ECOLOGY OF ALPINE ARID PASTURES WITH SPECIAL REFERENCE TO LIVESTOCK GRAZING IN UPPER DHAULI VALLEY OF NANDA DEVI BIOSPHERE RESERVE, WESTERN HIMALAYA

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EXECUTIVE SUMMARY

Pastoral practices have been in existence in the alpine region of the Himalaya since millennia. The region is characterized by the presence of diverse pastoral practices such as sedentary, nuclear trans-humane, semi-nomadic, and nomadic pastoralism. These practices have strongly influenced the vegetation and ecology of the alpine rangelands, including local biodiversity. The region is broadly divisible into two distinct eco-climatic zones, *viz.*, a moist alpine zone of Greater Himalaya and cold arid zone of Trans-Himalaya. These zones differ considerably in terms of physiognomy, species composition, history of livestock grazing and their ability to withstand grazing pressure.

Although, several workers have studied the response of livestock grazing in the alpine zone of Greater Himalaya, very few studies have been conducted in the cold arid regions of Western Himalaya. Some of the pertinent questions that remain to be answered include (i) what are the spatio-temporal patterns of herding by the migratory pastoral groups in the alpine area, (ii) how do the floristic composition and biomass availability of the alpine pastures vary and how do wild animals and domestic livestock share the habitat? has been addressed in the present study. The objectives of the study were (i) To study the patterns of livestock grazing in the study area, (ii) To assess resource use by livestock, (iii) To assess the pasture quality (floristic) and quantity (biomass) in the study area, and (iv) to assess overlap in resource use between wild ungulates and livestock.

The study was conducted in Upper Dhauli valley, situated in the cold arid region of Nanda Devi Biosphere Reserve (hereafter NDBR; 30º 08’-31º 02’N, 79º 12’- 80º 19’E) in Uttarakhand. This area is located in the rain-shadow zone of NDBR. Upper reaches of the valley remain snowbound for more than six months in a year. Summer is very short and generally lasts from June to August. The study area receives a low amount of precipitation and remains dry and dusty above 3,200 m above mean sea level (msl). The average elevation of the study area ranges between 3,500–5,000 m above msl and is spread over *ca*. 727.7 km^2 area. The valley is named after the river Dhauli Ganga that forms one of the major tributaries of river Alaknanda. The valley is inhabited by Bhotiyas, an Indo-Mongoloid community who are primarily agro-pastoral in their profession. The vegetation of the study area is characterized by dry alpine scrub, alpine desert steppe, riverine scrub, and sedge meadows. The valley is comprised of three sub-watersheds: Amrit Ganga, Ganesh Ganga, and Satyagad.

This area is represented by high altitude faunal communities. Notable among them are Blue sheep (*Pseudois nayaur*), Himalayan marmot (*Marmota himalayana*), Himalayan musk deer (*Moschus chrysogaster*), Himalayan tahr (*Hemitragus jemlahicus*), Snow leopard (*Panthera uncia*), Red fox (Vulpes vulpes), Royle's Pika (*Ochotona roylei*) and Tibetan woolly hare (*Lepus oiostolus*).

The study was conducted in 2012 and 2014. Maps of the study area were generated using LANDSAT 8 satellite data in ArcGIS 9.3. The gradient measure, like slope and aspects, were generated using ASTER DEM of the Upper Dhauli Valley (UDV). The area under different slope and aspect classes were calculated using ArcMap (ESRI 2008). Data on spatio-temporal use of various pastures were collected using semi-structured, open-ended questionnaires. Locations of the stopovers were plotted on satellite images to generate route maps. Food habits of livestock were studied based on direct observations following standard methods, *i.e.*, focal animal sampling. A systematic survey of vascular plants was conducted in the study area to document the species availability. The aboveground biomass was estimated using harvest method at the monthly interval during the growing season. To understand the interaction between blue sheep and livestock belt transect method was used. The data generated through field work were analyzed using R software (R Core Team 2017) and Microsoft Excel workbook.

During the study period, eight pastoral groups with a total of 5900-6000 migratory livestock used the pastures of the study area. Of these, 64.4% were sheep and 34.1% goats. Horses and mules constituted a small percentage (less than 2%) of the livestock. The pastoral groups identified 74 camping sites where they halt and graze. The village Tapovan (1855m above msl) is most commonly used by the pastoralist during their migration to upper Dhauli valley. Kuari pass (3640m above msl) is another preferred stopover for pastoral groups to graze their animals in the meadow during migration. The study reveals that sheep had the broadest dietary spectrum with 36 species (65% of 55 palatable plant species), while the smallest range was of mules (11 species constituting 20% of the 55 palatable plant species). Graminoids formed a significant portion of the diet, except in the diet of goats, which showed a high contribution by shrub species (86% of 11366 bites).

The pasture area was *ca.* 31.70 km^2 in Amrit Ganga and *ca.* 19.41 km^2 in Kalajowar. In Amrit Ganga, the northeast aspect contributed to 26.7% of the area. The slopes having northern aspects have higher diversity as compared to the southern aspects, which is drier and receive more radiation. Kalajowar is dominated by southern and southwest aspects with 29.61% and 20.50% of the total area, respectively. One of the major landforms in the pastures is scree which was more in southern slopes. The majority of the pastures fall under a gentle slope.

Of the total 115 vascular plant species recorded in the study area, 92 species were found in Amrit Ganga and 70 species in Kalajowar. Graminoids were represented by the highest number of species in the pastures (22 species in Amrit Ganga and 18 species and Kalajowar). In the pastures, 52 palatable plant species were reported, of which 42 species were recorded from Amrit Ganga (total number of species recorded was 92 species) and 32 species from Kalajowar (total number of species was 70 species). The presence of opportunistic species such as *Rumex nepalensis* and *Urtica hyperborea* is an indication of the poor quality of the pastures. Biomass productivity showed an upward trend in July (128.3±3 g m^{-2}), reaching its peak in August (183.4±4 g m^{-2}) and declined by September (131.4±4 g m^{-2}). The increase in the biomass in July and August can be attributed to the ample supply of moisture available during this period. The results corroborate with the findings of other studies in the Greater Himalaya. Overall biomass in the area during the study period was estimated to be 95.16±2.15g m^{-2} Biomass availability of graminoids as compared with other forbs in the area was 37% of the total biomass. Total biomass of graminoids was estimated to be 35.4±11.5 g m^{-2}.

Blue sheep used the lower pastures only during June and October when the pastoral groups were absent in the valley. The maximum overlap between livestock and blue sheep was seen during October (C score= 0.85). Livestock was guided by a shepherd during foraging. Hence, they utilized all the available habitat types, whereas blue sheep preferred scrub steppe in comparison to other habitats.

From the present study, it was revealed that due to induction of charges for grazing in a particular land area, a conservative approach was initiated for sustainable resource management. The biomass dependent rotational grazing has also been documented as the pastoralists synchronized the grazing pattern depending on the availability of standing biomass in the grazing area. The route for the movement of pastoralist was identified during the study, and in future, the impact imparted by the pastoralist community and the livestock in the route can be studied, and the outcome would be of interest in managing the resource utilization in the landscape. During the study, winter sampling for ungulate presence was not done due to logistic constrains. In future winter, sampling is needed to generate information on the spatial and temporal niche or resource partitioning between ungulates and livestock.

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Chapter 1

Introduction

1.1 Introduction

Mountainous regions form a fascinating world with an ample range of biological diversity over smaller areas (Dash & Saxena 2012). The youngest and highest mountain chain, Himalaya is known for its unique and rich biodiversity. It exhibits an array of floral diversity distributed across diverse habitats from Shivaliks to the alpine meadows and dry arid rangelands of trans-Himalaya.

The Alpine Zone

The alpine zone represents the uppermost vegetated areas in the Himalaya. The zone is well known for its rich diversity of flora and fauna, aesthetic and cultural values. This zone occupies *ca.* 33% of the total geographical area in the Indian Himalaya, 26% of which is vegetated and remaining 7.1% area falls under perpetual snow (Lal *et al.* 1991). The region above 4000 m is characterized by low productivity, high intensity of solar radiation, and a high degree of resource seasonality. The alpine zone represents about 61% of endemic species and 49% of the endemic genera of flowering plants in India (Nayar 1996).

The prominent feature of alpine vegetation is the lack of trees, stunted vegetation and pasture lands with the abundance of grasses and other herbaceous plants exhibiting interesting patterns of adaptations to harsh and cold environments with a short growing season (Korner 1999; Vishnu-Mittre 1984). These zones remain snowbound for six months in winters. Snow melts in late April or early May resulting in flowering of plants which lasts till early September. Local inhabitants have had an intimate association with alpine meadows in terms of cultural, religious, and economic dependence from time immemorial. Moreover, this region forms the upper catchment of the majority of the Himalayan rivers, which support millions of people in the lower hills as well as in the Indo-Gangetic plains. Hence, the health of the alpine ecosystem is closely linked with the environmental and human welfare in the entire region. Ecologically, this region is of much interest due to the adaptability of organisms to climatic extremes, vegetation processes, phytogeography, and convergence of specialized life forms (Mani 1978).

Cold-arid region: Extremes of adaptive strategies

Trans-Himalaya is the arid mountainous tracts lying extreme north and parallel to the Great Himalayan range, constituting the sediments of the Tethys sea bed. It lies in the rain-shadow of the Himalayan region. The region has a unique ecosystem characterized by extreme climatic conditions, such as diurnal fluctuations in temperatures, scanty and erratic rainfall, heavy winds, and snowfall (Murti 2001).

The Indian Trans-Himalaya (ITH) usually described as High Altitude Cold Desert Zone (Zone 1). It is broadly divided into three biogeographic provinces, viz; Ladakh mountains in the north-west, Zanskar in Jammu and Kashmir and Lahul and Spiti in Himachal Pradesh (1A); eastern plains of Ladakh (Changthang plateau), adjacent parts of Spiti and small pockets of Uttarakhand along northern frontiers (1B) and Sikkim Plateau (1C; Rodgers et al. 2000; WII 2015 unpublished). Kumar *et al* (2017) suggested that cold–arid regions of Kinnaur, HP and Nilang, Niti, Mana, Johar, Darma, and Byans valleys in Uttarakhand along the Northern frontiers should be included under a new Trans-Himalayan Biogeographic Province (1C) of India, considering the unique floristic diversity, fauna, and geology of the areas. The cold-arid region of the state of Uttarakhand is thought to be an extension of Tibetan plateau and contributes 1% (*ca*. < 1000 km^2) of the total Trans-Himalayan region of India (*ca.* 98,660 km^2). Though, by large the plant species are adaptive in nature, increasing human pressures and activities such as grazing have posed a severe threat to the survival of these ecosystems.

Human intervention: Livestock grazing and its impact

Since millennia, the alpine pastures of the Himalayan region have been used for livestock grazing by a large number of agro-pastoral communities (Tucker 1986). The adverse effects of the interference caused by man and his beasts on the natural environment, whether intentionally or accidentally are well recognized (Wilcove *et al*. 1998). The major causes of habitat degradation and loss in the Himalayan region have been ill-planned developmental activities and uncontrolled levels of grazing by domestic ungulates (Kala & Rawat 1999). In Spiti majority of the rangelands are overstocked (Mishra 2001). In the semi-arid ecosystems, where pastoralism is a main subsistence occupation, grazing competition from domestic livestock is believed to displace the wild ungulates (Shreshtha & Wegge 2008a). Shreshtha & Wegge (2008b) studied the habitat relationships in Phu valley of Nepal, among Blue sheep and domestic livestock and found that at high stocking densities there was completion for a resource. Roder (2000) found that at high density, livestock could significantly reduce forage availability. The scarcity of forage can be brought about by immediate effects of forage consumption, as well as long term changes, such as a reduction in plant cover and changes in plant species composition (Prins 1989). Also, resource competition can be expected when the forage availability in the rangeland becomes limiting. Overstocking, alongside with increasing human populations and changes in land use patterns, have the potential to cause competitive exclusion of wild herbivores, "the pastoral road to extinction" (Prins 1992). Due to the high densities of livestock, predation of livestock by wild predators takes place, resulting in conflicts between the local communities and wildlife managers (Mishra 1997). According to Schaller (1977), livestock grazing and other disturbances may affect the nutritional balance of wild animals because they spend more energy moving away from the disturbance and may be forced to forage in poor habitats instead of high-quality patches, and consequently may be competitively excluded from better habitats. Mishra (2001) studied pastoralism, human-animal conflict, and livestock competition with blue sheep in the Spiti Valley and concluded the co-existence between pastoralism and wildlife is far from harmonious. Bagchi *et al.* (2002) showed that the large migratory herds of sheep and goat pose a major threat to Ibex; livestock removes large amounts of forage from the pastures (nearly 250 kg of dry matter/day for certain species), thereby reducing forage availability for Ibex. Sheep and goats imposed resource limitation on Ibex and excluded them spatially. Raghavan (2003) investigated the interaction between the Urial (*Ovis vignei*) and livestock and suggested a possibility that the Urail may be pushed to areas with sub-optimal resources, by livestock. Namgail *et al.* (2007) reported a shift in the habitat use by the Tibetan Argali in the presence of livestock in the Gya-Miru Wildlife Sanctuary, Ladakh. Several workers (Sathyakumar *et al.* 1993; Bhatnagar *et al.* 2000; Vinod & Satyakumar 2005) found that extensive grazing by livestock negatively affects the habitat and abundance of ungulates. According to Mishra *et al.* (2004), competition between livestock and bharal has led to a decline in bharal density in the Trans-Himalayan landscape of Lahul-Spiti, Himachal Pradesh. The low abundance of wild animals in most of the areas can be attributed to habitat degradation and loss due to excessive grazing by migratory and resident livestock (Rawat 2007). Kittur *et al.* (2010) studied the spatial and habitat use overlap between the Himalayan tahr and domestic migratory livestock (*Capra aegagrus hircus* and *Ovis aries*) in the sub-alpine and alpine areas of Kedarnath Wildlife Sanctuary, Uttarakhand and found a minimal spatial overlap. Livestock grazing causes a reduction in forage availability (Mishra *et al.* 2004). It has been reported that the movement of livestock, pastoralists, and accompanying dogs prohibit habitat use by wild animals (Mehra 2000). Apart from competing with wild ungulates for resources, there are various other adverse impacts of grazing, which can be summarized as soil compaction, erosion and fertility, disturbances to nests and predation by accompanying dogs, disease communication (Mehra 2000) and loss of species diversity (Mehra 2000 and Kala & Rawat 1999).

Pastoralism in Indian Himalaya

Pastoralism has been practiced in the Himalayan region for centuries. The pastoralists would take large herds of sheep, goats, bovids, and equids to alpine meadows every summer and move to lower altitudes afterward (Bhasin 1988). During summer, when high altitude pastures are snow free, pastoralists move up to these grounds to graze their animals. Soon after the monsoon, they move down to occupy lowland pastures for the winter months (Sharma *et al.* 2003). Pastoralism is characterized to exploit the characteristic variability of rangelands. Through planned mobility, pastoralism finds an advantage in the presence of dynamic fluctuation in the drylands, where sedentary agriculture or mixed farming finds an issue in their absence of consistency and dependability (Kratli *et al.* 2013). According to Bhasin (2011), the nomadic pastoralists of the Himalayan region make efficient use of the seasonally abundant natural resources, and their migration helps to uphold soil fertility, while grazing also controls spread of invasive plant species. Pastoralists play an important role in India's economy in terms of food security (mainly milk), provision for draught animal and foreign exchange (meat, fibre, Bhasin 2011). Earlier workers have pointed out the adverse effects of grazing as overgrazed pastures, eroded lands, and proliferating weeds (Casimir & Rao 1985; Shah 1988; Rawat & Uniyal 1993). While passing through forests during their migration to alpine areas, the transhumant herds adversely affect regeneration (Pirazizy 1992), destroy agricultural crops (Chatterjee 1989; Awasthi 2001) and at times create or increase conflicts between human-wildlife or lead to competition between livestock and wildlife in alpine regions (Mishra 1997; Mishra *et al.* 2004; Bagchi *et al.* 2004).

Pastoral management aptitudes utilizing the accessible grazing assets in extremely inhospitable conditions developed in light of the ideas of sharing assets and the survival of the society as a whole (Farooquee 1998). Livestock grazing has been a major component of the economy of local people, and its role has been far more important compared to other related activities. In Hindu Kush Himalaya, livestock contributes 20-40% or more to the income of the people (Tulachan 2000). According to Tashi (2000), livestock contributes 36-47% of the total agricultural income in the mountainous region of Nepal and 50% of the total gross production value in Tibet.

1.2 Present Study

The alpine pastures in the cold arid regions have a short growing season; albeit a high dependency on these areas. These areas are used by both wild ungulates as well as livestock for grazing, and any imbalance would result in increased competition among these groups. Overuse by livestock has led to degradation of high altitude grasslands, including habitats of wild herbivores in certain regions (Sundriyal 1989, 1992, 1995). There are several studies pointing out the desirable (Naithani *et al.*1992; Negi *et al.* 1993; Collins *et al.* 1998; Sternberg *et al.* 2000; Rook & Tallowin 2003; Bernues *et al.* 2005) and undesirable (Prins 1989; Prins 1992; Sathyakumar *et al.* 1993; Rawat 1998; Mehra 2000; Conant *et al.* 2002; FAO 2007; Bagchi & Ritchie 2010a&b) impacts of grazing in these alpine pastures. Therefore, keeping this in view, the quality of these pastures needs to be studied along with the effects of livestock grazing on wild ungulates. Keeping these objectives in perspective, questions about the ecology and conservation of alpine vegetation in the region, *i.e.*, Upper Dhauli Valley has been investigated in the present study.

1.3 Objectives of the Study

The principle aim of the current research is to understand the ecological aspects of the alpine pastures, resource use by livestock and its interaction with wild ungulates in the cold-arid region of Upper Dhauli Valley in Nanda Devi Biosphere Reserve, Western Himalaya. The present study is focused on the assessment of patterns of floristic diversity across the two pastures, where livestock grazing is predominant. The study also aims to understand the movement pattern of migratory pastoralists and resource use by their livestock and their habitat overlap with resident ungulates.

The objectives of the study are:

- To assess the patterns of livestock grazing,
- To assess resource use by livestock,
- To assess the pasture quality (floristic) and quantity (biomass) in the study area, and
- To assess resource overlap between wild ungulates and livestock.

1.4 Organization of the Thesis

Chapter one comprises a general introduction, rationale, and objectives of the study.

Chapter two covers the description and introduction of the study area, including location, topography, climate, geology and soil, vegetation, fauna, local community, and land use practices.

Chapter three deals with the first and second objectives. It gives an account of the herding practices of the pastoralists visiting the area, the predominant places of herding during the migration between lower and higher altitudes. The chapter also describes the resource use by livestock regarding plant species consumed.

Chapter four focuses on the third objective. It gives an elaborate account of the structural attributes such as plant composition, forage plants availability, and functional attributes (biomass).

Chapter five deals with objective four, which focuses on the habitats utilized by livestock and blue sheep.

Chapter six discusses the significant findings of the study.

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Chapter 2

Study Area

2.1 General Introduction

The study was conducted in Nanda Devi Biosphere Reserve. NDBR (30º 08'-31º 02'N, 79º 12'- 80º 19'E) is located in the Western Himalayan biotic province of the biogeographically classified zone, 2B (Rodgers *et al.* 2000). The reserve was second to be declared in India and first in the Himalaya. NDBR is distributed in parts of Chamoli district in Garhwal, Bageshwar and Pithoragarh districts in Kumaon of Uttarakhand. It forms an important site of wilderness and biodiversity; it harbours habitats for several rare and endemic species of flora and fauna. This region is characterized by temperate forests, subalpine forests, alpine meadows, high altitude lakes, glaciers and snowbound mountain peaks (Sahai & Kimothi, 1996).

In 1988, NDBR (2,237 km^2) was declared a Biosphere Reserve. In the year 2000, a total area of 5,860 km^2 was added to NDBR, to include the Valley of Flowers National Park (VoFNP; 30° 41' to 30° 48'N and 79° 33' to 79° 46'E; 87.5 km^2) and Nanda Devi National Park (NDNP) as part of the core zone. It covers an area of 5860.69 km^2 with core area (712.1 km^2), a buffer zone (5148.6 km^2) and transition zone (546.3 km^2). NDNP and VoFNP were designated as a 'World Heritage Site' in the years 1988 and 2004, respectively. The highest point is the Nanda Devi peak, considered as the world's second most robust peak to climb (Kaur 1982), which lies within the core area of NDNP and is the second highest peak (ca. 7,816 m) within the Indian Territory. NDBR is bordered by the upper catchments of river Saraswati and Malari-Lapthal area in the north; village Khati in the south, Kala glacier, and basin of river Girthi Ganga in the east; and the upper catchment of river Alaknanda, Nanda Ghunti peak and Roop Kund in the west (Quasin 2011). In the buffer zone, there are 47 villages and 52 villages in the transition zone. The buffer zone covers most of Alaknanda and entire Rishi Ganga catchments (the sub-catchments of the river Ganga).

A large portion of the reserve lies above the treeline and is covered with snow for more than six months in a year. Thus, about 81% of the core zone and 60% of the buffer zone remain snowbound by glaciers throughout the year (Sahai & Kimothi 1996). Average annual rainfall is 930 mm, and about 48% of annual rainfall occurs over a short period of two months (July-August; Sahai & Kimothi 1996).

Dramatic changes in elevation have resulted in the existence of some unique vegetation types. The buffer zone vegetation types comprise of temperate, sub-alpine and alpine. The area supports over 1,000 species of plants including fungi, lichens and bryophytes and 520 species of fauna (Samant 2001). Around 23 forest communities and over 62 alpine vegetation communities have been recorded from the buffer zone of the reserve. The buffer zone supports 29 species of mammals constituting of almost all endangered animals like musk deer, snow leopard and black bear (Sathyakumar 2004; Bhattacharya *et al*. 2006; Bhattacharya *et al*. 2009 and Kandpal 2010). In addition, species like Goral (*Naemorhaedus goral*), Indian crested porcupine (*Hystrix indica*), Yellow-bellied weasel (*Mustela kathiah*), etc., 229 bird species such as Indian white-backed vulture (*Gyps bengalensis*), Egyptian vulture (*Neophron percnopterus*), Peregrine falcon (*Faico peregrinus*), Chukor partridge (*Alectoris chukor*). White crested kaleej pheasant (*Lophura leuvumvlunu*), Himalayan red-billed blue magpie (*Cissa erythrorhyncha*), Yellow-bellied blue magpie (*C. flavirostris*), etc. and about 200 insect species, 13 molluscs species and six species of annelids are found in the buffer zone (Kumar *et al*. 2001; Prajapati 2005).

2.2.1 Intensive Study Area: Upper Dhauli Valley (UDV)

The present study was conducted in Upper Dhauli Valley (UDV), a Trans-Himalayan region in the buffer zone of NDBR, Uttarakhand (Figure 2.1). The valley with an average elevation ranging from 3500 to 5000 m is spread over *ca.* 727.7 km^2. Figure 2.2 and Figure 2.3 shows the slope and aspect map of the valley. Upper Dhauli Valley can be divided into three major areas *viz.*, Amrit Ganga, Ganesh Ganga, and Kalajowar. The Amrit Ganga valley is situated on the western side. Kalajowar is situated on the eastern side. The Ganesh Ganga valley forms the extreme northern side of the valley and shares boundary with China. All the three valleys are used as summer pastures by the migratory pastoralists of the area.

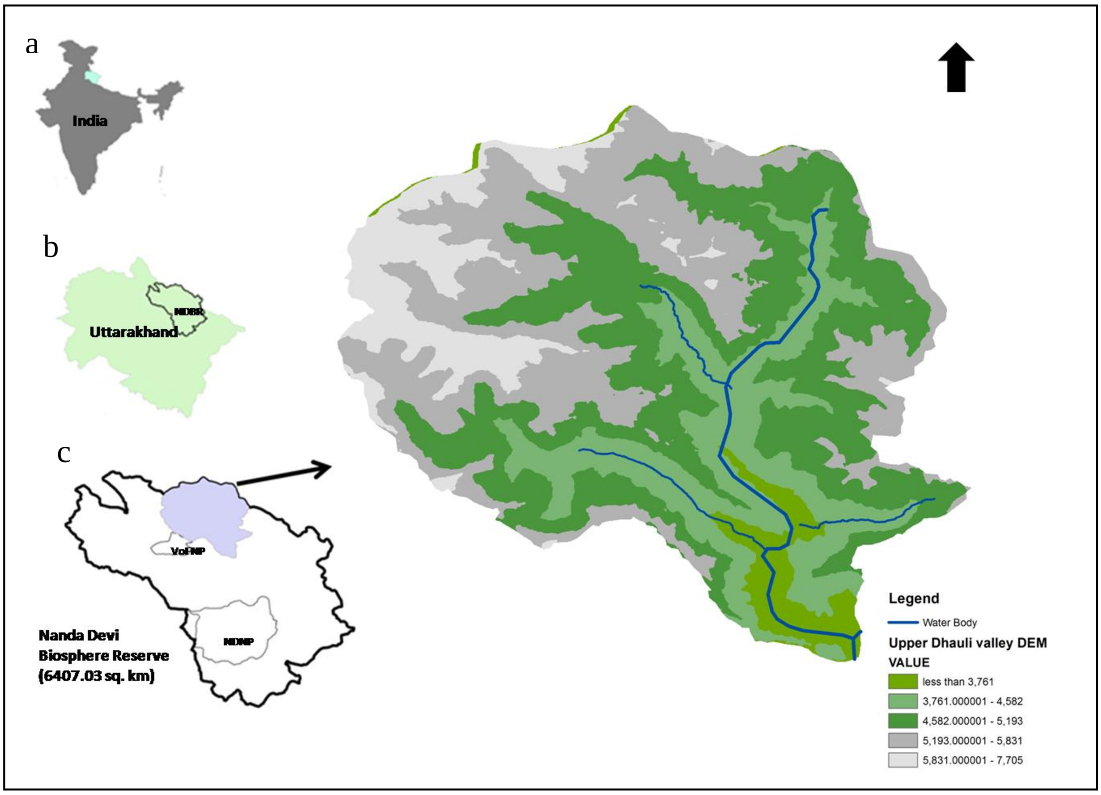

Figure 2.1. Map showing the study area; a-India showing Uttarakhand state; b-NDBR within Uttarakhand; c-NDBR with its two core areas (Nanda Devi National Park and Valley of Flowers National Park) and Upper Dhauli Valley (shaded)

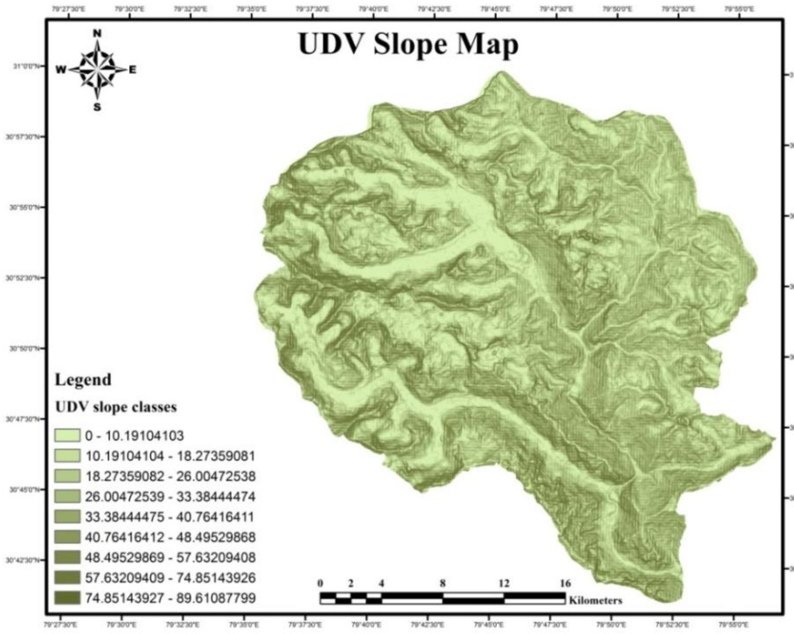

Figure 2.2. Slope map of Upper Dhauli Valley, Nanda Devi Biosphere Reserve, Western Himalaya

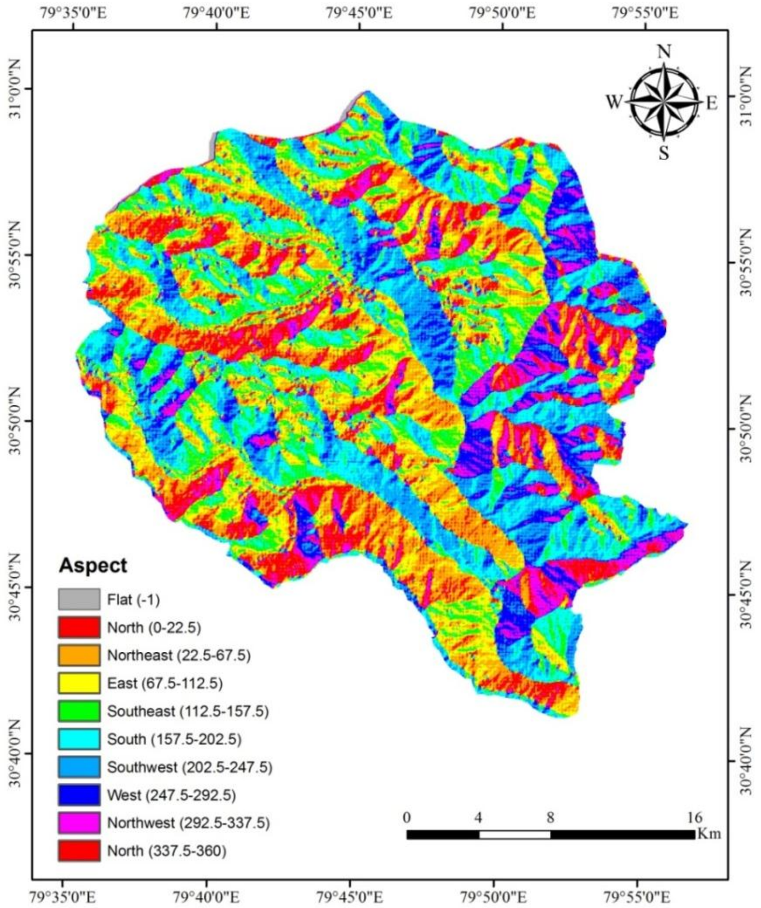

Figure 2.3. Aspect map of Upper Dhauli Valley, Nanda Devi Biosphere Reserve, Western Himalaya

2.2.2 Flora and Fauna

The vegetation of the study area is broadly divisible into following classes: (i) dry temperate forests dominated by blue pine (*Pinus wallichiana*), deodar (*Cedrus deodara*) and spruce (*Picea smithiana*) in the lower reaches of the valley, (ii) sub-alpine forests dominated by birch (*Betula utilis*), fir (*Abies pindrow*) and juniper (*Juniperus* spp.), (iii) riverine scrub community (*Hippophae, Salix* and *Myricaria*), (iv) alpine dry scrub (*Caragana* sp., *Juniperus* sp., *Krascheninnikovia ceratoides*, *Potentilla rigida*, *Devendraea spinosa* and *Lonicera* spp. and (v) alpine mixed herbaceous formations (*Kobresia* sp., *Trachydium roylei*, *Danthonia* sp. and *Potentilla* sp.). Most of the area (>70%) falls under alpine dry scrub and alpine mixed herbaceous formations, which is further divisible into several communities depending upon topographic features such as elevation, aspect, and slope (Kumar *et al.* 2016).

The mammalian fauna inhabiting the valley include Blue sheep (*Pseudois nayaur*), Himalayan marmot (*Marmota himalayana*), Himalayan musk deer (*Moschus chrysogaster*), Himalayan tahr (*Hemitragus jemlahicus*), Snow leopard (*Panthera uncia*), Red fox (Vulpes vulpes), Royle's Pika (*Ochotona roylei*) and Tibetan woolly hare (*Lepus oiostolus*).

2.2.3 Temperature and Rainfall

The valley is situated in the rain-shadow area of Dhauli Ganga, which is a major tributary of the river Ganga. Winters are long, and the region remains snowbound for more than six months in a year whereas summers are very short and last from mid-May to late August. The area receives a low amount of precipitation and remains dry and dusty (Figure 2.4).

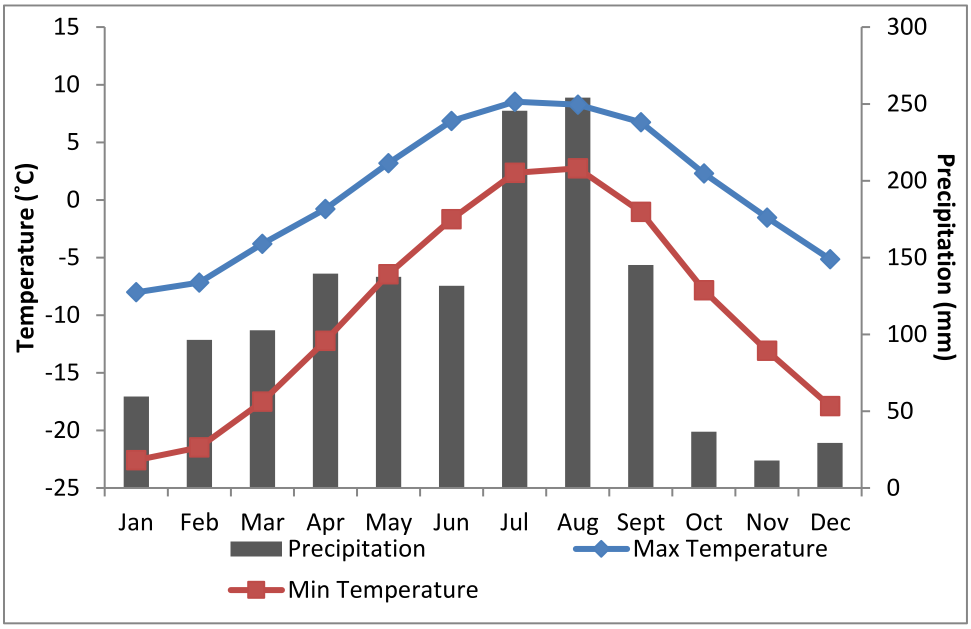

Figure 2.4. Graph showing climatic data (Source: http://globalweather.tamu.edu data from 2000-2013)

2.2.4 Local inhabitants, forest resources and their use pattern

There are seven villages *viz,* Mahargaon, Kailashpur, Gurgutti, Pharkia, Bampa, Gamsali and Niti inhabited by Bhotiya's, an indigenous community of Indo-Mongoloid origin. Upper Dhauli Valley is inhabited by two clans of Bhotiya community, locally known as Tolchha's and Marchha's. Niti is the last village of the region that borders to China. The Bhotiya ethnic community has their unique customs, folklore and religious beliefs. Additionally, this indigenous community has its perspective on conservation which manifests itself through local archetypes (Kumar *et al.* 2013b). They are depended on natural resources from the adjacent forests, and alpine pastures for sustenance and livelihood, and the alpine zone of the area continues to be used for transhumant pastoralism (Mitra *et al.* 2013). Due to lack of education facility and socio-economic transformations, the practice of utilizing medicinal plants in the local healthcare system of Bhotiyas is sharply declining and has lead to lack of knowledge as well as a transfer of knowledge to younger generations (Kumar *et al.* 2015b). Before 1962, residents of this valley carried cross-border trade with Tibet, primarily in salt and wool which was their primary source of income (Silori 2001). In recent decades, sheep and goat rearing, and weaving of woolen items such as shawl (pankhi), mattress (chutka or gudma), carpet (dann or kalin), cap (topi), vascot (fatuli) and sweater (baniyan) have become restricted to a few families. As per Census of India (2011), a total population in the area was 864 people (47.5% males and 52.5% females), with a total number of households of 292.

The inhabitants have two permanent dwellings; one in UDV, i.e., a cold-arid region which lie between 3000 to 3600m asl and the other in lesser Himalaya between 1000-1500m asl. Earlier, livestock (sheep and goat) rearing and weaving were the primary occupations, but now small-scale agriculture has taken precedence over pastoralism. Most of the families are engaged in small-scale farming such as, kidney bean (*Phaseolus vulgaris*), potato (*Solanum tuberosum*), green pea (*Pisum sativum*) and buckwheat (*Fagopyrum esculentum*) are the agricultural crops while apricot (*Prunus armeniaca*), akhrot/walnut (*Juglans regia*) and apple (*Malus domestica*) are the horticultural crops.

2.3 Amrit Ganga and Kalajowar

This study was carried out in Amrit Ganga valley and Kalajowar area within upper Dhauli valley (Figure 2.5), used as pastures for livestock grazing, which is the dominant form of anthropogenic activity apart from some incidences of medicinal plant collection by the villagers (Plate 1 and Plate 2). Ganesh Ganga is subjected to other developmental activities along with livestock grazing. Hence, the pastures in Ganesh Ganga were not included in the study.

