INFLUENCE OF PASTORALISM PRACTICES ON WILD UNGULATES IN UPPER GORI VALLEY, WESTERN HIMALAYA

A THESIS

Submitted by

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For the award of the degree of

DOCTOR OF PHILOSOPHY

IN

WILDLIFE SCIENCE

Under the guidance of

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&

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DECLARATION

I declare that the thesis entitled **Influence of Pastoralism Practices on Wild Ungulates in Upper Gori Valley, Western Himalaya**, has been prepared by me under the guidance of **Dr. G.S. Rawat, Former Dean, Faculty of Wildlife Sciences & Research Affiliate, Wildlife Institute of India, Dehradun** and **Dr. Bilal Habib, Scientist E, Head of Department of Animal Ecology & Conservation Biology, Wildlife Institute of India, Dehradun**. No part of this thesis has formed the basis for the award of any degree or fellowship previously.

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CERTIFICATE

This is to certify that the thesis of **Ms. Ankita Bhattacharya** entitled **"Influence of Pastoralism Practices on Wild Ungulates in Upper Gori Valley, Western Himalaya"** is an original and independent piece of work submitted to the Saurashtra University, Rajkot, (Gujarat), for the award of the degree of **Doctor of Philosophy (Ph.D.) in Wildlife Sciences.**

Ms. Ankita Bhattacharya has put in more than six terms of research work embodied in this thesis under our guidance and supervision. The work presented in this thesis has not been submitted to any other university or institution and it fulfills all the requirements laid down by the Saurashtra University.

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Abstract

In recent years, an integrated landscape vision for ecological, production, development and livelihood outcomes has come forth. In this regard, management of vast rangelands outside protected areas has been given importance for sustaining a distinct kind of habitat for a unique biodiversity as well as social communities. In the IHR, rangelands include the Trans-Himalayan zone and the alpine meadows of the Greater Himalayan zone. Rangelands are home to significant concentrations of large mammals and plants with an ecological and economic value. Excluding human influence, knowledge of the conditions allowing species to coexist requires identifying how the co-occurring species use and share space and resources. Species of the same trophic level, such as large herbivores, are of fundamental interest in that context because competition for resources is likely. This competition may be reflected by complete or partial avoidance of livestock grazing areas by wild ungulates. My study revolves around the distribution and resource utilization patterns of wild ungulates (blue sheep, Himalayan tahr and Himalayan musk deer) in the upper Gori valley of western Himalaya and the influence of pastoral practices on these aspects. The study area is a part of the Askot Conservation Landscape and a zone of transition between the biogeographical elements of the Greater and Trans Himalaya. I studied the current distribution status of the study species with and without livestock in Johar valley. Inclusion of the livestock parameter reduced their distribution range considerably. All species preferred covariates concurring with their foraging behavior which was the nutritious vegetation of the monsoon season. My results gave an idea regarding the current population status of the study species. I tried to evaluate the resource selection patterns of blue sheep, tahr and livestock. The study revealed that though blue sheep selected similar vegetation types as those of livestock, they shifted their niche based on other topographic factors. This led to selection of probable suboptimal grazing patches. On the other hand, tahr having different diet and topographic preferences remained separated from livestock in terms of resource selection as well. I tried to explain the influence of livestock intensity on these ecological aspects. I found that the distribution and resource selection patterns of blue sheep was affected the most due to livestock intensity and areas which were highly preferred by blue sheep overlapped with high livestock use intensity areas. Musk deer also showed a similar pattern but they were separated temporarily as mentioned before. Himalayan tahr was least affected by livestock intensity though their distribution and resource selection ranges overlapped the most. However, because of topography, tahr ecologically separated themselves from livestock. The smaller alpine patches had the highest livestock use intensities in the Johar valley. It is important to conserve the rangeland habitat harboring these mountain ungulates and prevent them from being overused by livestock. I posit that conservation of threatened and important prey species in Himalayan rangelands depends on managed pastoral practices and community participation.

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Chapter 1: Introduction

"The high altitudes are a special world. Born of the Pleistocene, at home among pulsating glaciers and wind-flayed rocks, the animals have survived and thrived, the harshness of the environment breeding a strength and resilience which the lowland animals often lack. At these heights, in this remote universe of stone and sky, the fauna and flora of the Pleistocene have endured while many species of lower realms have vanished in the uproar of the elements." – George B. Schaller (Mountain Monarchs)

1.1 Background

Himalayas are a special world. They invite us to unveil their misty layers beyond which lies answers to several mysteries beholding in these mountains. The magnificence of the Himalaya is reflected by their unique biogeographic and cultural elements. An intimate part of these extensive mountain ranges is the Indian Himalayan Region (IHR) covering ~16% of the country's total geographical area, forming the northern boundary of the country (Bhatnagar, Mathur & McArthy 2001), Pandit et al 2014). The IHR spreads across 10 states namely Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Meghalaya, Nagaland, Manipur, Mizoram, Tripura and hill regions of Assam and West Bengal (Bhatnagar, Mathur & McCarthy 2001). Based on geographical distribution and climatic conditions, the widespread IHR has been broadly divided into 2 biogeographic zones which includes 8 biogeographic provinces (Rodgers and Pawar 1988). The western Himalaya is represented by the states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand and depending upon physiographic conditions, has been divided into the Shiwaliks, lesser Himalaya, Greater Himalaya and Trans Himalaya.

Uttarakhand, the land of gods, falls under the biogeographic provinces 1C – Trans Himalaya and 2B – West Himalaya (Kumar, Adhikari & Rawat 2017). There are two administrative divisions of the state namely Kumaon and Garhwal. The state contributes ~1.5% of the total cold– arid region of India covering upper catchments of Nilang (Jadh Ganga, Uttarkashi) and Niti and Mana (Chamoli) valleys in Garhwal region, and Johar, Darma and Byans (Pithoragarh) valleys in Kumaon region (Kumar, Adhikari & Rawat 2017). Alongside, the state includes aspects of the Greater Himalaya including the alpine, subalpine, temperate, subtropical and tropical regions. The Greater Himalayan region, thus, being a mosaic of different habitat types supports a unique biodiversity as well as an economic influx through various ecosystem services.

Among the 428 species of mammals recorded from India, about 291 species are found in the IHR. Studies from the different zones of the IHR have reported 40 species of mammals from the Indian Trans-Himalaya, 77 species from the North-West Himalaya, 102 species from the Western Himalaya and 172 species from the Eastern Himalaya (Sharma et al. 2015; Pal et al. 2016). Most of the mammalian species of India have been given protection under different Schedules of the Indian Wildlife (Protection) Act, 1972 and listed in different categories of IUCN Red List of Threatened Species and CITES. All existing conservation efforts in the IHR have been limited to protected areas, however, due to the sparse distribution of most of these species spread across large mountain landscapes, a major portion of the areas of conservation importance lie outside the protected area boundaries (Gurung et al. 2006).

1.2 Sustenance of the high altitude rangelands

In recent years, an integrated landscape vision for ecological, production, development and livelihood outcomes has come forth. In this regard, management of vast rangelands outside protected areas has been given importance for sustaining a distinct kind of habitat for a unique biodiversity as well as social communities. Rangelands are vast landscapes which can be grasslands, woodlands, shrub lands, wetlands or desert, grazed by livestock and wild herbivores. They include natural grasslands, savannas, shrub land, many deserts, tundra, alpine communities, marshes, and meadows (Society for Range Management 2001). The indigenous vegetation (climax or natural potential) of rangelands consist predominantly of grasses, grass-like plants, forbs, and shrubs. They are a distinguished habitat as they primarily grow native vegetation without any human influence (Rawat 2008). Rangelands exist in most parts of the world except Antarctica and wherever they exist, they are important for the national economy, environment, and cultural heritage.

In the IHR, rangelands include the Trans-Himalayan zone and the alpine meadows of the Greater Himalayan zone. Rangelands are home to significant concentrations of large mammals and plants with an ecological and economic value. The alpine zone occupies nearly 33% of the geographical area in the Himalayan region and represents one of the most fascinating biomes, well known for its biological, geo-hydrological, aesthetic and cultural values. The striking feature of the alpine vegetation is an abundance of herbaceous plants along narrow climatic gradients exhibiting interesting patterns of adaptations to harsh environments and short growing season (Korner 1999). The characteristics of alpine meadows as described by Rawat and Adhikari (2005) are (i) alpine moist meadows on the south facing slopes of the Greater Himalaya which are dominated by herbaceous formations, locally termed as *bugyal* in Uttarakhand, *kanda* in Himachal Pradesh and *marg* in Jammu and Kashmir, (ii) alpine dry pastures located in the rain shadow zone or Trans-Himalayan zone characterized by dry scrub and desert steppe dominated by graminoids. Different rangelands differ considerably in terms of plant community composition, primary productivity and history of grazing by domestic and wild ungulates (Bagchi et al. 2004). Globally, more than 120 million pastoralists rely on more than 5 billion hectares of rangelands for their livelihood. The geographic extent and resources of the rangelands make their proper use and management essential. While traditional management practices were sustainable, increasing pressure on land and inappropriate management and development policies are now causing degradation. Rangelands produce a wide variety of ecosystem services such as forage for livestock grazing, wildlife habitat, mineral resources, and other products, carbon sequestration and storage, storage and regulation of water, maintaining landscape beauty, and maintaining biodiversity. The Greater Himalayan and Trans-Himalayan rangelands support some of the globally threatened, rare, characteristic and endemic mammal species such as Snow Leopard (*Uncia uncia*), Blue Sheep / Bharal (*Pseudois nayaur*), Himalayan tahr (*Hemitragus jemlahicus*), Himalayan Musk deer (*Moschus chrysogaster*), Tibetan Argali *(Ovis ammon hodgsoni)*, Himalayan Ibex *(Capra sibirica hemalayanus)*, Urial *(Ovis orientalis vignei)*, Wolf *(Canis lupus sp)*, Asiatic Black Bear (*Ursus thibetanus*), Tibetan Wild Ass / Kiang *(Equus kiang)*, Red Fox *(Vulpes vulpes)*, Pikas and Marmots (Sharma et al. 2014).

