2007), Angmo (2013), Kumar and Mitra (2015)
	Moraine	*Betula utilis, Cassiope fastigiata*, *Bistorta affinis, Salix denticulata*	Kala and Mathur (2002), Tambe (2007), Chandola (2009), Angmo (2013), Kumar and Mitra (2015)
	River bed	*Hippophae tibetana, Myricaria germanica, Salix flabellaris, S. pycnostachya*	Joshi et al. (2006), Tambe (2007), Rawat (2007a), Chandola (2009), Kumar and Mitra (2015)
3500-4000	Herbaceous meadow	*Kobresia* spp., *Carex* spp., *Trachydium roylei, Potentilla* spp., *Pedicularis* sp.	Joshi et al. (2006), Tambe (2007), Angmo (2013), Kumar and Mitra (2015)
	Moraine	*Betula utilis, Cassiope fastigiata, Bistorta affinis, Salix denticulata*	Kala and Mathur (2002), Tambe (2007), Chandola (2009), Angmo (2013), Kumar and Mitra (2015)
	Dry sub-alpine & temperate Forests	*Betula utilis* (remnant patches), *Juniperus semiglobosa, Pinus* spp., *J. indica, J. communis, Rosa* spp., *Berberis* spp.	Chandola (2009), Kumar and Mitra (2015)

Elevation range (m)	Landforms/ Habitats	Characteristic species	Reference
	River bed	*Hippophae rhamnoides, Myricaria germanica, M. elegans, Salix flabellaris*	Joshi et al. (2006), Tambe (2007), Rawat (2007a), Chandola (2009), Kumar and Mitra (2015)
3000-3500	Herbaceous meadow	*Trachydium roylei, Potentilla* sp., *Pedicularis* sp., *Bistorta* sp., *Anemone* sp.	Joshi et al. (2006), Tambe (2007), Angmo (2013), Kumar and Mitra (2015)
	River bed	*Hippophae rhamnoides, Myricaria germanica, M. elegans, Salix flabellaris*	Joshi et al. (2006), Tambe (2007), Rawat (2007a), Chandola (2009)
	Dry sub-alpine & temperate Forests	*Betula utilis* (remnant patches), *Juniperus semiglobosa, Pinus* spp., *J. indica, J. communis, Rosa* spp., *Berberis* spp.	Chandola (2009), Kumar and Mitra (2015)

Conclusion

Rangeland vegetation of the ITH is strongly influenced by topography, altitude, moisture availability and pastoral practices. Distribution and abundance of several plant communities can be predicted based on the land forms. There is an urgent need to carry out geospatial analysis of these rangelands and establish baselines for long term monitoring in a coordinated manner. A cadre of trained rangeland managers within Forest and Wildlife Departments would be needed to work closely with the pastoral communities (who have inherited rich knowledge on the management of livestock and optimum utilization of rangelands) so as to evolve strategies for better management. Some of the important parameters for monitoring rangeland vegetation and ecosystem health include: Land use and Land cover classes using Remote Sensing (RS) and Geographic Information System (GIS); Primary productivity and proportion of quality forage which determine the carrying capacity of rangelands and livestock production; Vegetation dynamics; Livestock composition; and Dependence of fuel wood for cooking and heating. Though a few attempts have been made to map the rangeland vegetation, land use and land cover for some pockets, a consolidated and comprehensive vegetation map for the entire trans-Himalaya would be needed for better conservation planning. Similarly geospatial analysis of rangelands showing the distribution of certain keystone species such as *Caragana versicolor* and *Kraschenninikovia ceratoides* would be crucial for predicting the dynamics of rangeland vegetation. For the restoration of degraded rangelands these species along with other leguminous forbs and grasses need to be taken up. Alpine marsh meadows dominated by *Kobresia pygmaea* are the crucial winter season grazing areas for livestock in Changthang, Ladakh. In order to conserve these critical winter feeding grounds of livestock and important wildlife habitats, e.g., nesting areas of threatened birds, it would be necessary to develop integrated rangeland management plans based on participatory processes. Self regulated and good herding practices traditionally followed by the herders in many pockets of ITH would go a long way in maintenance of alpine rangelands (Bhatnagar, 1997; Rawat, 1998; Mitra et al., 2013).

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Plate 2.12: Alpine marsh meadow in Ladhak.

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