Amrit Ganga river which is a tributary of river Dhauli has a catchment area of 31.70 km^2. Both the banks of the river are used for summer grazing of livestock. The source of the river is a glacier situated at the northern end of the pasture locally known as *Sagar*. One bank (the one behind Gamsali village) is locally called as *Dhaman*, which is the only place where cattle (cow and ox), horses and mules along with sheep-goat are allowed for grazing throughout the summer season. The other bank is exclusively reserved for livestock (sheep-goat) grazing; exceptions are made in the case of animals (horses and mules) accompanying the herders as an animal of burden, for short period. The pastoralist visiting the area has to pay a nominal charge to the head of Gamsali village as *charan* (Mitra *et al*. 2013). Kalajowar occupies an area of 19.41Km^2 is the catchment area of a glacial stream locally known as *Satyagad Nala*. The area is mainly used for migratory livestock grazing along with a small number of mules and horses brought by the herders for a short period. Niti village head is responsible for collecting *charan* from the pastoralists halting in Kalajowar.

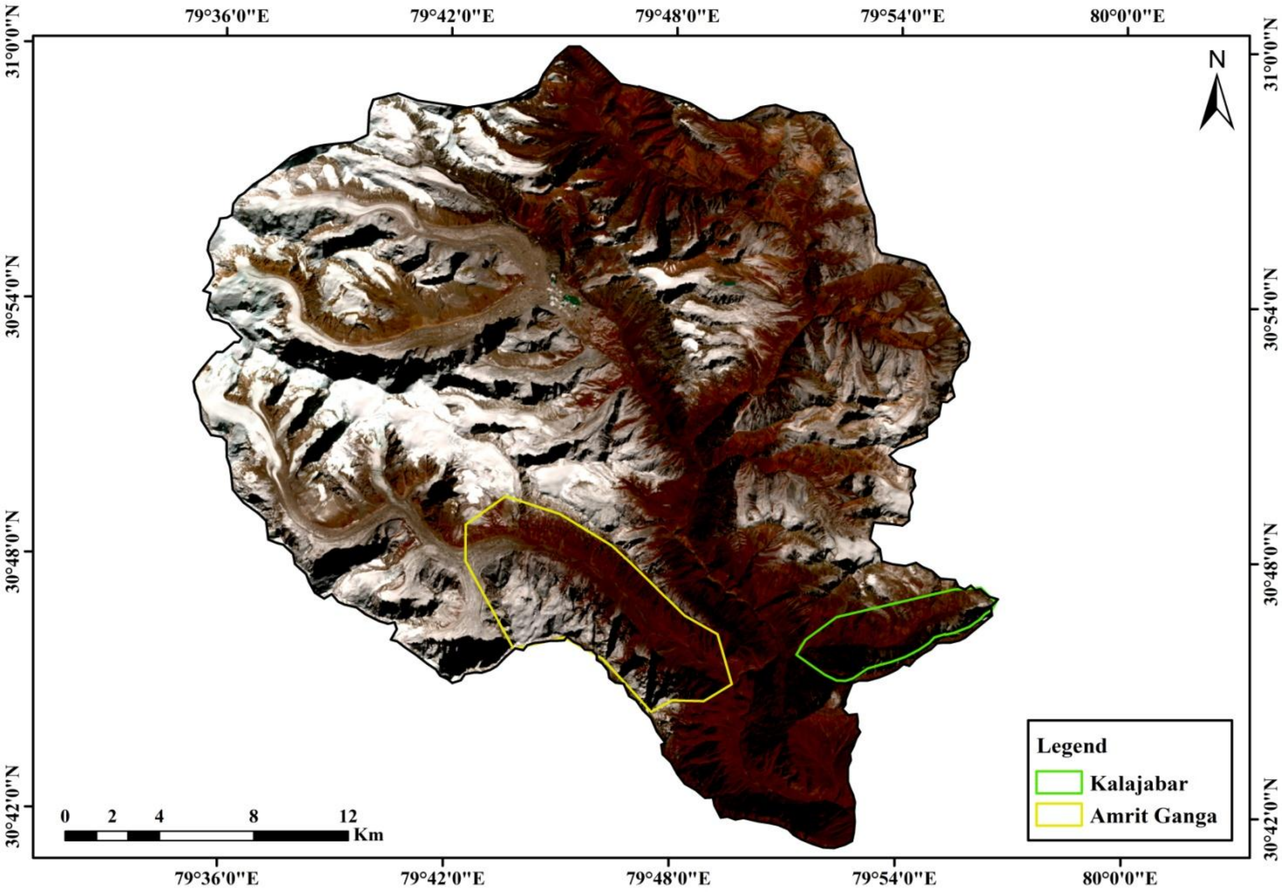

Figure 2.5. Map (LANDSAT image) showing the locations of Amrit Ganga and Kalajowar in Upper Dhauli Valley (UDV)

Plate:1. Glimpses of study area: Pastures and livestock

Amrit Ganga watershed

Kalajowar watershed

Herd of livestock grazing the valley

Livestock grazing

Plate:2. Glimpses of study area: Wildlife

Blue sheep

Yellow-billed chough

Marmot

Himalayan poppy

Chapter 3

Patterns of migration and resource use

3.1 Introduction

Pastoralism can be defined as a traditional way of management and utilization of grazing resources through the domestication of animals. In the Himalayan region, it has been practiced by various ethnic communities, such as the Bakarwals, Gujjars, Gaddis, Lepchas, Tawang Monpas, Tolchhas, Marchhas, Shoukas and Jadhs (Farooquee 1994; Hoon 1996; Kala 2002). Mobile pastoralism makes use of environmental variability by utilizing vegetation scattered over distances and transforming it into economically useful products such as milk, wool, meat derived from livestock. Pastoralism is characterized by specialization to exploit the inherent instability of rangeland situations. Through planned mobility, pastoralism finds an advantage in the presence of dynamic fluctuation in the drylands, where sedentary agriculture or mixed farming finds an issue in their absence of consistency and dependability (Krätli *et al.* 2013). In Himalaya, pastoralism is based on cyclical movements of pastoralists between lower altitude pastures to higher altitude pastures for utilizing the seasonally available pastures at different elevations (Bhasin 1988). During summer, when high altitude pastures are snow free, pastoralists move up to these grounds to graze their animals. Soon after the monsoon, they move down to occupy lowland pastures for the winter months (Sharma *et al.* 2003).

Pastoralists in India have been defined as the members of a caste or ethnic groups that have a strong tradition of livestock rearing. A substantial proportion of the group derives household consumption from livestock products or their sale (over 50%), and where households over 90% of animal consumption are from natural pasture or browse, and where families are responsible for the full cycle of livestock breeding (Sharma *et al.* 2003). Pastoralist rear animals like camels in dry areas, goats in areas where trees and shrubs dominate, sheep rearing is preferred in mountainous or on dry pastures that are adapted to particular environmental and economic niches (Imperative 2003).

The actual number of pastoral groups in Indian Himalaya utilizing the alpine areas has declined considerably. The decline in the intensity of high altitude grazing in parts of the Kumaon region, Uttarakhand can be attributed to change of traditional lifestyle induced by developmental activities, urban sprawl, and the market economy. Moreover, families with livestock preferred to hire labour rather than accompany their livestock to the alpine area themselves (Farooquee 1998). Migratory pastoralism is common throughout Himalaya, some pastoral groups include, Bakrawals from Jammu and Kashmir, the buffalo rearing Gujjars in Kashmir, parts of Himachal Pradesh and Uttar Pradesh (now Uttarakhand), then the Gaddis of Himachal Pradesh and Bhotias of Uttar Pradesh (now Uttarakhand; Table 3.1). Nomadic pastoralism, a conventional type of human-animal grassland association is still prevalent in the drylands of western India, the Deccan Plateau along within the rugged areas of the Himalaya. Approximately 200 castes practice pastoral nomadism, with endogamous (discrete) social units, and work in the breeding of customary animal sub-types (Roy & Singh 2013).

Table 3.1.Major transhumance pastoral practices in Indian Himalayan region

S.No	Pastoral Group	Location	Migration Pattern
1	Bakarwals	Kashmir	Winter months: Jammu and Punjab plains Summer months: Kishtwar and other higher alpine valleys of Kashmir Himalayas
2	Gujjars	Jammu, Himachal Pradesh and Uttarakhand	Winter months: Regions of Jammu, Punjab and lower districts of HP and UP, Saharanpur regions and to the areas adjoining Rajaji National Park. Summer months: Higher (non-alpine) regions of Himachal Pradesh and Uttranchal.
3	Changpas	Eastern Ladakh	Various high altitude pastures of Rupshu plains in Changthang region of Ladakh.
4	Gaddis	Kangra and Dharamsala regions of Himachal Pradesh, parts of UP and Punjab	Winter months: Punjab plains and lower districts of HP Summer months: Lahaul and Dhauladhar pastures in summer months.

5	Bhotias	Upper regions of Garhwal and Uttarakhand	Winter months: Lower districts of Uttarakhand like Dehradun, Himalayan foothills Summer months: Higher pastures of Garhwal and Kumaon Himalayas.
6	Bhuttias	North district of Sikkim	Winter months: Alpine regions of Lachung and Lachen valleys of the North districts of Sikkim Summer months: Lower forest below Mangan.
7	Monpas	Tawang and west Kameng district of Arunachal Pradesh	Summer months: Higher reaches of East Kameng and Tawang district of Arunachal Pradesh Winter months: Low lands around Tawang.
8	Kinnauras	Kinnaur region of Himachal Pradesh	Winter months: Foothills of Uttarakhand and H.P. Summer months: Higher parts inside HP

Source: Modified from Sharma *et al.* (2003), Singh (1996)

In the Himalayas, the nomadic pastoralists make efficient use of the seasonal pastures, and their migration routine upholds soil fertility by generating manure from livestock, while grazing also controls spread of invasive plant species (Bhasin 2011). The livestock grazing has been a significant component of the economy of local people, and its role has been far more critical as compared to other related activities. Pastoralists have an essential role in India's economy concerning food security (mainly milk), provision for draught animal and foreign exchange (meat, fiber, e.g., pashmina (cashmere); Bhasin 2011). In the Hindu Kush Himalaya, livestock contributes 20-40% or more to the income of the people (Tulachan 2000). According to Tashi (2000), livestock contributes 36-47% of the total agricultural revenue in the mountainous region of Nepal and 50% of the total gross production value in Tibet.

Pastoral management aptitudes utilize the available grazing assets in extremely inhospitable conditions developed in light of the ideas of sharing assets and the survival of the society as a whole. In Kumaon Himalaya, the Bhotiya’s are affected by the market-oriented economy leading to quickly changing social structures and qualities. These have influenced the unequal distribution of power and assets. These factors are responsible for the weakening of the Bhotiya's indigenous knowledge regarding utilization of land, livestock administration, income generation, plant and animal assets (Farooquee 1998)

The grazing resources, especially that pertains to the description of plant species and communities, production potential, resource management, and quality monitoring has been studied by Roder (2000). A comparative study on foraging ecology and grazing impacts of livestock on the Tibetan Changtang was carried out by Cincotta *et al.* (1991). The forage consumption by wild Bactrian camels and other large ungulates in south-western Mongolia was studied by Reading *et al.* (1999). Studies in Tibetan Plateau on the status of rangeland and forage productivity by Weikai *et al.* (2000) and the integrated ecological studies of pasture problems by Holzner *et al.* (2000) are few of the earlier studies on these aspects. The native herbivore species serve as keystone species in tall grass ecosystem; they increase habitat heterogeneity and in turn increase species diversity (Collins *et al.* 1998). The degradation of pastureland due to overgrazing occurs because livestock tends to defoliate selectively rather than indiscriminate foraging on the herbage as per its availability (Walker 1995). According to Crawley (1983), by selective feeding herbivores modifies the competition among plant species, which in turn affects the species richness of the area. According to Nautiyal *et al.* (2004), the main reason for habitat destruction and changes in vegetation composition of Garhwal Himalaya is human-induced changes. A review of information available on the food plants and feeding habits of Himalayan ungulates (Awasthi *et al.* 2003) revealed a total of 140 forage plants that are palatable to different ungulate species, including livestock. It was found that out of 140 plant species, 13 are common in the diet of wild and domestic ungulates. Bhattacharya *et al.* (2012) studied the diets of various wild ungulates and their overlap with livestock. At Bedini-Ali, of the total 53 food plant species recorded in the study area, 26 (49 %) were consumed by both wild ungulates and livestock. Bagchi *et al.* (2002) revealed that livestock removes a considerable amount of forage (nearly 250 kg of dry matter/day by certain species).

Objectives

The objectives of this study were to generate baseline information regarding the herding practices of the pastoralists along with documenting the migratory routes, traditional management practices, their views and income through pastoralism. The second objective deals with resource use by the livestock after entering the study area.

The present investigation in Upper Dhauli Valley, a cold arid region in the buffer zone of Nanda Devi Biosphere Reserve was undertaken with the following objectives.

1. To assess the patterns of livestock grazing
2. To assess resource use by livestock

Key research questions

Using the data collected from the study area, the specific research questions attempted to answer are as follows:

1. What are the pastoral communities' migration and herding patterns? And
2. What are the preferred forage plant species by the livestock in the study area?

3.2 Methodology

During the summer months, the transhumant pastoralists are scattered in the entire alpine regions of the western Himalaya. Some of the pastures in Uttarakhand are Bedni, Ali, Dyara, Gidara, Sahstratal, Auli, Rudranath, Pindari, and Chhiplakedar. Except for the alpine regions of a few protected areas, most of the alpine regions are used for grazing. Niti valley situated in the Trans-Himalayan zone of Nanda Devi Biosphere Reserve (NDBR) in Uttarakhand state is one of the areas used by these migratory pastoralists in the summer months. These transhumant herders are generally people who belong to the lower elevations of the Himalaya, whose primary occupation is to rear livestock and small-scale agriculture. They bring their herds to higher alpine meadows during summers for grazing. All the groups visiting the area have to furnish their personal details i.e. about their herd composition, their duration and location of stay to the Indo-Tibetan Police Force (ITBP) officials at Ghamsali check post as well as to the headman or village head of the villages, as the Niti valley is situated on the border of India and China. Resource use by livestock was assessed through the plant species consumed by the animals through direct observation as well as pellet analysis of the livestock. Simultaneously, pellets of Blue sheep (bharal) were opportunistically collected and were analyzed further for understanding the dietary characteristics of the animal in the valley.

3.2.1 Field methods

A reconnaissance survey was undertaken to gather information regarding the number of migratory pastoral groups and the location of their summer camps. Information on their location was also obtained from official sources, e.g., the village headman and ITBP officials.

Resource use by herders

Eight shepherd groups visiting the study area were interviewed to get information on the patterns of pasture use and the seasonal movement patterns following Rawat & Adhikari (2005b). Each group comprised of two to four persons (average number of persons accompanying the livestock is 3.4±0.3 persons per group), all males, along with three to four horses/mules and three to four dogs (Tibetan mastiff, a breed of the high altitude region). The shepherds within one group may or may not be family members. They are persons from the same village who bring their herds together for summer grazing. Sometimes, they also bring the livestock belonging to other people of their native villages. These people would hire these shepherds to take their animals to alpine meadows during summer. The money paid to these shepherds for bringing their animals varied between Rs.60 to Rs.150 per animal (usually sheep or goat) with an average price of Rs.111.25±12.31 per animal per season. During their migration and stay in the valley all the members in the group does not remain continuously with the herder for the whole grazing season of four-five summer months; instead they make groups of two or three shepherds, and at one time one group stays with the animals, while the others go back to their families. The data on the native village, migratory route, stay period, perceptions regarding the conservation of alpine meadows were gathered through a semi-structured open-ended questionnaire (Balram & Dragicevic 2005; Gedif & Hahn 2003; Mbow *et al.* 2000; Burgess 1982).

Food habits of livestock

The food habits of livestock were studied by direct observation following Wallmo *et al.* (1973) and Bagchi *et al.* (2002). To identify forage plants, food habits of livestock was studied using focal sampling using binoculars (8x40) and was cross-checked through interviews with the migratory herders. The plant species consumed and the number of bites on each species was estimated by observing the individual animal. A continuous sequence of 10–100 bites were considered to be a single feeding event, and after 100 bites a different individual was chosen for observation (Wallmo *et al.* 1973; Bagchi *et al.* 2002). Since the accuracy of the method depends on the identification of individual plant species (Wallmo *et al.* 1973), all grasses and sedges were categorized as graminoids, as identification at the species level in the field was not possible. The herb and shrub species growing in the pastures were identified and recorded separately. The animal group was followed from morning hours (9:00 hours) when the flock left the camp till evening (17:00 hours) when they returned to the camp. The food habits of livestock were assessed through dung analysis, a widely accepted method used to study the diet of ungulates (Holechek *et al.* 1982; Green 1987; Mishra 2001; Shrestha *et al.* 2005; Bhattacharya *et al.* 2012; Plate 4).

Dung Analysis

For dung analysis, twenty samples of dung/pellets for each animal species (cattle, livestock, horses, mules and blue sheep) were collected. The method for dung analysis given by Holecheck *et al*. (1982) was used to study the food composition of ungulates. It involves the micro-histological analysis of dung and its composition with reference slides of plant species available in the area. The steps are as follows:

Preparation of plant reference slides

The dried plant samples were ground using a grinder with a 1mm mesh to regulate the size of the material. These are stored in plastic vials and proceed for micro-histological examination based on the method of Sparks & Malechek (1968) with a modification in the bleaching process.

A small quantity of plant material is washed under running water over a fine sieve to remove very fine particles that are too small for identification and may hinder the identification of other fragments. The materials remaining in the sieve is then transferred to a microscopic slide. To this added a drop or 2 of Hertwig's cleaning solution is added (Scot and Dhal 1880). The slide is then slightly heated until the liquid evaporated. The solution acts as a cleaning agent in removing the pigments by its bleaching action. After the slide has cooled, a drop of Hoyer's mounting medium was added to it; the plant material is mixed with a pointer and spread evenly on the slide. A coverslip is then placed on the content. The slide is then heated slightly to remove excess mounting medium and cooled on a moist cloth to remove air bubbles below the coverslip. The slides are oven dried at 60^0 till the mounting medium had hardened.

Modified bleaching method

A small quantity of sample is soaked for 8 to 10 hrs (overnight) in 6% H_2O_2 (Hydrogen Peroxide). The material is then washed over a fine sieve to remove very fine particles and the remaining pigments and H_2O_2. The material remaining in the sieve is then placed on a slide and then mounted in Hoyer’s solution, as mentioned earlier. The procedure was repeated for all the species.

Micro-histological analysis of fecal samples

Fresh pellet samples of livestock were collected. The pellet samples were dried and ground over a 1mm mesh grinding machine. The material was processed by the second method since it gives better results. For each sample, five slides were prepared, and the frequency of fragments of various plant species was estimated.

Floristic diversity

A systematic survey of vascular plants was undertaken during the growing season from May to October in the years 2012 and 2014. Within each pasture, plots (50×50m) were selected and twenty-five 1×1m quadrats were laid randomly within each such plot for vegetation quantification following Misra (1968) and Rawat & Adhikari (2005a); details are given in chapter 4.

Biomass utilization by livestock

The biomass utilized by livestock was investigated by clipping the available biomass in the area before and after incidences of grazing. During the study, the aboveground biomass was estimated using harvest method (Negi *et al.* 1993) from each site closest to the ground, by ten selected 1mx1m quadrats before livestock reached the area (A). After grazing, when the livestock has left the area, ten quadrats adjacent to the previous quadrats was harvested (B). The utilized biomass was obtained as the difference (A-B= utilization by livestock) between the two cases.

3.2.2 Data Analysis

The data obtained from the herders through questionnaires were analyzed in MS-Excel. Percentages and averages were calculated to interpret the opinions of the herders regarding various questions asked. Names of the places/villages which were used as stopovers by the herders during their migration were obtained from the herders themselves. Later on, the co-ordinates of some of these places were recorded using Garmin GPS device while the rest of the points were obtained using toposheets. The toposheets of the region was available from the library of Wildlife Institute of India, Dehradun. Digital Elevation Model (DEM) was used as a background for plotting the co-ordinates of the selected locations in ArcGIS 9.3 (ESRI 2008). Route map of each group of shepherd's migration route was generated using ArcMap 9.3 (ESRI 2008). The maps visualize the location of the camps in the upper Dhauli valley along with the locations that it visits during its migration from lower altitude to a higher altitude and from higher altitude to lower altitude.

All the data collected was analyzed using MS- Excel. Food selection by animals was measured using a modified version of Ivlev's electivity index (Jacobs 1974) calculated as:

$$D=(r-p)/(r+p-2pr)$$

Where r is a fraction of the given plant species in the animals' diet, p is explained as a fraction on the same plant species available in the environment.

Diet composition of livestock was estimated as the number of different plant species the animal was seen feeding on, during the study. The frequency of a species in diet composition was calculated as the percentage of total bite count recorded for the species divided by the total number of bite in all the species in diet.

Diet composition of all the animals was compared to understand if any significant difference exists among them. Kruskal-Wallis (Kruskal & Wallis 1952) test was conducted to test the difference between the diet compositions between the five domesticated animals *viz;* sheep, goat, mule, horse, and cattle in the study area.

3.3 Results and Discussions

3.3.1 Pattern of herding

The pastoral groups enter the upper Dhauli valley during mid-June and settle into different pastures distributed in the valley. Of the three prominent valleys present, Amrit Ganga and Kalajowar are visited by one pastoral group each, while six pastoral groups spend their summer in different pastures in Ganesh Ganga. The shepherds came from different villages/blocks in Chamoli districts such as Ghat (50%), Pana (25%), Ramni (12.5%) and Birahi (12.5%; Table 3.2). They have permanent settlements in these villages and are involved in agriculture and other activities for their livelihood. Usually, one or two male members of the family move out from the village with the herd over summer to the alpine region, while the rest of the family stays back, taking care of the crops. The group may visit the same area every year, and the selection of summer grazing area is mainly based on their assessment of the quality of fodder and area available.

Table 3.2. Pastoralist group's details with their winter and summer pastures

Pastoralist Group	Native Villages	Winter pastures	Number of shepherds in the group	Number of animals		Summer Pastures in UDV
				Total Number of sheep	Total Number of goat	
Herd 1	Pana	Pana	4	400	300	Lal Dhang
Herd 2	Charbang, Ghat	Gairikhet, Nainital	3	455	170	Sheilakang Pass
Herd 3	Ghat	Ghat	4	550	300	Thali
Herd 4	Pana	Pana	3	425	100	Geldung
Herd 5	Ramni/ Pana	Pana	3	300	75	Geldung
Herd 6	Ghat	Ghat	2	430	270	Dhaman Payar
Herd 7	Ghat	Ghat	4	600	400	Kalajowar
Herd 8	Birahi	Birahi	4	650	400	Keolangmandi /Geldung

The shepherds have no land ownership rights in the valley and have to pay grazing fee to the respective village head for grazing their animals during the season. The fee, locally known as *charan* is paid to village *panchayat* (an institution of self-government for the rural areas) for using the pasture. *Charan* is paid according to the number and kind of animals belonging to the herders' groups. The average *charan* is Rs. 5.62 per sheep/goat and Rs. 70.62 per horse/mule for the entire season. This can be considered as an indigenous method for regulating land use by the pastoralists. Since the pastures are not freely available and a fee is imposed on them, the shepherds avoid overcrowding, i.e., one alpine pasture is usually occupied by one shepherd group. The shepherd giving *Charan* to panchayat of Gamsali village stays at an adjoining alpine area locally known as *Dhaman payar*. This kind of traditional management system has also been observed in other parts of the Himalayan region, wherein the headman decides areas for animal grazing. Changpas of Changtang in Ladakh and Bhutias of Lachen and Lachung have similar regulation for communal pastureland with strong community regulation of land usage (Bhasin 2011). In the year 2012, only one such shepherd group occupied the *Dhaman payar*. Shepherds, who paid

Charan to Niti village *panchayat*, spend their summers in areas locally known as *Kalajowar*, *Gothing*, and *Geldung* area. The pastoralist groups (70%) halt at Niti before moving on *Kalajowar*, *Gothing* and *Geldung* area. They buy their food rations there since Niti is the last village of the Indian territory on this route. *Geldung* area, with an elevation range from 4400-5500m, has three mountain passes where these shepherds go for grazing: Niti pass, Lepcha pass, and Selakang pass. Other than these passes, a few pastoralists (one or two groups) also tend to stay in adjoining areas locally known as *Laldhang* and *Keolangmandi*.

Herd composition

The total number of livestock with these eight herder groups was 5914, of which 64.4% were sheep and 34.1% goats. Horse and mules constituted a very small percentage (less than 2%) of the herd (Figure 3.1). Sheep are reared for wool as well as meat, while goats are an important source of meat and to a lesser extent for their rough wool (the long outer body hair) used to make rope and handicrafts (Plate 3). Horses and mules are used primarily for carrying loads (ration and clothing). Each herder group keeps three to four dogs for the safety of livestock, protection from wild animals such as common leopard, wolf, and jackal in the lower regions and snow leopard and feral dogs in the alpine regions. An average percentage of 32.75±4.19 livestock belongs to the accompanying herders while the rest is other villagers' livestock that they bring for summer grazing. This is also a way for income generation apart from the sale of wool for the herders.

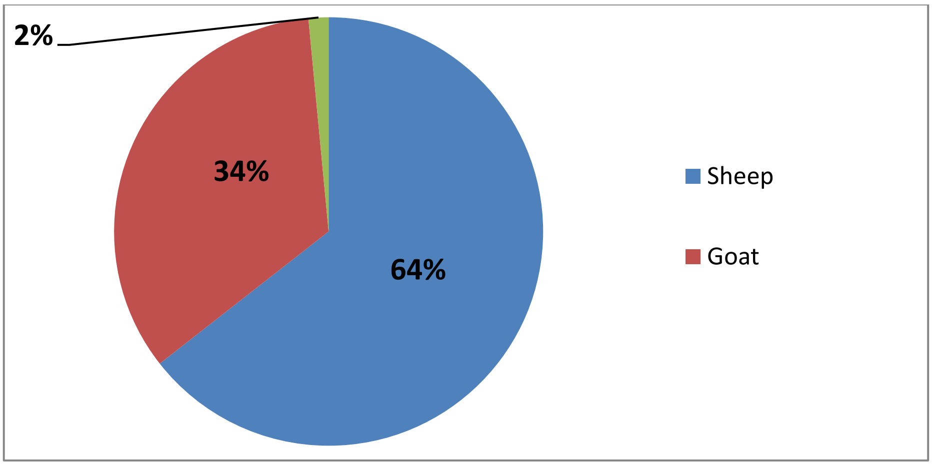

Figure 3.1. Grazing herd composition visiting the valley

Sustenance during migration

For livelihood, while they are in the alpine valley, the shepherds sell sheep and goats to the resident villagers which they buy to sacrifice during religious ceremonies and sometimes only for meat. The shepherds also sell wool to the villagers and sometimes part of *charan* is paid in the form of wool. The prices offered for the wool varies, it depends on the quality and the colour of the wool. Wool with fewer impurities fetches more money. During grazing seeds and fruits of plants like *Xanthium* sp., *Rumex nepalense* and other plants get stuck to the body of the animals. These are considered to be impurities since time and money has to be spent to get them removed from the wool before further processes. The price of wool per kg varies from Rs. 20 to Rs. 45, with an average cost of Rs. 36 per kg. Usually black coloured wool fetches a higher price up to Rs. 46 per kg as compared to white or grey coloured wool (Table 3.3). The black coloured wool is preferred by the buyers as no money is spent on dyeing and it is preferred by the buyers for making *pakki* (a type of local garment for the women).

Table 3.3. Prices of wool as told by different herders in 2012

Pastoralist Groups	**Selling Price of wool (Rs.Kg^{-1})**	
	White	**Black**
Herder 1	40	45
Herder 2	45	60
Herder 3	30	45
Herder 4	40	40
Herder 5	20	35
Herder 6	35	45
Herder 7	40	50
Herder 8	35	50

The income generated through the sale of wool is Rs.16106±1837 group^{-1}. Apart from the sale of wool, there is another source of income for the herders, i.e., by charging money from the people whose livestock they bring during migration. Income from such activity is Rs. 53781±7782 season^{-1}. Gross income for during the season through pastoralism (wool sale as well as from money received from other villagers) is Rs.69888±8445 group^{-1}. As mentioned earlier each herder groups need to pay a royalty to the village head where they intend to graze their livestock, the average cost of grazing in the valley amounts to Rs.5234±1600 group^{-1}season^{-1}. Net average income, which is the money the pastoralists has after paying the royalty for grazing their animals is Rs. 64654±9166 group^{-1}. Individual income during the season was estimated to be Rs. 19558.4±2713.

Routes and common camping places

Eight different routes were documented based on the descriptions given by the herders (Figure 3.2a-3.2h). They came from different regions of Uttarakhand, some spending their winter months in their respective villages while others migrated further down to Bhabar area in Gairikhet. Out of the eight herders interviewed, six of them spent the winter months in villages of Pana and Ghat (three in Pana and three in Ghat, respectively). The remaining two spent the winters in Birahi (one herder's group) and Gairikhet (one herder's group). These pastoralists groups have permanent houses in the lower elevations, where they spend the winters while moving to higher pastures in summer. In this respect, their pattern of migration is quite similar to that of Gaddis of Bharmour, Himachal Pradesh and Bhutias of Lachen and Lachung, Sikkim who have permanent houses at middle altitude. Gaddis and Bhutias move with their flocks to high altitude in summer and lower altitude in winter (Bhasin 1988, 1989, 1996). The herders went to pastures locally known as Keolangmandi, pastures of Geldung, Lal Dhang, Sheilakang pass, Thali and Kalazabar near Niti village and Dhaman near Ghamsali village. Apart from the summer and winter stopovers, the herders named 74 other places which were used by them during their migration. Some of the places used as stopovers by the eight herders were common while some differ. Most common places that were used by all the herders entering or leaving the valley were Gaddi Bridge or Suraithota and Kuwari pass. Rewal Bagar near Gurgutti village in the Niti valley and Tapovan followed the list of favorite stopovers with 87.5% of the herders using them as stopovers. The stopovers are mainly small villages/outskirt like Rewal Bagar, Suraithota, Irani Village or villages with market places like Dhakwani, Tapovan or alpine or forested areas such as Kuwari Pass, Sem Kharak. They stop in small villages or outskirts of villages to rest for the day and resume their journey again. Villages like Tapovan, Suraithota are treated as markets where the pastoralists replenish their resources like food items and sell wool to shop keepers or animals for slaughter to butchers. During their journey, they stop at alpine meadows and forested areas for few days to months to rest and graze their animals in the alpine or forested areas in between the lower altitude winter pasture and the alpine pastures.

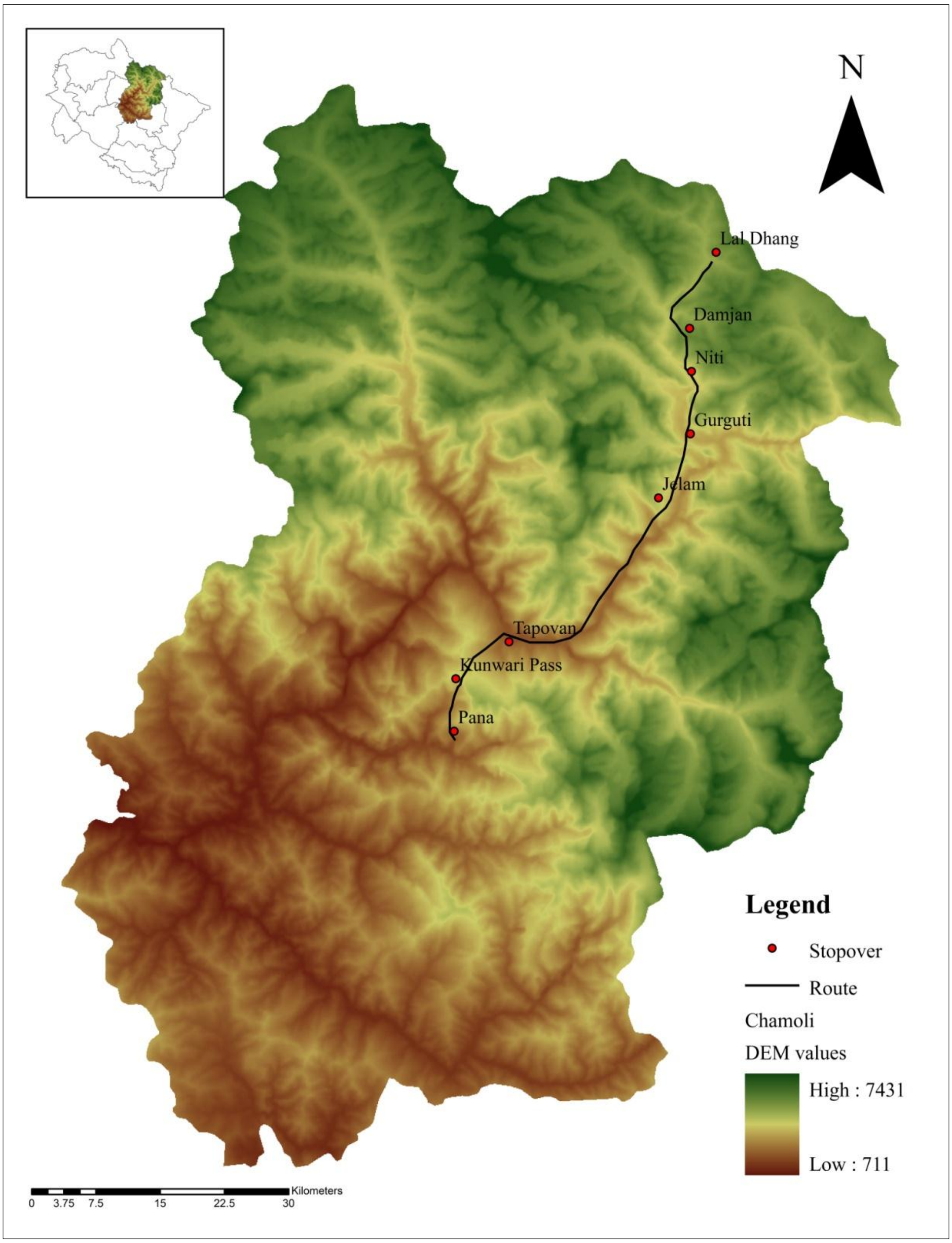

Figure 3.2a. Route used by pastoralist group 1 while visiting the valley during summer months

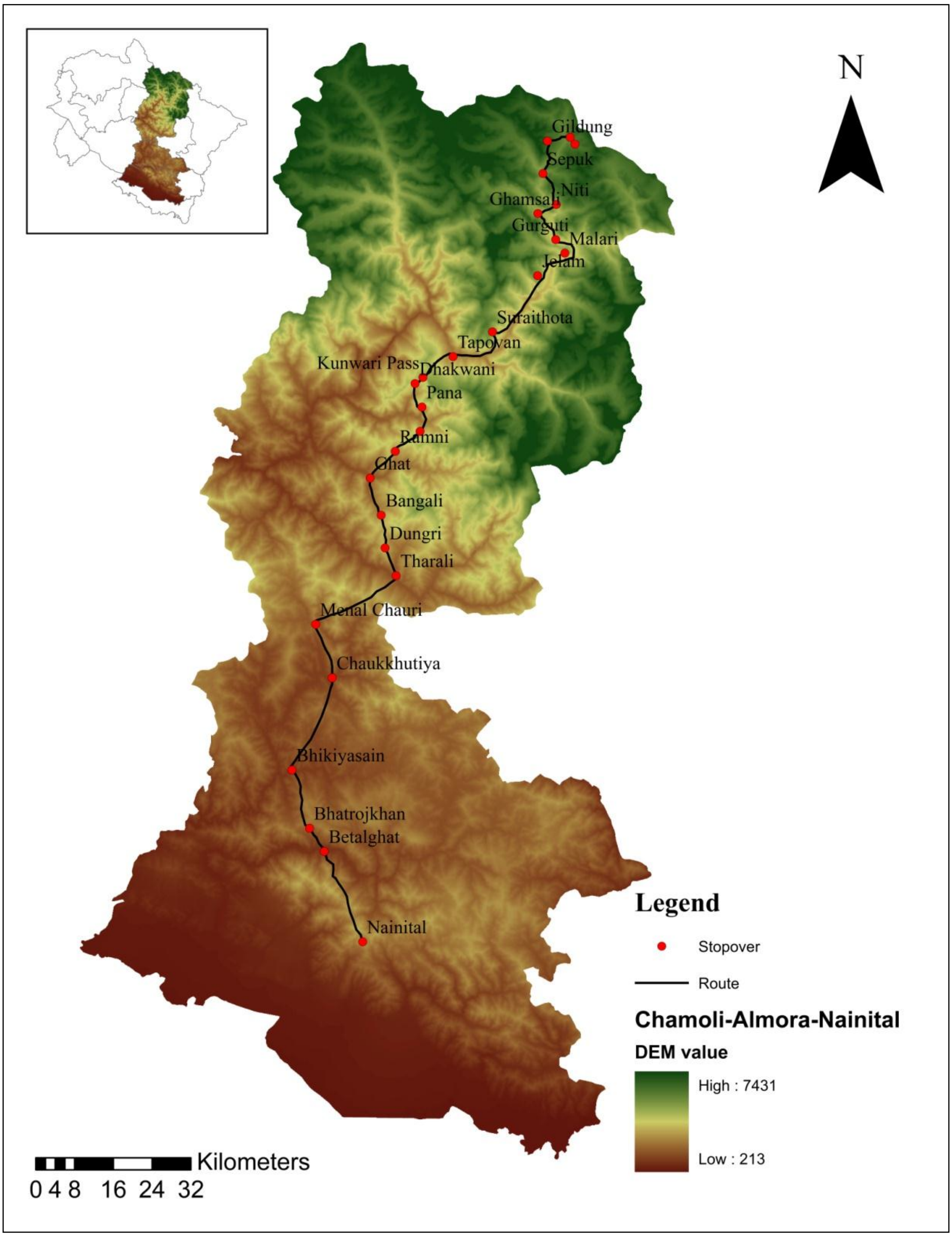

Figure 3.2b. Route used by pastoralist group 2 while visiting the valley during summer months