1.3 Transhumant pastoralism

Transhumant pastoralists exploit the seasonal abundance of grazing resources in marginal environments. Pastoralism has been seen as a major driver of ecological changes in the Himalaya (Mishra et al. 2010). Sheep, goat, yak, horse, mule, and cows are constant features of traditional mountain society which make use of the resources of high mountain pastures. Traditional pastoralism practices has benefitted both humans and the mountain ecosystem, maintaining and shaping up the vegetation composition. Pastoralism contributes to soil formation, fertility, water regulation and maintains plant species composition. In the last few decades, however, growth in livestock holding, loss of traditional resource use patterns and knowledge systems (Farooquee and Nautiyal 1999) have started to ecologically effect the rangeland habitat and wildlife. All these in turn effect the survival of wildlife dependent on these rangelands especially the wild ungulates. In need of livelihood improvement, more and more numbers of livestock are increasing day by day causing overstocking and overgrazing. Thus, degradation of habitat, substitution of optimal foraging patches with less nutritious patches, risk of predation as well as hunting are the major problems faced by the ungulates due to overstocking and overgrazing.

The alpine meadows of western Himalaya have been used for livestock grazing by a large number of agro-pastoral communities for several centuries (Tucker 1986). Five distinct pastoral practices are prevalent across the alpine landscape in the western Himalaya: nomadic, semi nomadic, nuclear transhumance, trans-migratory and sedentary (resident). Trans-migration (seasonal altitudinal movement by the entire family along with the livestock) is practiced mainly by the *Bhotiya* communities in various parts of Uttarakhand, such as Byans, Darma, Johar and the upper basins of Alaknanda and Bhagirathi. Historically, when the human population was relatively low, the human exploitation of rangelands was not problematic. But this is changing with the increase in human populations and demand for land for other uses, which are having a significant impact on the flora and fauna of the rangelands. Fragmentation, for example, represents a major threat to biodiversity in rangelands. Species diversity can be affected by livestock grazing and fire. Livestock can also enhance the conservation of particular species or plant communities and structures. Grazers influence diversity by selective grazing and trampling of plant species. Moderate grazing and trampling can increase the diversity of plants by decreasing the dominance of a single species. Grazing can also create gaps in the plant community, making light, moisture, and nutrients more available to other species. The effects of grazing on plant community diversity depend on the grazing intensity, evolutionary history of the site, and climate. However, it is also known that if grazing is excluded, the number of species may increase in the short term, but may decline over the long term. (Ning et al. 2013).

1.4 Mountain ungulates

Ungulates form an important part of the Himalayan ecosystem. The geological, climatic, altitudinal and vegetation variations along with the topographical complexity of the Himalaya make them an abode of around 19 ungulate species (Bhatnagar 1993; Vinod and Sathyakumar 1999). These ungulates belong to four families: Moschidae, Cervidae, Bovidae and Equidae and are specialized in living in the rugged mountainous terrains. Mountain ungulates play a crucial role in maintaining the rangeland ecosystem by shaping the vegetation structure, plant species composition and nutrient cycling (McNaughton 1979; Bagchi and Ritchie 2010). They change their behavior according to changes in habitat, seasons and natural disturbance which could act as a sensitive indicator of the environment around them (Owen-Smith 1979). The availability of wild ungulate prey is one of the most important determinants of large carnivore density (Karanth et al. 2004; Bhattacharya and Sathyakumar 2011) in the mountains. In India, the Greater Himalayan zone of the western Himalaya in Uttarakhand provide resources for 5 mountain ungulate species of which Himalayan tahr, Himalayan serow (*Capricornis thar*), and Himalayan musk deer are the threatened species. These ungulates form a prey base to other threatened Himalayan carnivore species like the snow leopard, Eurasian lynx (*lynx lynx*) and Himalayan wolf (*Canic lupus chanco*). There is a considerable overlap in the distribution of these predator and prey species across the Greater Himalayan region and thus presence of one species indicates the occurrence of other.

1.5 Rationale of the study

Grassland composition, livestock grazing and ecology of wild ungulates are linked. Their degree of interaction is a matter of grassland properties (biomass, palatability, and accessibility), patterns of pastoralism and density/competitive ability of wild ungulates as well as their susceptibility to other influences (diseases, hunting). Present grassland condition, livestock utilization patterns, distribution and abundance of wild ungulates and finally the standard of living of mountain people reflect this pattern. This has been shaped very much by historical events (Bauer 1990). Hence, rangelands have been considered as areas of conservation importance. Knowledge about the degree to which pastoralism effects the ecology of these species can help in better management for conservation of mountain ungulates as well the rangelands. The sustainability of seasonal grazing by large flocks of migratory sheep and goats in the alpine meadows in summer and the Himalayan foot-hills in winter has been much debated recently (e.g. Saberwal 1996; Mishra and Rawat 1998). Alpine pastures play an important role in relieving the grazing pressure on the forests and grazing lands of the lower altitudes, but the increased number of livestock and overuse of certain pastures can lead to degradation of high altitude grasslands including habitats for wild herbivores (Bhatnagar 1997).

Excluding human influence, knowledge of the conditions allowing species to coexist requires identifying how the co-occurring species use and share space and resources. Species of the same trophic level, such as large herbivores, are of fundamental interest in that context because competition for resources is likely. This competition may be reflected by complete or partial avoidance of livestock grazing areas by wild ungulates. The herders select good nutritious patches for their livestock to rear and arrive at the best time of production of these nutritious grasses. Selection of unpalatable or sub optimal foraging sites by wild ungulates may lead to decrease in their reproductive rate and thus a cause for declining population trends. There may also be a tradeoff between safety and suboptimal forage sites, the optimal foraging sites being a part of their escape terrain (anti – predator). There might be shifting of foraging patterns spatially and temporally. Lack of palatable species and predation risks come into play which in turn change their resource utilization patterns. In this regard, wild ungulate distribution and habitat use in the presence or absence of livestock grazing need to be analysed in order to evolve site specific management strategies for effective conservation of these species.

Himalayan research in India has taken a new turn with the advancement of new tools and techniques to sample and analyze the data. This advancement tied with interesting results and new records from lesser known areas has urged the need to fill research gaps across the IHR for a comprehensive ecological information. My study revolves around the distribution and resource utilization patterns of wild ungulates (blue sheep, Himalayan tahr and Himalayan musk deer) in the upper Gori valley of western Himalaya and the influence of pastoral practices on these aspects. The study area is a part of the Askot Conservation Landscape and a zone of transition between the biogeographical elements of the Greater and Trans Himalaya (Kumar, Adhikari & Rawat 2017). There has been no previous scientific baseline ecological information from this landscape regarding mountain ungulates. The upper Gori valley consists of alpine pastures and subalpine patches where the wild ungulates inhabit. Because of the landscape characteristics some patches are naturally protected from human influence. The area includes vegetation types of temperate, subalpine and alpine which form the main source of livelihood for the local people living there. Since the habitats are patchy and most of the areas are inaccessible to humans, the accessible patches have all been utilized by the local people for Non Timber Forest Products (NTFP) collection and pastoralism. Thus, the study area has the perfect blend of elements to study the influence of anthropogenic activities on ecology of wild ungulates. The three study species represent three characteristic habitat types of the greater

Himalaya viz. temperate, sub alpine and alpine with seasonal migration of the animals in between these habitats. These are sympatric species and all three of them have different levels of interactions with livestock. The selection of these species is based on the fact that the habitat of these species is most affected by anthropogenic activities. This may be a cause for their low detection probability and declining population trends in the study area. Knowledge of distribution, habitat suitability, resource selection patterns along with the influence of pastoralism on these aspects will help in species specific monitoring in future and preparing monitoring protocols. My study also provides a baseline ecological information on wild ungulates for this area for the first time.

1.6 Study Species

1.6.1 Blue sheep/ bharal (*Pseudois nayaur*)

Status: Indian Wildlife (Protection) Act - Schedule I, Part I; Red Data Book – Vulnerable (V); CAMP- LR/lc (Nationally), Least Concerned (LC) (Globally); more than 25,000 individuals in the Himalayan region (Nowak 1999)

Blue sheep is a widely distributed mountain ungulate forming the main prey base for the snow leopard (Schaller 1977; Chundawat and Rawat 1994). Blue sheep occur in open slopes and plateaus with abundant grass between elevations 3500 m-5500 m. They feed and rest alternatively throughout the day on the grassy slopes of the mountains. Their diet consists of mainly grasses and herbs during summer and dried grass and lichens in the winters (Wang and Hoffman 1987). Social structure may vary seasonally and in relation to availability of resources. It forms herds of as many as 400 individuals; males tend to separate from the females after the mating season and either become solitary or form the bachelor herds. Few males associate with the females throughout the year (Schaller 1977). Mating occurs from October to January and the young are born from May to early July. Sexual maturity is attained in 18 months (Schaller 1977; Wang and Hoffman 1987). Although it is still widespread, its range is becoming increasingly fragmented by human activity and it is subjected to the hunting and competition with domestic livestock. (Shackleton 1997; Kittur et al. 2010).

1.6.2 Himalayan Tahr (*Hemitragus jemlahicus*)

Status: Indian Wildlife (Protection) Act - Schedule I, Part I; Red Data Book – Endangered (EN), CAMP- LR/ near threatened (nt) (Nationally), Least Concerned (LC) (Globally) (Alfred et al. 2002)

Himalayan tahr is a group living mountain goat and inhabits the most inaccessible terrain characterized by open steep slopes, scattered trees scrub and grassy blanks, cliffs and rocks as well as forests. They are mostly found between 2800 m – 4800 m in the western Himalaya and occur in the alpine, subalpine, upper temperate and mid temperate zones. They prefer the alpine meadows in spring and summer and the subalpine and scrub habitats during autumn and winter (Sathyakumar et al. 2015). They are primarily grazers, subsisting on grasses, sedges, herbs, ferns and mosses. They prefer to feed actively during early mornings and late afternoons and rest during mid-day (Sathyakumar 2002). They form prey base for carnivores like common leopard, snow leopard and Himalayan yellow throated marten. In fact the Himalayan tahr is the largest prey of snow leopards (Ale and Brown 2009). They live in mixed herds (1-80) for most of the year except for a brief period in spring when adult males segregate after rut to higher elevations. Mating takes place during mid-October to mid-January and usually a single offspring is born. Some of the major threats faced by this species is poaching, habitat loss and competition with livestock for which they are distributed patchily, restricted to isolated pockets and have a declining population trend (Green 1978; Sathyakumar 1994).

1.6.3 Alpine musk deer (*Moschus leucogaster)*

Status: Indian Wildlife (Protection) Act - Schedule I, Part I; Red Data Book- Vulnerable (V), Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) - Appendix I, CAMP- CR endangered (En) (Nationally), Near Threatened (NT) (Globally) (Alfred et al. 2002).

Alpine musk deer inhabit forested and alpine scrub habitats from 2500 m till the treeline and are distributed across the states of Himachal Pradesh, Uttarakhand and Sikkim in the IHR (Johnsingh and Manjrekar 2015; Ilyas 2015). They tend to remain in dense cover by day and use open habitat at night, when they are usually more active (Green 1987). The species is shy, timid and generally solitary. Musk deer form a prey base for the common leopard, snow leopard, Himalayan yellow throated marten and red fox in the Greater Himalayan region.

Their diet consists of a variety of vegetation such as grass, moss and tender shoots. In winter they eat twigs, buds and lichen (Syed et al. 2016). They are primarily browsers or can be considered as ‘nibblers’ because of their feeding pattern. Unlike the other two study species, the musk deer is well adapted to live in the alpine, sub alpine and upper temperate habitats during winter as well and do not need to migrate to the lower altitudes. During the mating season that primarily occurs in November – December, both sexes defecate at common place. Sexual maturity is reached in 16-24 months. Offspring are born between May to June and 1-2 fawns are born at a time. After birth the young deer lie hidden in secluded areas essentially independent of their mothers except at feeding times. A musk gland in the abdomen of the male (3 years of age or older) secretes a wax like substance. About 28 gm of this secretion can be obtained from a single individual (Nowak 1999). The musk has economic value for which the species are widely hunted. They are highly elusive in nature and thus, there is very less information regarding ecology of this species.

Blue sheep (top) (Image credit: Dr. Amit Kumar); Alpine musk deer (bottom) (Image credit: Google Images)

Himalayan tahr (Image credit: Nilanjan Chatterjee)

1.7 Previous studies

The earliest publication on mammals of the IHR dates back to 1841. This included detailed investigations or doctoral studies and short-term studies on species ecology and behavior and the remaining were largely status surveys (Sathyakumar 1994, Sathyakumar and Bhatnagar 2002, Sathyakumar and Bashir 2010; Haleem et al. 2014). The second half of the 20th century shows a marked increase in research (207 publications) which begin to broaden in scope from just geography and taxonomy to behaviour, ecology, conservation, and evolution. (Pal et al. 2016). Several studies have been done in the Trans Himalayan and Greater Himalayan regions of India and Nepal regarding grasslands, mountain ungulates and pastoralism. Rawat (1998) reviewed the ecology and conservation of grasslands within the Himalayan region. Mehra and Mathur (2001) did a landscape level assessment for livestock grazing in the Great Himalayan National Park Conservation Area (GHNPCA), Himachal Pradesh. Compared to adjoining areas, the overall grazing pressure in the GHNPCA was found to be quite low and its impact was localized and insignificant at the level of overall landscape. The study suggested a more careful delineation of Protected Area boundaries in the high altitude landscapes based on physical characteristics and the presence of representative natural resources. Kala et al. (2002) studied the effects of sheep and goat grazing on plant species diversity, richness and composition in the Valley of Flowers (VOF) National Park and the Great Himalayan National Park (GHNP). Their investigations indicated that there was high species diversity and richness in the VOF which was a Protected Area than GHNP where 20,000 sheep and goats annually graze. Bhattacharya et al. (2012) studied the diet overlap between blue sheep, Himalayan musk deer, sambar and domestic livestock in Bedini-Ali and between Himalayan Tahr and livestock at Tunganath, Uttarakhand. The diet of wild ungulates and livestock comprised mainly of grasses, sedges, forbs, shrubs, ferns, lichens, and mosses. Trophic niche overlap showed high percentage of diet overlap between wild ungulates and livestock. In the eastern Himalaya, Bhattacharya et al. (2010), studied the distribution, relative abundance and habitat use by mountain ungulates in Prek Chu catchment, Khangchendzonga Biosphere Reserve, Sikkim, India and indicated that the National Park is subjected to a high degree of livestock grazing through the practice of domestic yak herding in the Alpine zone along with cattle and goat-sheep grazing in all the habitats. All these studies suggest that there are different degrees of interactions between livestock and wild ungulates.

1.8 Major objectives

Pertaining to the essence of the previous studies, I framed my research objectives in terms of a baseline study for wild ungulates for a lesser known yet ecologically important area joining the dots for a comprehensive Himalayan research in future. The major objectives of my study are:

1. To find the distribution pattern and population estimation of wild and domestic ungulates in the Upper Gori valley
2. To find out the resource selection and habitat utilization patterns of wild and domestic ungulates in the Upper Gori valley
3. To find out the influence of pastoral practices on wild ungulates on these aspects in the Upper Gori valley

In subsequent chapters I have technically explained each aspect and discussed the results in details. Since, I used a common methodology for all objectives I explained this in one chapter and different analytical techniques have been explained in respective technical chapters.

Chapter 2: Study area and Methodology

2.1 Study area

2.1.1 Background

The Askot Conservation Landscape, situated in the Pithoragarh district of Uttarakhand, encompasses an area of ~4500 km^2 and shares an international border with the Tibetan Autonomous Region of the Peoples' Republic of China in the north (Figure 1a & 1b). The Kali River forms the southeastern border of the landscape, as well as an international border between India and Nepal (Government of India 2011). The Kali River has three tributaries on the Indian side namely Gori, Dhauli and Kuti, which form the major catchments of the Askot Conservation Landscape. The landscape is governed by a successive variety of bio-climatic conditions created by a wide range of altitude ranging from 500 m - 6900 m. This forms an amazing assemblage of diverse biomes which makes the landscape an area of very high biodiversity values. Of the three catchments, the Gori catchment is the richest in biodiversity, as within a short geographical distance, exceptional floral and faunal assemblages are encountered.

The intensive study area for this research which forms a part of the Askot Conservation Landscape is situated in Upper Gori Valley (PEACE – ELDF – Samrakshan – NR International 2007) and lies between 80° to 81° 5' E, and 29° 5' to 30° N in the Western Himalaya. Administratively, it forms part of Kumaon region of the Uttarakhand state. The upper reaches of the Gori River which originates at Milam glacier is usually referred as Johar valley (Figure 1c). The entire Johar valley, comprising of 9 micro watersheds covers an area of ~950 km^2 with an elevation range of 1918 m – 6727 m and falls in the Biogeographic Province 1C (cold arid regions of Kinnaur, Himachal Pradesh and Uttarakhand) under the Trans-Himalayan biogeographic zone of India (Kumar, Adhikari & Rawat 2017). This forms a transition zone of biogeographical elements of western Himalaya and Tibetan plateau (Mani 1978; Negi 2010, 2017). The valley is accessed from the Munsiyari Tehsil of Pithoragarh District through a foot trail following the Gori River. This foot trail historically functioned as a trade route between the Johar valley and Tibet and is now the soul link between the lower and upper villages of the valley.

2.1.2 Habitat, flora and fauna

The topography consists of river valleys, rangelands, grassy plateaus and glaciated peaks. The variation in altitude characterizes the habitat into subalpine and alpine birch (*Betula utilis)* forests associated with alpine shrubs and herbs, Krummholz zones of *Rhododendron campanulatum* and *Juniper* scrub, widespread moist (Greater Himalayan area) and dry (Trans Himalayan area) alpine habitats (locally known as *bugyals)*, beyond which lie the glaciers and cold desert merging with the Tibetan plateau (Government of India 2011; Negi 2010). The valley mainly falls under the Eurasian high montane (Alpine and Tibetan) Biome (Kumar, Adhikari & Rawat 2017; IBCN 2015).