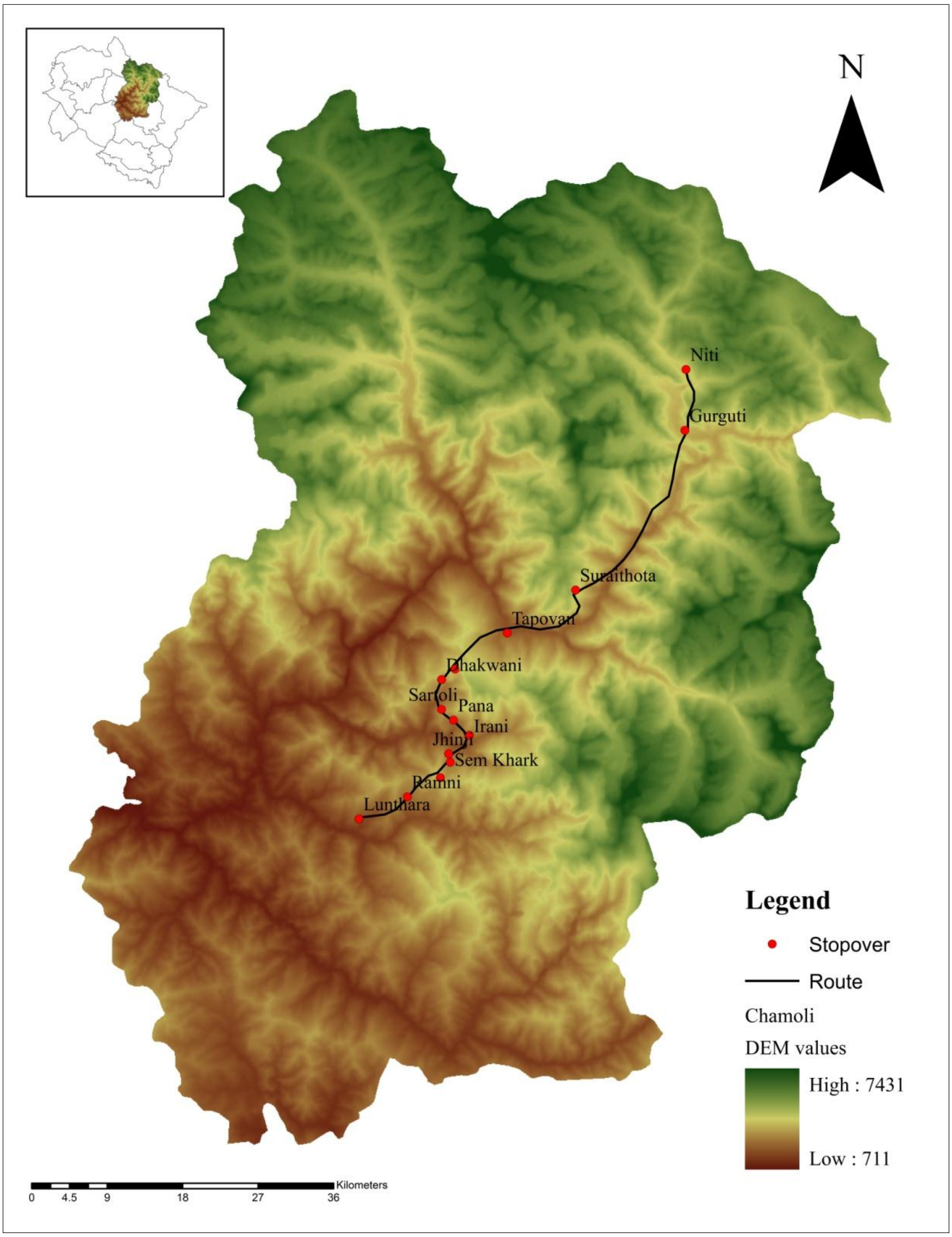

Figure 3.2c. Routes used by pastoralist group 3 while visiting the valley during summer months

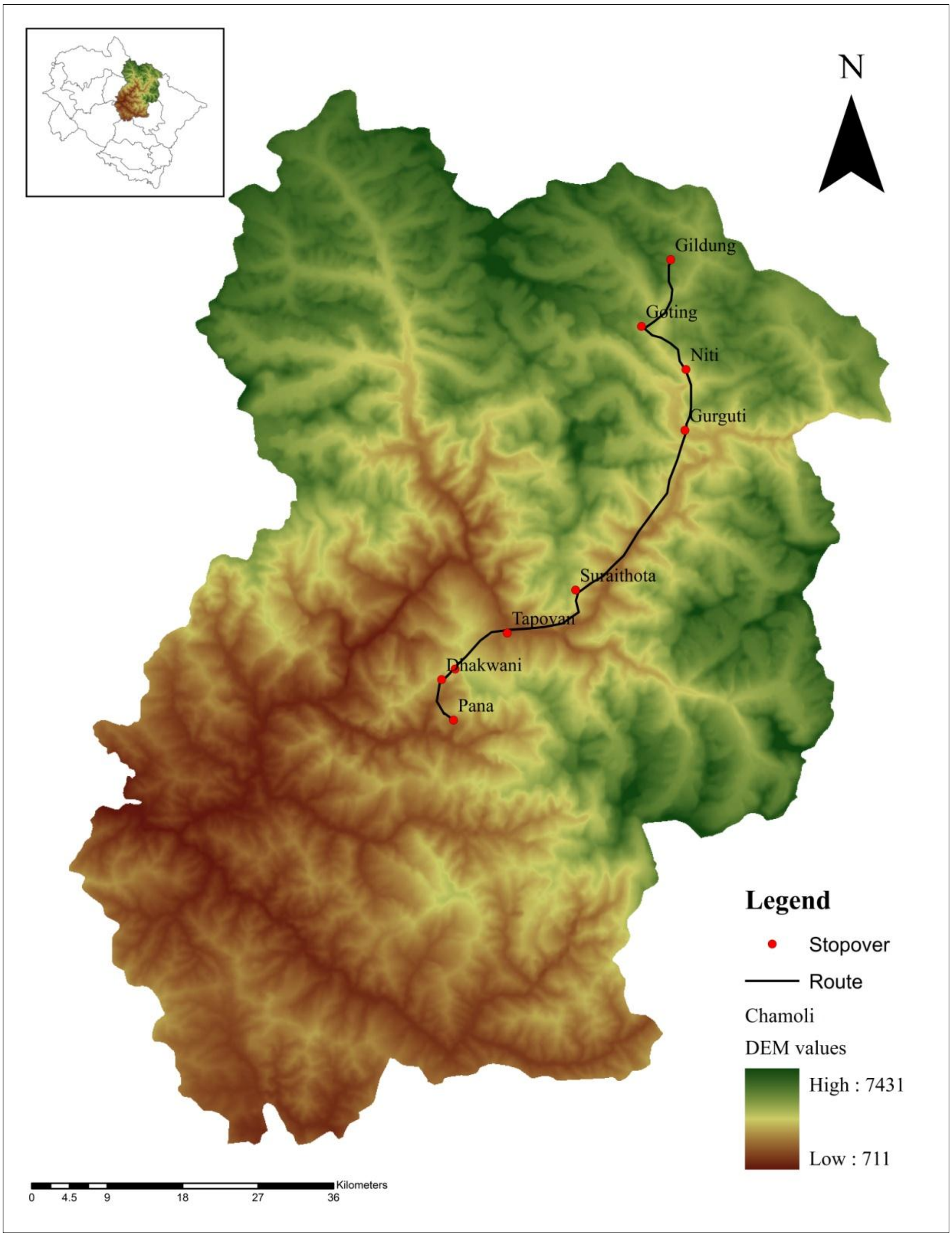

Figure 3.2d. Routes used by pastoral group 4 while visiting the valley during summer months

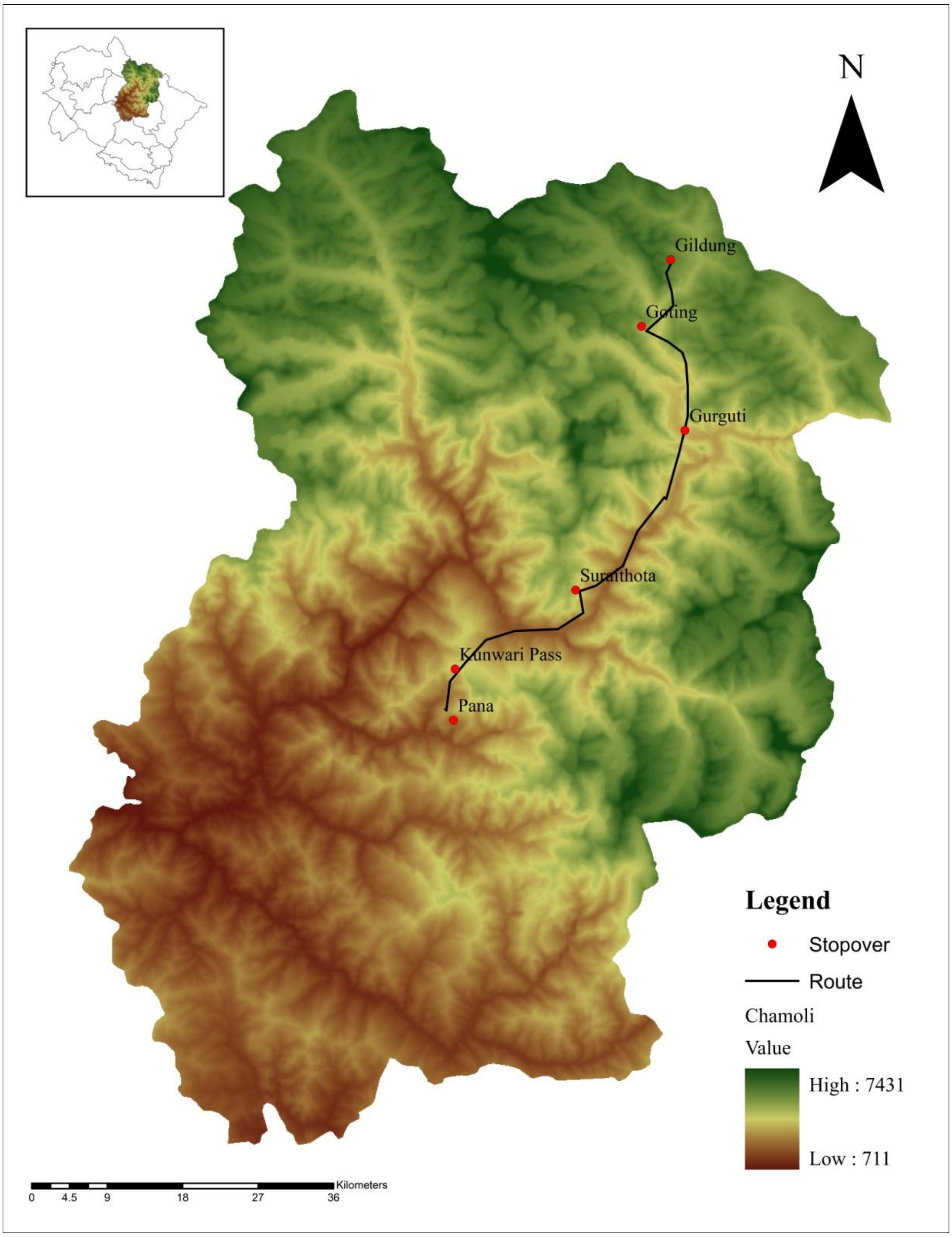

Figure 3.2e. Routes used by pastoral group 5 while visiting the valley during summer months

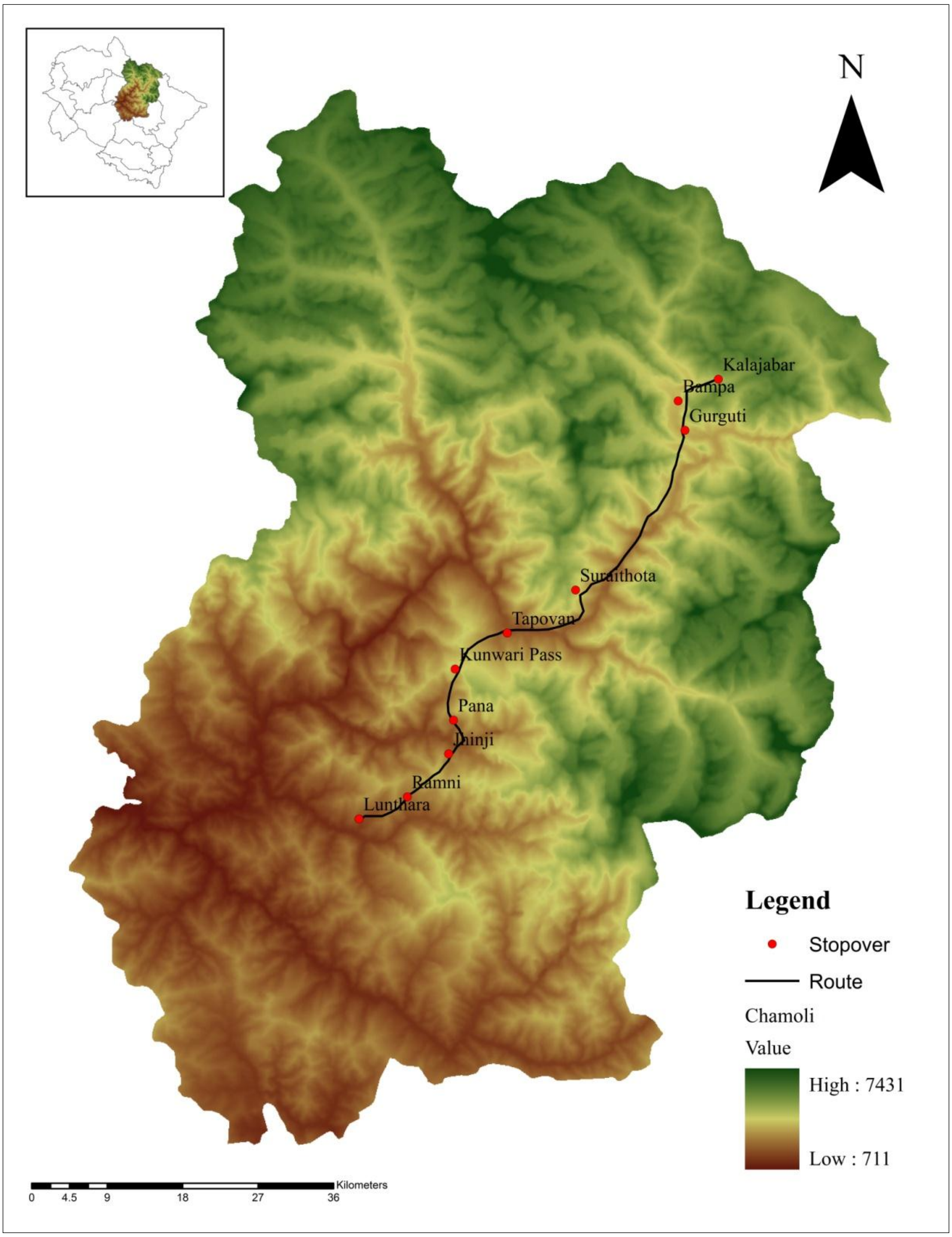

Figure 3.2f. Routes used by pastoral group 6 while visiting the valley during summer months

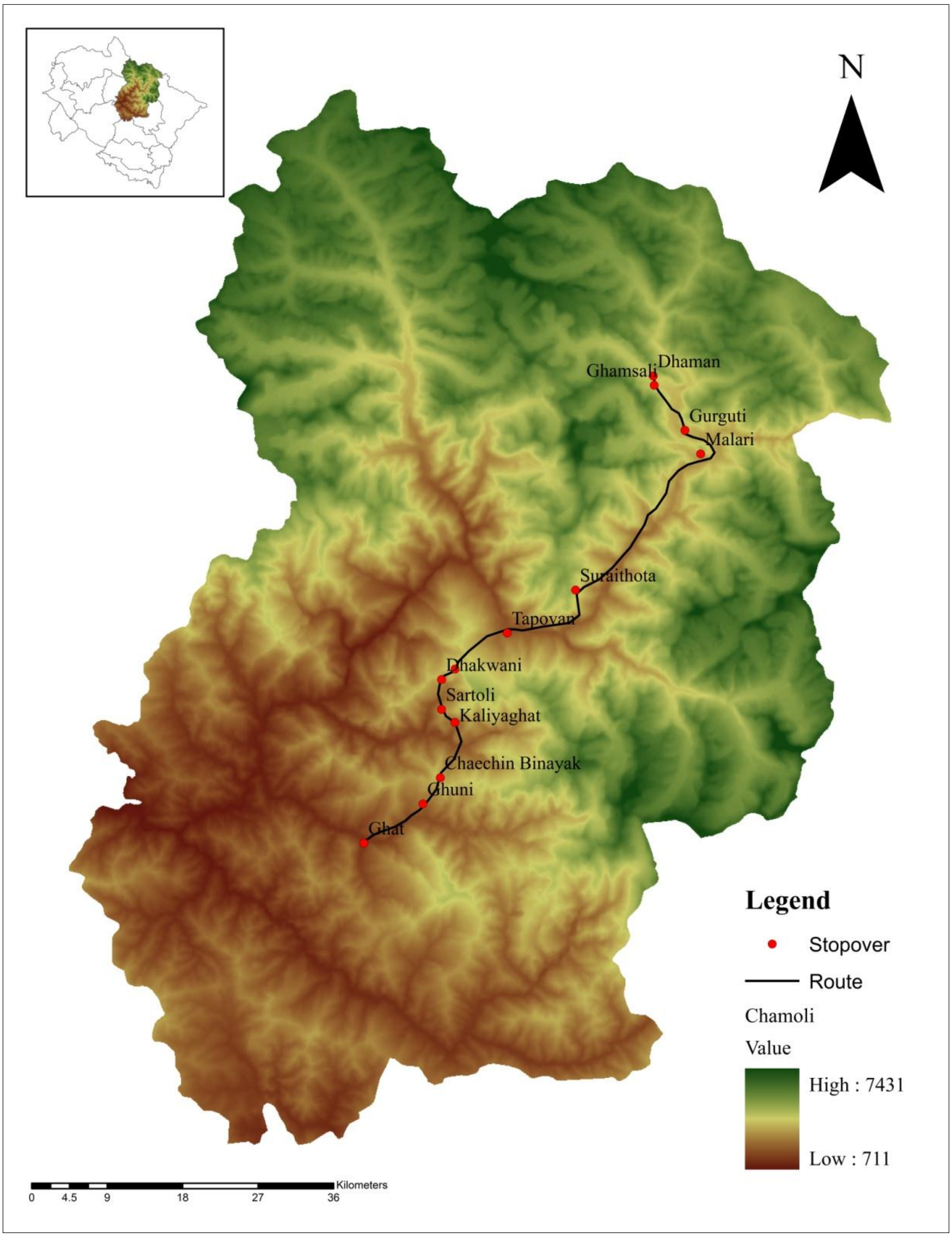

Figure 3.2g. Routes used by pastoral group 7 while visiting the valley during summer months

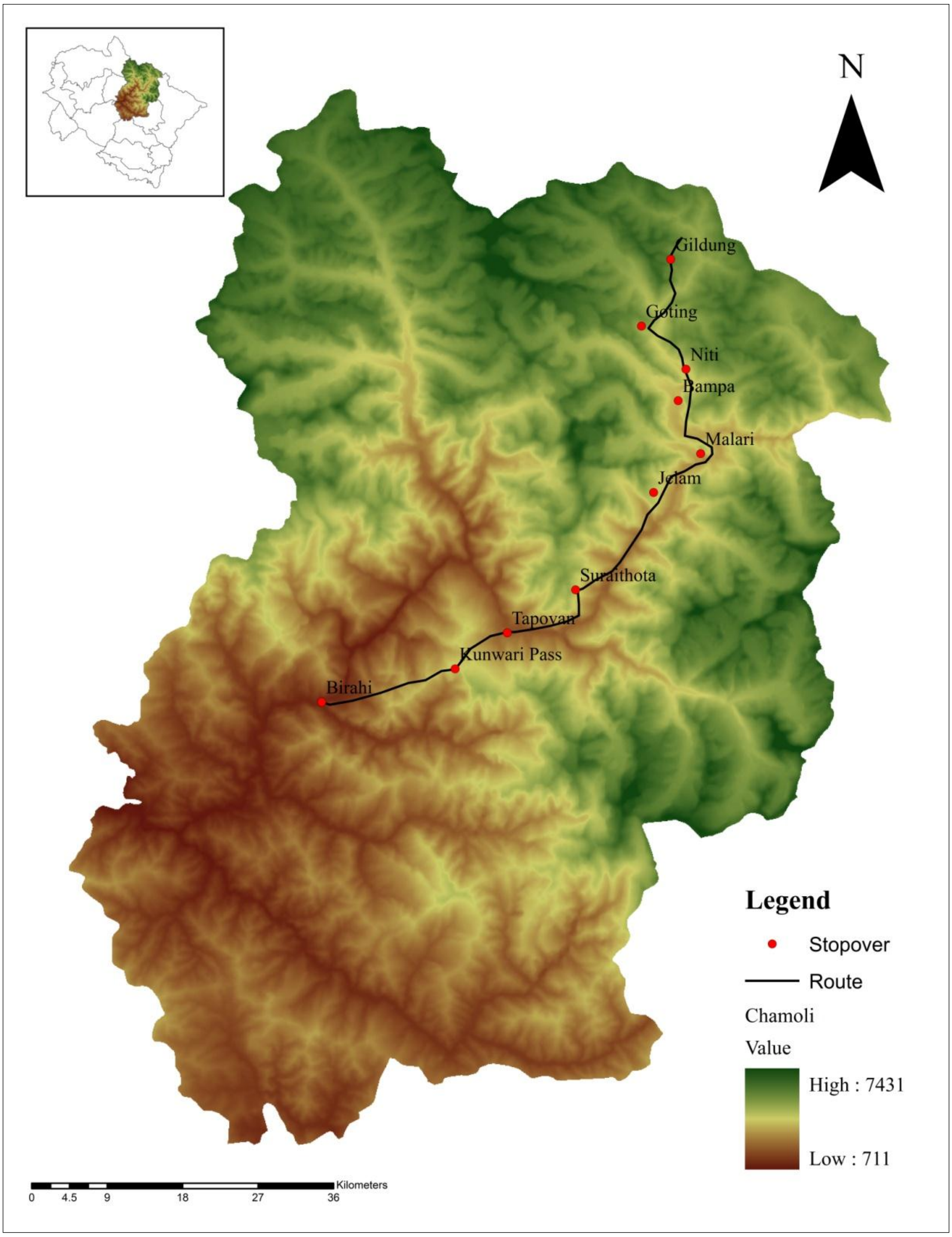

Figure 3.2h. Routes used by pastoral group 8 while visiting the valley during summer months

Use of common camping sites

The areas which are most common camping sites of transhumant pastoralists during the migration are Kuari pass and Tapovan (Figure 3.3). Kuari pass (3640m) is a junction where most of the shepherds from lower altitudes camp for a few days to rest and then disperse to different alpine areas. Tapovan, a small town, is the last major market enroute to Niti valley. They also do business with the local villagers by selling their animals; since markets are important in permitting them to exchange their unique goods for grains and other necessities of life nearly all the groups visiting the valley spend a considerable amount of time here. Shepherds take the motor road from Tapovan to their summer camps and halt at several places at night. The routes taken by the eight shepherds and the use percentage of different stopovers are indicated in Figure 3.3. The use percentage of these camping sites were calculated based on the number of groups mentioned that they halt at these places.

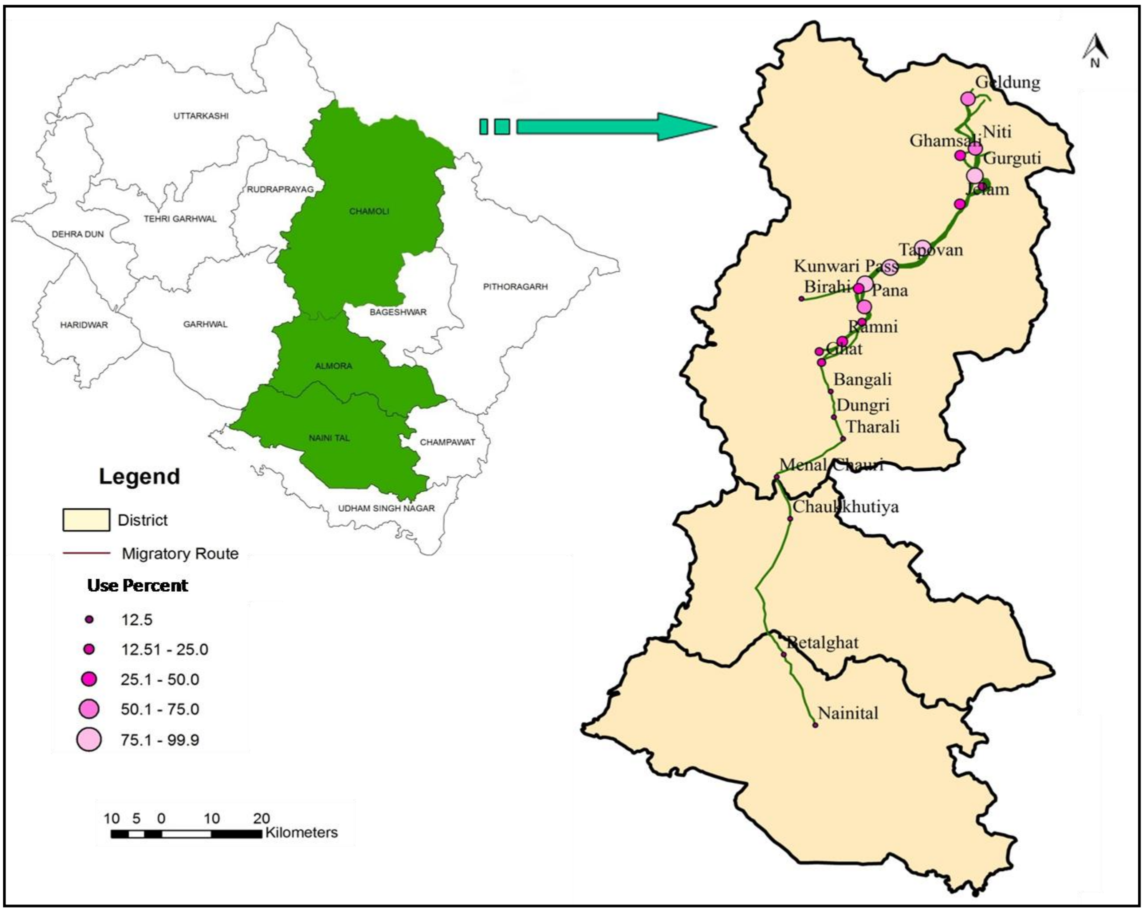

Figure 3.3: Percent use of different places along the route followed by transhumant herders visiting Niti Valley (Map not to Scale). Use Percentage: The percentage of herders using a place. Inset: Map of Uttarakhand

The duration of their stay in Niti valley depends on the availability of fodder and climatic conditions, mainly precipitation. Generally, the shepherds stay in the valley for three to four months, from late June to August. There are various environmental issues linked with grazing, fodder and firewood collection from the forests. Moreover, there is an increasing chance of danger of human-wildlife conflict due to habitat fragmentation and destruction by humans, and resource competition, as the forests and alpine meadows provide habitat to many wild mountain ungulates such as bharal (*Pseudois nayaur*) and Himalayan tahr (*Hemitragus jemlahicus*) and carnivores such as common leopard (*Panthera pardus*), and snow leopard (*Uncia uncia*).

Livestock loss during migration

Over their usual stay and migration from foothills to alpine regions and back, the shepherds come across many challenges, such as livestock mortality caused by natural factors (by wild carnivores, e.g., leopard, rains, landslides, road accidents and occasional encounters with thugs; Figure 3.4). All the herders reported the loss of their animals due to accidents both natural and human-induced. Natural accidents include cases of livestock getting injured due to landslides, rolling rocks or falling from a cliff during grazing, while accidents caused by humans include loss of livestock due to road kills during the journey. Predation of livestock by wild carnivores like common leopard (in lower altitudes) and snow leopard (high altitude pastures) along with feral dogs are next common reason cited by the herders (50 % of the respondents mentioned the reason in each case). The shepherds (25% of respondents) also mentioned that some animals are lost due to diseases, while 12.5% of respondents reported the theft of animals during migration as one of the causes for animal loss.

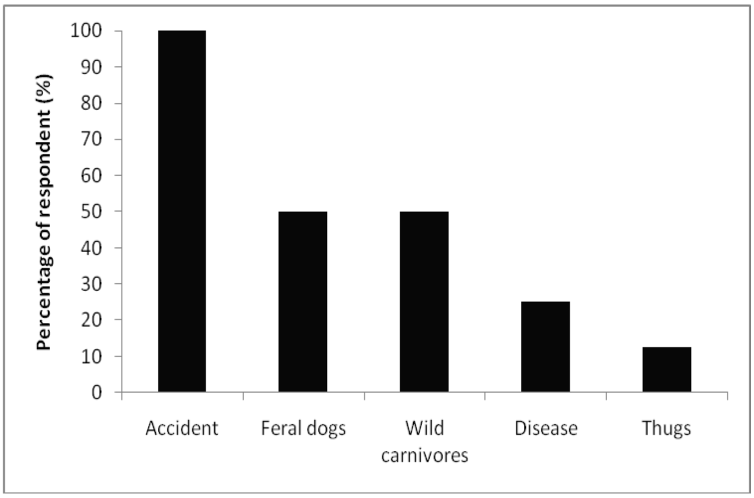

Figure 3.4. Reasons behind livestock mortality based on respondents answer (n=8 groups)

Perceptions towards conservation

The herders were asked about their perceptions regarding the creation of protected areas for the conservation of wildlife. The pastoral groups visiting upper Dhauli valley, 75% of the herders gave a positive response, while 12.5% of the respondents thought of it negatively and remaining 12.5% of the respondents were neutral (Figure 3.5). Bhiru *et al.* (2017) and Mir *et al.* (2015) also reported similar results where a majority of respondents showed a positive response towards conservation. Negative reactions from the respondents usually result due to the loss of their rights from the area (Kumssa & Bekele 2014). But, in this case, the pastoral groups who were interviewed had not faced any such consequences. Maybe, this is the reason for the pastoral community to show a positive response.

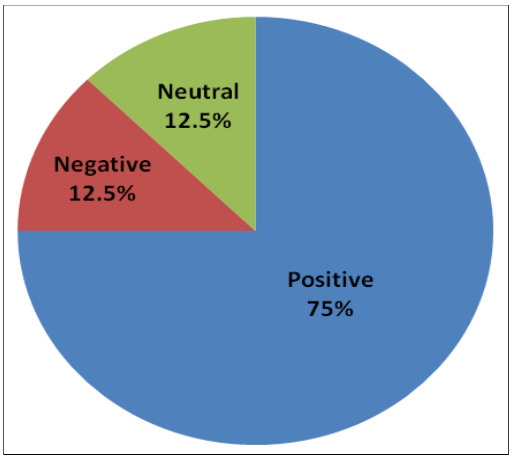

Figure 3.5. Perception of herders on proctected areas

3.3.2 Resource use pattern

Food habit of livestock

Observations were made to study the feeding habits of livestock. Total of 55 plant species was consumed by livestock belonging to 30 families (including pteridophytes). The maximum number of plant species was found in the diet of sheep (37 plant species) while mule had a minimum number of plant species in its diet (12 plant species). The dietary spectrum of cattle, goat, and horse showed 23, 22 and 22 plant species, respectively (Figure 3.6).

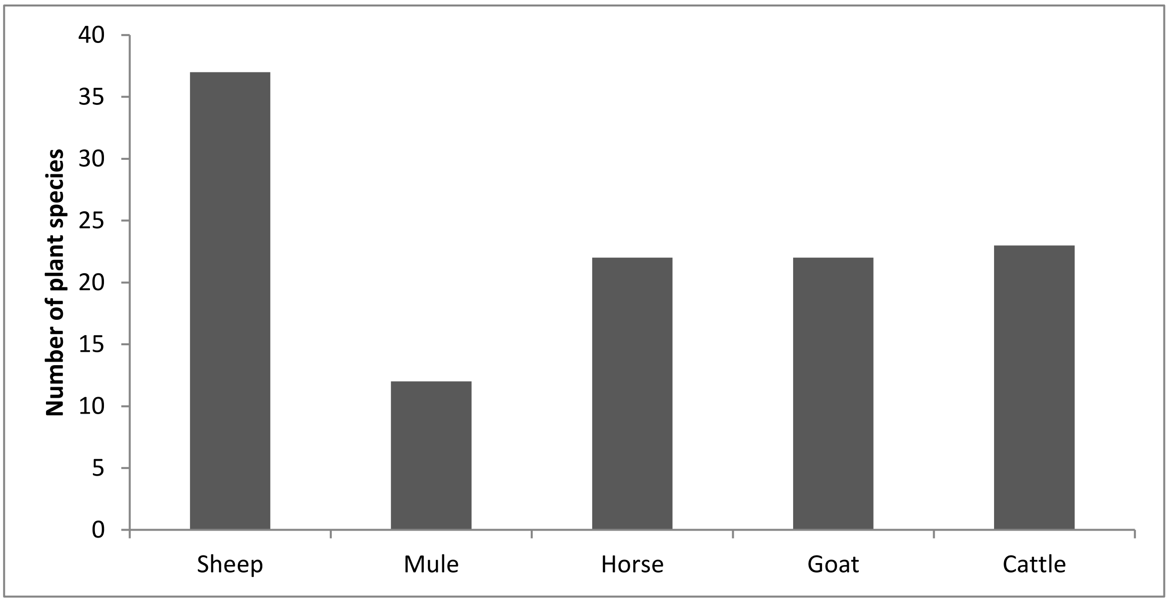

Figure 3.6. Number of plant species eaten by different animal species

Among the 30 families found in the diet of livestock, the family with most forage plants was Rosaceae comprising eight species followed by Asteraceae with six species and Caprifoliaceae with five species. Awasthi *et al.* (2003) through the perusal of previous literature also reported that the two families Rosaceae and Asteraceae has most of the forage species. The family Polygonaceae had four species, while Apiaceae, Lamiaceae, and Orobanchaceae had three species each, while family Fabaceae represented by two species. Other families (Berberidaceae, Brassicaceae, Campanulaceae, Crassulaceae, Cupressaceae, Elaeagnaceae, Ephedraceae, Equisetaceae, Ericaceae, Euphorbiaceae, Geraniaceae, Onagraceae, Orchidaceae, Papaveraceae, Plantaginaceae, Primulaceae, Rubiaceae, Salicaceae, and Tamaricaceae) represented by single species (Table 3.4).

Table 3.4. Families and number of species under each family (excluding the plants belonging to Cyperaceae and Poaceae)

Family	Number of species
Rosaceae	8
Asteraceae	6
Caprifoliaceae	5
Polygonaceae	4
Apiaceae, Lamiaceae, Orobanchaceae	3
Fabaceae	2
Berberidaceae, Brassicaceae, Campanulaceae, Crassulaceae, Cupressaceae, Elaeagnaceae, Ericaceae, Ephedraceae, Equisetaceae, Euphorbiaceae, Geraniaceae, Onagraceae, Orchidaceae, Papaveraceae, Plantaginaceae, Primulaceae, Rubiaceae, Salicaceae, Tamaricaceae	1

A total of 55 plant species (i.e., 66% herbs including graminoids, 29% shrubs, 2% trees, and 3% fern) were used by the livestock (sheep-goat), horses and mules and cattle.