The prominent floral feature of *bugyals* is the profusion of alpine herbs sometimes to the exclusion of grasses and sedges. The dominant grasses throughout the valley include species of *Staria, Phleum, Alopecurus, Agropyron, Elymus, Oryzopsis, Festuca, Trisetum, Pennisetum, Colpidium, Poa, Bromus, Kobresia, Agrostis* and *Danthonia* with several species of sedges (Rawat 1998; Negi 2010). These are important nutritious foraging species for both wild and domestic ungulates (Kala et al. 2002; Suryawanshi et al. 2009). The subalpine birch forests are often associated with *Rhododendron campanulatum, Lonicera* spp*, Salix* spp and *Cotoneaster* spp (Negi 2010), which serve as good cover for musk deer, blue sheep and tahr (Personal Observation). The alpine habitats beyond the limits of forest harbor many rare medicinal herbs such as Kutki (*Picrorhiza kurroa*), Hatta Jadi (*Dactylorhiza hatagirea*), Kuth (*Saussurea lappa*), Thoya (*Carum carvi*) and Jatamansi (*Nardostachys grandiflora*).

The diverse characteristics of the valley makes it an abode of a great variety of rare, threatened, charismatic and endemic species of Himalayan mammals. Major ungulate species of the valley include Himalayan goral *(Naemorhedus goral)*, Himalayan tahr *(Hemitragus jemlahicus)* Himalayan serow (*Capricornis thar*) and Himalayan musk deer *(Moschus chrysogaster)* at lower altitudes (below 3500 m); and blue sheep *(Pseudois nayaur)* towards the higher ranges (above 3500 m). The top predators include Snow leopard (*Panthera uncia*), Asiatic black bear (*Ursus thibetinus*) and Red fox (*Vulpes vulpes*). Other mammal species include Stoat *(Mustela erminea)*, Royle's pika *(Ochotona roylei)*, Himalayan weasel *(Mustela altaica)* and Yellow throated marten (*Martes flavigula*).

Henceforth, I will refer to my study species as blue sheep, tahr and musk deer.

2.1.3 The valley and the people

The valley is divided into *Malla* (upper) Johar and *Talla* (lower) Johar. There are 14 villages in *Malla* Johar, all situated at elevations above 3000 m in the sub alpine and alpine zones, which form the summer residences of the local people. The people residing in the upper Himalayan valleys of the Kumaon and Garhwal regions of Uttarakhand are referred to as *Bhotiya*. The *Bhotiyas* of the Johar valley are known as *Shaukas*. One of the defining characteristic of the *Bhotiya* community is the practice of transhumance, or migration between summer and winter villages to use grazing land and grow crops. The main pastoralist community using the alpine meadows include *Shaukas* and *Anuwals* who migrate seasonally to these pastures with their animals (Sharma, Rollefson & Morton 2003). The movement of pastoralists with their livestock continues between sites in a regular pattern (Sharma, Rollefson

& Morton 2003). There are altogether more than 38 pastures in the entire Johar valley where 45 pastoralists graze their livestock. Although transhumance is on the decline in many parts of the IHR, the practice is still observed in this valley till the month of September, which coincides with the end of the harvest and grazing season as villagers make preparations to return to their lower altitude villages for the winter. Largely because the loss of trade with Tibet (Farooque 1998), the demand for livestock and agriculture products as well as other professions linked to trade and agriculture including wool crafting and freight shepherding has dropped considerably. The *bugyals* also support an economic influx through *Ophiocordyceps sinensis* and medicinal herb collection. I have discussed the sustenance of people in details in the fifth chapter.

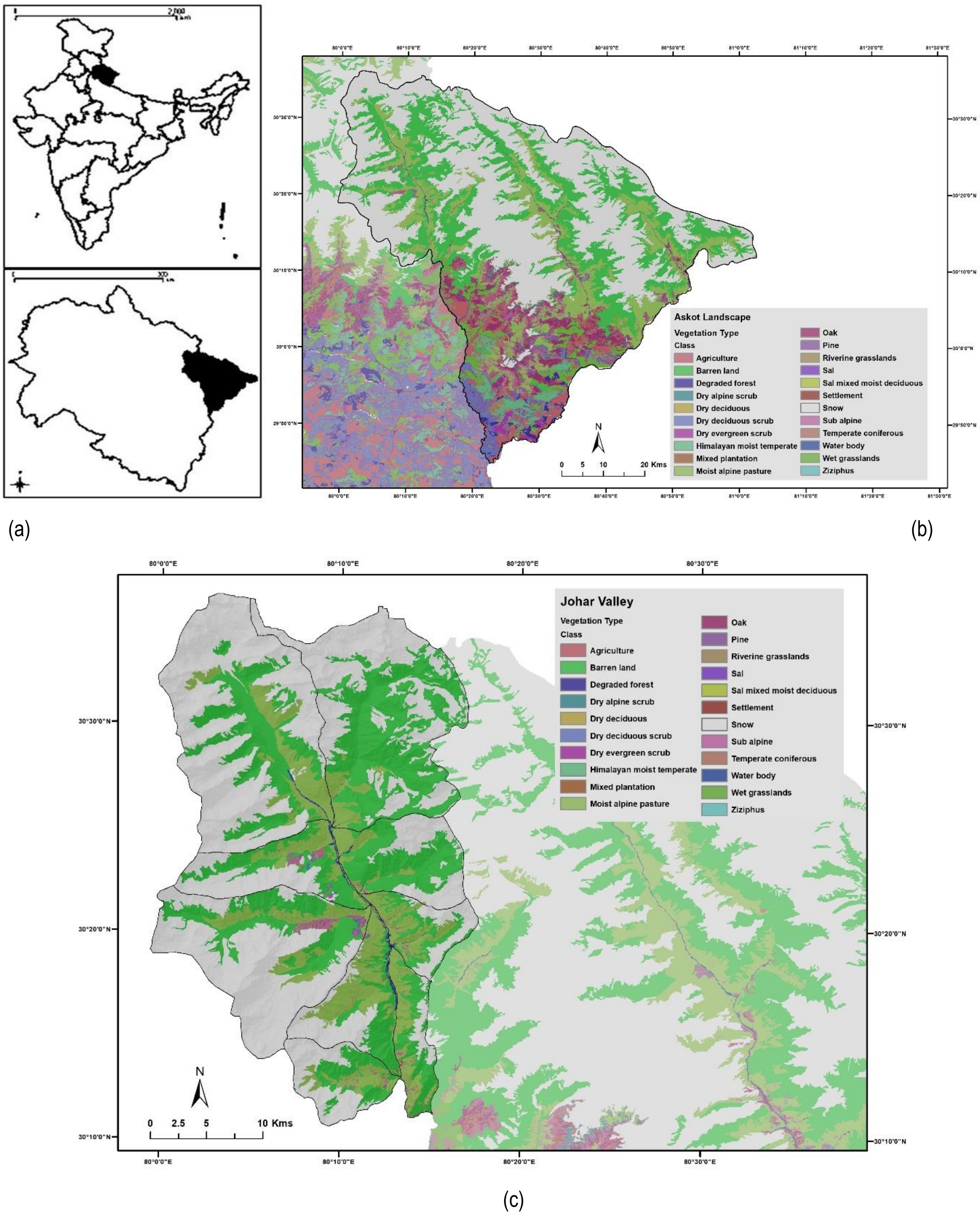

Figure 1: Study area map showing (a) Location of Askot landscape in India and Uttarakhand; Vegetation type map of (b) Askot landscape and (c) Johar valley

2.2 Methodology

Prior to field visit, I divided the entire study area into 38 grids of 25 km^2 using ArcGIS 9.3 (Esri Inc, 2008). The grid size was chosen in a way to incorporate the average daily movement distance (Garland 1983) of blue sheep (2.9 ± 0.5km), tahr (male: 3.45 ± 0.1km; female: 3 ± 0.1km) and musk deer (2.15 ± 0.09km) to avoid duplication of sampling across grids and considering all the three species. I calculated their average daily movement based on their body sizes (Garland 1983). The grids were put for feasibility of sampling, maintaining the optimal distance between spatial replicates in order to avoid autocorrelation. I used random and stratified random sampling approaches to conduct the study for three years (2015-2017) in the summer - monsoon season (May – September). The sampling time coincided before the arrival and after departure of pastoralists in the valley.

2.2.1 Field data collection

Direct observations:

During the field sampling, I selected vantage points with maximum visibility in each grid, depending on accessibility (Figure 2). I ensured maximum visibility by visiting each sampling grid and surveying for elevated locations with ~360-degree visibility of the surroundings. I conducted point counts of 10 minutes each from each vantage point with binoculars (10 X 50 mm). I sampled 20 out of the 38 grids with 40 vantage points (two in each grid) and did 13 repeated point counts at each vantage point at an hour's interval (6:00 am to 6:00 pm). Along with this, I surveyed pre-existing trails of 2 to 11 km (n = 24) en route to the vantage points and sampling grids for direct evidence (Bhattacharya et al 2009). 2 trails per day were sampled and the trails were walked in the mornings (6:00 am to 9:00 am) and evenings (3:00 pm to 6:00 pm). There were 3 replicates of trail sampling in 3 years. To avoid inter-observer bias, all field observations were made by a single observer (me). When encountered, I recorded species type (wild or livestock), projected sighting locations, number of individuals, date and time. I calculated the GPS locations of the direct sightings as projected locations by obtaining the sighting distance and the sighting angle. The sighting distance was calculated as per Shrotriya et al. (2015), where I used manual maps of the area to find the distance to animal from the point in already defined distance categories (0-200 m, 200-500 m, 500-1000 m, 1000-1500 m, 1500-2000 m, 2000-3000 m, and 3000-5000 m). I also interviewed experienced pastoralists (n=45) with open-ended semi structured questionnaires regarding locations of blue sheep, tahr and musk deer as observed and remembered in the past five years. These are the only pastoralist groups that graze their livestock every year in pre-decided alpine patches and have experiences of more than 20 years in the study area. I surveyed probable areas accumulating sighting locations from the pastoralist community. The total sighting locations for blue sheep accumulated from the herders were 23, in which I obtained direct sightings in 14 locations (~60% parity). Based on this, I considered the herders' locations to be correct. The information collected from the herders contributed to around 17% (n=9) of the blue sheep direct data in the study. I included this information as direct evidence for analysis. The total sighting locations for tahr accumulated from the herders were 6, in which I obtained direct sightings at all locations (100% parity). I also did a rapid assessment exercise for collecting presence locations of blue sheep, tahr and musk deer along with their habitat covariates in 10 - 15 day expedition modes covering parts of the entire valley twice in a year. This data mainly included opportunistic sightings of the species and I recorded species type, projected sighting locations, number of individuals, date, time and broad habitat type. I did this rapid assessment to increase the encounter rate of the species and incorporate a portion of the information which could have been missed during the vantage point count and trail sampling. Since my three study species were rare, elusive and difficult to sight, I conducted this rapid assessment to accumulate a considerable amount of data for a proper analysis.

Indirect observations:

I sampled 30 out of the 38 alpine pastures (regular encampments) and areas *en route* to these, which are used for livestock grazing, for pellet enumeration (Harkonen and Heikkila 1999) of blue sheep, tahr, musk deer and livestock (sheep and goat). This was done within the potential habitat of the three wild ungulates, wherever possible and accessible. I sampled a total of 304 random pellet plots, each of 10 m radius across the entire study area (Figure 3), separated by at least 300 m. Previous literatures suggested that belt transects are relatively more prone to missed groups error of pellets than circular plots for large ungulates (Neff 1968). It was also suggested that for plot size for pellet counts of ungulates, the optimal plot size should not be too large or too small. The smaller plot may have a greater proportion of perimeter pellet groups making its inclusion or exclusion a subjective matter. Also in order to capture the richness of species present, smaller plots would need to be in much more number, thus becoming a time exhaustive method. The disadvantage of using larger plots is a chance of missing pellet groups (Smith 1968; Noor et al. 2010). The optimal plot size was found to be plots of 10 m radius (Smith 1968).

Since the terrain was not suited for a systematic sampling, I placed the circular plots randomly, covering all possible habitat types. I recorded information on number of pellet groups, species, and locations. I recognized wild ungulate pellets from areas devoid of livestock presence and by visiting their previously observed presence locations in those areas, wherever accessible. Wild ungulate pellets were distinguished from each other by their pellet size and shape. Distinguishing blue sheep pellets from those of livestock (sheep and goat) posed confusion initially. However, after careful study and consultation with experienced herders this problem could be resolved. Further, I also collected blue sheep pellets for future verification. However, to get rid of any identification bias of blue sheep pellets at livestock grazed areas, I relied on pellets only from areas without livestock grazing for analysis. Collection of tahr pellets were not possible due to their inaccessible habitat, because tahr mostly access very steep slopes and cliffs, which are difficult to survey as well as the pellets tend to roll down to a completely different location. There were only two plots in which I observed musk deer pellets. Again, since no direct evidences for musk deer were observed, 20 camera traps were deployed in the 20 sampled grids (Figure 4) for vantage point count (one in each grid) for a session of 40 days (800 trap nights). The locations for camera traps were selected after previous consultations with the herders and local people, so as to optimize the capture of musk deer.

A total of 40 sampling points with 520 point count replicates for 5200 minutes (single season) along with 149 km of trail walk for 4172 minutes per season (three seasons) and 304 pellet plots of 315 m^2 each (single season) was the survey effort for this study. The rapid assessment included an additional walk of ~315 km per season for three years.

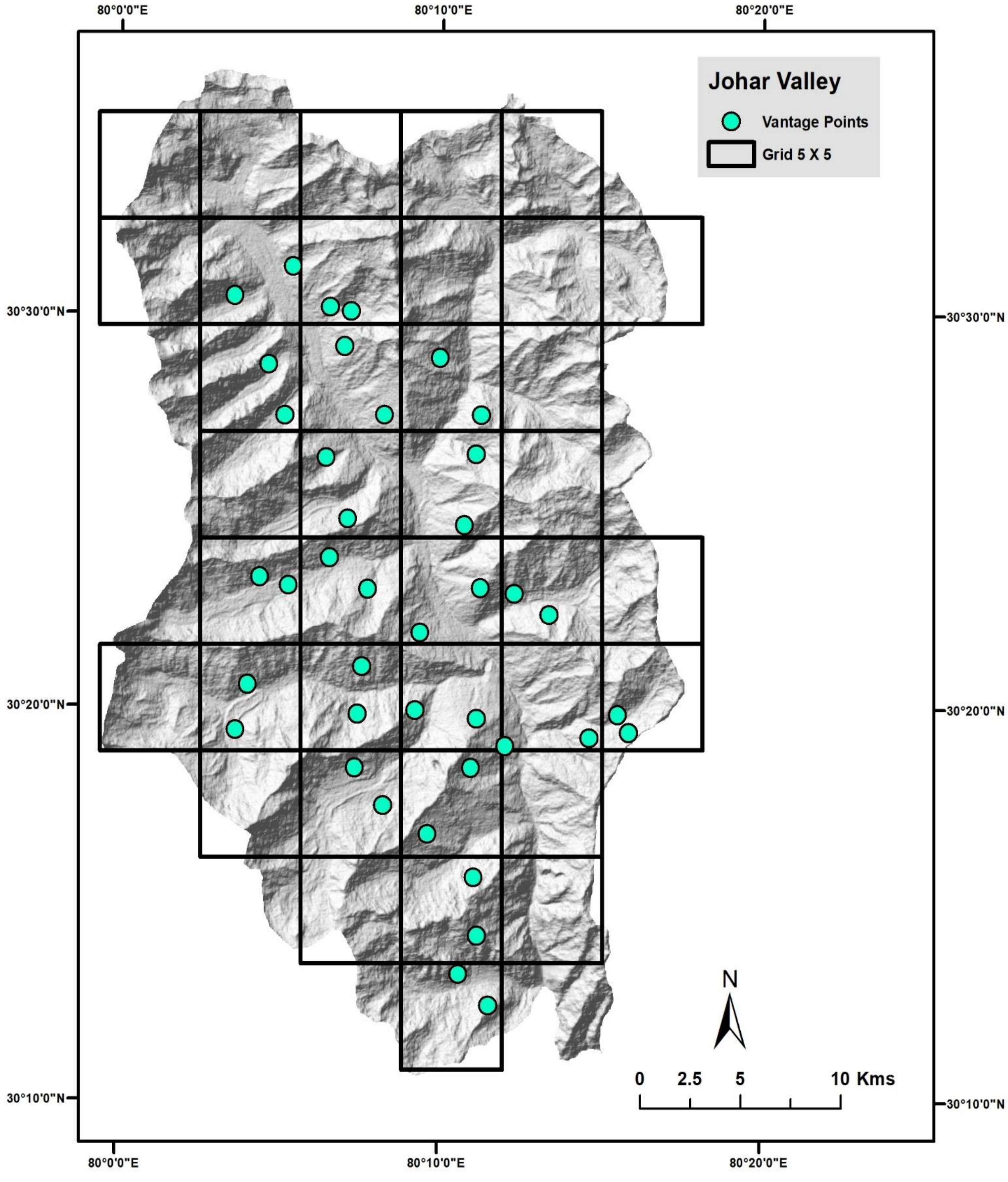

Figure 2 : Map of Johar valley divided into grids (5X5 km^2) with locations of vantage points