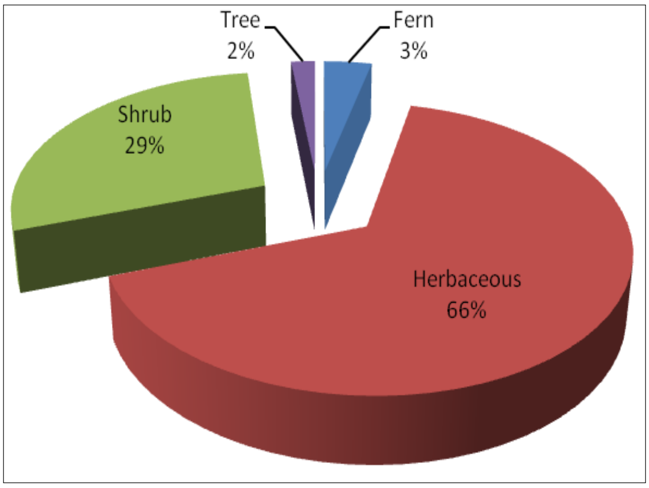

Figure 3.7. Number of plant species consumed under different growth forms

Goats preferred shrub species (12 plant species out of 21) more as compared to other growth forms present (7 species of herbs and one species of fern). Moreover, goats were noticed browsing on small trees of *Juniperus* sp. The preferences of goats towards shrubby and tree species can be attributed to the fact that they are predominantly browsers rather than grazers in their feeding habits. Sheep diet contained 25 species of herbaceous plants. Sheep were observed eating on small shrubby plants (11 plant species). Horses were observed feeding on all the growth forms except trees (1 species of shrub, 19 species of herbs and 1species of fern). Mules restricted their feeding habits to two groups *viz;* herbaceous and ferns (10 species of herbs and one species of fern). Ferns were consumed by horses, mules, cattle, and goats to a small extent (Figure 3.8). Sheep had the broadest dietary spectrum (36 species) while mules have the shortest (11 species). Horses, goats, and cattle had the same number of plant species in their dietary spectrum (21 species). Mishra *et al.* (2004) in his study in Indian Trans-Himalayan landscape also reported similar pattern in the dietary spectrum during summer with goats and cows feeding on 26 plant species whereas sheep feeding of a maximum number of plant species (32 species).

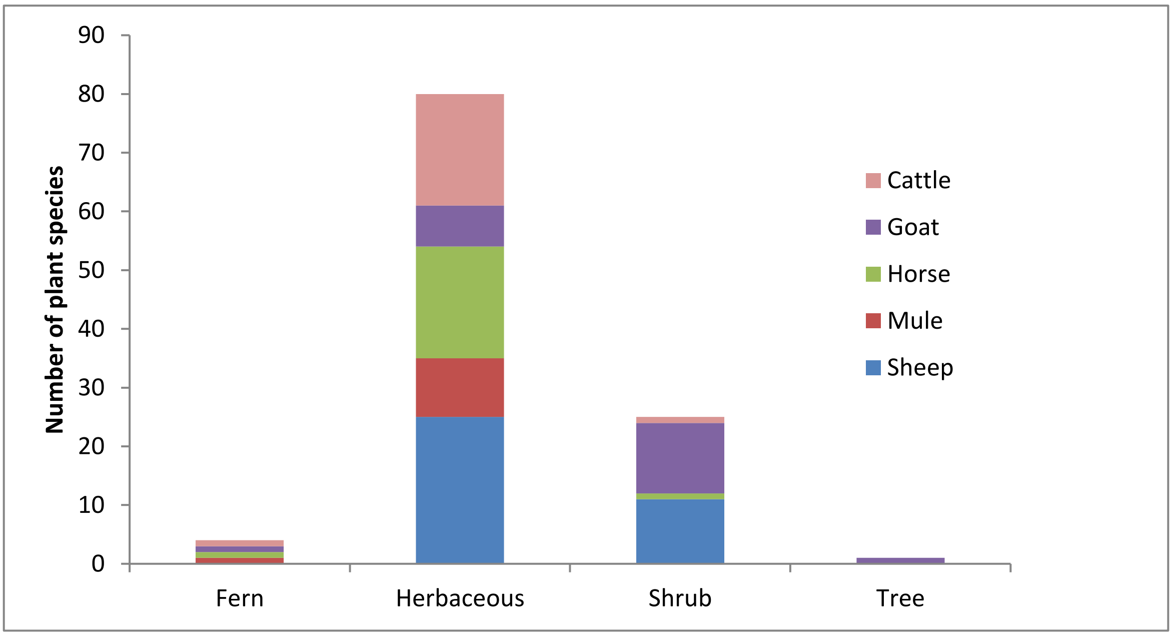

Figure 3.8. Number of plant species consumed by different animal species under different growth forms

Diet Composition

For determining the dietary habits of the domesticated animals, the dietary spectrum of sheep, mule, horse, goat, and cattle was estimated separately. Those instances where the animal took a bite but the plant species could not be identified were categorized under the group *unknown*. Species constituting less than 4% of the diet of animals were categorized as *others*. Graminoids formed the major portion of the diets of livestock (sheep=36%, mule=55%, horse=60% and cattle=52%) except for goats. Earlier workers have reported that livestock prefers graminoids during summer months (Rawat & Adhikari 2005b; Mishra *et al*. 2004).

Sheep

Sheep were recorded feeding on 36 plant species (excluding graminoids, number of bites recorded (N)= 4680 bites). They had a mixed diet with graminoids (36%) forming the major proportion of it. In case of sheep, *unknown* feeding instances constituted 5%. Graminoids formed 36% of the diet, while *Devendraea myrtillus*, *Trachydium roylei*, *Astragalus*, *Oxytropis* and *Potentilla cuneifolia* formed 11%, 10%, 9% 6% and 6%, respectively. In *others* category, 31 species were grouped, which formed 17% of the diet. The species included in this group were *Sibbaldia* (2.76%), *Rumex nepalensis* (1.90%), *Lonicera obovata* (1.82%), *Anaphalis* (1.41%), *Rosa sericea* (1.22%), *Scutellaria prostrata* (1.03%), *Cyananthus* (0.68%), *Taraxacum officinale* (0.64), *Nepeta* (0.58), *Sedum* (0.49), *Berberis jaeschkeana* (0.47%), *Euphorbia* (0.45%), *Gerbera gossypina* (0.45%), *Bistorta* (0.45%), *Devendraea spinosa* (0.30%), *Gaultheria trichophylla* (0.28%), *Artemisia* (0.26%), *Primula* (0.26%), *Herminium monorchis* (0.21%), *Cousinia thomsonii* (0.17%), *Thymus linearis* (0.17%), *Ephedra gerardiana* (0.17%), *Rosa webbiana* (0.17%), *Polygonum plebeium* (0.13%), *Salix* (0.11%), *Myricaria* (0.06%), *Bupleurum* (0.04%), *Morina coulteriana* (0.04%), *Pedicularis* (0.04%), *Galium* (0.04%) and *Ajania* (0.02%; Figure 3.9).

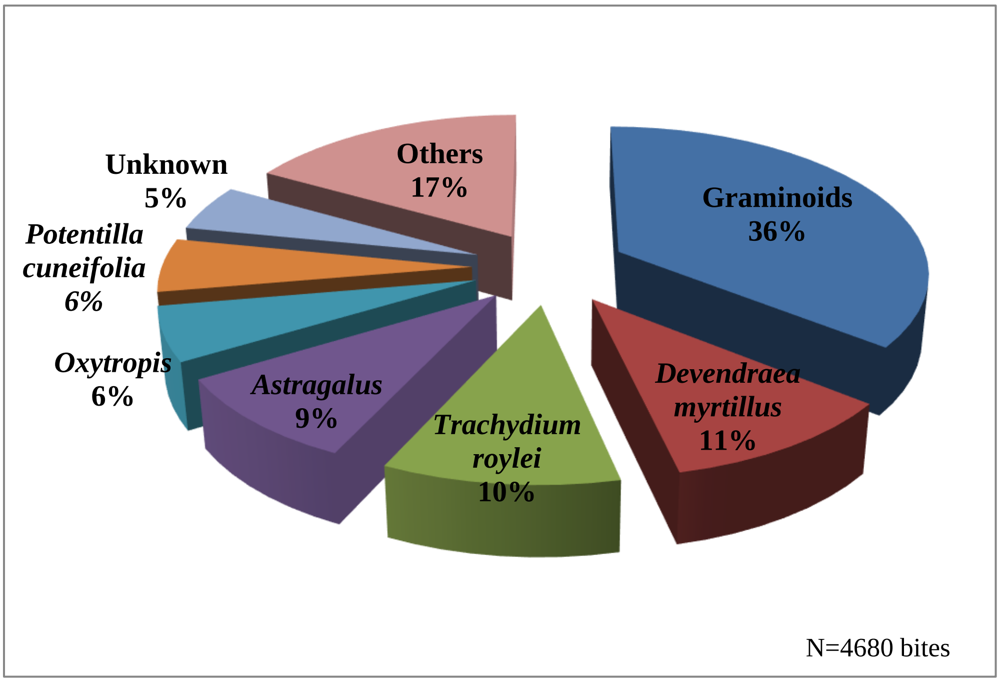

Figure 3.9. Percent consumption of different plant species by sheep (N=4680 bites)

Mule

In the case of a mule, 18% of the feeding instances (total number of bites (N)= 21292 bites) belonged to the *unknown* category. Graminoids formed 55% of the diet, while *Equisetum diffusum* and *Oxytropis* formed 12% and 8%, respectively. In *others* category, nine species were grouped, which formed 7% of the diet. The species included in the group were *Sibbaldia parviflora* (3.43%), *Trachydium roylei* (1.37%), *Thymus linearis* (0.86%), *Anaphalis* (0.33%), *Potentilla cuneifolia* (0.28%), *Potentilla* (0.13%), *Taraxacum officinale* (0.11%), *Rumex nepalensis* (0.93%) and *Artemisia* (0.07%; Figure 3.10).

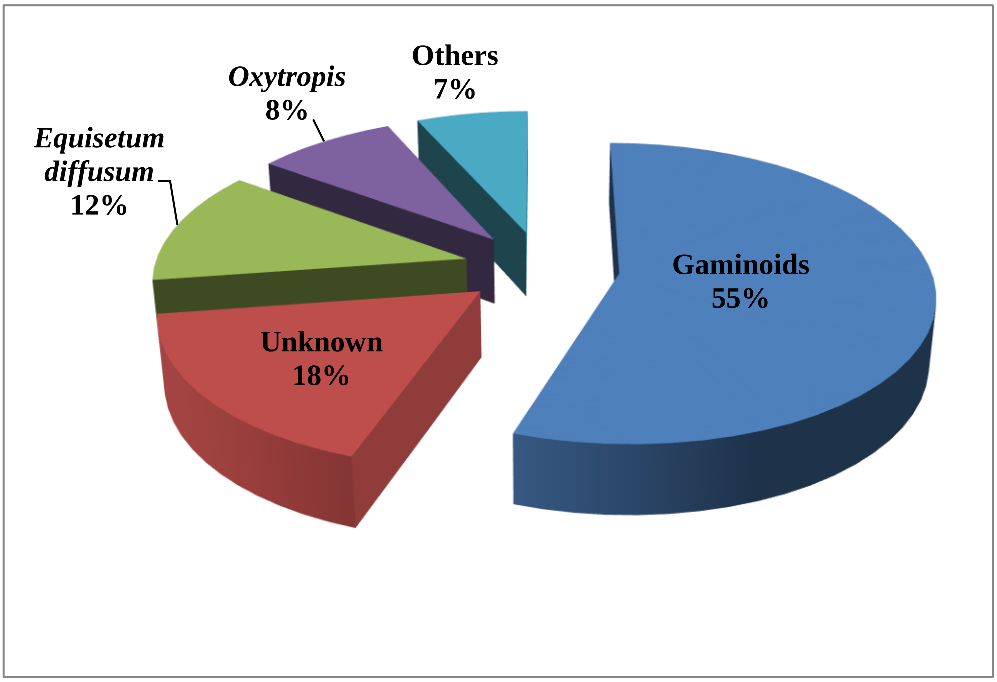

Figure 3.10. Percent consumption of different plant species by mule (N=21292 bites)

Horse

In case of horse, 18% of the feeding instances (total number of bites (N)= 15651 bites) belonged to the *unknown* category. Graminoids formed 60% of the diet, while *Equisetum diffusum* formed 9%. In *others* category, 20 species were grouped, which formed 13% of the diet. The species included in the group were *Sibbaldia parviflora* (4.07%), *Oxytropis* (3.41%), *Trachydium roylei* (2.50%), *Anaphalis* (1.18%), *Potentilla cuneifolia* (0.84%), *Thymus linearis* (0.37%), *Primula* (0.17%), *Vicatia coniifolia* (0.16%), *Epilobium laxum* (0.15%), *Pedicularis* (0.12%), *Taraxacum officinale* (0.10%), *Gerbera gossypina* (0.07%), *Bupleurum* (0.05%), *Artemisia* (0.05%), *Rumex nepalensis* (0.05%), *Arabidopsis* (0.03%), *Plantago himalaica* (0.02%), *Herminium monorchis* (0.01%), *Potentilla* (0.01%) and *Astragalus* (0.01%; Figure 3.11).

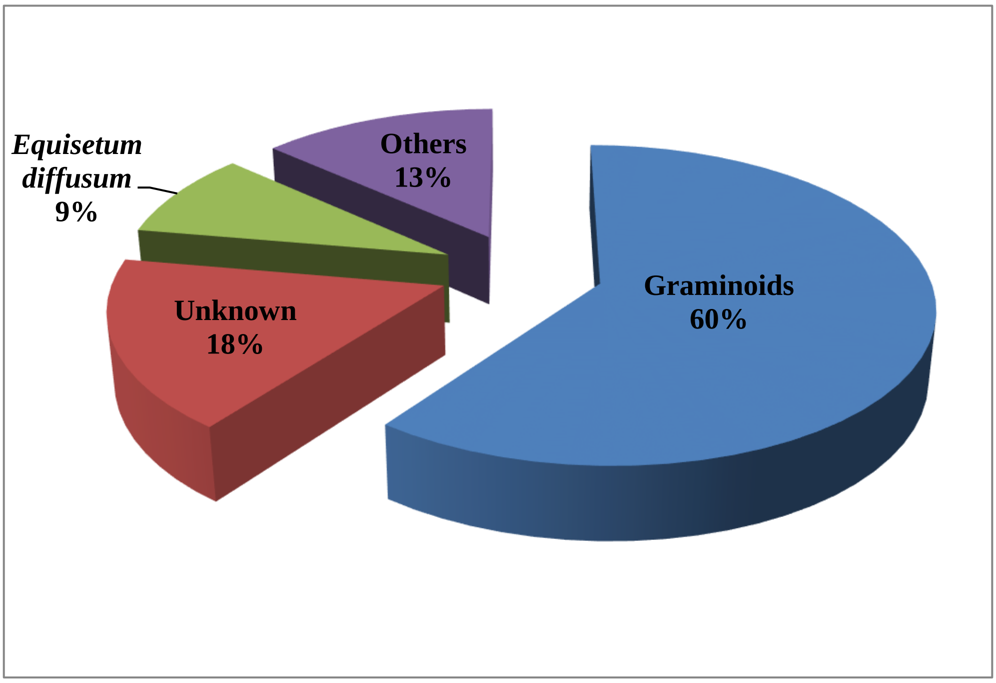

Figure 3.11. Percent consumption of different plant species by horse (N=15651 bites)

Goat

In the case of goat, 0.26% of the feeding instances (total number of bites (N)= 11366 bites) belonged to the *unknown* category. *Devendraea myrtillus* constituted 46% of the diet, while *Lonicera obovata*, *Berberis jaeschkeana*, *Astragalus* and *Devendraea spinosa* formed 11%, 10%, 7%, and 5%, respectively. In *others* category, 17 species were grouped, which formed 17% of the diet. The species included in the group were *Rosa sericea* (4.25%), *Juniperus* sp (3.27%), *Rumex nepalensis* (1.83%), *Rosa webbiana* (1.65%) *Morina coulteriana* (1.48%), *Bistorta* (1.41%), *Spiraea* (1.16%), *Geranium* (1.09%), *Potentilla cuneifolia* (0.93%), fern (0.87%), graminoids (0.80%), *Hippophae tibetana* (0.52%), *Rheum* (0.39%), *Rosa* sp. (0.38%), *Artemisia* (0.05%), *Prunus cornuta* (0.18%) and *Viburnum cotinifolium* (0.14%; Figure 3.12).

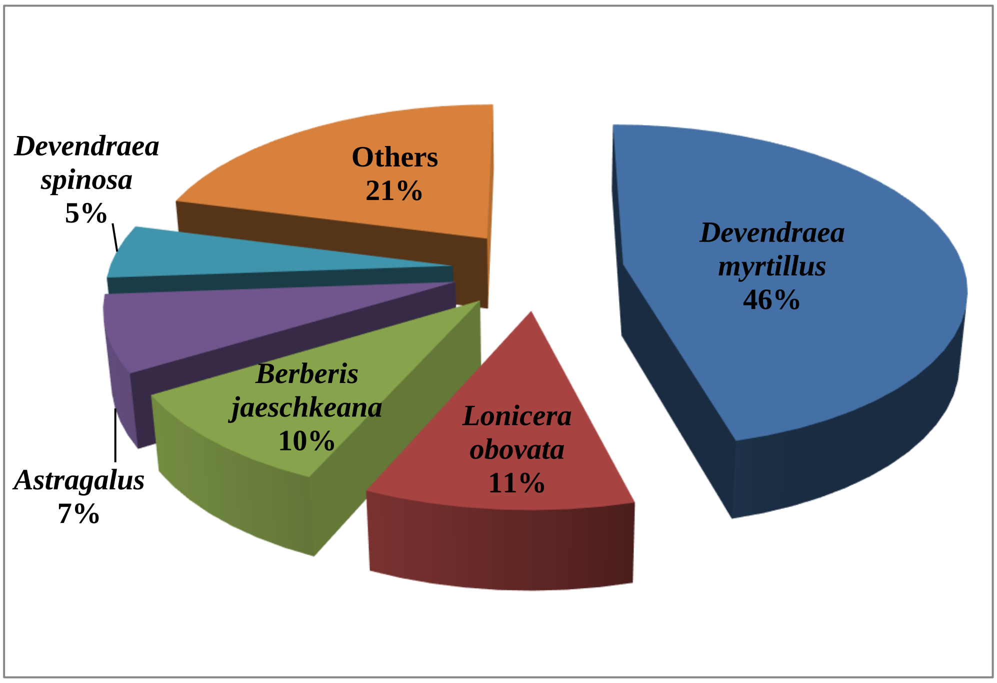

Figure 3.12. Percent consumption of different plant species by goat (N=11366 bites)

Cattle

In case of cattles, 11% of the feeding instances (total number of bites (N)= 11560 bites) belonged to the *unknown* category. Graminoids formed 52% of the diet, while *Sibbaldia parviflora*, *Potentilla cuneifolia* and *Anaphalis* formed 11.34%, 5.80% and 5.62%, respectively. In *others* category, 18 species were identified, which formed 15% of the diet. The species included were *Equisetum diffusum* (3.07%), *Epilobium laxum* (2.32%), *Trachydium roylei* (2.23%), *Oxytropis* (1.67%), *Primula* (0.99%), *Artemisia* (0.89%), *Scutellaria prostrata* (0.85%), *Thymus linearis* (0.59%), *Pedicularis* (0.36%), *Bupleurum* (0.32%), *Euphrasia himalayica* (0.28%), *Bistorta* (0.28%), *Taraxacum officinale* (0.21%), *Corydalis casimiriana* (0.18%), *Astragalus* (0.13%), *Potentilla* (0.08%), *Arabidopsis* (0.03%) and *Plantago himalaica* (0.03%; Figure 3.13).

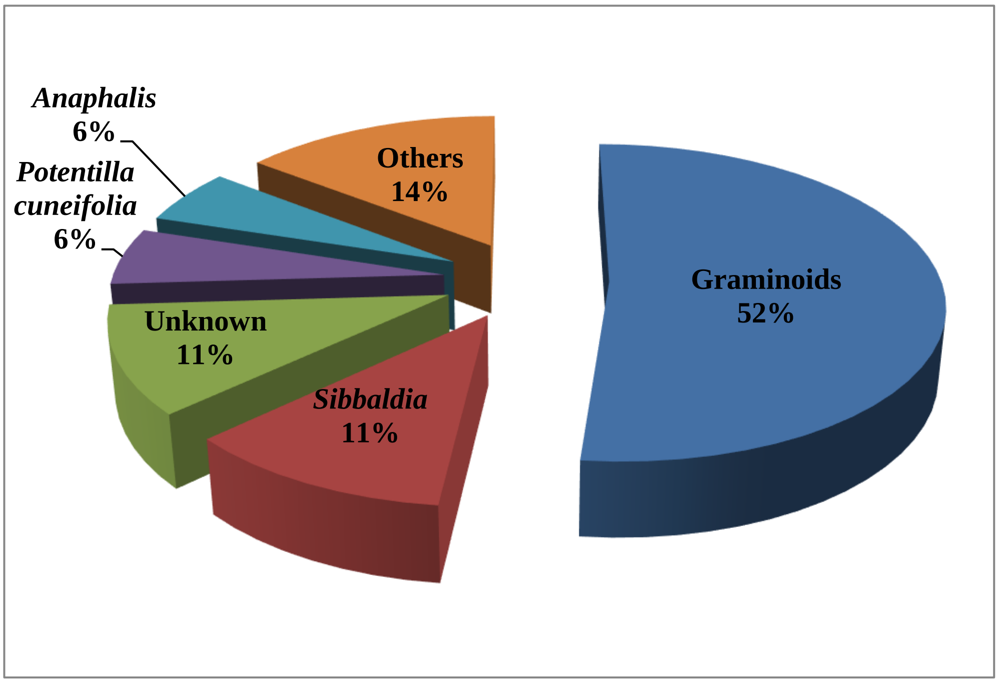

Figure 3.13. Percent consumption of different plant species by cattle (N=11560 bites)

Difference in diet composition among the animals

Kruskal-Wallis test results indicated that there is a significant difference between the diet composition between the five domesticated animals as $H_{(observed\ value)}(12.602) > H_{(critical\ value)}(9.488)$. Mann-Whitney's U test was conducted to test the difference between the diet compositions between domesticated animals. The result indicated that there is a significant difference between diet compositions as far as diet between goat-mule, horse-sheep and mule-sheep are considered as $Z_{(observed\ value\ for\ goat-mule)}(\ 2.07) > Z_{(critical\ value\ for\ goat-mule)}(1.96)$, $Z_{(observed\ value\ for\ horse-sheep)}(\ 2.36) > Z_{(critical\ value\ for\ horse-sheep)}(1.96)$ and $Z_{(observed\ value\ for\ mule-sheep)}(\ 3.55) > Z_{(critical\ value\ for\ mule-sheep)}(1.96)$, respectively. No significant difference was found between diet compositions of cattle-goat, cattle-horse, cattle-mule, cattle-sheep, goat-sheep, goat-horse and horse-mule ($Z_{(observed\ value\ for\ cattle-goat)}(\ 0.34) < Z_{(critical\ value\ for\ cattle-goat)}(1.96)$, $Z_{(observed\ value\ for\ cattle-horse)}(0.57) < Z_{(critical\ value\ for\ cattle-horse)}(1.96)$, $Z_{(observed\ value\ for\ cattle-mule)}(1.88) < Z_{(critical\ value\ for\ cattle-mule)}(1.96)$, $Z_{(observed\ value\ for\ cattle-sheep)}(1.41) < Z_{(critical\ value\ for\ cattle-sheep)}(1.96)$, $Z_{(observed\ value\ for\ goat-sheep)}(0.83) < Z_{(critical\ value\ for\ goat-sheep)}(1.96)$, $Z_{(observed\ value\ for\ goat-horse)}(0.85) < Z_{(critical\ value\ for\ goat-horse)}(1.96)$ and $Z_{(observed\ value\ for\ horse-mule)}(1.50) < Z_{(critical\ value\ for\ horse-mule)}(1.96)$, respectively).

Availability versus utilization of resources

The availability-utilization graph (Figure 3.14) indicates selective feeding by the domesticated animals. Animals showed positive selection for plant species like *Sibbaldia parviflora*, *Anaphalis*, *Rheum*, *Astragalus*, *Pedicularis*, *Trachydium roylei*, *Morina coulteriana*, *Equisetum diffusum*, and *Oxytropis*. Twenty-three plant species were less consumed or avoided in spite of ample availability, which included species like *Plantago*, *Galium aparine*, *Gaultheria trichophylla*, *Polygonum plebeium*, *Taraxacum officinale*, *Euphorbia*, *Herminium monorchis*, *Vicatia coniifolia*, *Euphrasia himalayica*, *Potentilla atrosanguinea*, *Nepeta*, *Gerbera gossypina*, *Rumex nepalensis*, *Thymus linearis*, *Bistorta*, *Artemisia*, *Geranium*, *Corydalis casimiriana*, *Potentilla cuneifolia*, *Scutellaria prostrata*, *Bupleurum*, *Primula denticulata* and *Epilobium laxum* falls under this category. The animals showed maximum positive selection towards *Equisetum diffusum* (D value=0.95), *Oxytropis* (D value=0.94), *Morina coulteriana* (D value=0.80) and *Trachydium roylei* (D value = 0.64). However, animals showed maximum negative selection towards *Plantago* (D value = -0.98), *Galium aparine* (D value = -0.98), *Gaultheria trichophylla* (D value = -0.91) and *Taraxacum officinale* (D value = -0.90; Table 3.5).

Table 3.5. Species preference by animals based on Ivlev's electivity index (Jacobs 1974)

Plant Species	D values
Plantago himalaica	-0.98396
Galium aparine	-0.98099
Gaultheria trichophylla	-0.90682
Taraxacum officinale	-0.90477
Polygonum plebeium	-0.89921
Euphorbia stracheyi	-0.88473
Herminium monorchis	-0.88071
Vicatia coniifolia	-0.86999
Euphrasia himalayica	-0.85242
Potentilla atrosanguinea	-0.83447
Nepeta sp.	-0.82698
Rumex nepalensis	-0.70488
Gerbera gossypina	-0.70265
Thymus linearis	-0.68025
Bistorta sp.	-0.65867
Artemisia maritima	-0.6352
Geranium wallichianum	-0.57398
Corydalis casimiriana	-0.56315
Potentilla cuneifolia	-0.33922
Scutellaria prostrata	-0.28775
Primula denticulata	-0.23066
Bupleurum sp.	-0.2297
Epilobium laxum	-0.01313

Plant Species	D values
Equisetum diffusum	0.949604
Oxytropis sp.	0.94456
Morina coulteriana	0.803107
Trachydium roylei	0.641882
Pedicularis longiflora	0.536929
Astragalus sp.	0.526865
Rheum sp.	0.412899
Anaphalis triplinervis	0.310917
Sibbaldia parviflora	0.24052

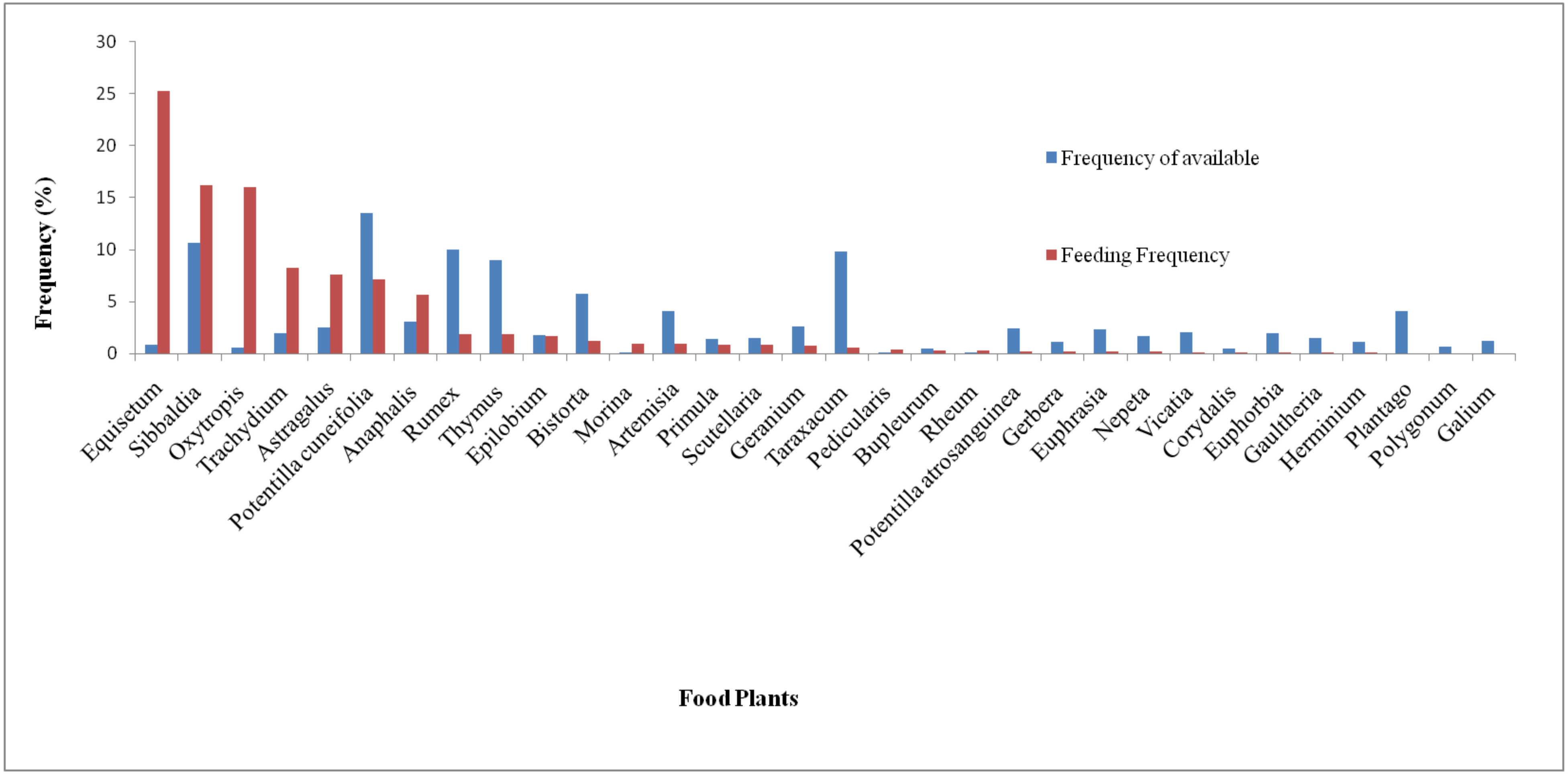

Figure 3.14. Frequency of relative availability versus Utilization (in %) of different food plants

The percentage utilization of monocot and dicot plants against their availability by different animals was estimated (Figure 3.15). Horses and mules preferred monocotyledon plants to dicotyledon as indicated by the ratio of monocotyledons to dicotyledons in their diet (2.15:1) while in case of Blue sheep and livestock (sheep and goats) the reverse was true. In the case of these two groups, the percentage of dicotyledon plants was more as compared to monocotyledons in their diet (1:1.3 and 1:2.7, respectively). In the valleys where animals were allowed to graze the monocotyledon, and dicotyledonous plants were distributed in the ratio of 1:1.8.

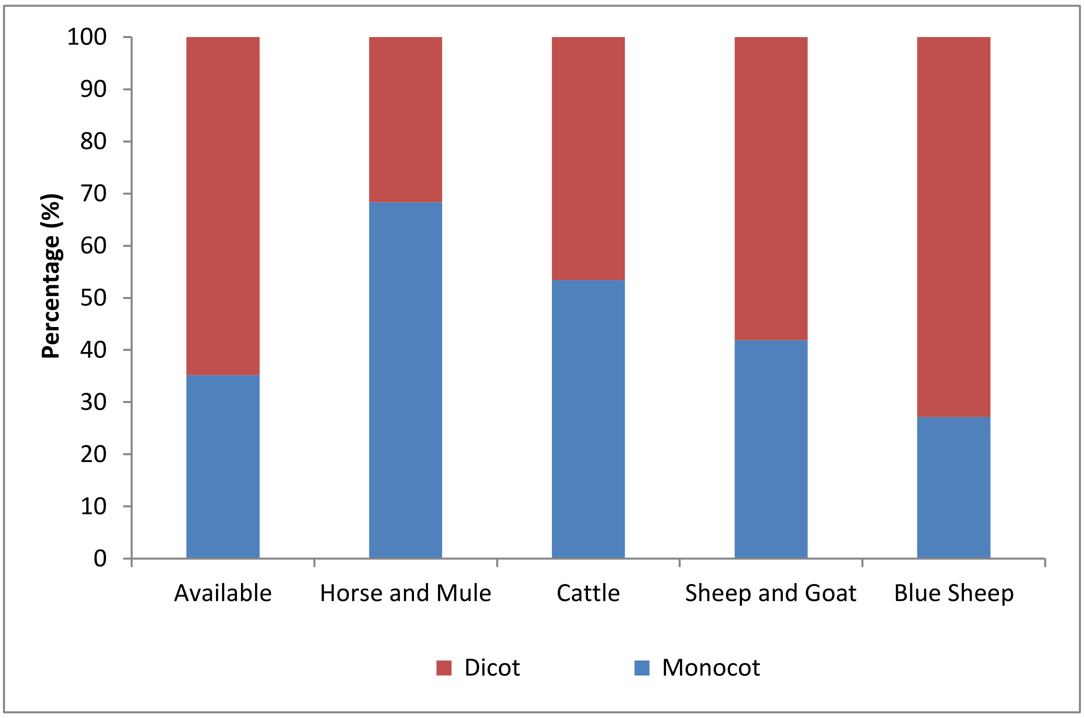

Figure 3.15. Relative frequency of availability and Utilization (in %) of monocots and dicots

Biomass utilization by livestock

Livestock is herded by the shepherds for grazing. Grazing activities began in the morning hours and continued till the evening, with an average of six hours of grazing in the meadows. The biomass utilized by livestock was estimated to be 15.1±2.20 g/hr/animal.

3.4 Conclusion

The village Tapovan is used by most of the pastoralist visiting Niti valley as one of the major stops since it is the largest market before entering the valley. Kuari pass is a preferred stopover for pastoralist groups to graze their animals in the meadow. Hence, the health and development in these areas directly affect the pastoralists. Out of 92 plants found in Amrit Ganga, 55 plant species were used by the animals. Graminoids formed the major portion of the diet except in the diet of goats which had a high consumption of shrub species in its diet. Large size animals like horse, mule, and cattle preferred to graze on the plain marshy meadow with abundant *Equisetum* population. Horses and mules preferred monocotyledon plants to dicotyledon plants, while blue sheep and livestock (sheep and goats) preferred dicotyledon plants to monocotyledon plants. Cattle showed no distinct preferences towards monocotyledons or dicotyledons. There was no significant difference in the diet composition of cattle-goat, cattle-horse, cattle-mule, cattle-sheep, goat-sheep, goat-horse and horse-mule, diet composition of goat-mule, horse-sheep and mule-sheep showed a significant difference between diet compositions.

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Plate:3. Glimpses of life of pastoralists

Shepherds with their herd

Interaction with shepherds

Instruments used by shepherds

Shepherds at work

Shepherds gathering wool

Shepherds drying wool

Shepherds drying meat for preserving

Shepherds spinning wool

Plate:4. Methodology

Observing the animals during field work

Animals feeding on *Rumex*

Plant samples

Slides for micro-histological study

Chapter 4

Pasture Quality and Quantity

4.1 Introduction

In the Himalayan region, alpine zone occupies 33% of the geographical area with *ca*. 26% area under vegetation and remaining *ca*. 7% of the area under perpetual snow (Lal *et al.* 1991). These regions are represented by fascinated biomes, well known for their diversity, aesthetic and cultural values. The salient characteristic of the alpine vegetation is the wealth of herbaceous plants that exist along narrow climatic gradients exhibiting remarkable patterns of adaptations to harsh environments with a short growing season and relatively recent Palaeo-history (Korner 1999; Vishnu-Mittre 1984). The alpine meadows have had an intimate association with local inhabitants regarding cultural, religious and economic dependence. The health of the alpine ecosystem is closely linked with the environmental stability and human welfare in the entire region since; this region forms the upper catchment of the majority of the Himalayan rivers, which support millions of people in the lower hills as well as in the Indo-Gangetic plains.

The alpine meadows are locally known by different names in different regions such as '*Bugyal*,' '*Kanda'* and '*Marg'* in Uttarakhand, Himachal Pradesh, and Jammu and Kashmir, respectively. These areas are characterized by the dominance of one or more favoured forage species (Rawat 2005). Rawat (2005) classified the alpine meadows of Uttarakhand into several types based on the predominance of the various species *viz,* Dudh Bugyal dominated by *Euphorbia stracheyi*, Bus Bugyal dominated by *Saussurea graminifolia*, Dhaniya Bugyal dominated by *Trachydium roylei* and Mamla Bugyal dominated by *Kobresia* species. Apart from these, the Trans-Himalayan dry alpine pastures which are located in the rain shadow zones have dry scrubs and desert steppe dominated by graminoids as characteristic vegetation (Rawat and Adhikari 2005). According to Rawat (2005), local herders of Uttarakhand described good pasture as areas characterized by the dominance of one or other forage species, adequate size of pasture that could support larger herds of grazing animals and absence of weedy or unpalatable species. Ecologically, the status of pastures, representing a full range of alpine habitats and species without human-induced soil erosion can be considered better than those devoid of it. The alpine pastures of Himalaya regions have been used for livestock grazing since time immemorial (Tucker 1986). Alpine areas of the Uttarakhand Himalaya has been subjected to grazing, both by migratory animals, i.e., buffaloes, horses, sheep and goats of trans-human pastoralists as well as of the local inhabitants (Ram 2005). Human activities apart from livestock grazing include extraction of wild medicinal plants species for local as well as commercial use, pilgrimage, recreational activities such as trekking, camping, and skiing.

Increased and uncontrolled livestock grazing has been a significant reason for the degradation of alpine habitats (Rawat 1998; Sundriyal 1989, 1992, 1995). There are several studies pointing out the desirable (Naithani *et al.*1992; Negi *et al.* 1993; Collins *et al.* 1998; Sternberg *et al.* 2000; Rook and Tallowin 2003; Bernues *et al.* 2005) and undesirable impacts (Prins 1989; Prins 1992; Sathyakumar *et al.* 1993; Rawat 1998; Mehra 2000; Conant *et al.* 2002; FAO 2007; Bagchi & Ritchie 2010a&b) of livestock grazing in alpine pastures. The arid alpine pastures have been investigated by various workers in diverse aspects of vegetation and animal ecology across the world. Studies in Tibetan Plateau on the status of rangeland and forage productivity by Weikai *et al.* (2000) and the integrated ecological studies of pasture problems by Holzner *et al.* (2000) are few of the earlier studies on these aspects. Klein *et al.* (2000) worked on grazing and climate change and its effects on fundamental ecological characteristics of rangeland in north-eastern Tibetan Plateau. In studies focused on assessing the effect of grazing on soil properties, it was well established that grazing alters soil respiration in an alpine meadow (Cao *et al*. 2004), and at higher grazing intensity soil-plant carbon pool ratio had a potential to increase leading to alteration of the forage production rates (Gao 2007). Roder (2000) covered studies on grazing resources, especially about the description of plant species and communities, production potential, resource management, and quality monitoring. Jobbagy and Sala (2000) studied the controls of grass and shrub aboveground production in Pantagonain steppe. Relationships between the satellite-derived vegetation index and climatological parameters have been studied for the Siberian region by Suzuki *et al.* (2000).

Studies on the grazing concerning alpine meadows in Western Himalaya have been covered by several workers. The livestock density was found to be higher in the alpine areas of Uttarakhand when compared to Himachal Pradesh and Jammu and Kashmir (Rawat 2007). The majority of rangelands in Spiti, Himachal Pradesh, were found to be overstocked, *i.e.*, they are grazed at intensities much higher than what is biologically optimal (Mishra 2001). In a study, Abule *et al.* (2005) studied the carrying capacity of the system concerning its dependency on the stores found within it and its ability to replenish the depletions through consumption. Joshi *et al.* (1990) emphasized that the alpine grasslands of the Garhwal region have grazing pressure ten times of its existing carrying capacity. While testing the efficiency of a Natural Resource Management Plan in NDBR and VOF, Nautiyal & Kaechele (2007) noted that the implementation of land use policies hindered animal husbandry system on the one hand and contributed to overstocking in pastures on the other. Since after the formation of the Nanda Devi National Park (NDNP) and Valley of Flowers National Park (VoFNP) in Nanda Devi Biosphere Reserve during 1982, there have been reductions in grazing areas, as these major alpine pastures were the part of the livestock grazing land of the local inhabitants. Many studies have indicated that livestock grazing in alpine pasture maintains the diversity of the ecosystems/landscape (Naithani *et al.* 1992; Bernues *et al.* 2005) and grazing seems to contribute to high plant species diversity (Negi *et al.* 1993; Sternberg *et al.* 2000; Saberwal 1996). It is also useful in enhancing biodiversity in anthropogenically stressed grasslands (Collins *et al.* 1998). The impact on vegetation is not only in terms of productivity and quality but also concerns the significance of vegetation dynamics. The native herbivore species serve as keystone species in tall grass ecosystem; they increase habitat heterogeneity and in turn increase species diversity (Collins *et al.* 1998).

Moreover, it has been reported that response to grazing follows a hump-shaped curve, in which low and high intensity of grazing reduces diversity, whereas the moderate intensity of grazing promotes diversity (Sternberg *et al.* 2000). Moderate level of herbivory is accounted for the increase in the species diversity of the area (Milchunas *et al.* 1988). According to Rook and Tallowin (2003), grazing affects grassland biodiversity by maintaining and enhancing structural heterogeneity of sward canopy. The alpine meadows have indicated that tussock grass is more abundant where grazing is relatively low (Ram 2005). The degraded alpine meadows are often dominated by spiny thistles like *Cirsium falconeri, C. verutum* and unpalatable herbs such as *Morina longifolia, Rumex nepalensis andPhlomis bracteosa* (Rawat 2005a,b). The human-induced changes are the main reason for habitat destruction and changes in vegetation composition of the alpine region of Garhwal Himalaya (Nautiayal *et al.* 2004).

Biomass and productivity is an important parameter to assess the quality of the habitat as a resource of energy to the herbivores. Biomass is regarded as a vital indicator of ecological and management processes in the science of vegetation. Plants that dominate a site, concerning biomass are a reflection of the plants that are controlling the nutrient, water and solar resources of the site and productivity of an individual species best explains the role of that species in an ecosystem (Bonham 1989; Cook & Stubbendieck 1986). Therefore, as pointed out by Zobel and Liira 1997, biomass is often measured to assess the ecological status of a site. Singh *et al.* (2005) correlated primary productivity positively with species richness in alpine grasslands of the Himalaya. Measures of standing crop reflecting the amount of energy stored in the vegetation can be indicative of the potential productivity of the site. Hydrologic properties of the habitat including infiltration, runoff, and erosion are found to be influenced by biomass estimation (Bonham 1989). Net biomass production will be highest where there is an ample supply of moisture to meet the needs of plants (Carmody 2010). In regions with a dormant season for herbaceous plants in winter, aboveground biomass (that also represents production per year) is at its maximum in the middle of summer, but before abundant flowering.

Regarding aboveground graminoid biomass, the Trans-Himalayan regions fall at the low-end in comparison to other ecosystems at a global level (Mishra 2001). The overall standing phytomass in Tso Kar Basin of Changthang Plateau found to range between 319-2156 kg ha^{-1}, which was higher than the standing biomass in north-western Tibet (117-307 kg ha^{-1}) and other parts of Trans-Himalaya (Rawat *et al.* 2006). Hence, biomass along with floristic diversity, presence, and distribution of forage species play an essential role in assessing the quality of pastures.

Objective

This chapter deals with pasture quantity and quality in Upper Dhauli Valley with the objective:

To assess the pasture quality (presence of forage species and species richness) and quantity (biomass) in the study area.

Key research questions

1. What is the extent of pastures?
2. What are the biomass structure and relative contribution of forbs and graminoids in the area concerning forage?
3. What is the diversity of the forage plants across the area?

4.2 Methodology

4.2.1 Field methods

Pasture area

The aerial extent of pastures was estimated. To estimate the area under these pastures, each pasture was delineated by visual interpretation technique using remotely sensed LANDSAT 8 data (Figure 2.5), taken in October 2015 having a 30m spatial resolution.

Floristic diversity

A systematic survey of vascular plants was conducted during the growing season from May to October in 2012 and 2014. Within each pasture, 50m×50m size plots were selected and twenty-five, 1m×1m quadrats were laid randomly within each plot for vegetation quantification following Misra (1968) and Rawat & Adhikari (2005a). To assess the floristic diversity of the area, twenty plots were laid in these pastures, twelve in Amrit Ganga within an altitudinal range of 3577m to 4057m and eight in Kalajowar (altitudinal range of 4084m to 4352). To supplement the process of correct identification, important taxonomic characters including habit and information on parameters such as elevation, aspect, slope, and habitat of the species were also gathered. The identity of plant specimens was crosschecked with specimens housed in herbaria (Botanical Survey of India, Northern Regional Centre, Dehradun (BSD), Forest Research Institute, Indian Council of Forestry Research and Education, Dehradun (DD), and herbarium of Wildlife Institute of India, Dehradun) and based on field characters with the aid of existing floras and literature (Naithani 1984a,b; Hajra and Balodi 1995; Chandola 2009; Pusalkar & Singh 2012; Kumar 2016). Percentage cover was also recorded for each plot.

Biomass estimation

Quantification of biomass was carried out in 25m×25m plots in grazed pastures. The aboveground biomass was estimated using harvest method (Negi *et al.* 1993) at the monthly interval during the growing season, from each site closest to the ground, by ten selected 1mx1m quadrats (Plate 5) within 25m×25m plot. Sixteen, 25m×25m plots were sampled. The harvested material was separated into live and dead shoots. The dead shoots were discarded while the live parts were brought to the laboratory and dried at 60 °C to constant weight for biomass estimation.

4.2.2 Data Analysis

Pasture area

Both the selected pastures were subsetted from the LANDSAT 8 satellite data using ArcGIS 9.3 (ESRI 2008). The gradient measure like slope and aspects were generated using ASTER DEM of the Upper Dhauli Valley (UDV). The area under different slope and aspect classes were calculated using ArcMap (ESRI 2008).

Floristic diversity

R software (R Core Team) was used for preparing species rarefaction curves for various pastures. Software Past (Hammer *et al.* 2001) was used to calculate species diversity through Shannon Weiner index (H') (Magurran 2004). Species richness was determined as the total number of the species in an area. Vegetation data were quantitatively analyzed for density, frequency, and abundance based on Curtis and Mclntosh (1950) Misra (1968) and Muller-Dombois & Ellenberg (1974), using MS-Excel spreadsheet.

Biomass estimation

Nonparametric Kruskal-Wallis test (Kruskal & Wallis 1952) was performed to determine the variation in biomass production across the months and different sites. Mann-Whitney U test (MacFarland & Yates 2016) was done to test differences in biomass production between the years. All the statistical analyses were performed using XLSTAT in MS Office-Excel.

4.3 Results and Discussion

4.3.1 Extent of the Pastures

The valley can be divided into three smaller valleys *viz.*, Amrit Ganga, Ganesh Ganga, and Satya Gad. The Amrit Ganga watershed is situated in the western side of the valley and is used by one pastoral group and cattle, horses and mules belonging to locals. Kalajowar_forms the summer pasture for one pastoral group. The Ganesh Ganga watershed forms the extreme northern side of the valley and shares boundary with China. The alpine pastures in this valley are *Bamplas*, *Rekhana* (base of Mount Kamet), *Gotting* and *Geldung* which are utilized by several pastoral groups but due to unavoidable conditions, this valley was not undertaken for the present study.

Amrit Ganga

The total area of the Amrit Ganga alpine pasture was 31.70 km^2. The northeastern slopes were dominants covering 27%, followed by southwest (20%), and flat areas are very marginal and negligible (0.02%; Table 4.1, Figure 4.1). The area has undulating slopes, and the maximum area lies in the between 40º-48º (18%) followed by 32º-40º (18%), while minimum area falls under the category of steep slope 72º -80º (0.14%; Table 4.2, Figure 4.2). The high proportion of northeastern slopes supports more species richness with high density, and in combination with gentle terrain on the area, it offers an ideal and favourite grazing area for the pastoralists.

Table 4.1. Aspect class and percentage area under each class

Aspect	Flat	North	Northeast	East	Southeast	South	Southwest	West	Northwest
Area (Percentage)	0.02	13.29	26.77	12.97	4.42	17.35	19.62	3	2.56

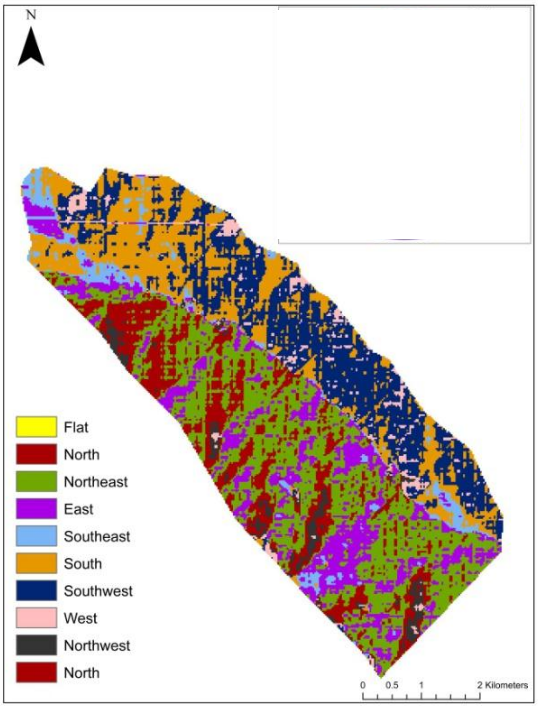

Figure 4.1. Aspect map of Amrit Ganga along with percent area under each aspect, inset chart showing percentage of area under each aspect class

Table 4.2. Slope class and percentage area under each class

Slope	Area (Percentage)
0-8.03	6.53
8.03-16.06	10.54
16.06-24.09	13.39
24.09-32.12	15.79
32.12-40.16	17.79
40.16-48.18	17.98
48.18-56.22	11.52
56.22-64.25	4.94
64.25-72.28	1.37
72.28-80.31	0.14

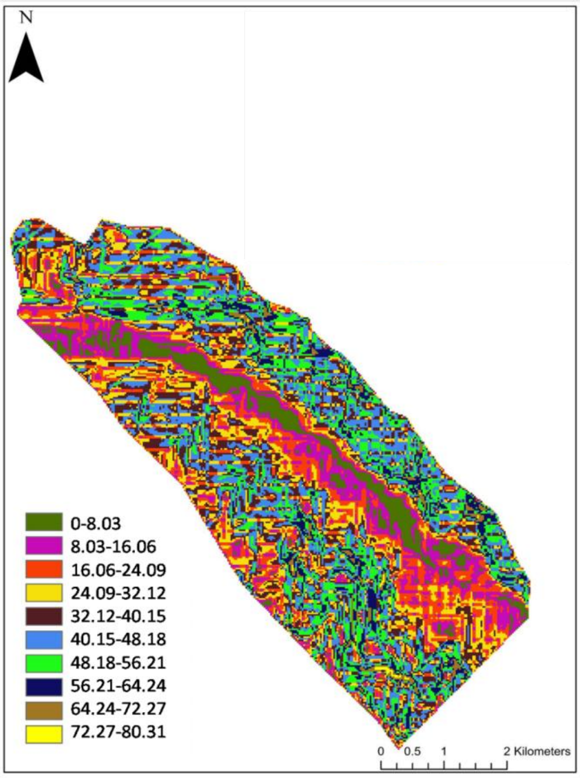

Figure 4.2. Slope map of Amrit Ganga along with percent area under each slope class, inset chart showing percentage of area under each slope class

Kalajowar

Kalajowar occupies an area of 19.4 km^2 and forms the banks of a glacial stream called as *Satyagad*. The area was classified into nine zones as per their aspects *viz;* flat, north, northeast, east, southeast, south, southwest, west and northwest. The maximum area lies in southern aspect (30%), followed by southwest (21%), while the minimum area was under flat category (0.01%), which is negligible (Table 4.3, Figure 4.3). The area was classified into ten slope classes (Table 4.4, Figure 4.4) with the help of ArcGIS. The maximum area lies in the slope class 29º-36º (19.6%), followed by slope class 22º-29º (19.5%), while negligible area falls under the steep slope (66º-73º; 0.1%).

Table 4.3. Aspect class and percentage area under each class

Aspect	South	Southwest	North	Northwest	Southeast	West	East	Northeast	Flat
Area (percentage)	29.61	20.5	13.99	11.48	9.78	5.59	5.03	4.03	0.004

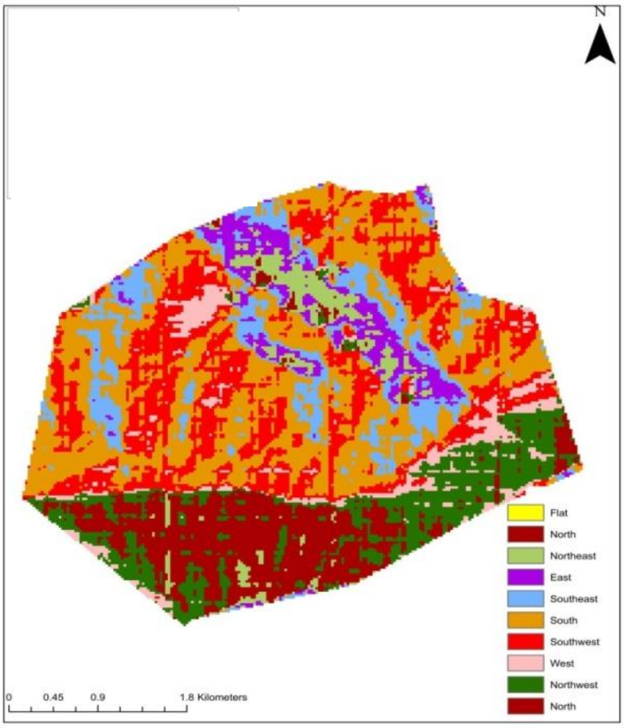

Figure 4.3. Aspect map of Kalajowar along with percent area under each aspect, inset chart showing percentage of area under each aspect class

Table 4.4. Slope class and percentage area under each class

Slope Class	Area (percentage)
0-7.36	2.99
7.36-14.72	11.23
14.72-22.09	16.38
22.09-29.45	19.54
29.45-36.82	19.65
36.82-44.18	17.48
44.18-51.55	9.30
51.55-58.91	2.75
58.91-66.28	0.58
66.28-73.64	0.10

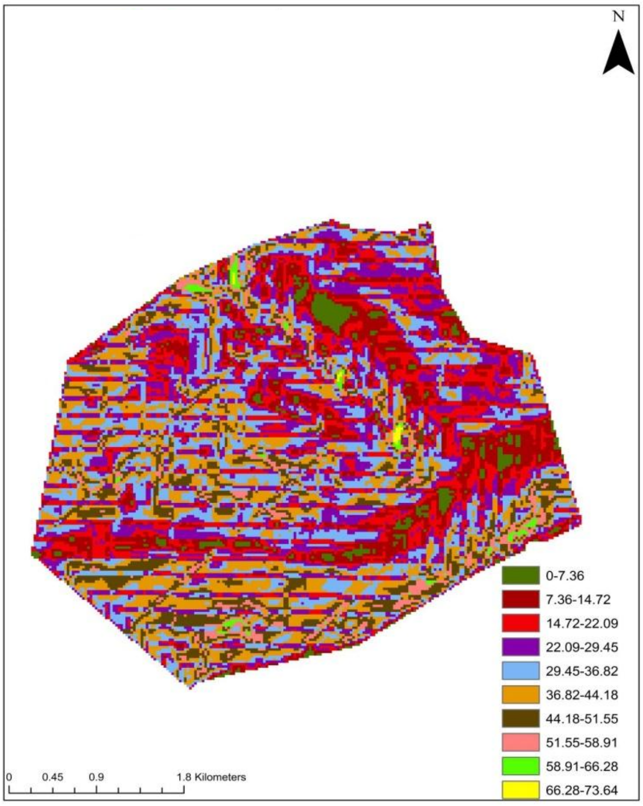

Figure 4.4. Slope map of Kalajowar along with percent area under each slope class, inset chart showing percentage of area under each slope class

4.3.2 Floristic composition

The rarefaction curves of both the sampling areas showed asymptotic convergence for the number of species. It reflected the adequacy of sampling effort in the study sites. Though, Amrit Ganga had a significantly higher number of species than Kalajowar. Also, the number of sampling sites at Amrit Ganga was more than the number of sites at Kalajowar (Figure 4.5).

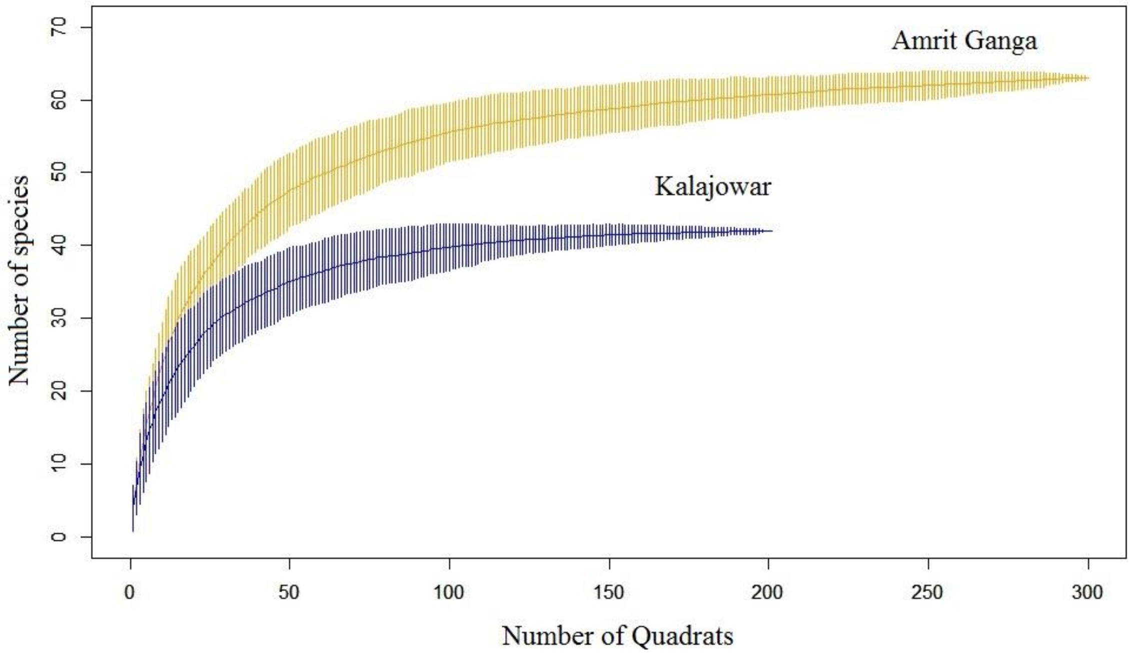

Figure 4.5. Rarefaction curve of the species present in both the pastures. The blue and orange vertical lines shows the 95% confidence interval of number of species of Kalajowar and Amrit Ganga, respectively

The systematic floristic survey and detailed inventory of Upper Dhauli valley revealed the presence of 495 species of vascular plants (angiosperms, gymnosperms, and pteridophytes) belonging to 267 genera and 73 families (Kumar *et al.* 2013a; Kumar *et al*. 2016a). Of the 495 species of vascular plants recorded in Upper Dhauli, 115 species were found in the pastures *viz*., Amrit Ganga with 92 species distributed under 29 families i.e., Poaceae, Asteraceae, Cyperaceae, Apiaceae, Caryophyllaceae, Araceae, Equisetaceae, Euphorbiaceae, Fabaceae, Gentianaceae, Geraniaceae, Lamiaceae, Orobanchaceae, Plantaginaceae, Polygonaceae, Primulaceae, Ranunculaceae, Rosaceae, Rubiaceae, Urticaceae, Violaceae, Balsaminaceae, Caprifoliaceae, Crassulaceae, Ericaceae, Iridaceae, Onagraceae, Orchidaceae and Papaveraceae and Kalajowar with 70 species distributed under 22 families i.e.,Poaceae, Asteraceae, Cyperaceae, Apiaceae, Caryophyllaceae, Araceae, Euphorbiaceae, Fabaceae, Gentianaceae, Geraniaceae, Lamiaceae, Orobanchaceae, Plantaginaceae, Polygonaceae, Primulaceae, Ranunculaceae, Rosaceae, Rubiaceae, Urticaceae, Violaceae, Amaranthaceae and Saxifragaceae. In both the valleys the dominant families are Poaceae, Asteraceae and Cyperaceae (Figure 4.6), whereas the dominant families in terms of high species richness in UDV were Asteraceae (32 genera with 58 species), followed by Poaceae (22 genera with 41 species) and Lamiaceae (15 genera with 19 species; Kumar 2016).

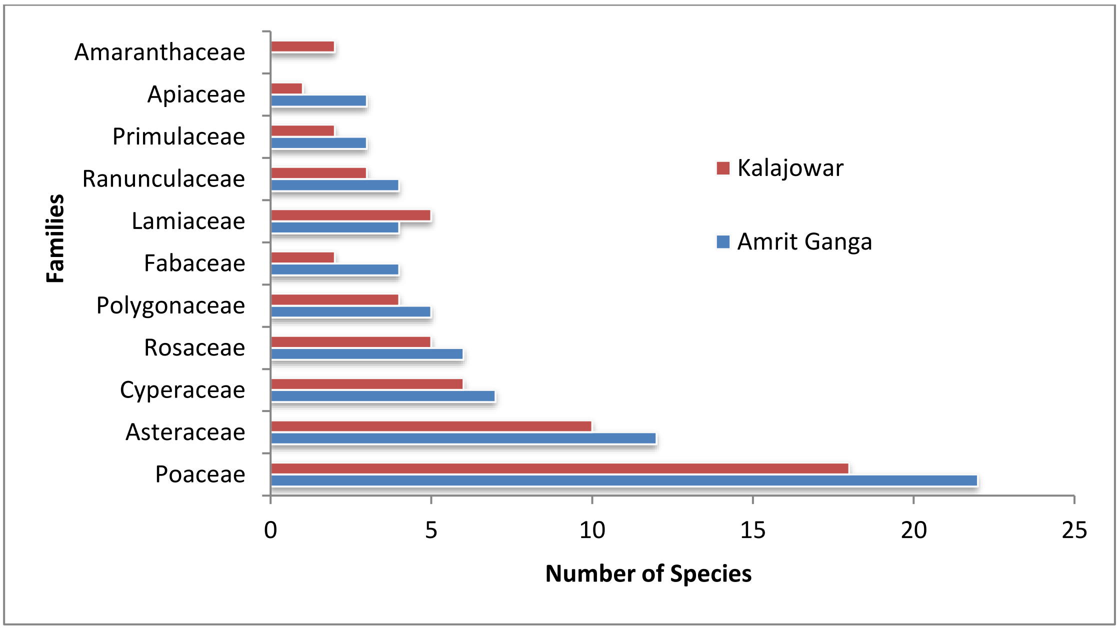

Figure 4.6. Dominant families in Amrit Ganga and Kalajowar

Twenty families were common to Amrit Ganga and Kalajowar (Figure 4.7). Apart from the common families, Amaranthaceae and Saxifragaceae were reported only from Kalajowar while Balsaminaceae, Caprifoliaceae, Crassulaceae, Equisetaceae, Ericaceae, Iridaceae, Onagraceae, Orchidaceae, and Papaveraceae were recorded from Amrit Ganga valley.

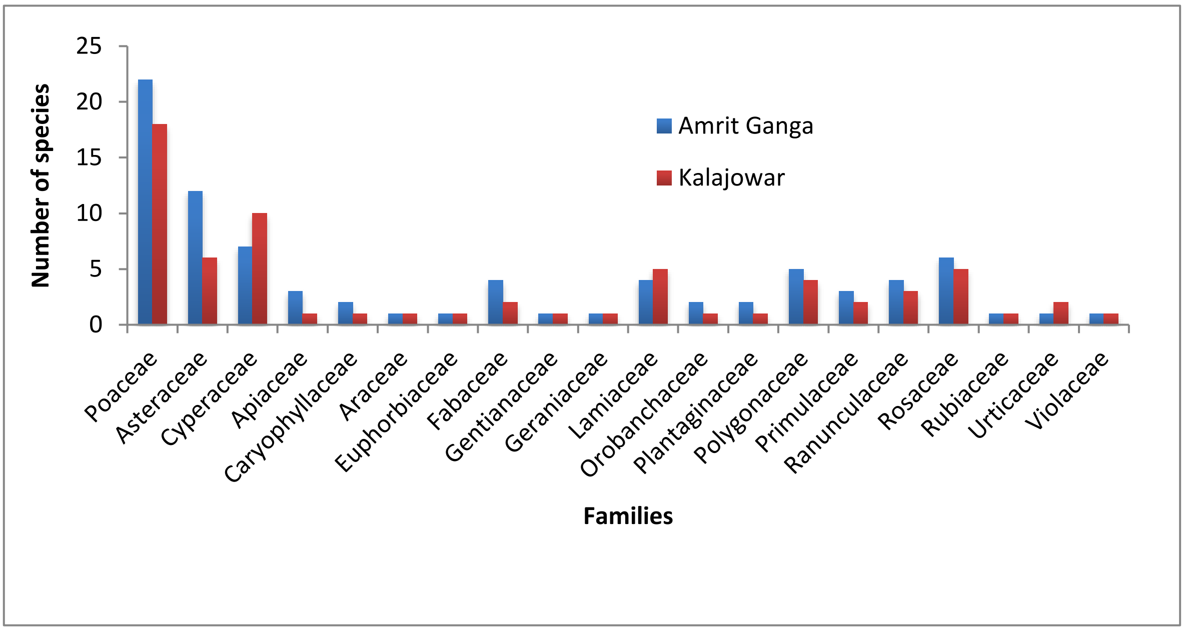

Figure 4.7. Comparative account on the families present in both the pastures

Of the recorded species in Amrit Ganga, 59 were dicots, and 32 were monocots. *Equisetum diffusum* D.Don, a Pteridophyte (Equisetaceae), was recorded in the marshy areas of Amrit Ganga. In Kalajowar area, out of 70 species recorded, 41 belong to dicots and 29 to monocots (Table 4.5).

Table 4.5. Distribution of Monocotyledonous and Dicotyledonous in the pastures

	Family		**Genera**		**Species**	
	Amrit Ganga	**Kalajowar**	**Amrit Ganga**	**Kalajowar**	**Amrit Ganga**	**Kalajowar**
Monocotyledonous	5	3	21	14	32	29
Dicotyledonous	23	19	50	34	59	41

Comparison of the floristic composition of the pastures to that of the Upper Dhauli valley shows that the pastures together constitute 23.2% of the total vascular plants of the Upper Dhauli valley, with an area of *ca.* 7% of the entire area. Amrit Ganga forms *ca.* 4% of the region's area and constitutes 19% to the flora of the region, while Kalajowar constitutes *ca.* 3% and 14% of the area of the region and floristic contribution, respectively (Table 4.6).

Table 4.6. Comparative study of the pasture lands and Dhauli valley

	Amrit Ganga	**Kalajowar**	**Dhauli valley** (Kumar *et al*. 2013a; Kumar *et al*. 2016a)
Area (sq.km)	31.70	19.41	727
Species Richness	92	70	495

Floristic composition of the Amrit Ganga and Kalajowar, reveals the dominance of graminoids (Poaceae and Cyperaceae) which reflects the characteristic features of the grazing landscapes since grazing transforms vegetation and induces a clear graminoid dominance (hemicryptophytic and chamaephytic life-forms; Rawat and Adhikari 2005a).

Floristic diversity across the pastures

Mann-Whitney's U test was conducted to test the difference between the floristic composition across the two pastures regarding, (a) density, (b) the total number, and (c) frequency of occurrence of the plant species found in the pastures. The result indicated that there is a significant difference between the pastures as far as a total number of individuals of plant species are considered as $Z_{(observed\ value)}$(3.78) > $Z_{(critical\ value)}$(1.96). The difference between the density and frequency of the plant species from the two pastures were also significant as $Z_{(observed\ value\ for\ density)}$(3.17) > $Z_{(critical\ value\ for\ density)}$(1.96) and $Z_{(observed\ value\ for\ frequency)}$(2.55) > $Z_{(critical\ value\ for\ frequency)}$(1.96), respectively. The difference in the floristic components of the two pastures may be attributed to the fact that the two pastures have different topographic features and grazing regimes. In Amrit Ganga, northern aspect is prevalent with moraines being the dominant landform whereas Kalajowar is comparatively dry with southern slopes and scree is the dominant landform in the area. The species diversity in Amrit Ganga was 3.219, while the diversity in Kalajowar was 2.836. Amrit Ganga also accounted for a higher vegetation cover percent (91.64±1.4 to 33.40±1.8) as compared to Kalajowar (91.64±1.4 to 19.32±1.4). The higher species richness and diversity in the Amrit Ganga valley as compared to Kalajabar can be attributed to the fact that the former has more affinities towards Greater Himalaya which is moist as compared to Kalajabar which is drier and has higher similarities towards Trans-Himalaya (Kumar *et al.* 2016).

4.3.3 Forage Species distribution

Out of 115 species reported from the pastures, 52 species were known palatable species (Bhattacharya *et al.* 2012; Awasthi *et al.* 2003; Negi *et al.* 1993; Table 4.7). Of the 52 species, 42 species and 32 species were found in Amrit Ganga (92 species reported) and Kalajowar (70 species reported), respectively. The forage plants were distributed among 24 families, with the most number of species belonging to graminoids (11 species from Poaceae, two species belonging to Cyperaceae). Rosaceae, Polygonaceae, and Lamiaceae were represented by four species, respectively.

Table 4.7. Palatable species distribution in Amrit Ganga and Kalajowar

Plant species	Family	Amrit Ganga	Kalajowar
Agrostis munroana	Poaceae	-	+
Agrostis sp.	Poaceae	+	+
Anaphalis sp. *#	Asteraceae	+	+
Anemone sp.	Ranunculaceae	+	-
Artemisia spp.*	Asteraceae	+	+
Astragalus spp.*	Fabaceae	+	-
Bistorta spp. *#	Polygonaceae	+	+
Bromus inermis	Poaceae	+	+
Bupleurum sp. *	Apiaceae	+	-
Carex sp.	Cyperaceae	+	+
Corydalis casimiriana *	Papaveraceae	+	-
Danthonia sp.	Poaceae	+	-
Elymus longe-aristatus	Poaceae	+	+
*Epilobium laxum**	Onagraceae	+	-
*Equisetum diffusum**	Equisetaceae	+	-
Euphorbia sp. *	Euphorbiaceae	+	+
*Euphrasia himalayica**	Orobanchaceae	+	-
Festuca kashmiriana	Poaceae	-	+

Festuca valesiaca	Poaceae	+	+
Galium aparine *	Rosaceae	+	+
Gaultheria trichophylla *	Ericaceae	+	-
Gentiana sp.	Gentianaceae	+	-
Geranium sp. *#	Geraniaceae	+	+
Herminium monorchis *	Orchidaceae	+	-
Kobresia sp.	Cyperaceae	+	+
*Morina coulteriana**	Caprifoliaceae	+	-
Nepeta sp.*	Lamiaceae	+	+
Oryzopsis munroi	Poaceae	+	+
Oxytropis sp.*	Fabaceae	+	-
Pedicularis sp. *	Orobanchaceae	+	+
Phlomis bracteosa	Lamiaceae	-	+
Plantago himalaica * #	Plantaginaceae	+	-
Poa pratensis	Poaceae	-	+
Poa sp.	Poaceae	+	+
Polygonum plebeium *	Polygonaceae	+	-
*Potentilla cuneifolia**#	Rosaceae	+	+
Potentilla sp. *#	Rosaceae	+	+
Primula sp. *	Primulaceae	+	+
Ranunculus sp.	Ranunculaceae	+	+
Rheum sp.*	Polygonaceae	+	+
*Rosularia alpestris**	Crassulaceae	+	-
Rumex nepalensis *#	Polygonaceae	+	+
Saxifraga sp.	Saxifragaceae	-	+
Scutellaria prostrata *	Lamiaceae	+	-
Setaria spp.	Poaceae	+	-
*Sibbaldia parviflora**#	Rosaceae	+	+
Swertia sp.	Gentianaceae	-	+
Taraxacum officinale *#	Asteraceae	+	-
*Thymus linearis**#	Lamiaceae	+	+
*Trachydium roylei**#	Apiaceae	+	-
Vicatia coniifolia * #	Apiaceae	+	+
Viola sp.	Violaceae	+	+

Source: Modified from list of palatable plant species documented in different studies (Bhattacharya *et al.*2012; Awasthi *et al.* 2003; Negi *et al.* 1993) done in Himalayan region. * Present study record; # Dominant species in the pastures (density)

Sibbaldia parviflora Wild. (4.72±0.57 individuals m^{-2}) had the highest density, followed by *Potentilla cuneifolia* Bertol. (4.49±0.40 individuals m^{-2}). *Rumex nepalensis* Spreng. was found near the livestock camping sites and had a density of 1.91±0.23 individuals m^{-2} (Table 4.8). The presence of *Rumex nepalensis* at a high density indicates towards poor quality of pasture since Rawat (2005) regarded alpine meadows dominated by spiny thistles like *Cirsium falconeri, C. verutum* and unpalatable herbs such as *Morina longifolia, Rumex nepalensisand Phlomis bracteosa* as degraded. *Thalictrum alpinum* L. (3.49±0.72 individuals m^{-2}) was the only species not reported as forage plant previously.