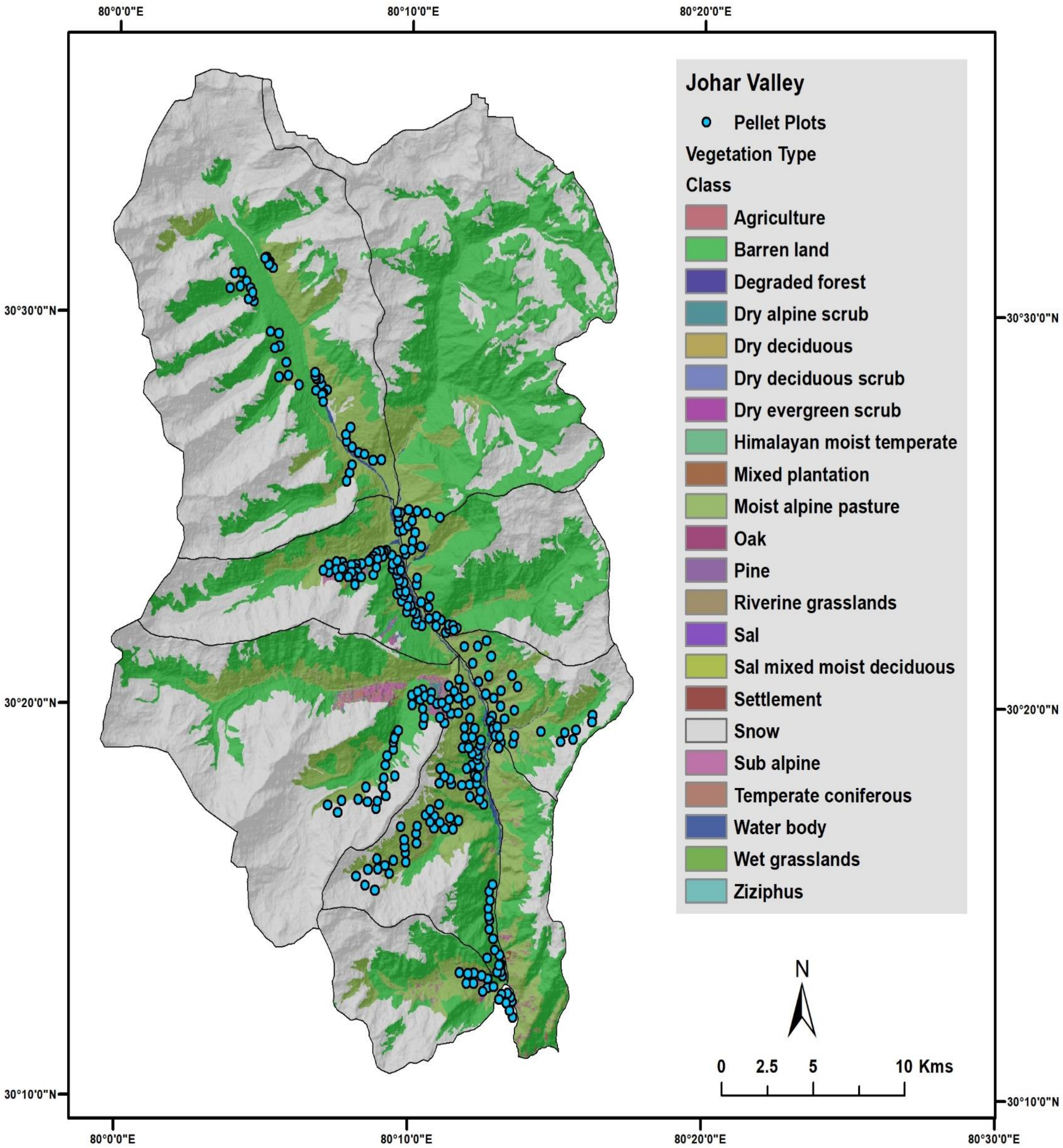

Figure 3 : Vegetation type map of Johar valley showing locations of pellet plots

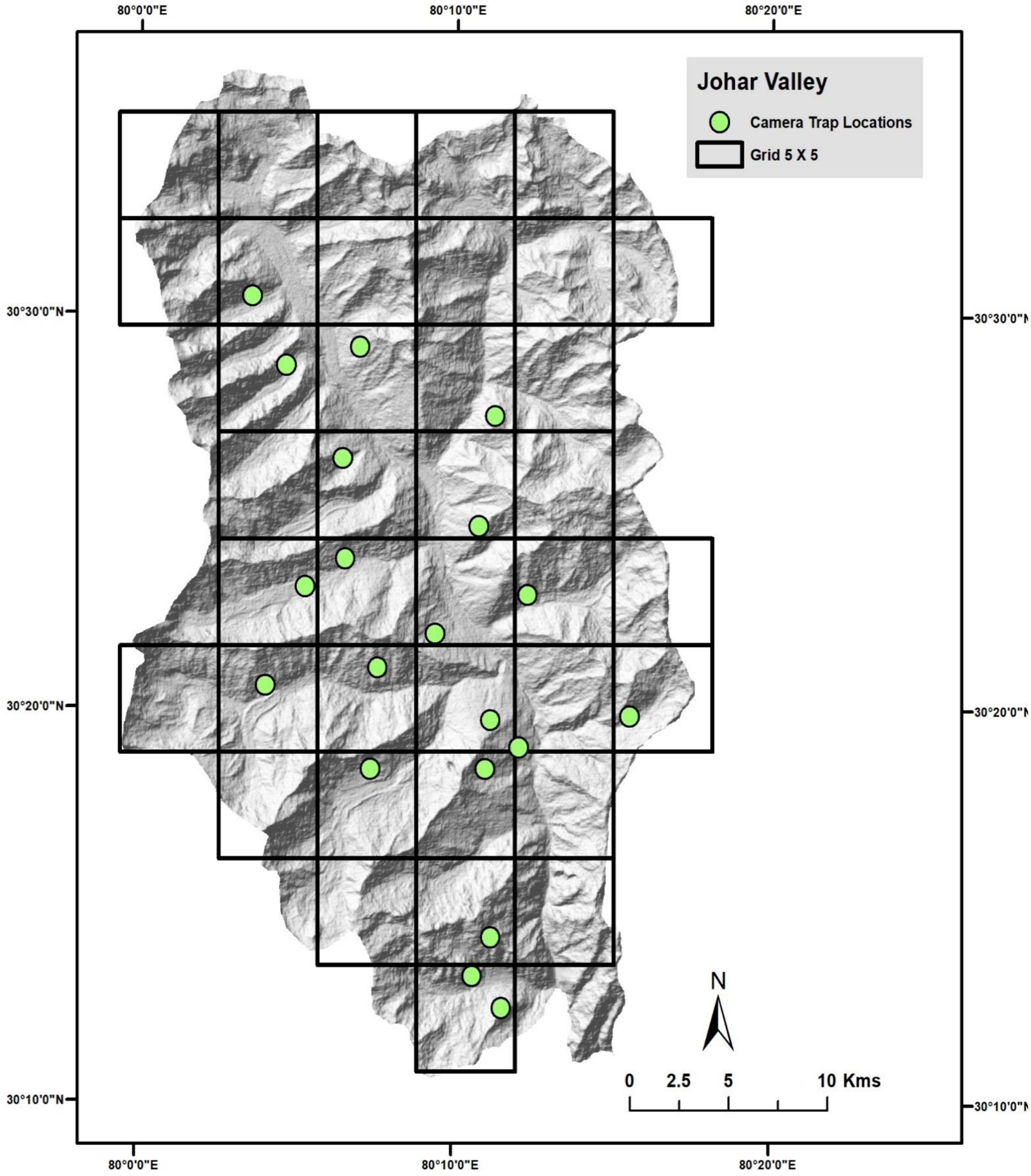

Figure 4 : Map of Johar valley showing locations of camera traps

2.2.2 Preparation of geospatial layers

I acquired the vegetation type layer from the Biodiversity Information System portal of Indian Institute of Remote Sensing (http://bis.iirs.gov.in). The original resolution of this data is 23.5m as per Roy et al. (2015) and according to their study, the layer was prepared at a scale of 1:50000 using medium resolution IRS LISS-III. This map has an accuracy of 90%. The vegetation type map had 20 classes for my study area (Figure 5) from which I selected the most relevant for my study species and clubbed the least relevant categories as miscellaneous. Thus, I finalized 12 vegetation categories for the study area. The final categories were moist alpine pasture, wet grasslands, dry alpine scrub, barren land, snow, *Rhododendron*, sub alpine, dry deciduous scrub, dry evergreen scrub, Himalayan moist temperate, agriculture and miscellaneous. I acquired Digital Elevation Model (ASTER 30 m DEM) of Johar valley from (Figure 6) Ecological Mapping Atlas of Askot Landscape, Uttarakhand, India (WII-BCRLIP 2015). Raster layers of aspect, slope and terrain ruggedness index (TRI) were derived from DEM (Figure 7, 8 & 9). I classified slope into two classes (0-45 and 45-80 degrees). Slopes above 45 degrees were considered as cliffs (Namgail et al. 2004; Ahmed et al. 2016) to calculate the distance to escape terrain (DET). I calculated Euclidean distances from the cliffs at 100 m intervals (maximum distance 2 km) to generate DET raster layer (Figure 10). This was done as wild ungulate sightings from nearest escape terrain varied from 100–2000 m during the study. Based on the average daily movement distances of my study species, I used DET intervals of 100 m from the cliffs so that the results are not skewed towards a particular escape terrain category. Normalized Difference Vegetation Index (NDVI) data for the months May, June, July, August and September were obtained from LANDSAT-8 data, red and near-infrared band. Bioclim layers (version 2) from 1970-2000 were obtained from www.worldclim.org. I used five Bioclim layers – Annual Mean Temperature (Bio1), Temperature Seasonality; standard deviation *100 (Bio4), Temperature Annual Range (Bio7), Annual Precipitation (Bio12) and Precipitation Seasonality; coefficient of variation (Bio15) as these were the most relevant for the study.