Table 4.8. Density of dominant plant species

Plant Species	Density ± SE (individuals m^{-2})
Sibbaldia parviflora	4.72±0.57
Potentilla cuneifolia	4.49±0.40
Thalictrum alpinum	3.49±0.72
Bistorta affinis	3.43±0.34
Thymus linearis	3.37±0.46
Trachydium roylei	2.96±0.82
Plantago himalaica	2.47±0.56
Vicatia coniifolia	2.42±0.63
Taraxacum officinale	2.08±0.37
Rumex nepalensis	1.91±0.23

Amrit Ganga

The dominant families in terms of high species richness were Poaceae (22 species under 16 genera) followed by Asteraceae (12 species under ten genera) and Cyperaceae (7 species under two genera) (Figure 4.8). Sixteen families (Balsaminaceae, Caprifoliaceae, Crassulaceae, Ericaceae, Euphorbiaceae, Gentianaceae, Geraniaceae, Onagraceae, Papaveraceae, Rubiaceae, Urticaceae, Violaceae, Equisetaceae, Araceae, Iridaceae, and Orchidaceae) were represented by one species while Rosaceae and Polygonaceae were represented by 6 and 5 species distributed among 2 and 5 genera, respectively. Fabaceae, Ranunculaceae, and Lamiaceae consisted of four species belonging to 3, 3 and four genera respectively. Three species represented Apiaceae (3 genera) and Primulaceae (3 genera) while the family Orobanchaceae and Plantaginaceae were represented by two species belonging to two genera. Forage plants constituted 45.6% of the plant species (92 species) reported from the area. In the pasture, 42 forage species were distributed among 23 families. The most diverse family of forage plant species was Poaceae (8 species), followed by Rosaceae and Polygonaceae (4 species each, respectively).

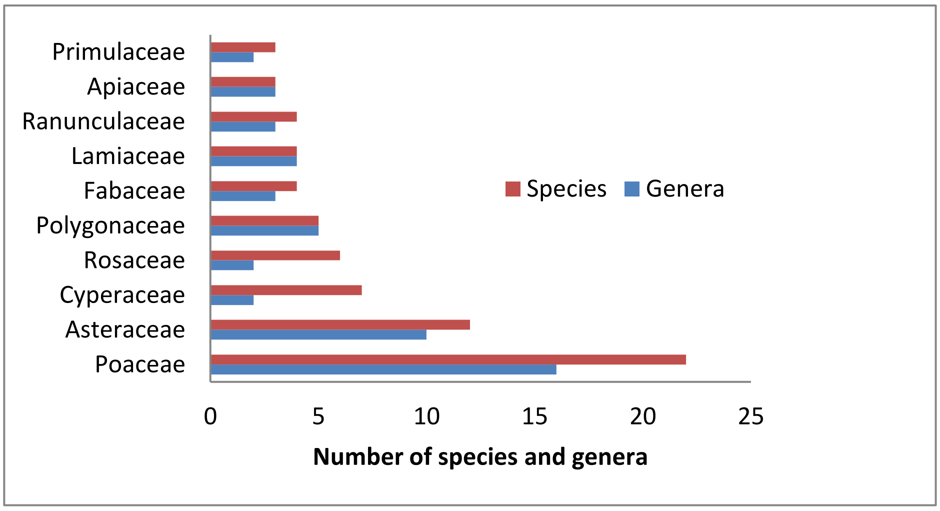

Figure 4.8. Dominant families in Amrit Ganga

Sibbaldia parviflora Willd. (7.28±1.20 individuals m^{-2}) has the highest density, followed by *Thalictrum alpinum* L. (5.82±1.90 individuals m^{-2}). *Rumex nepalensis* Spreng. was found near the livestock camping sites and had a density of 3.08±0.44 individuals m^{-2} (Table 4.9). Apart from *Thalictrum alpinum* L. (5.82±1.90 individuals m^{-2}), the dominant species are also the forage species.

Table 4.9. Density and frequency of dominant plant species of Amrit Ganga

Name of Plants	Density (individuals m^{-2})	Frequency (%)
Sibbaldia parviflora Willd.	7.28±1.20	32.67
Thalictrum alpinum L.	5.82±1.90	9.67
Trachydium roylei Lindl.	4.94±3.20	6.00
Thymus linearis Benth.	4.91±1.11	27.67
Plantago himalaica Pilg.	4.12±1.91	12.67
Potentilla cuneifolia Bertol.	4.04±0.83	28.00
Vicatia coniifolia DC.	3.86±2.35	6.33
Taraxacum officinale F.H.Wigg.	3.46±0.95	30.33
Rumex nepalensis Spreng.	3.08±0.44	30.67
Bistorta affinis Greene	2.34±0.54	17.67

Kalajowar

The dominant family was Poaceae comprising of 18 species belonging to 11 genera, followed by Cyperaceae with ten species under two genera and Asteraceae with six species belonging to five genera (Figure 4.9). Eleven families were monotypic from the area viz., Apiaceae, Caryophyllaceae, Euphorbiaceae, Gentianaceae, Geraniaceae, Orobanchaceae, Plantaginaceae, Rubiaceae, Saxifragaceae Violaceae, and Araceae, while Rosaceae and Lamiaceae were represented by five species each distributed among two and five genera, respectively. Ranunculaceae and Polygonaceae consisted of four and three species belonging to three genera, respectively. Amaranthaceae with one genus, Urticaceae (one genus), Primulaceae (two genera) and Fabaceae (two genera) were represented by two species each. Forage plants constituted 46% of the plant species (70 species) reported from the area. In the pasture 32 forage species was noted distributed among 15 families. The most diverse family of forage plant species was Poaceae (9 species), followed by Rosaceae (4 species).

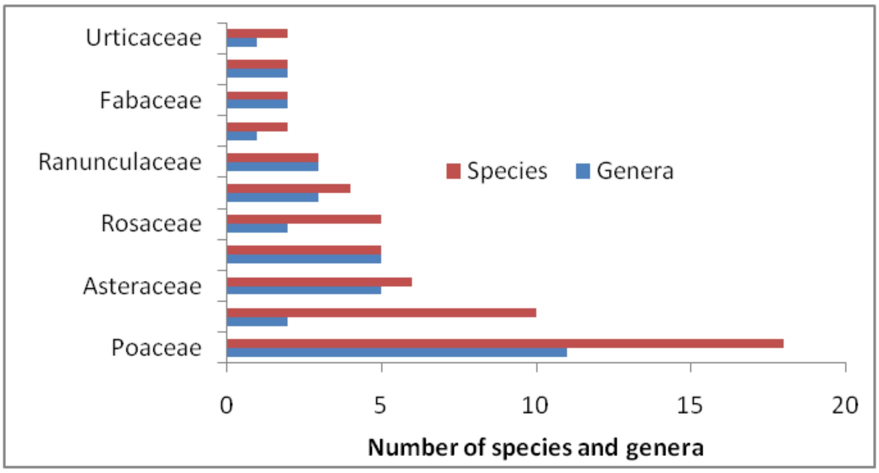

Figure 4.9. Predominant families of Kalajowar

Potentilla cuneifolia Bertol. (5.18±.51 individuals m^{-2}) had the highest density with a frequency of 42.50%. *Bistorta tenuifolia* (5.08±.63 individuals m^{-2}), followed *P. cuneifolia* with a frequency of 29.50% (Table 4.10). Apart from *Potentilla bifurca* L. (1.43±0.33 individuals m^{-2}), *Leontopodium brachyactis Gand.* (1.05±0.18 individuals m^{-2}) and *Urtica dioica L.* (0.97±0.24 individuals m^{-2}), the dominant species are also foraging species.

Table 4.10. Density and frequency of dominant plant species of Kalajowar

Name of Plants	**Density** (Ind. m^{-2})	**Frequency (%)**
Potentilla cuneifolia Bertol.	5.18±0.51	42.50
Bistorta tenuifolia (H.W.Kung) Miyam. and H.Ohba	5.08±0.63	29.50
Geranium wallichianum D.Don	2.91±0.59	31.00
Potentilla bifurca L.	1.43±0.33	10.50
Potentilla argyrophylla Wall. ex Lehm.	1.29±0.13	44.00
Thymus linearis Benth.	1.05±0.26	8.50
Leontopodium brachyactis Gand.	1.05±0.18	17.50
Urtica dioica L.	0.97±0.24	9.50
Anaphalis royleana DC.	0.96±0.18	15.50
Sibbaldia parviflora Wild.	0.89±0.20	10.50

4.3.4 Biomass estimation

The biomass was harvested from June to October during the snow-free period in the years 2012 and 2014. A total of 18 plant species belonging to 13 families were recorded in 16 biomass plots in two pastures, which were harvested during the study period of two years. Maximum and minimum biomass was recorded in August (183.4±4 g m^{-2}) and October (14.7±1.3 g m^{-2}), respectively. The biomass showed an upward trend in July (128.3±3 g m^{-2}), reaching its peak in August (183.4±4 g m^{-2}) and started declining by September (131.4±4 g m^{-2}; Figure 4.10). The increase in the biomass in July and August can be attributed to the ample supply of moisture available during this time which is needed by the plants. The relationship between the availability of moisture and biomass production has been studied by Carmody (2010), and it was observed that net biomass production was highest where there was an ample supply of moisture. Kala and Rawat (1999) also reported a similar trend, where biomass increased from June from the onset of monsoon, attained a peak in early September and declined after that. Overall biomass in the area during the study period was estimated to be 95.16±2.15 g m^{-2} (951.6±21.5 kg ha^{-1}) which is comparable with phytomass estimated in Tso Kar region (319-2156 kg ha^{-1}; Rawat *et al.* 2006).

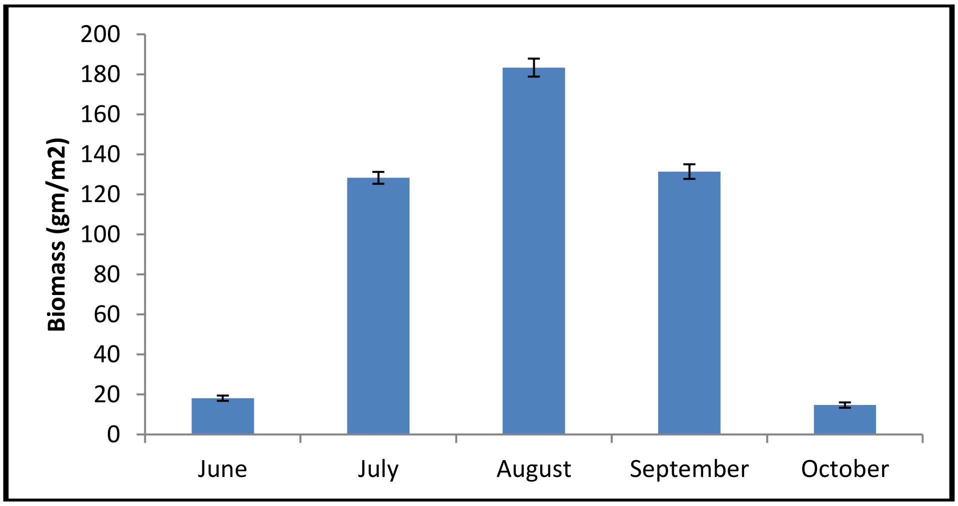

Figure 4.10. The average biomass (mean±SE) production in grazed conditions across different months in the pastures with respective standard error

The number of species contributing to the biomass of the area also varied across the months. The maximum number of species (15) was recorded in July, which has contributed to the biomass of the area (Table 4.11), followed by August (14 species) and September (12 species). Least number of species was seen in October (4 species).

Table 4.11: Average biomass (Mean ±SE g m^{-2}) of individual species across the months

Plant names	June	July	August	September	October
Anaphalis triplinervis	-	-	1.56±0.39	0.97±0.25	-
Artemisia maritima	0.80±0.19	4.59±1.03	10.97±1.23	7.13±1.11	-
Bistorta tenuifolia	-	3.22±0.51	2.66±0.60	-	-
Brachyactis roylei	-	1.56±0.35	-	2.31±0.53	-
Gaultheria trichophylla	-	4.56±1.05	-	2.50±0.57	-
Geranium wallichianum	0.65±0.15	8.31±1.12	9.41±1.05	14.41±1.80	1.73±0.32
Grasses	7.47±0.59	40.56±1.66	65.46±2.58	53.33±2.64	10.22±1.09
Iris kemaonensis	1.31±0.30	6.16±1.39	13.47±3.02	1.91±0.45	0
Pedicularis spp.	-	-	1.03±0.25	-	-
Plantago himalaica	-	-	1.19±0.29	-	-
Potentilla atrosanguinea	1.19±.27	21.41±2.03	30.01±2.29	20.75±2.33	2.00±0.65
Potentilla cuneifolia	-	9.78±1.27	17.08±2.15	11.09±1.45	-
Primula sp.	0.65±0.15	2.63±0.46			
Rumex nepalensis	3.86±0.63	11.77±1.38	14.30±1.43	7.66±0.89	
Sibbaldia parviflora	0.63±0.20	8.03±0.84	9.94±1.15	6.78±0.99	
Taraxacum officinale	0.91±0.21	1.94±0.44	4.50±0.71	-	
Trachydium roylei	0.66±0.15	2.06±0.47	1.78±0.41	2.56±0.59	
Urtica dioica	-	1.69±0.39			0.75±0.24

The graminoids (Poaceae and Cyperaceae) contributed 37% of the total biomass (Figure 4.11). Graminoids contributed the highest biomass in all the months and ranged from 7.5 g m^{-2} in June to 65.5 g m^{-2} in August. Overall biomass of graminoids was estimated to be 35.4±11.5 g m^{-2} (345±115 kg ha^{-1}), which is higher than the graminoid biomass reported by Mishra *et al.* (2004) in a intensively grazed rangeland (134 kg ha^{-1}; 95% confidence limits 97-194 kg ha^{-1}) while being less than that of a moderately grazed rangeland (535 kg ha^{-1}; 95% confidence limits 434-632 kg ha^{-1}).

Among other species, *Potentilla atrosanguinea* (16%), *Potentilla cuneifolia* (8%), *Rumex nepalensis* (8%), *Geranium wallichianum* (7%) and *Sibbaldia parviflora* (5%)

contributed for biomass and ranged from 1.2 g m^{-2} to 30 g m^{-2}, 9.8 g m^{-2} to 17.1 g m^{-2}, 3.9 g m^{-2} to 14.3 g m^{-2}, 0.7 g m^{-2} to 14.4 g m^{-2} and 0.63 g m^{-2} to 10 g m^{-2}, respectively. All the plant species as mentioned earlier are known as palatable to the wild as well as livestock. The high biomass contribution by *Rumex nepalensis* (8%) may be due to its abundant distribution near livestock camping sites and its relative unpalatability.

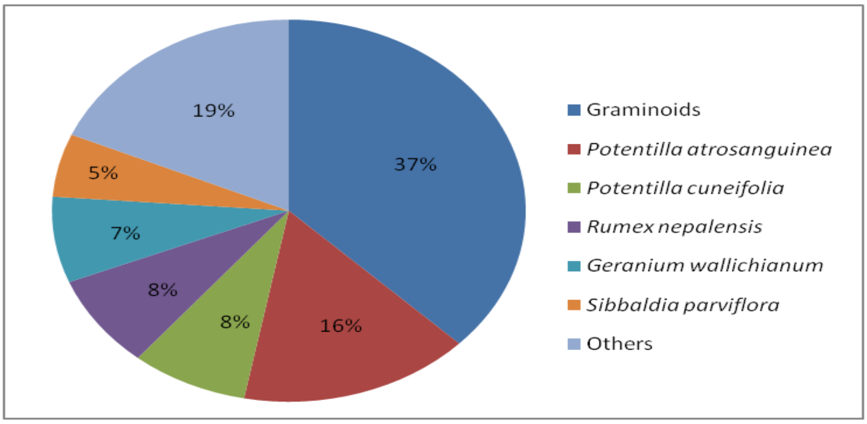

Figure 4.11. Biomass contribution by individual species

Moreover, species like *Artemisia maritima, Iris kemaonensis, Taraxacum officinale, Trachydium roylei*, *Gaultheria trichophylla*, *Bistorta tenuifolia*, *Brachyactis roylei*, *Primula* sp., *Anaphalis triplinervis*, *Urtica dioica*, *Plantago himalaica*, and *Pedicularis* spp. contributed less than 5% of the total biomass and was categorized as “others” (Table 4.12).

Table 4.12: Biomass contribution by individual species in others

Species	Biomass (%)	Species	Biomass (%)
Artemisia maritima	4.94	*Brachyactis roylei*	0.81
Iris kemaonensis	4.80	*Primula* sp.	0.69
Taraxacum officinale	1.54	*Anaphalis triplinervis*	0.53
Trachydium roylei	1.48	*Urtica dioica*	0.51
Gaultheria trichophylla	1.48	*Plantago himalaica*	0.25
Bistorta tenuifolia	1.23	*Pedicularis* spp.	0.22

4.4 Conclusion

Species like *Sibbaldia parviflora* and *Potentilla cuneifolia* were palatable plant species and were present in the pastures in high density, but these were not preferred forage species by animals (Ilvel's selectivity index; previous chapter). The presence of opportunistic species like *Rumex*, *Urtica*, and *Polygonum* indicates the poor quality of the pastures. Nevertheless, the pastures had high availability of graminoids (the biomass contribution of Poaceae along with Cyperaceae (forage species) was highest (37%) as compared to other families) which formed a substantial portion of the livestock's diet.

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Plate: 5. Field work

Quadrat of 1m X 1m

Marking of Plots for repetitive sampling

Biomass collection in field

Chapter 5

Habitat use and interaction between blue sheep and livestock

5.1 Introduction

The adverse effects of the human-caused interventions on the environment are well recognized (Wilcove *et al*. 1998). The significant causes of habitat degradation and loss in the Himalayan region are ill-planned developmental activities and uncontrolled levels of grazing by livestock (Kala & Rawat 1999). Pastoralism has been practiced in the Himalayan region for centuries, where large herds of domesticated animals are taken to the alpine meadows every summer and brought back to lower altitudes during mid-autumn. However, livestock composition and abundance has changed considerably under the wake of recent changes in the economy and market forces (Kala & Rawat 1999).

Rawat (2007) reported that the densities of livestock in Uttarakhand alpine areas are higher as compared to Himachal Pradesh and Jammu and Kashmir. Majority of rangelands in Spiti, Himachal Pradesh are overstocked (Mishra 2001). In the semi-arid ecosystems, where pastoralism is the main subsistence occupation, grazing competition from domestic livestock is believed to displace the wild ungulates (Shreshtha & Wegge 2008a). In Phu valley, Nepal, Shreshtha & Wegge (2008b) studied habitat relationships between blue sheep and livestock and found that at high stocking densities, all animal groups were competing for the resource (vegetation type). At high density, livestock could significantly reduce resource (forage) availability in rangelands (Roder 2000). This can be brought about by immediate effects of forage consumption, as well as long-term changes, such as a reduction in plant cover and changes in plant species composition (Prins 1989). Also, resource competition can be expected when the forage availability in the rangeland becomes. Overstocking alongside with increasing human populations and changes in land use has the potential to cause competitive exclusion of wild herbivores, which has been termed as "the pastoral road to extinction" by Prins (1992). In Protected Areas, conflicts between the local communities and wildlife managers' takes place due to the predation of livestock by wild predators (Mishra 1997).

Studies dealing with livestock and wild ungulate interactions in the Indian Trans-Himalaya include Johnsingh *et al.* 1999, Mishra 2001, Bagchi *et al.* 2002, Raghavan 2003, Namgail *et al.* 2007. Johnsingh *et al.* (1999) studied the ecology of the Ibex (*Capra sibirica*) in Pin Valley National Park and its interaction with livestock. Ibex and herd were attitudinally separated during summer since the latter used the lowest elevation while the former preferred to use the higher terrain. However, there was a spatial overlap between them in spring and autumn when Ibex mainly used steeper areas, closer to escape terrain but were also observed feeding nearby of livestock on some occasions. Johnsingh *et al.* (1999) also identified two potential conservation threats to Ibex. Firstly, the migratory livestock from the neighbouring areas used the area between June to August every year, but there was no control over the number entering the area. The other problem identified was the locals, who extract fuelwood by uprooting shrub species like, *Rosa webbiana* which forms essential food species for Ibex during autumn and winter months.

Mishra (2001) studied pastoralism, human-animal conflict and livestock competition with blue sheep in the Spiti Valley and concluded the co-existence between pastoralism and wildlife is far from harmonious. Bagchi *et al.* (2002) showed that the large migratory herds of sheep and goat pose a major threat to the ibex and found that these also had a significant overlap with the Ibex diet. Sheep and goats imposed resource limitation on Ibex and excluded them spatially. Raghavan (2003) investigated the interaction between the Urial (*Ovis vignei*) and livestock and suggested a possibility that the Urail may be pushed to areas with sub-optimal resources, by livestock that used relatively resource-rich regions. Namgail *et al.* (2007) reported a shift in the habitat use by the Tibetan Argali in the presence of domesticated animals in the Gya-Miru Wildlife Sanctuary, Ladakh. Sathyakumar *et al.* (1993); Bhatnagar *et al.* (2000); Vinod & Satyakumar (2005) found that extensive grazing by the migratory livestock has adverse impacts on the habitat and ungulate abundance. A review of information available on the food plants and feeding habits of Himalayan ungulates revealed a total of 140 wild plant species which are palatable to different ungulate species (Awasthi *et al.* 2003). Of 140 plant species, 13 are common in the diet of wild and domestic ungulates. The diet overlap between Blue sheep (*Pseudois nayaur*), Himalayan musk deer (*Moschus chrysogaster*), Sambar (*Cervus unicolor*), and livestock was studied by Bhattacharya *et al.* (2012) at Bedini-Ali, Uttarakhand and between Himalayan tahr (*Hemitragus jemlahicus*) and livestock at Tungnath, Uttarakhand. At Bedini-Ali, a total of 53 food plant species were recorded, of which, 26 (49 %) were consumed by both wild and domestic ungulates, whereas 68% (n=22) out of 32 species of food plants were found to occur in the diet of both Himalayan Tahr and livestock at Tungnath. A study by Bagchi *et al.* (2002) revealed that goats and sheep impose resource limitations on Ibex and exclude them from certain pastures. Ibex remained relatively unaffected by other livestock such as yaks, donkeys, and cattle. However, livestock removes large amounts of forage from the meadows (nearly 250 kg of dry matter/day for certain species), thereby reducing forage availability for Ibex. According to Mishra *et al.* (2004) competition between livestock and bharal has led to a decline in bharal density in the Trans-Himalayan landscape of Lahul-Spiti, Himachal Pradesh. The low abundance of wild animals in most cases can be attributed to habitat degradation and loss due to over-grazing by livestock (Rawat 2007; Rawat & Adhikari 2005b). Kittur *et al.* (2010) studied the spatial and habitat use overlap between the Himalayan tahr and domestic livestock (*Capra aegagrus hircus* and *Ovis aries*) in the sub-alpine and alpine areas of Kedarnath Wildlife Sanctuary, Uttarakhand and found a minimal spatial overlap. Livestock grazing also causes a considerable reduction in the standing crop (Mishra *et al.* 2004). It has been reported that the movement of livestock, pastoralists, and accompanying dogs prohibit habitat use by wild animals (Mehra 2000). Apart from competing with wild ungulates for resources, there are various other adverse impacts of grazing which can be summarized as soil compaction, erosion and fertility, disturbances to nests and predation by accompanying dogs, disease communication (Mehra 2000) and loss of species diversity (Mehra 2000 and Kala & Rawat 1999). Pastoralism and its interaction with wild animals in the alpine regions have more often been detrimental to the wild animals.

Objective

The present investigation aims to address the interaction between blue sheep and migratory livestock, regarding habitat overlap during the study period, in Upper Dhauli Valley, a cold arid region of Nanda Devi Biosphere Reserve with the following objective.

1. To assess resource overlap between wild ungulates and livestock.

Key research questions

Using the species presence/absence data collected from the trail sampling, specific research questions that were attempted to answer are as follows:

Does habitat use of blue sheep overlap with those of livestock?

5.2 Methodology

The wild ungulates found in the study area include blue sheep (*Pseudois nayaur*), Himalayan musk deer (*Moschus* sp.) and Himalayan tahr (*Hemitragus jemlahicus*) (Habib *et al.* 2016). Of these blue sheep (*Pseudois nayaur*) is the most commonly encountered species. Besides the wild herbivores, the study area is used by migratory livestock during the summer months. Amrit Ganga and Kalajowar are the two pastures were studied. Dhaman payar in Amrit Ganga valley is the only pasture where horses, donkeys, mules, and cattle are allowed to graze. Other pastures are utilized only for grazing goats and sheep. Horses, mules, and donkeys are allowed into these pastures for a brief period to act like an animal of burden. During June, before the migratory herders enter the valley, only domesticated animals from the villages occupy the pastures.

5.2.1 Field methods

Habitat use and separation between blue sheep and livestock

To understand the overlap in habitat use by blue sheep and livestock, trails were selected randomly by passing through various altitudinal and topographic features in the study area. Along each trail, indirect evidence of habitat use by blue sheep and livestock were collected. Pellets and dung were searched within 2 m X 20 m belt transect at every 100 m along trails (Bennett *et al.* 1940; Bhattacharya & Sathyakumar 2011). All the pellets and dung from these belts were removed after every survey to check fresh use of these areas by the groups of animals. Identification of pellets belonging to blue sheep and livestock, especially sheep and goats was possible with reasonable confidence after close observations of known samples and aided by shepherds and locals at the field site. Various parameters such as vegetation cover, habitat type, elevation, and dominant plant species were also recorded along the trails. Trails were walked in two watersheds namely, *Amrit Ganga* (8.62 km) and *Kalajowar* (3.96 km). A total of 110 belt transects (2 x 20 m) were laid at a distance of every 100 m trails of varying lengths (three in Dhaman and two in Kalajowar) and transects on the trails were marked for repeated observations. The total length of the trail walked was 12.58 km, which were repeated for ten times (five times in one year), from June to October for two years to record sign presence in the area. The transects on which signs were detected, were assigned a score of "1", whereas, in the absence of animal sign (pellets), it was assigned a score of "0".

5.2.2 Data analysis

The extent to which habitat was shared by blue sheep and livestock was calculated by analyzing the relationship of blue sheep and livestock regarding their co-occurrence patterns across all transects and the maps generated using the transect points. Data from all surveys were pooled to obtain a transect-wise presence-absence matrix for blue sheep and livestock. Transect-based spatial co-occurrence between blue sheep and various livestock was calculated by the C-score index (Stones & Robert 1990) in R software (R Core Team 2017). C-score is a measure of the tendency of a species not to occur together in the same grid/transect; larger values indicating lower average co-occurrence (greater separation) among species pairs.

The ground truth points of transects were plotted in Google Earth, and hence an occupancy map was generated. Different colour codes (Table 5.1) were given to distinguish between animal occupancy.

Table 5.1: Colour codes used for different criteria

Criteria used	Colour used
Livestock present	Red
Blue sheep present	Yellow
Both present	Blue
Both absent	Green

5.3 Results and Discussion

The present study dealt with the use of the pastures by blue sheep and livestock through indirect method during the study period. During June livestock occupancy in the area was minimum (9.09%; n=220). Livestock arrives in the area by June, so the presence was less during this time, but then in the coming months, they graze in the whole valley with the highest sign presence in August. During October the percentage of sign presence decreases (12.73%; n=220), this is because during this month the migratory herders are not present and few horses, mules, and cattle from the villages constitute the livestock group using the valley. Maximum blue sheep occupancy (10.45% (n=220) and 10.91% (n=220), respectively) was recorded during June and October. Signs of livestock presence were maximally encountered during August (82.27%, n=220) during the study. The minimum livestock occupied transects were recorded during June (n=220) 9.09%. The maximum number of transects with blue sheep pellets were recorded during October (10.91%, n=220) and June (10.45%, n=220). During July, August, and September, blue sheep pellets were not encountered in the area. As the pastoralists depart from the area in September, blue sheep again comes down to the lower altitude, and their sign gets recorded in October (Figure 1). Blue sheep pellets were encountered only during June and October. Hence the probability of overlap occurs during this time. The C score value indicates that there is a maximum overlap during October (C score= 0.850075) between the two groups. Owing to migratory settlements, no livestock was recorded in winter months. According to the villagers, blue sheep visit the valley in the winters when the water bodies at higher reaches freeze, and during the summers they move to better pastures in the higher reaches (pers. conversation). The altitudinal migration of blue sheep has been reported by Chundawat (1992). He indicated that blue sheep moved to higher elevations in summers in the Hemis National Park, Jammu, and Kashmir. But the number of livestock using the valley has some effect on the use of the area by the blue sheep. The percentage of transects occupied by livestock and blue sheep showed an inverse relationship. With the increase in the percentage of livestock occupied transects those with blue sheep decreased. The study revealed that, at a higher percentage of livestock presence, the blue sheep was absent from the pastures in the valley (Figure 5.1). The distribution and use of transects by blue sheep and livestock across different months have been shown using Google Earth imagery (Figure 5.3-5.22).

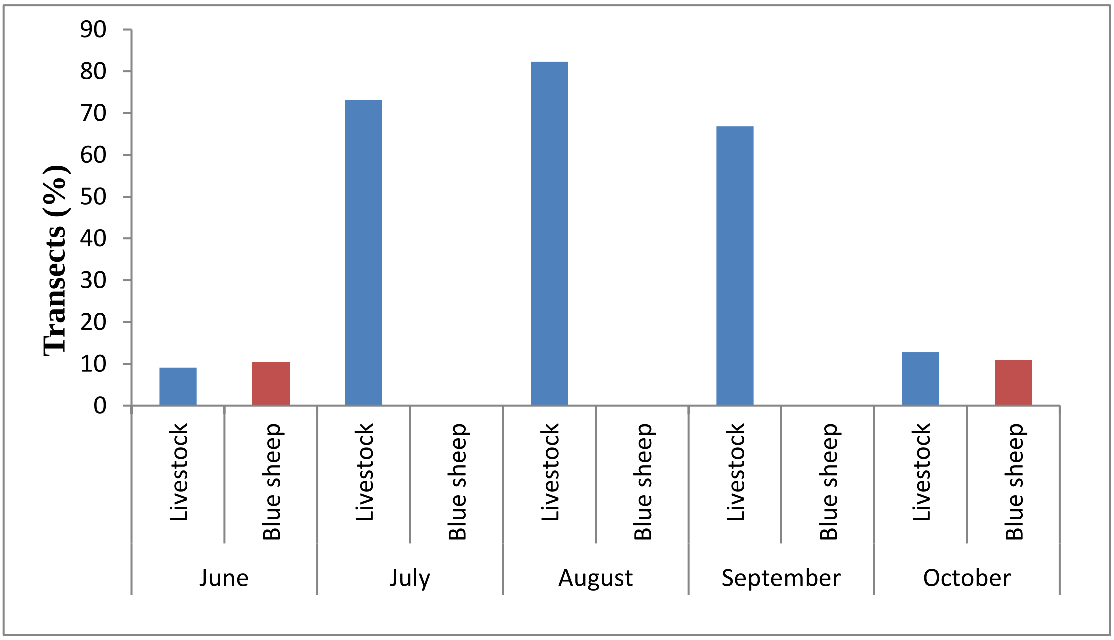


Figure 5.1. Monthwise percentage of transects with the sign-presence of Blue-sheep and livestock

Habitat utilization by animals

Habitat provides food and covers essential for a species to survive. Different landforms *viz;* moraine, scrub steppe, livestock camping site, and scree, have their distinct features in terms of physical as well as biological aspects. Specific plant communities colonize different landforms depending upon its topographical and climatic (microclimatic) variables. These make them preferred habitats for animals during different seasons.

Of the total (110) transects laid, 39% were in moraines, followed by 26% in the scrub steppe, 14% in scree slopes, 16% in the herbaceous meadow and the rest 5% were others (dry river bed and animal camping site). On examining the availability and utilization of the landforms, livestock and blue sheep utilized all the landforms proportionate to its availability. Livestock used all the habitat types proportionately since the herders monitored their movements while grazing.

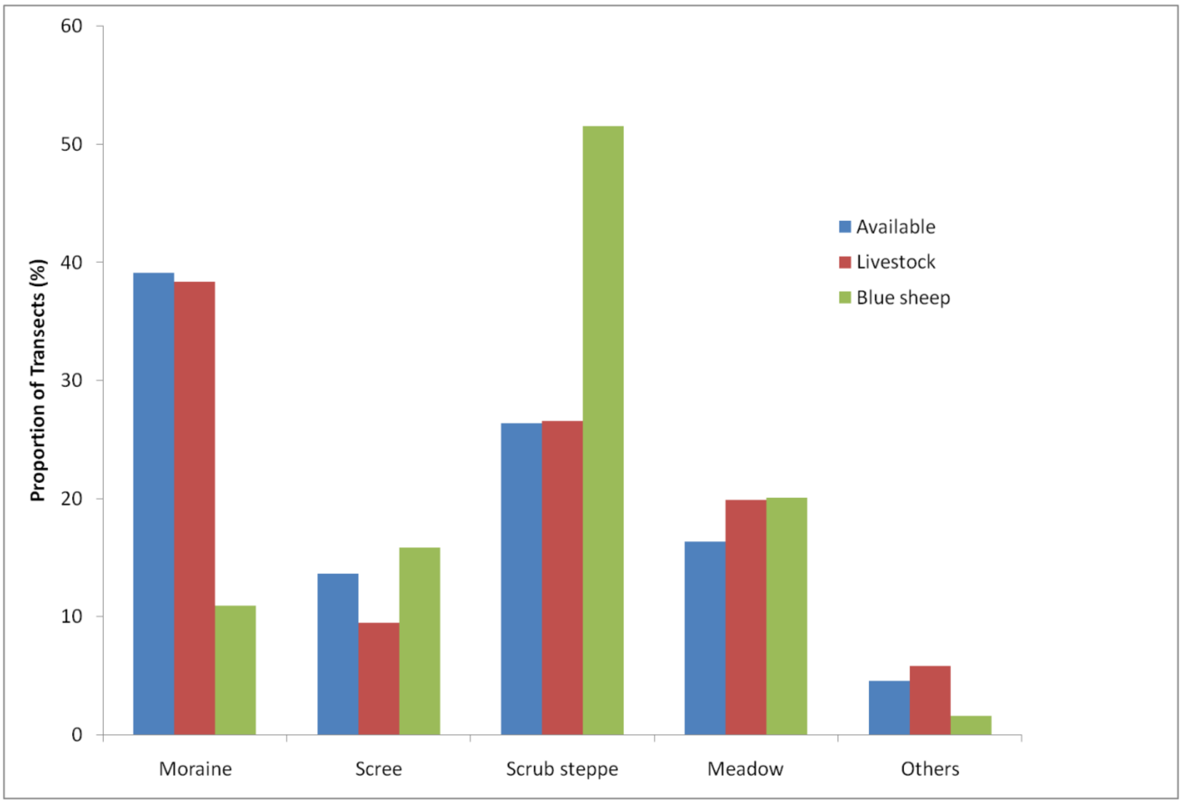
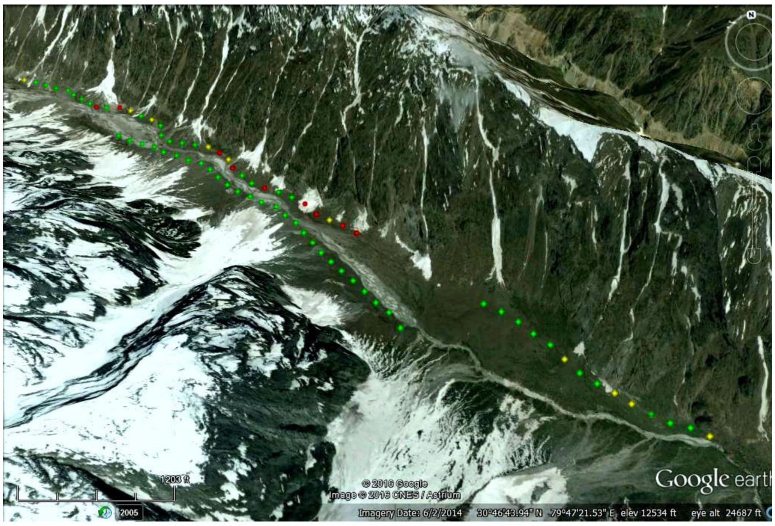


Figure 5.2. Proportion of transects in different habitats and use by livestock and blue sheep

Although, there was a temporal difference in the livestock and blue sheep grazing as shown in the previous graph. During the study, efforts were made to study how their signs were distributed in different habitats. Livestock used the transects proportionally to the availability of the habitats. The movements of the livestock were governed by the shepherds; they choose the areas based on species richness, distance from a water source and available area for grazing. Morainic deposits and scrub steppe, being frequent landforms and marked by higher species richness (Kumar 2016) could be the reason for the high presence of livestock. Scree slopes were comparatively avoided by shepherds due to sudden landslides and rock fall (personal coversation). Blue sheep use scrub steppe most, followed by meadow and scree. The blue sheep used scrub steppe more than the proportion availability. A higher presence of blue sheep in herbaceous meadow could be because, in June and October, the glacial springs in higher reaches of a mountain are frozen, and the river at the valley bottom is the only source of water. While in scrub steppe the animal can find shrub cover for protection and food when the open areas are snow covered, or the herbaceous vegetation has dried off. Although, there was a temporal difference in the livestock and blue sheep grazing, both the groups were using the same habitats. Since livestock removes large amounts of forage from the pastures, thereby reducing forage availability for wild ungulates (Bagchi *et al.* 2002), blue sheep have to spend the winters with scanty resources.

5.4 Conclusion

The migratory livestock stays in the valley from mid-June till September. After October till mid-June, there was no livestock present in the valley. During July, August and September blue sheep presence-signs were not encountered. Blue sheep pellets were reported in June and October when the pastoral groups were absent from the valley. Only livestock availing the region during these months were few cattle, horses, and mules belonging to the villagers. The maximum overlap between livestock and blue sheep was seen during October (C score= 0.85). Livestock was guided by a shepherd during foraging; hence, they utilized all the available habitat types, whereas, blue sheep used scrub steppe comparatively more than other habitats.



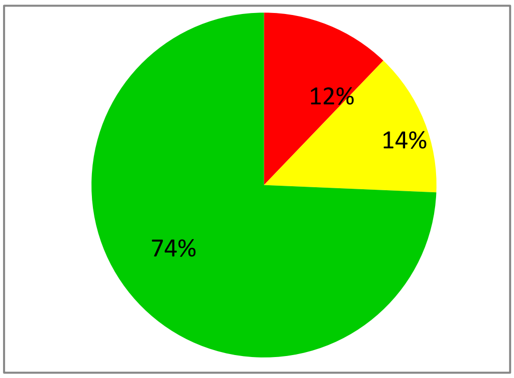
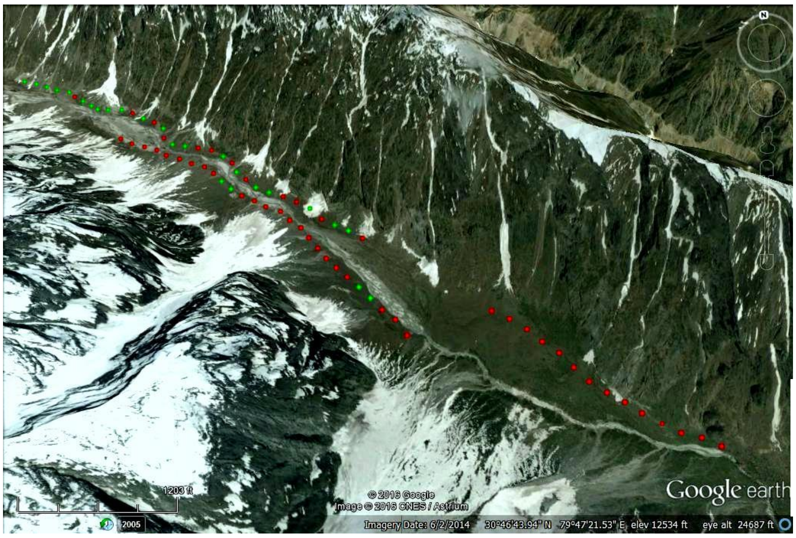


Figure 5.3. Distribution of transects occupied by different animal groups in June 2012 in Amrit Ganga



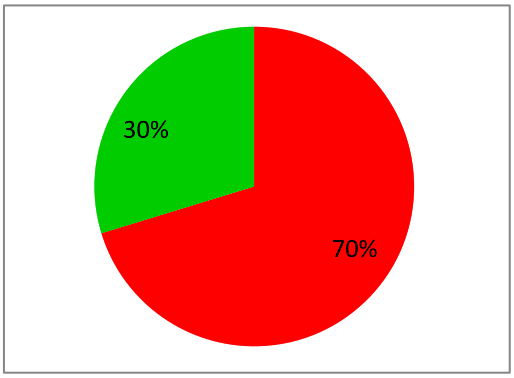
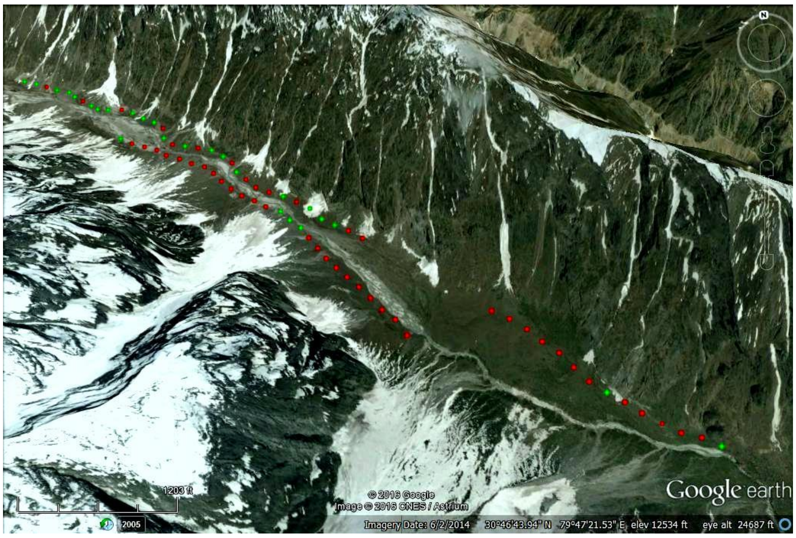


Figure 5.4. Distribution of transects occupied by different animal groups in July 2012 in Amrit Ganga



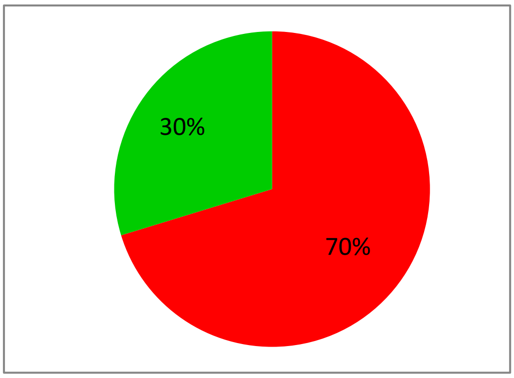
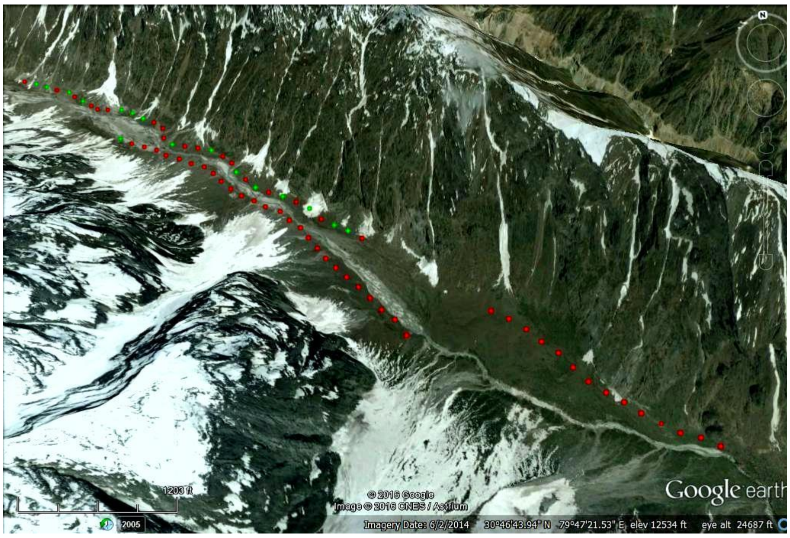


Figure 5.5. Distribution of transects occupied by different animal groups in August 2012 in Amrit Ganga



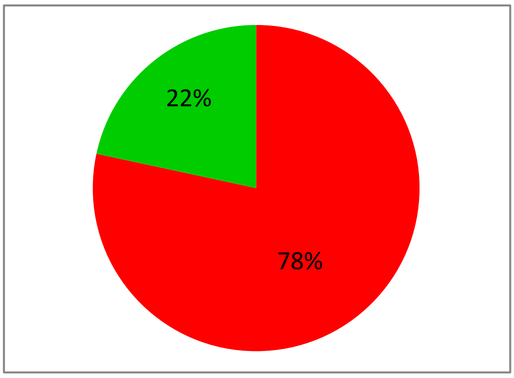
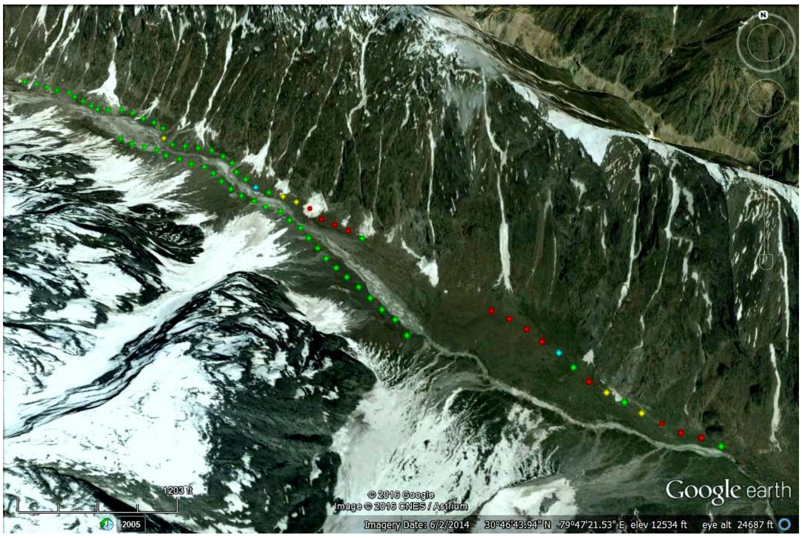


Figure 5.6. Distribution of transects occupied by different animal groups in September 2012 in Amrit Ganga



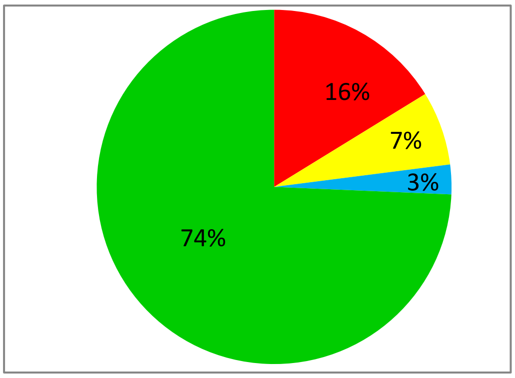
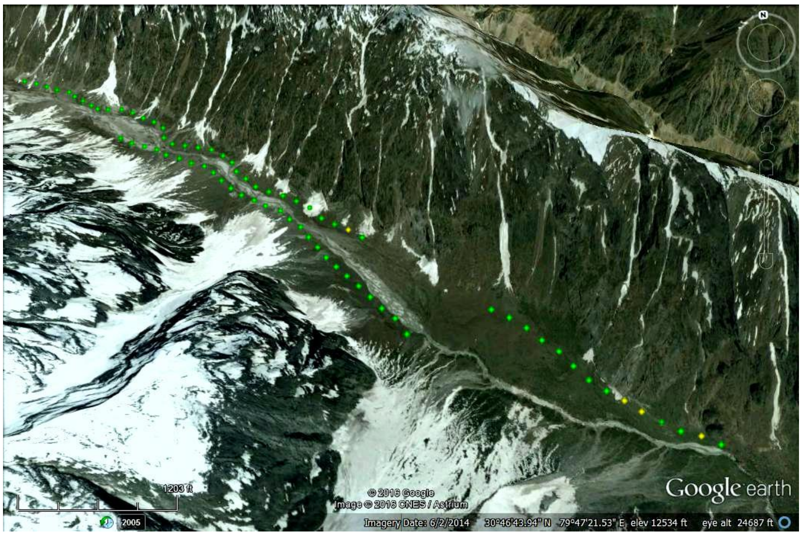


Figure 5.7. Distribution of transects occupied by different animal groups in October 2012 in Amrit Ganga



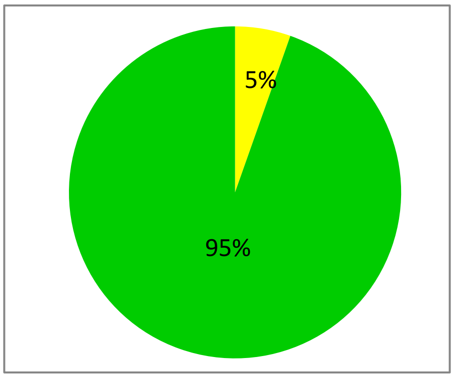
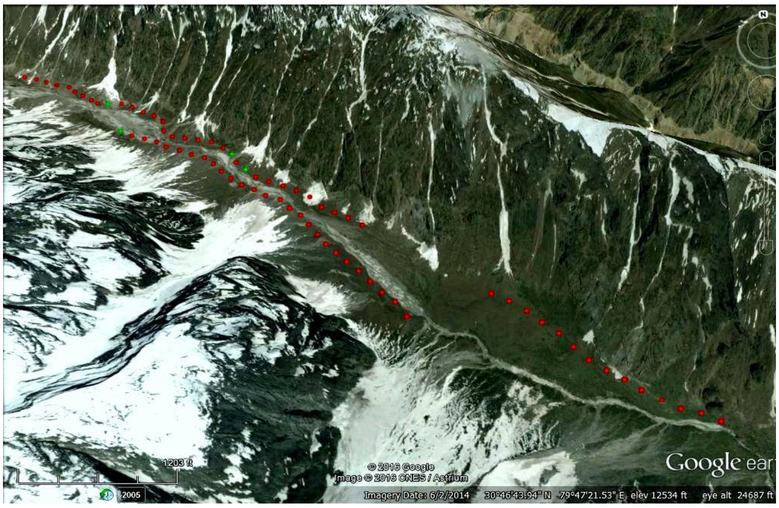


Figure 5.8. Distribution of transects occupied by different animal groups in June 2014 in Amrit Ganga



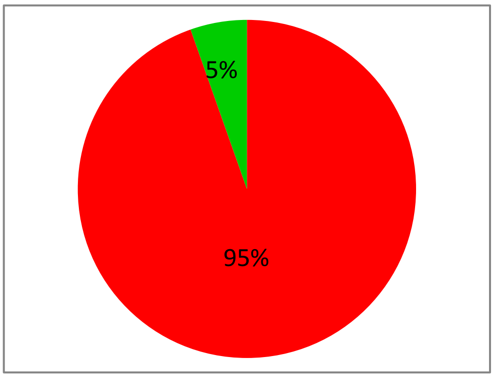


Figure 5.9. Distribution of transects occupied by different animal groups in July 2014 in Amrit Ganga

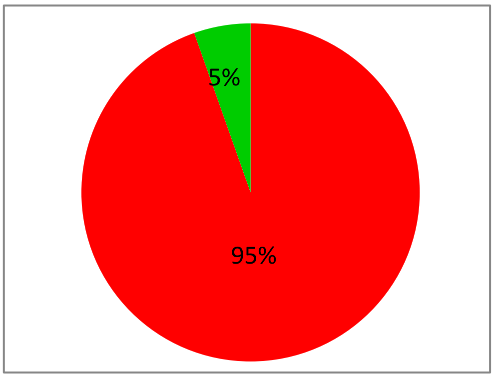
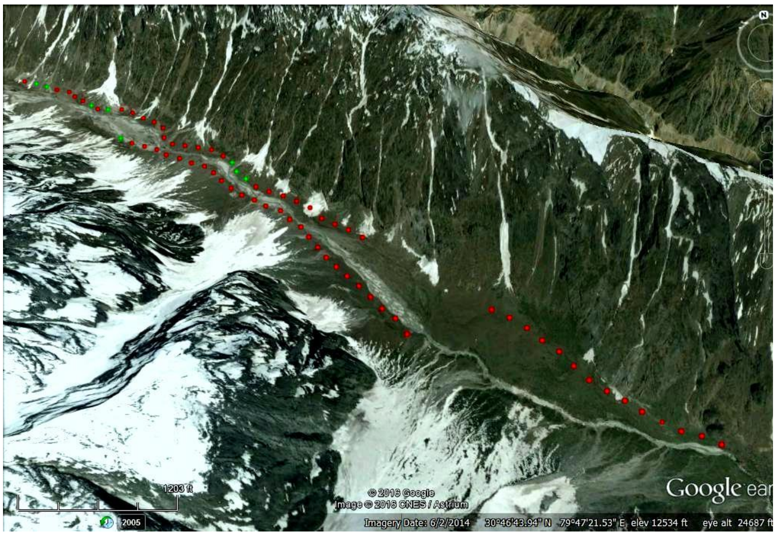


Figure 5.10. Distribution of transects occupied by different animal groups in August 2014 in Amrit Ganga



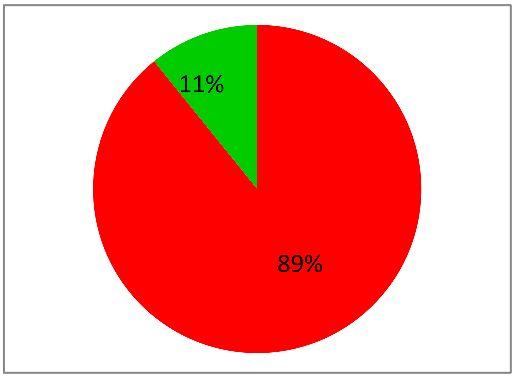
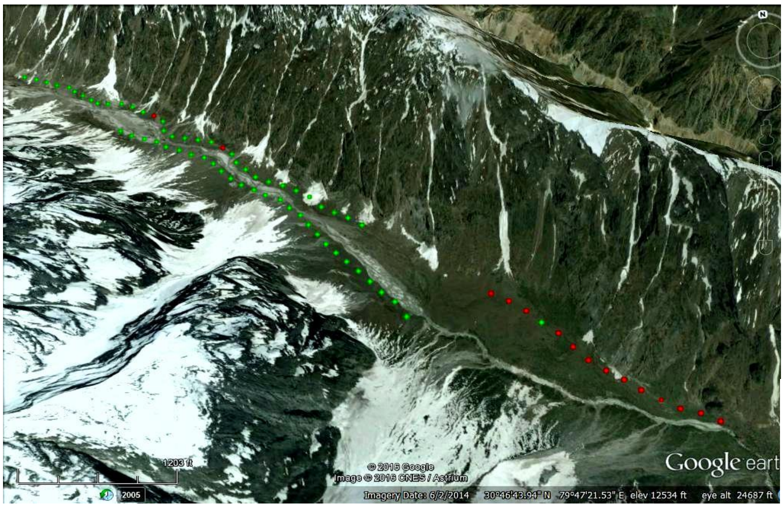


Figure 5.11. Distribution of transects occupied by different animal groups in September 2014 in Amrit Ganga



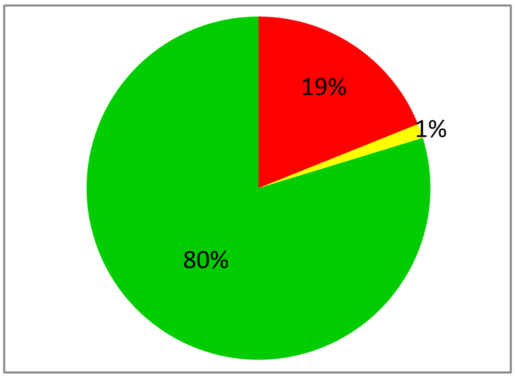
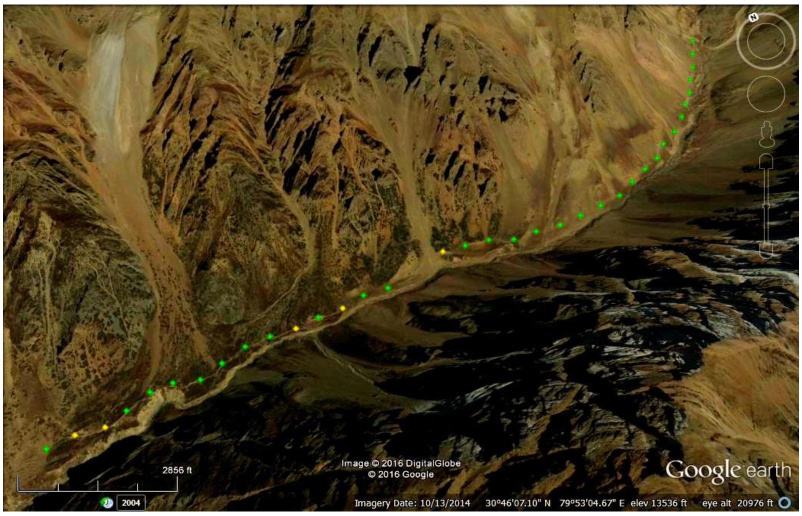


Figure 5.12. Distribution of transects occupied by different animal groups in October 2014 in Amrit Ganga



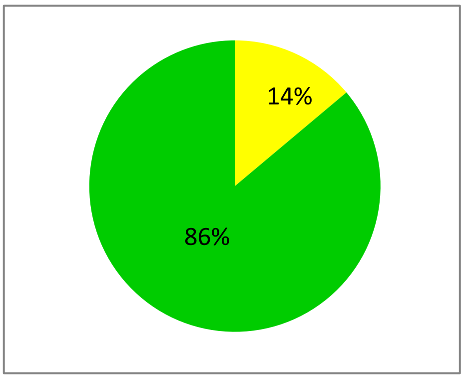
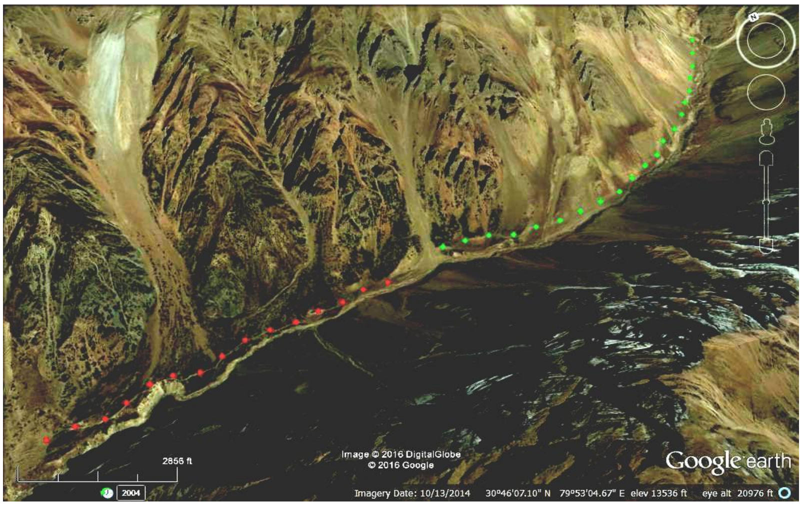


Figure 5.13. Distribution of transects occupied by different animal groups in June 2012 in Kalajowar



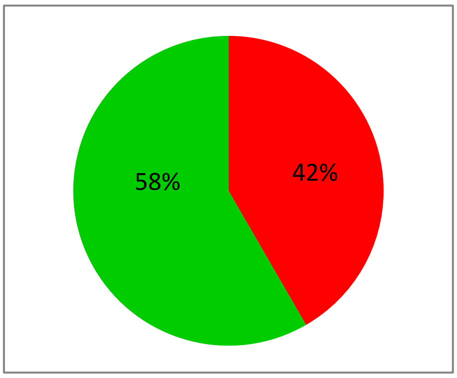


Figure 5.14. Distribution of transects occupied by different animal groups in July 2012 in Kalajowar

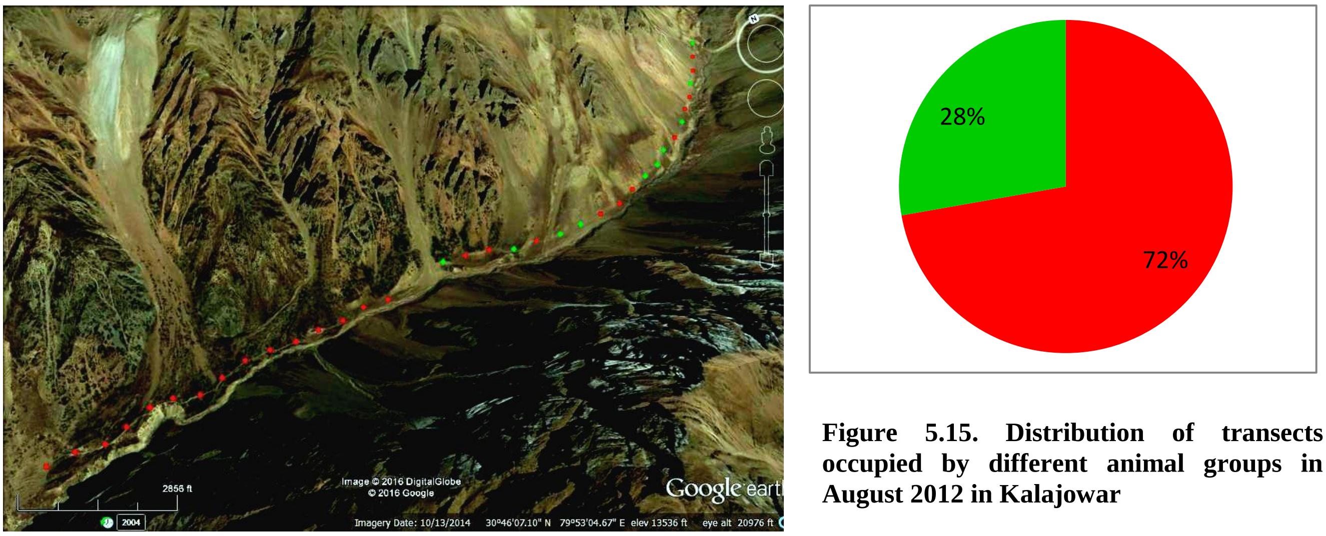


Figure 5.15. Distribution of transects occupied by different animal groups in August 2012 in Kalajowar

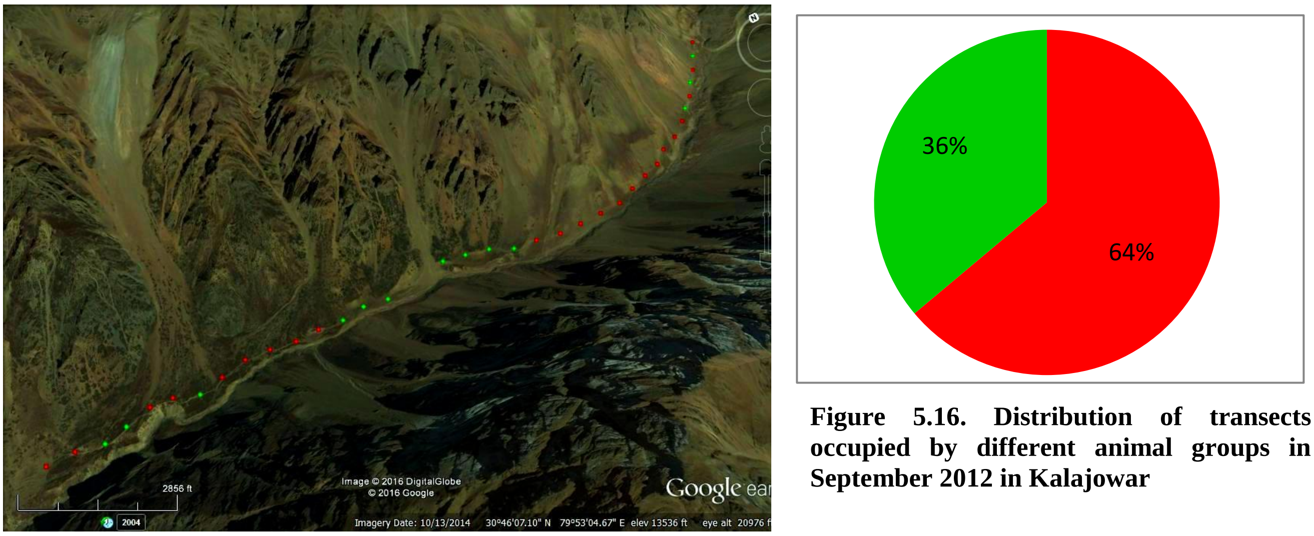


Figure 5.16. Distribution of transects occupied by different animal groups in September 2012 in Kalajowar

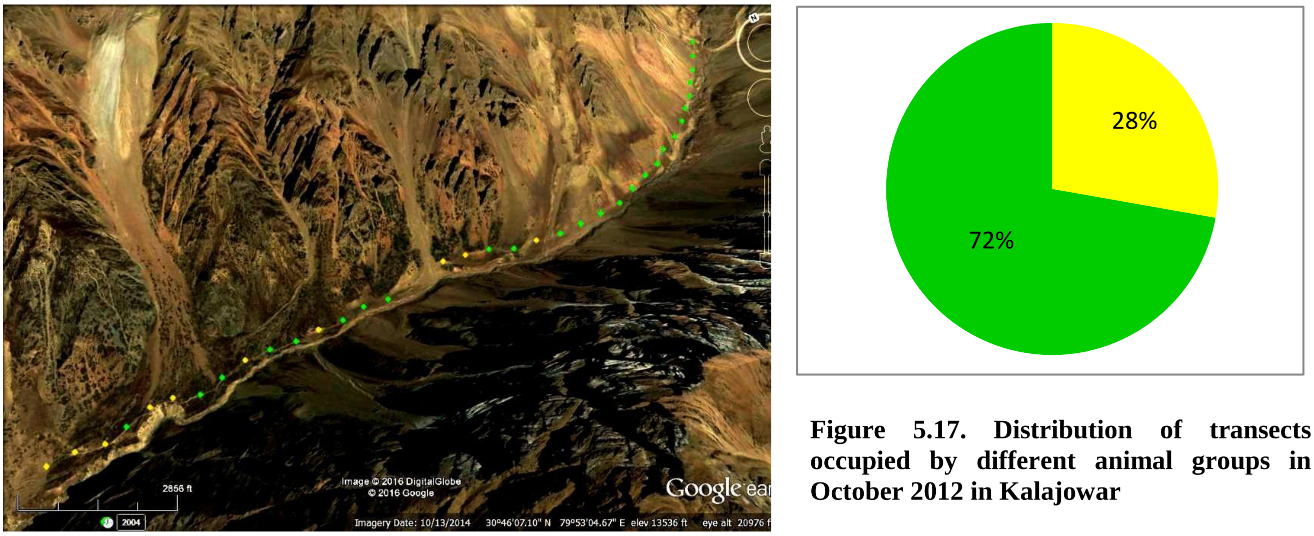
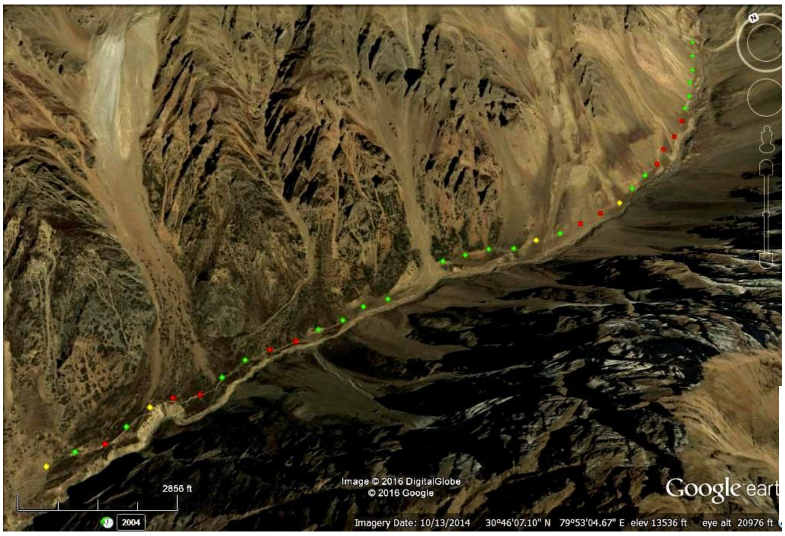


Figure 5.17. Distribution of transects occupied by different animal groups in October 2012 in Kalajowar



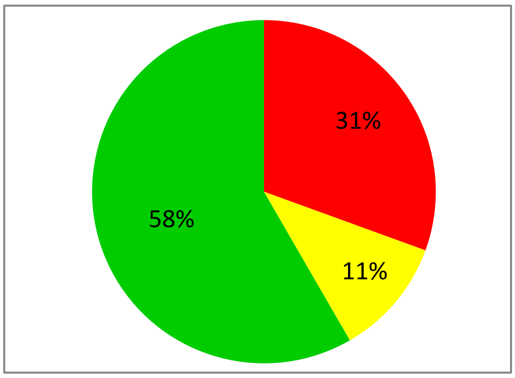


Figure 5.18. Distribution of transects occupied by different animal groups in June 2014 in Kalajowar

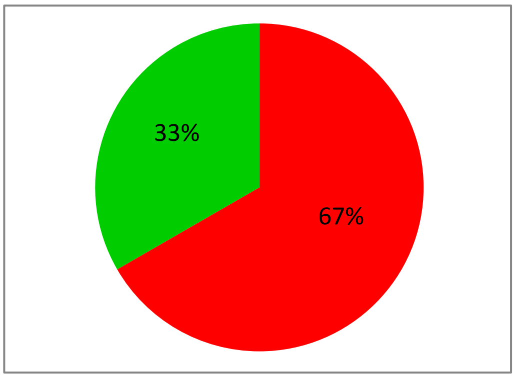


Figure 5.19. Distribution of transects occupied by different animal groups in July 2014 in Kalajowar

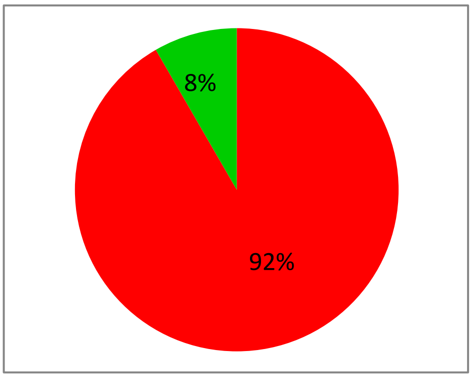


Figure 5.20. Distribution of transects occupied by different animal groups in August 2014 in Kalajowar

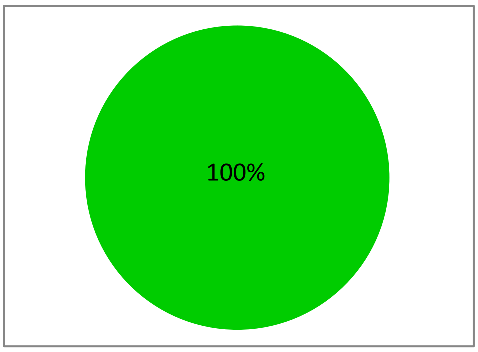


Figure 5.21. Distribution of transects occupied by different animal groups in September 2014 in Kalajowar

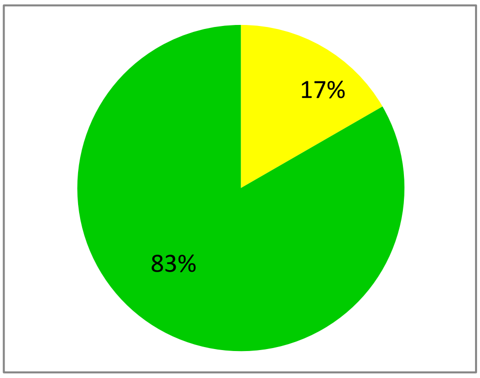


Figure 5.22. Distribution of transects occupied by different animal groups in October 2014 in Kalajowar

Chapter 6

General Discussion and Conclusion

The salient feature of the alpine vegetation is the wealth of herbaceous plants growing along narrow climatic gradients showing remarkable patterns of adaptations to harsh environments with a short growing season and relatively recent Palaeo-history (Korner 1999; Vishnu-Mittre 1984). During the study period, eight migratory herders visited the alpine region for resting place for summer migration along with few locals utilizing the floral diversity and biomass during their stay. This sometimes also leads to conflict with the resident wild ungulates as reported by various workers (Shreshtha & Wegge 2008a; Roder 2000; Prins 1992; Johnsingh *et al.* 1999, Mishra 2001, Bagchi *et al.* 2002, Raghavan 2003, Namgail *et al.* 2007; Sathyakumar *et al.* 1993; Bhatnagar *et al.* 2000; Vinod & Satyakumar 2005; Mishra *et al.* 2004; Mehra 2000) in the alpine regions for resource competition as well as have some adverse impact on the native vegetation of the area (Mehra 2000; Rawat 2007; Rawat & Adhikari 2005b; Prins 1989; Kala & Rawat 1999; Rawat 1998; Sundriyal 1989, 1992, 1995; Nautiayal *et al.* 2004). In the present study, the ecology of the pasture concerning floristic diversity and biomass availability was studied along with the pastoral animal's interaction with the floral and faunal wealth of the areas. The significant outcomes of the study have been discussed below.