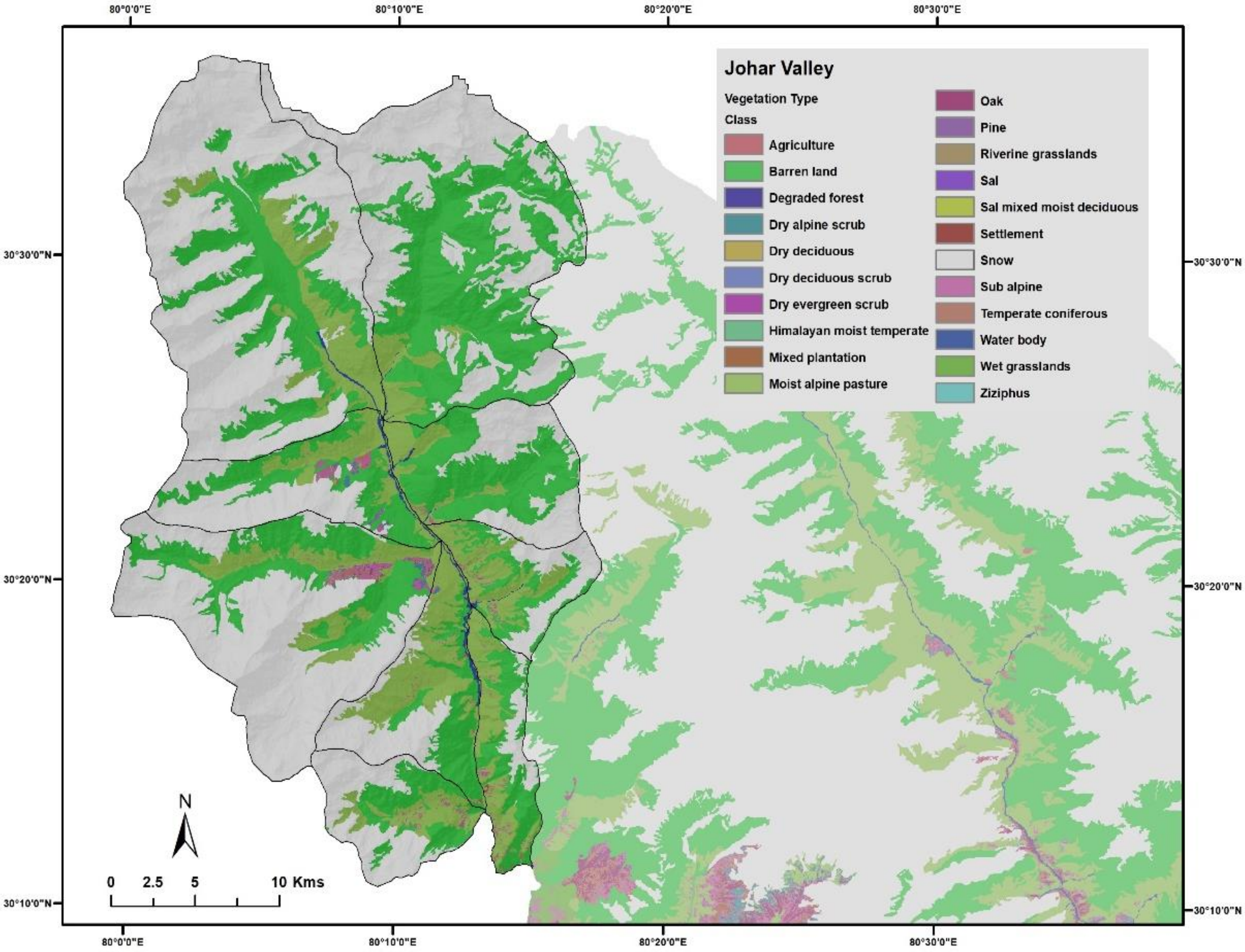

Figure 5 : Map of Johar valley showing vegetation type classes

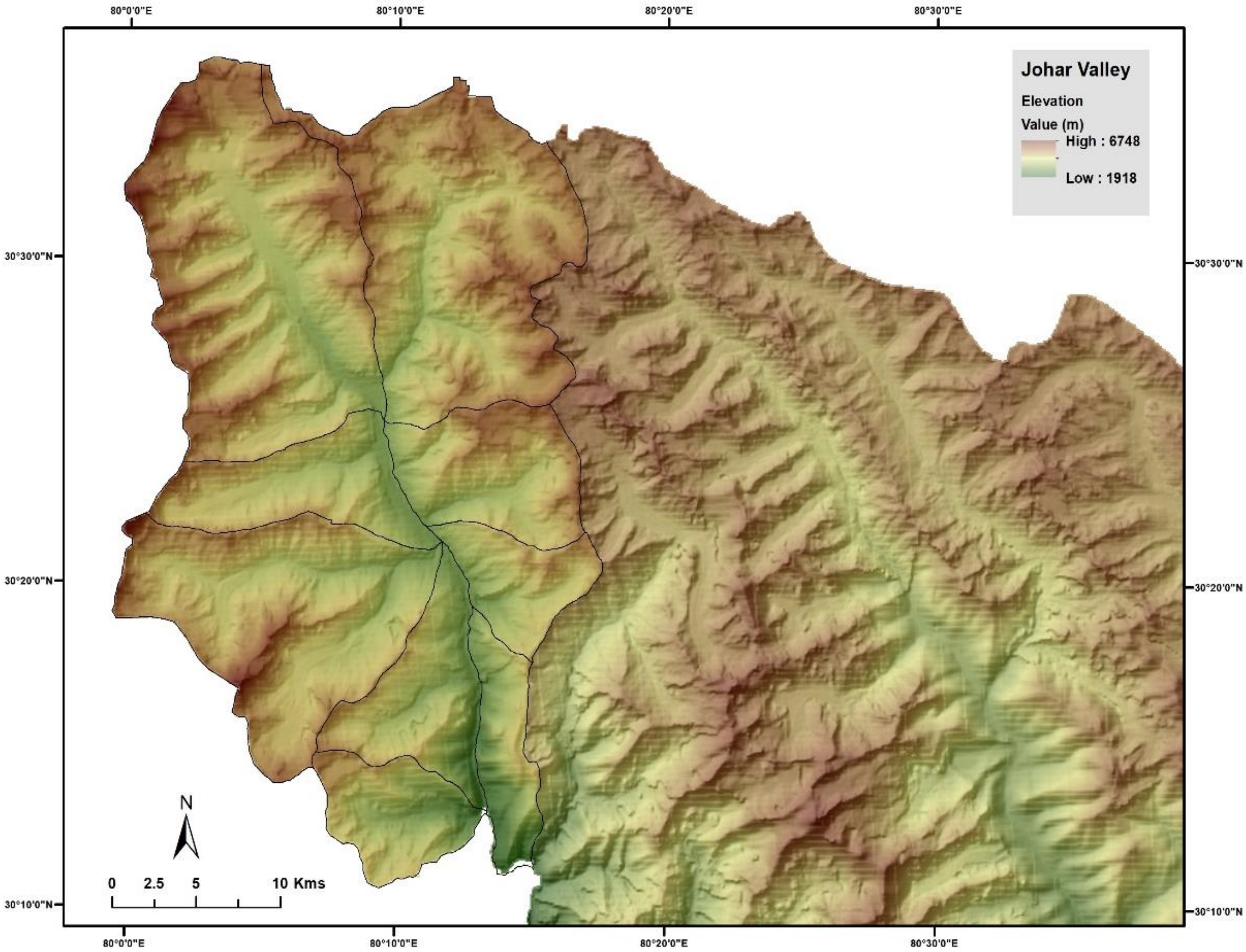

Figure 6 : Digital Elevation Model map of Johar Valley

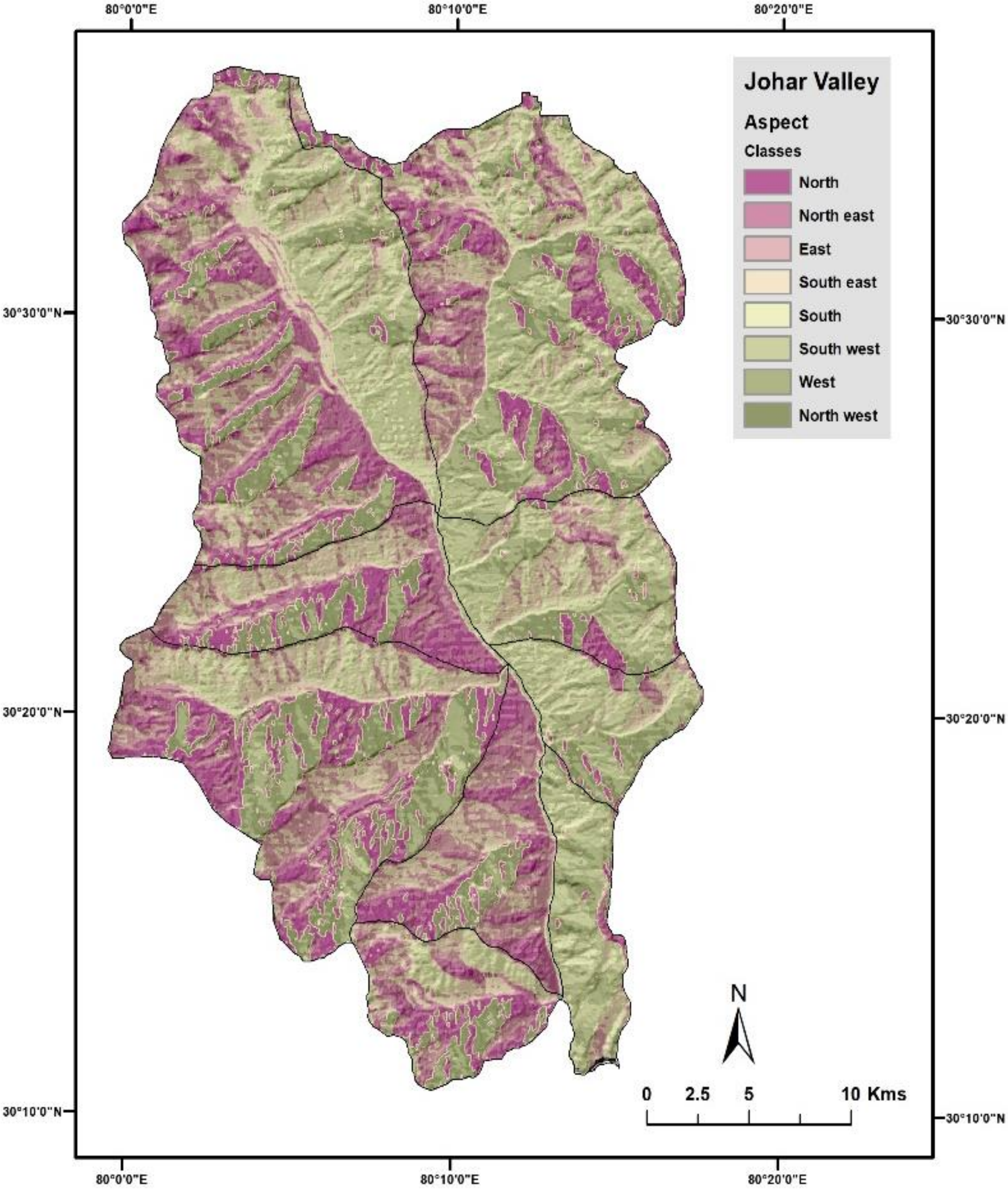