Floristic diversity

Amrit Ganga was represented by 92 species (72 genera; 29 families) distributed within *ca.* 31.70 km2 whereas Kalajowar was represented by 70 species (48 genera; 22 families) distributed within *ca.* 19.41 km2. The recent study by Kumar *et al*. (2016a) reported 495 species (267 genera; 73 families) from Niti Valley covering an area of 727 km2 in the cold arid zone of NDBR. Both the pastures are part of Niti valley, Srivastava (2010) reported 1405 species (490 genera; 98 families) in western Himalaya (J&K, H.P., UK) distributed over an area of *ca.* 98,980 km2. A comprehensive study on plants from Nanda Devi Biosphere Reserve was made by Hajra and Balodi (1995) who recorded 801 species of vascular plants (406 genera; 120 families) covering the then area of reserve (*ca.* 2000 km2). In both the valleys the dominant families were Poaceae, Asteraceae, and Cyperaceae, whereas the dominant families in terms of high species richness in UDV were Asteraceae (32 genera with 58 species), followed by Poaceae (22 genera with 41 species) and Lamiaceae (15 genera with 19 species; Kumar 2016). The difference in the floristic components of the two pastures may be attributed to the fact that the two pastures have different topographic features and grazing regimes. In Amrit Ganga, northern aspect is prevalent with moraines being the dominant landform whereas Kalajowar is comparatively dry with southern slopes and scree is the major landform in the area. The higher species richness in the Amrit Ganga valley as compared to Kalajabar can be attributed to the fact that the former has more affinities towards Greater Himalaya which is moist as compared to Kalajabar which is drier and has greater similarities towards Trans-Himalaya (Kumar *et al.* 2016). Floristic composition of the Amrit Ganga and Kalajowar, reveals the dominance of graminoids (Poaceae and Cyperaceae) which reflects the characteristic features of the grazing landscapes since grazing transforms vegetation and induces a clear graminoid dominance (hemicryptophytic and chamaephytic life-forms; Rawat & Adhikari 2005b).

Biomass

The biomass showed an upward trend in July (128.3±3 g m-2), reaching its peak in August (183.4±4 g m-2) and started declining by September (131.4±4 g m-2). The increase in the biomass in July and August can be attributed to the ample supply of moisture available during this time which is needed by the plants. The relationship between the availability of moisture and biomass production has been studied by Carmody (2010), and it was observed that net biomass production was highest where there was an ample supply of moisture. Kala & Rawat (1999) also reported a similar trend, where biomass increased from June from the onset of monsoon, attained a peak in early September and declined after that. Overall biomass in the area during the study period was estimated to be 95.16±2.15 g m-2 (951.6±21.5 kg ha-1) which is comparable with phytomass estimated in Tso Kar region (319-2156 kg ha-1) (Rawat *et al.* 2006). Biomass availability of graminoids as compared with other forbs in the area was 37% of the total biomass. Overall biomass of graminoids was estimated to be 35.4±11.5 g m-2 (345±115 kg ha-1), which is higher than the graminoid biomass reported by Mishra *et al.* (2004) in a intensively grazed rangeland (134 kg ha-1; 95% confidence limits 97-194 kg ha-1) while being less than that of a moderately grazed pastureland (535 kg ha-1; 95% confidence limits 434-632 kg ha-1).

Resource use by livestock

Domestic livestock had a wide dietary spectrum, consuming 60% of the total 92 plant species reported from the area (55 plant species). As reported by previous workers that due to its wide dietary spectrum livestock may have a dietary overlap with wild ungulates in the Himalayas (Awasthi *et al.* 2003; Bhattacharya *et al.* 2012). Although competition in spring/summer may not exist but in autumn and winter when wild ungulates move to lower altitudes (where livestock graze during summer), they have to survive on the scanty and less nutritious resources leftover by the livestock (Awasthi *et al.* 2003). Mule (55% grass, 45% other plants), horse (60% grass, 40% other plants) and cattle's (52% grass, 48% other plants) dietary composition contained graminoids more as compared to other plant species, while sheep had 64% of other plants and 36% of graminoids in diet. Graminoids formed the major portion of the diets of livestock (sheep=36%, mule=55%, horse=60% and cattle=52%) except for goats. Earlier workers have also reported that livestock preferred graminoids during summer months and it formed a major part of their diet (Rawat & Adhikari, 2005b; Mishra *et al.* 2004). Among the 30 families found in the diet of livestock, the family with most forage plants was Rosaceae comprising eight species followed by Asteraceae with six species and Caprifoliaceae with five species. Awasthi *et al.* (2003) through the perusal of previous literature also reported that the two families Rosaceae and Asteraceae have most of the forage species.

Habitat overlap with blue sheep

The current work demonstrates no overlap in the habitat use between blue sheep and migratory livestock in Upper Dhauli Valley during July, August, and September that is the growing period. The maximum overlap between livestock and blue sheep was seen during October (C score= 0.850075). After October till mid-June, there is no livestock present in the valley. This could be mainly attributed due to the inhabitation of a small portion of the area for a limited time (June to October) by the migratory livestock. The migratory herders leave the area by the end of August or early September. During June and October, few livestock (mainly cow, horses and donkeys) of the local inhabitants use the pastures. Owing to migratory settlements, no livestock was recorded in winter months. According to the villagers, blue sheep visit the valley in the winters when the water bodies at higher reaches freeze, and during the summers they move to better pastures in the higher reaches (pers. conversation). The altitudinal migration of blue sheep has been reported by Chundawat (1992). He indicated that blue sheep moved to higher elevations in summers in the Hemis National Park, Jammu, and Kashmir. But the number of livestock using the valley has some effect on the use of the area by the blue sheep. Blue sheep presence during the year 2012 was higher as compared to 2014. This can be attributed because, in 2014, the number of livestock using the area was far more than to 2012. Hence, it can be hypothesized that although the livestock may not pose any competition directly but they do act as a deterrent for the blue sheep at high densities. Blue sheep can be detected in the inaccessible areas of upper Dhauli valley during July-September, it has been confirmed by the local inhabitants and the migratory herders (personal observation); however, expeditions to these inaccessible areas were beyond the scope of this study due to inaccessibility and stringent permission procedure from the local administration due to the political boundaries of foreign lands like China in proximity with the study area.

Conclusion

Pastoralism in the high altitude alpine region is going on from ancient time. It affects both the high altitude habitats as well as the pastoral communities. The pastoral communities depend on it for financial benefits through resource use by livestock. The services used by livestock for grazing is enormous. The ecological interaction between wild animals and livestock is well studied in these regions. The plant communities also get affected by the cyclic grazing activities. Grazing regimes affect the distribution and diversity of plant species in such ecosystems. It may also have some impact on the sereal stages of the community.

The availability of forage (standing biomass) and movements of the pastoralists are well synchronized through socio-cultural traditions of the pastoral communities. The pastoral groups reach the alpine meadows when the growth of the plants being (onset of monsoon) and move away from such pastures as biomass declines. It can be seen as an indigenous way of rotational grazing where the plants are provided with time to compensate for the loss due to grazing. The ecosystem services utilized during the time of migration and stay at the alpine regions should be studied in detail to develop an understanding of the actual economic benefits of such practices.

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Abule, E., Snyman, H. A., and Smit, G. N. 2005. Comparisons of pastoralists perceptions about rangeland resource utilisation in the Middle Awash Valley of Ethiopia. Journal of Environmental Management, *75*(1), 21–35. https://doi.org/10.1016/j.jenvman.2004.11.003

Awasthi, A. 2001. Ecological Impact of anthropogenic pressures on high altitude forests along Bhagirathi Catchment. Ph.D. thesis. FRI Deemed University. Dehradun: iii-vi pp.

Awasthi, A., Uniyal S. K., Rawat G. S. and Sathyakumar S. 2003. Food plants and feeding habits of Himalayan ungulates. Current Science, 85(6).

Bagchi, S., and Ritchie, M. E. 2010a. Introduced grazers can restrict potential soil carbon sequestration through impacts on plant community composition. Ecology Letters, 13: 959–968 pp.

Bagchi, S., and Ritchie, M. E. 2010b. Herbivore effects on above- and belowground plant production and soil nitrogen availability in the Trans-Himalayan shrub-steppes. Oecologia, 164(4), 1075–1082 pp. https://doi.org/10.1007/s00442-010-1690-5

Bagchi, S., Mishra, C., and Bhatnagar, Y. V. 2004. Conflicts between traditional pastoralism and conservation of Himalayan ibex (Capra sibirica) in the Trans-Himalayan mountains. Animal Conservation, 7(2), 121-128 pp.

Bagchi, S., Mishra, C., Bhatnagar, Y. V. & McCarthy, Y. 2002. Out of steppe? Pastoralism and ibex conservation in Spiti. CERC Technical report no. 7. Nature Conservation Foundation, Mysore, Wildlife Institute of India, Dehradun & International Snow Leopard Trust, Seattle. Pg 1+37 pp.

Balram, S., and Dragicevic, S. 2005. Attitudes toward urban green spaces: integrating questionnaire survey and collaborative GIS techniques to improve attitude measurements. Landscape and Urban Planning 71: 147-162 pp.

Bernues, A., Riedel J.L., Asensio, M. A., Blanco M., Sanz, A. and Revilla, R. 2005. An integrated approach to studying the role of grazing systems in the conservation of rangelands in a protected national park (Sierra de Guara, Spain). Livestock production Science, 96(1): 75-85 pp.

Bennett, L.J., English, P.F. and McCoun R. 1940. A study of deer populations by pellet group counts. Journal of Wildlife Management 4:398–403.

Bhasin V. 1988. Himalayan Ecology. Transhumance and Social Organisation: Gaddis of Himachal Pradesh. Delhi: Kamla-Raj Enterprises. Pg 1+272 pp.

Bhasin V. 1989. Ecology, Culture and Change: Tribals of Sikkim Himalayas. New Delhi: Inter-India Publications. Pg 1+407 pp.

Bhasin V. 1996. Transhumants of Himalayas: Changpas of Ladakh, Gaddis of Himachal Pradesh and Bhutias of Sikkim. Delhi: Kamla Raj Enterprises. Pg 1+280 pp.

Bhasin, V. 2011. Pastoralists in India. Journal of Human Ecology 33(3): 147–177 pp.

Bhatnagar, Y.V., Rawat, G.S., Johnsingh, A.J.T. and Stuwe, M. 2000. Ecological separeation between Ibex and resident livestock in a Trans-Himalayan protected area, 70-83. In: Grassland Ecology and Management in protected areas of Nepal. Richard C., Basnet K., Shah, J.P. and Raut, Y. (eds.) International Centre for Integrated Mountain Development, Kathmandu, Nepal.

Bhattacharya, T., and Sathyakumar, S. 2011. Natural resource use by humans and response of wild ungulates: A case study from Bedini-Ali, Nanda Devi Biosphere Reserve, India. Mountain research and development, 31(3), 209-219.

Bhattacharya, T., Kittur, S., Sathyakumar, S. and Rawat, G.S., 2012. Diet overlap between wild ungulates and domestic livestock in the Greater Himalaya:

Implications for management of grazing practices, 11-21. In Proceedings of the Zoological Society (Vol. 65, No. 1). Springer-Verlag.

Bhattacharya, T., Sathyakumar, S. and Rawat, G.S. 2006. Studies on the Animal–Habitat interactions in the buffer zone of Nanda Devi Biosphere Reserve. Ministry of Environment and Forests, Govt. of India, New Delhi, 103 pp.

Bhattacharya, T., Sathyakumar, S. and Rawat, G.S. 2009. Distribution and abundance of Galliformes in response to anthropogenic pressures in the buffer zone of Nanda Devi Biosphere Reserve. International Journal of Galliformes Conservation, 1: 78-84 pp.

Biru, Y., Tessema, Z. K., and Urge, M. 2017. Perception and attitude of pastoralists on livestock-wildlife interactions around Awash National Park, Ethiopia: implication for biodiversity conservation. Ecological Processes, 6(1), 13.

Bonham, C.D., 1989. Measurements of Terrestrial Vegetation. Wiley, New York. X+338 pp.

Burgess, R. G. 1982. The unstructured interview as a conservation, 100-107. In: Field research: A source book and field manual. Burgess, R.G. (ed.). George Allen and Unioun. London, U.K.

Cao, G., Tang, Y., Mo, W., Wang, Y., Li, Y., and Zhao, X. 2004. Grazing intensity alters soil respiration in an alpine meadow on the Tibetan plateau. Soil Biology and Biochemistry, 36(2), 237–243. https://doi.org/10.1016/j.soilbio.2003.09.010

Carmody, J. 2010. Wet Tropics of Queensland World Heritage Area Tour Guide Handbook. Published by the Reef & Rainforest Research Centre Ltd., Cairns. 220 pp.

Casimir, M.J., and Rao, A. 1985. Vertical control in the Western Himalaya: Some notes on the pastoral ecology of the nomadic Bakerwal of Jammu and Kashmir. Mountain Research and Development 5(3): 221–232.

Census India. 2011. Available at: [http://censusindia.gov.in/PopulationFinder/Sub_Districts_Master.aspx?state_code=05anddistrict_code=02] (accessed on 28.12.15.).

Chandola, S. 2009. Vegetational inventory of cold desert habitat of Nilang area of Jadh Ganga catchment (Uttarkashi) in Garhwal Himalaya, Ph.D thesis, H.N.B. Garhwal University, Srinagar Garhwal: 299 pp.

Chatterjee, P.C. 1989. Nomadic graziers of Garhwal, 93-99. In Studies in Himalayan Ecology and developmental strategies. Singh, T.V. and J. Kaur (eds.), New Delhi: Himalayan Books.

Chundawat, R. S. 1992. Ecological studies of snow leopard and its associated prey species in Hemis high altitude national park. P.hD thesis. University of Rajasthan, Jaipur, India. 52-66 pp.

Cincotta, R.P., Soest, P.J.V., Robertson J.B., Beall, M. and Goldstein, M.C. 1991. Foraging ecology of livestock on the tibetan changtang: a comparison of three adjacent grazing areas. Arctic and Alpine Research, 23(2): 149-161.

Collins, S., Knapp, A., Briggs, J. and Blair, J. 1998. Modulation of diversity by grazing and mowing in native tallgrass prairie. Science, 280: 745-7.

Conant, R.T., Paustian, K. and Elliott, E.T. 2002. Grassland management and conversion into grassland: effects on soil Carbon. Ecological Application, 11: 343–355.

Cook, C.W., Stubbendieck, J., 1986. Range Research: Basic Problems and Techniques. Soc. Range Manage., Denver, CO, pp. 317.

Crawley, M.J. 1983. Herbivory: The Dynamics of Animal-Plant Interactions. Studies in Ecology. Vol. 11. Berkeley (CA): University of California Press. 1-400 pp.

Curtis, T. and McIntosh, P. 1950. The interrelations of certain analytical and synthetic phytosociological characters. Ecology, 31: 434-455.

ESRI, I. 2008. ArcGIS 9.3. Environmental Systems Research Institute, Redlands.

FAO, 2007. Livestock's Long Shadow. Food and Agriculture Organization of the United Nations, Rome, Italy.

Farooquee, N. A. 1998. Changes in pastoralism in the Indian Himalaya.In: Uprooted: Dispossession in Africa. 22 (4). https://www.culturalsurvival.org/publications/cultural-survival-quarterly/changes-pastoralism-indian-himalaya

Farooquee, N.A. 1994. Transhumance in the central Himalaya: a study of its impact on environment. Ph.D. Thesis, Department of Political Science, H.N.B Garhwal University, Srinagar, India: 98-190 pp.

Gao, Y.H., P. Luo, N. Wu, H. Chen & G.X. Wang 2007. Grazing intensity impacts on Carbon sequestration in an alpine meadow on the Eastern Tibetan plateau. Research journal of Agricuture and Biological Sciences, 3(6): 642-647.

Gedif, T. and Hahn, H. 2003. The use of medicinal plants in self-care in rural central Ethiopia. Journal of Ethnopharmacology, 87 (2-3):155-161.

Green, M.J.B. 1987. Diet composition and quality in Himalayan musk deer based on fecal analysis. Journal of Wildlife Management. 51: 880–892.

Habib, B., Mohan D., Bhattacharya, A., Shrotriya, S., Mondal, I. and Rawat, G.S. 2016. Status of wildlife in Trans-Himalayan Regions of Uttarakhand State, India-2015. Uttarakhand Forest Department and Wildlife Institute of India.

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

Hammer, Ø., Harper, D.A.T., Ryan, P.D. 2001. PAST: Paleontological statistics software package for education and data analysis. Palaeontologia Electronica 4(1): 9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm

Holechek, J.L., Vavra M. and Pieper R.D. 1982. Botanical composition determination of range herbivore diets: a review. Journal of Range Management 35: 309–315.

Holzner, W., Kriechbaum, M., Ramble, C. and Diemberger, H. 2000. Integrated ecological studies of pasture problems in the Tibetan Autonomous Region, P.R. China. In*:* Yak production in central Asian highlands Proceedings of the third international congress on yak held in Lhasa, P.R. China, 4–9 September 2000.

Hoon, V. 1996. Living on the Move: Bhotiyas of the Kumaon Himalaya. Sage Publications, New Delhi, India, 1+354 pp.

Imperative, G.D. 2003. Pastoralism and Mobility in Drylands. Challenge Paper. UNCCD, 1-25 pp.

Jacobs, J. 1974. Quantitative measurement of food selection. Oecologia, 14(4): 413-417.

Jobbagy, E.G. and Sala, O.E. 2000. Controls of Grass and Shrub Aboveground Production in the Patagonian Steppe. *Ecological Applications*, 10(2):541-549.

Johnsigh, A.J.T., Stuwe, M., Rawat, G.S., Manjrekar, N. and Bhatnagar, Y.V. 1999. Ecology and conservation of Asiatic Ibex in Pin Valley National Park, Himachal Pradesh, India. Wildlife Institute of India, Dehradun, India, 36-111 pp.

Joshi, S.P., Raizada, A. and Srivastava, M.M. 1990. Carrying Capacity of an Alpine Grazing land of Garhwal Himalayas. Range Management and Agroforestry, 11(2):141-150.

Kala, C.P. 2002. Indigenous knowledge of Bhotiya tribal community on wool dyeing and its present status in the Garhwal Himalaya, India. Current Science 83: 814–817.

Kala, C.P. and Rawat, G.S. 1999. Effects of livestock grazing on the species diversity and biomass production in the alpine meadows of Garhwal Himalaya, India. Tropical Ecology, 40(1): 69-74.

Kandpal, V. 2010. Evaluating threatened species in relation to anthropogenic pressures and their management strategy in Nanda Devi Biosphere Reserve, Western Himalaya. Ph.D thesis, Forest Research Institute (Deemed) University, Dehradun: 266 pp.

Kaur, J. 1982. Nanda Devi, Himalaya's superlative nature phenomenon, 79-87. In T. Singh, J. Kaur and D. Singh (eds.) Studies in Tourism, Wildlife Parks, Tourism. Metropolitan, New Delhi.

Kittur, S., Sathyakumar, S. and Rawat, G.S. 2010. Assessment of spatial and habitat use overlap between Himalayan tahr and livestock in Kedarnath Wildlife Sanctuary, India. European journal of wildlife research, 56(2):195-204.

Klein, J., Xinquan, Z. and Harte, J. 2000. Climatic and grazing controls on vegetative aboveground biomass: Implications for the rangelands on the north-eastern Tibetan Plateau. In: Yak production in central Asian highlands Proceedings of the third international congress on yak held in Lhasa, P.R. China, 4–9 September 2000.

Korner, C. 1999. Alpine plant life. Springer Verlag, Berlin. Pp. 1-38.

Krätli, S., Huelsebusch, C., Brooks, S. and Kaufmann, B. 2013. Pastoralism: A critical asset for food security under global climate change. Animal frontiers, 3(1):42-50.

Kumar, A. 2016. A study on floristic diversity and plant functional types across various landforms in upper dhauli valley, nanda devi biosphere reserve, western Himalaya. Ph.D. thesis. FRI Deemed University. Dehradun: 20-141pp.

Kumar, A., Adhikari, B.S. and Rawat, G.S. 2017a. Biogeographic delineation of the Indian Trans-Himalaya: need for revision. Current Science, 113(6):1032-1033.

Kumar, A., Adhikari, B.S. and Rawat, G.S. 2015b. Rangeland vegetation of the Indian Trans-Himalaya: An ecological review, 28-41: G.S. Rawat and B.S. Adhikari (eds.) Ecology and Management of Grassland Habitats in India, ENVIS Bulletin: Wildlife and Protected Areas. Dehradun: Wildlife Institute of India.

Kumar, A., Mitra, M., Adhikari, B.S. and Rawat, G.S. 2013a. Additions to plant wealth of Nanda Devi Biosphere Reserve, Western Himalaya. The Indian Forester, 139(10): 959-961.

Kumar, A., Mitra, M., Adhikari, B.S. and Rawat, G.S. 2013b. Archetype conservation in Trans-Himalayan region of Nanda Devi Biosphere Reserve, Western Himalaya. e Journal of Applied Forest Ecology, 1(1): 84-86.

Kumar, A., Mitra, M., Adhikari, B.S. and Rawat, G.S. 2016. Flora of Niti Valley: a cold arid region of Nanda Devi Biosphere Reserve, Western Himalaya, India. Check List, 12(1): 1824.doi: http://dx.doi.org/10.15560/12.1.1824

Kumar, K., Oli, B.P., Joshi, B.M. and Samant, S.S. 2001. The faunal diversity of Nanda Devi Biosphere Reserve in Western Himalaya, Himalayan Biosphere Reserve, 3 (I and II): 18-57.

Kumssa, T., and Bekele, A. 2014. Attitude and perceptions of local residents toward the protected area of Abijata-Shalla Lakes National Park (ASLNP), Ethiopia. Journal of Ecosystem & Ecography, 4(1), 1.

Kruskal, W. H., and Wallis, W. A. 1952. Use of ranks in one-criterion variance analysis. Journal of the American statistical Association, 47(260), 583-621.

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

MacFarland, T. W., and Yates, J. M. 2016. Mann–whitney u test. In Introduction to nonparametric statistics for the biological sciences using R (pp. 103-132). Springer.

Magurran, A. E. 2004. An index of diversity. Measuring biological diversity, 100-133.

Mbow, C., Nielsen T.T. and Rasmussen K. 2000. Savanna fires in East-Central Senegal: distribution patterns, resource management and perceptions. Human Ecology, 28 (4): 561-583.

Mehra, B.S. 2000. Livestock Grazing and conservation of biodiversity in the high altitude ecosystem- An integrated landscape management approach, Ph.D. Thesis, Saurashtra University, Rajkot (Gujarat): 222-224pp.

Milchunas, D.G., Sala, O.E. and Lauenroth, W.K. 1988. A generalized model of the effects of grazing by large herbivores on grass-land community structure. American Naturalist, 132: 87-106.

Mir, Z. R., Noor, A., Habib, B., and Veeraswami, G. G. 2015. Attitudes of local people toward wildlife conservation: a case study from the Kashmir valley. Mountain Research and Development, 35(4), 392-400.

Mishra, C. 1997. Livestock grazing and wildlife conservation in Indian trans-Himalaya. A Preliminary Survey. Centre for Ecological Research and Conservation, Mysore, India. 9-17 pp.

Mishra, C. 2001. High altitude survival: conflicts between pastoralism and wildlife in the Trans-Himalaya. Ph. D. dissertation. Wageningen University, Wageningen: 17-111pp.

Mishra, C., Wieren S.E.V., Ketner P., Heitkonig I.M.A. and Prins H.H.T. 2004. Competition between domestic livestock and wild bharal *Pseudois nayaur* in the Indian Trans-Himalaya. Journal of Applied Ecology, 41:344-354.

Mishra, R. 1968. Ecology Work Book. Oxford and IBH Publishing Co., Calcutta, 1-242 pp.

Mitra, M., Kumar, A., Adhikari, B.S. and Rawat, G.S. 2013. A note on transhumant pastoralism in Niti Valley, Western Himalaya, India. Pastoralism: Research, Policy and Practice, 3: 29. doi: 10.1186/2041-7136-3-29

Muller-Dombois, D. and Ellenberg, H. 1974. Aims and methods of vegetation ecology. John Wiley and Sons, New York, 547 pp.

Murti, S.R. 2001. Flora of Cold Deserts of Western Himalaya. Vol:1 (Monocotyledons). Botanical Survey of India. Dehradun. iii pp.

Naithani, B.D. 1984a. Flora of Chamoli. Vol. I. Dehradun: Botanical survey of India. 1-379 pp.

Naithani, B.D. 1984b. Flora of Chamoli. Vol. II. Dehradun: Botanical survey of India. 380-800 pp.

Naithani, B.D., Negi, J.D.S., Thapliyal, R.C. and Pokhriyal, T.C. 1992. Valley of flowers need for conservation and preservation. The Indian Forester, 118(5): 371-378.

Namgail, T., Fox, J.L. and Bhatnagar, Y.V., 2007. Habitat shift and time budget of the Tibetan argali: the influence of livestock grazing. Ecological Research, 22(1), p.25.

Nautiyal, S., and Kaechele, H. 2007. Adverse impacts of pasture abandonment in Himalayan protected areas: Testing the efficiency of a Natural Resource Management Plan (NRMP). Environmental Impact Assessment Review, 27(2), 109–125. https://doi.org/10.1016/j.eiar.2006.10.003

Nautiyal, M. C., Nautiyal, B. P., and Prakash, V. 2004. Effect of grazing and climatic changes on alpine vegetation of Tungnath, Garhwal Himalaya, India. Environmentalist, 24(2), 125-134.

Negi, G.C.S., Rikari H.C., Ram J. and Singh S.P. 1993. Foraging niche characteristics of horses, sheep and goats in an alpine meadow of the Indian Central Himalaya. Journal of Applied Ecology, 30(3): 383-394.

Pirazizy, A.A. 1992. Man and Environment, Himachal Himalayan perspectives: Shimla: Minerva Book House. Shimla, 155–174.

Prajapati, S.R. 2005. Five year perspective plan. Nanda Devi Biosphere Reserve. 148 pp.

Prins, H.H.T. 1989. East African Grazing Lands: overgrazed or stably degraded? 281-306 In: Nature Management and Sustainable Development. W.D Verwey (ed). IOS Amsterdam.

Prins, H.H.T. 1992. The pastoral road to extinction: competition between wildlife and traditional pastoralism in East Africa. Environmrntal Conservation, 19:119-123.

Pusalkar, P.K. and Singh, D.K. 2012. Flora of Gangotri National Park, Western Himalaya, India. Botanical Survey of India, Kolkata, 708 pp.

Quasin, S. 2011. Systematics and Diversity of Spiders (Araneae) in Nanda Devi Biosphere Reserve, Uttarakhand, India, thesis Ph.D., Saurashtra University, 9-18 pp.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Raghavan, B. 2003. Interaction between livestock and Ladakh Urial (*Ovis vignei vignei*). M.Sc. Dissertation. Wildlife Institute of India. 78 pp.

Ram, J. 2005. Biodiversity and conservation of High Altitude Meadows of Uttaranchal Himalaya. Bulletin of the National Institute of Ecology 15:11-17.

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

Rawat, G.S. 2005. Alpine meadows of Uttaranchal. Bisen Singh Mahendra Pal Singh, Dehradun, India. 219 pp.

Rawat, G.S. 2007. Pastoral practices, wild mammals and conservation status of alpine meadows in Western Himalaya. Journal of the Bombay Natural History Society, 104(1): 5-11.

Rawat, G.S. and Adhikari, B.S 2005b. Millenia of grazing history in eastern Ladakh, India, reflected in rangeland vegetation, 199-210. In: Land use change and Mountain Biodiversity, Spehn, E.M., Liberman, M. and Korner C.(eds.). CRC Press, NY, USA

Rawat, G.S. and Adhikari, B.S. 2005a. Floristics and Distribution of Plant Communities across Moisture and Topographic Gradients in Tso Kar Basin, Changthang Plateau, Eastern Ladakh. Arctic, Antarctic, and Alpine Research, 37 (4): 539-544.

Rawat, G.S. and Uniyal, V.K. 1993. Pastoralism and plant conservation: The valley of flowers dilemma. Environment Conservation 20(2): 164–167.

Rawat, G.S., Fox, J.L., Sathyakumar, S., Adhikari, B.S., Sankar, K., Johnsingh, A.J.T, Uniyal, S.K., Awasthi, A. and Upadhyay, A.K. 2006. Rangeland production ecology and habitat use by wildlife and livestock in Tso kar Basin, Eastern Ladakh. Wildlife Institute of India- University of Tromso, Norway, Institutuional Cooperation programme in Natural Resource Ecology and Management. Final Report 50 pp.

Reading, R.P., Mix, H., Lhagvasuren, B. and Blumer, E.S. 1999. Status of wild Bactrian camels and other large ungulates in south-western Mongolia. Oryx, 33 (3): 247-255.

Roder, W. 2000. Grazing resources for yak production systems in Bhutan. In: Yak production in central Asian highlands Proceedings of the third international congress on yak held in Lhasa, P.R. China, 4–9 September 2000.

Rodgers, W. A., Panwar, H.S. and Mathur, V.B. 2000. Wildlife Protected Area Network in India: A review (Executive summary). Wildlife Institute of India, Dehra Dun. 44 pp.

Rook, A.J. and Tallowin, J.R.B. 2003. Grazing and pasture management for biodiversity benefit. Animal Research, 52: 181- 189.

Roy, A.K. and Singh, J.P. 2013. Grasslands in India: Problems and perspectives for sustaining livestock and rural livelihoods. Tropical Grasslands-Forrajes Tropicales, 1(2):240-243.

Saberwal, V.K. 1996. Pastoral Politics, Gaddi Grazing, Degradation and Biodiversity Conservation in Himachal Pradesh, India. Conservation Biology, 10 (3): 741-749.

Sahai, B. and Kimothi, M.M. 1996. Remote sensing for surveying mapping and monitoring of conservation areas in Himalayas, 233-258: P.S. Ramakrishnan, A.N. Purohit, K.G. Saxena, K.S. Rao and Maikhuri R.K.. (eds.) Conservation and Management of Biological Resources in Himalayas. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi.

Samant, S.S. 2001. Nanda Devi Biosphere Reserve. (Nomination for UNESCO-MAB Net, Draft copy) G.B. Pant Institute of Himalayan Ecology and Development, Kosi Katarmal, Almora.

Sathayakumar, S., Prasad, S.N., Rawat, G.S. and Johnsingh, A.J.T. 1993. Conservation status of Himalayan Musk Deer and Livestock impacts in Kedarnath Wildlife Sanctuary, Western Himalaya. 240-245. In: High Altitudes of the Himalaya, Pangtey,Y.P.S. and Rawal, R.S.(eds.) Gyanodaya Prakashan, Nainital.

Sathyakumar, S. 2004. Conservation status of mammals and birds in Nanda Devi National Park: An assessment of changes over two decades, 1-14. In: Biodiversity monitoring expedition of Nanda Devi. A report, MoEF, Govt. of India.

Scott, G., and B. E. Dahl. 1980. Key to selected plant species of Texas using plant fragments. Occasional Papers number 64. The Museum, Texas Tech University, Lubbock, Texas, USA, 37 pp.

Shah, M.H. 1988. Role of nomads in the destruction of alpine and sub alpine pastures and future strategies, 148-152. In Rangelands: Resource and management, Singh, P. and Pathak, P.S. (eds.). Jhansi, India: Range Management Society of India.

Sharma, V.P., Köhler-Rollefson, I. and Morton, J. 2003. Pastoralism in India: a scoping study. Indian Institute of Management, Ahmedabad, iii-49 pp.

Shrestha, R, and Wegge, P. 2008a. Habitat relationships between wild and domestic ungulates in Nepalese trans- Himalaya. Journal of Arid Environments, 72(6): 914-925.

Shrestha, R, and Wegge, P. 2008b. Wild sheep and livestock in Nepal Trans-Himalaya: coexistence or competition? Environmental Conservation, 35: 125-136.

Shrestha, R., Wegge, P. and Koirala, R.A. 2005. Summer diets of wild and domestic ungulates in Nepal Himalaya. Journal of Zoology, 266: 111–119.

Silori, C. S. 2001. Status and distribution of anthropogenic pressure in the buffer zone of Nanda Devi Biosphere Reserve in western Himalaya, India. Biodiversity & Conservation, 10(7), 1113-1130.

Singh, K.S. 1996. Peoples of India series. Anthropological survey of India, New Delhi.

Singh, S.P., Sah, P., Tyagi, V. and Jina, B.S., 2005. Species diversity contributes to productivity–Evidence from natural grassland communities of the Himalaya. Current Science, 548-552.

Sparks, D.R. and Malechek, J.C. 1968. Estimating percentage dry weight in diets using a microscopic technique. Rangeland Ecology and Management Journal of Range Management Archives, 21(4):264-265.

Srivastava, S.K. 2010. Floristic diversity and conservation strategies in cold desert of western Himalaya, India. Botanica Orientalis, 7: 18-25. Doi: 10.3126/botor.v7i0.4369.

Sternberg, M., Gutman, M., Perevolotsky, A., Unger, E.D. and Kigel, J. 2000. Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. Journal of Applied Ecology, 37: 224- 237.

Stone, L. and Roberts, A. 1990. The checkerboard score and species distributions. Oecologia 85:74-79.

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. Journal of Hill Research, 8 (2): 135-150.

Sundriyal, R.C. 1992. Structure, productivity and energy flow in an alpine grassland in the Garhwal Himalaya. Journal of Vegetation Science, 3:15-20.

Suzuki, R., Tanaka, S. and Yasunari, T. 2000. Relationships between meridional profiles of satellite-derived vegetation index (NDVI) and climate over Siberia. International Journal of Climatology, 20(9), 955–967. https://doi.org/10.1002/1097-0088(200007)20:9<955::AID-JOC512>3.0.CO;2-1

Tashi, N. and Partap, T. 2000. Livestock based livelihood in Tibet, China and sustainability concerns. 171-202. In: Contributiion of livestock to mountain livelihoods. Research and Development Issues. Tulachan, P.M., Saleem, M.A.Md., Mak-Hokkanen, J. and Partap T. (eds.) ICIMOD, Kathmandu, Nepal.

Tucker, R. P. 1986. The evolution of transhumant grazing in the Punjab Himalaya. Mountain Research and Development, 6(1), 17–28.

Tulachan, P. 2000. Livestock production and management Strategies in the Mixed Farming Areas of the Hindu Kush-Himalayas, Asia. 123-134. In: Contribution of livestock to mountain livelihoods. Research and Development Issues. Tulachan, P.M., Saleem, M.A.Md., Mak-Hokkanen J. and Partap, T. (eds.) ICIMOD, Kathmandu, Nepal.

Vinod, T.R. and Sathayakumar S. 2005. Conservation status of mountain ungulates in Great Himalayan National Park, Himachal Pradesh, 35-39. In: Wildlife Conservation, Research and Management. Jhala, Y.V., Chellam R. and Qureshi Q. (eds.) Wildlife Institute of India, Dehradun.

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

Walker, J.W. 1995. Viewpoint: Grazing Management and Research Now and in the Next Millennium. Journal of Range Management, 48:350-357.

Wallmo, O. C., Gill, R.B., Carpenter, L.H. and Reichert, D.W. 1973. Accuracy of field estimates of deer food habits. Journal of Wildlife Management, 37: 556–562.

Weikai, B., Ning, W. and Zhaoguang, L. 2000. Development dynamics of fragile pastoral systems of the south-eastern Tibetan Plateau. In: Yak production in central Asian highlands Proceedings of the third international congress on yak held in Lhasa, P.R. China, 4–9 September 2000.

Wilcove, D.S., Rothstein, D., Dubow, J., Phillips, A. and Losos, E. 1998. Quantifying threats to imperiled species in the United States. BioScience, 48(8): 607-615.

Zobel, K. and Liira, J. 1997. A scale-independent approach to the richness vs. biomass relationship in ground-layer plant communities. Oikos, 80: 325-332.