Figure 7 : Map of Johar valley showing aspect classes

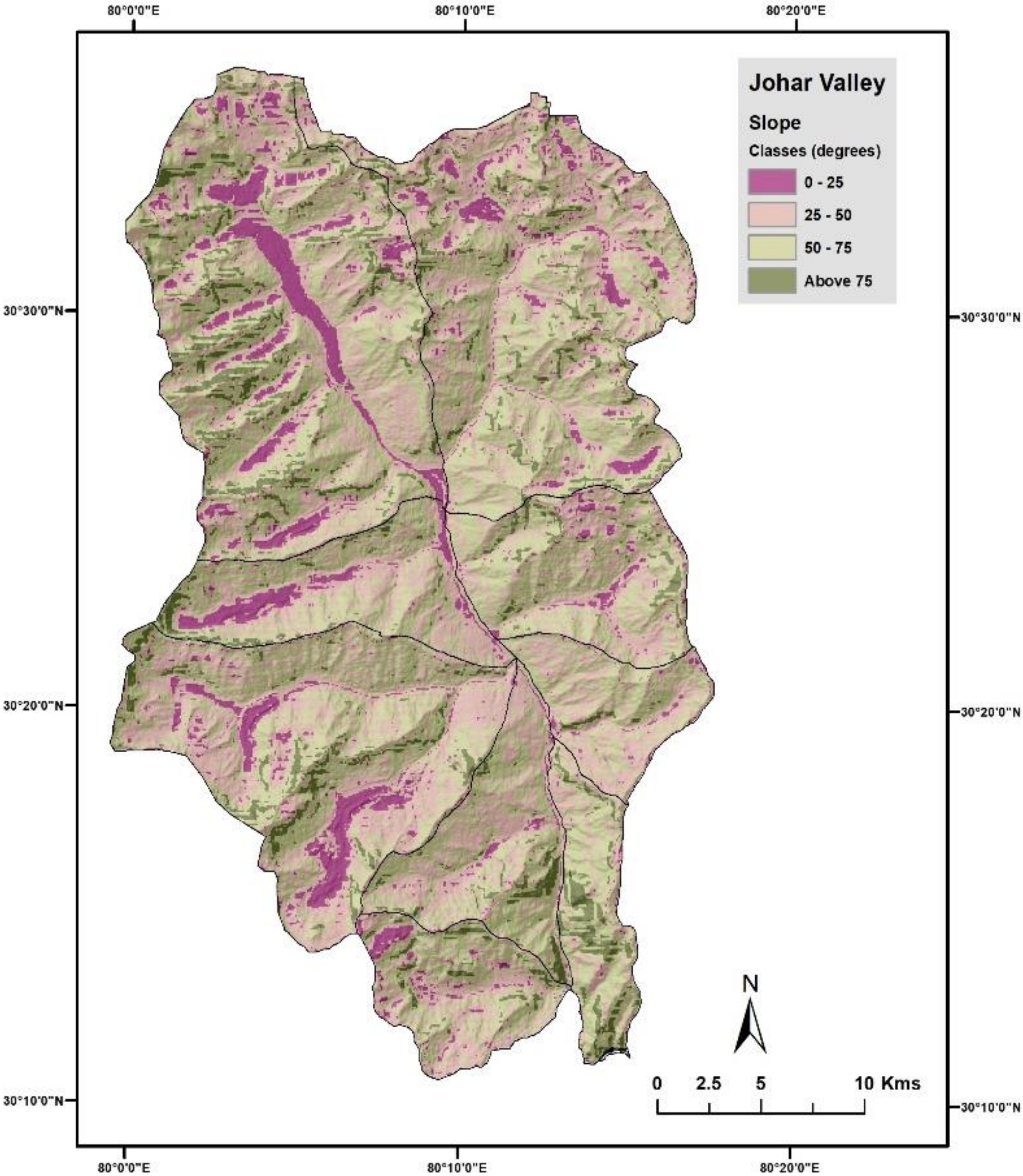

Figure 8 : Map of Johar valley showing slope classes

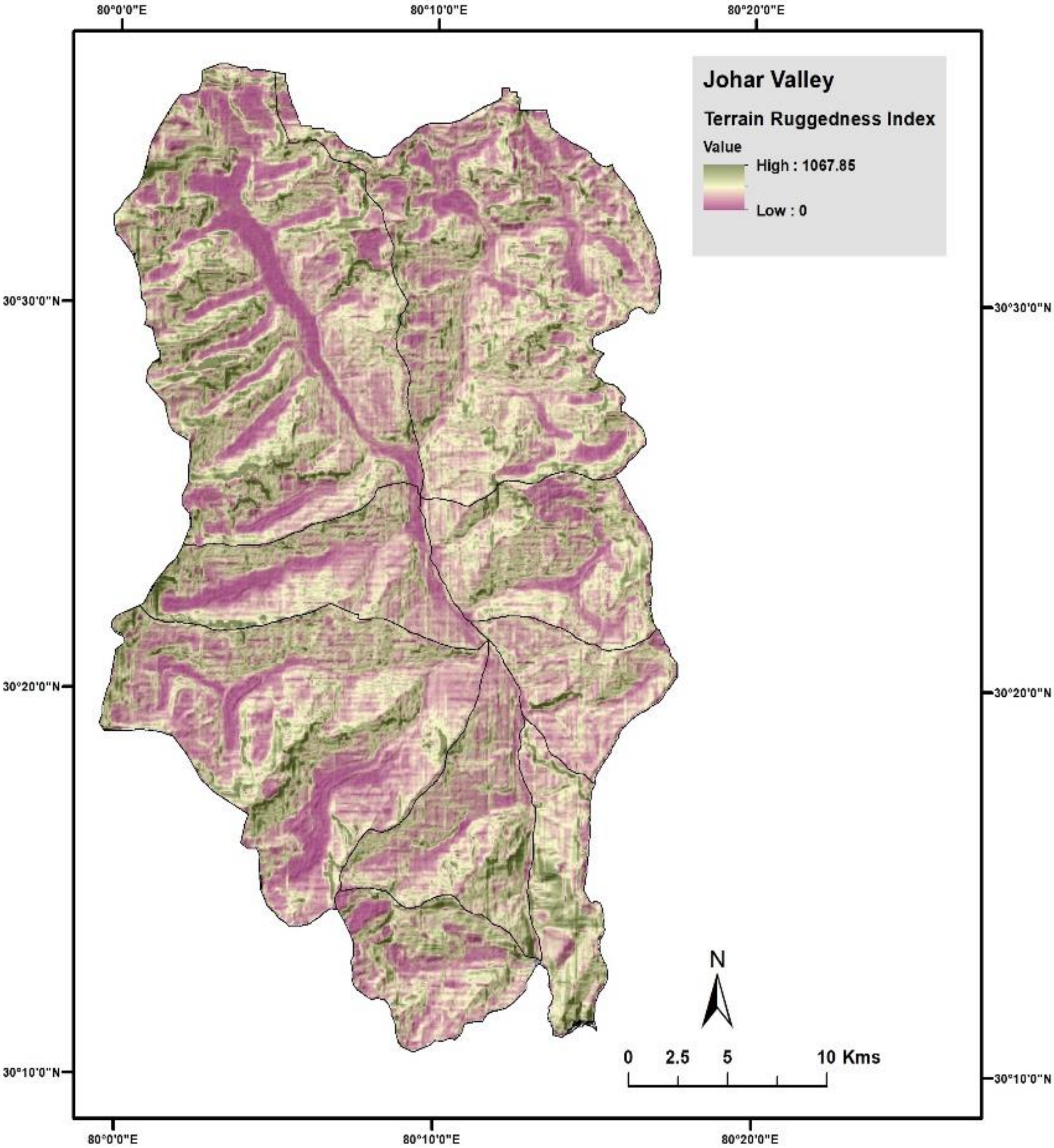

Figure 9 : Map of Johar valley showing Terrain Ruggedness Index

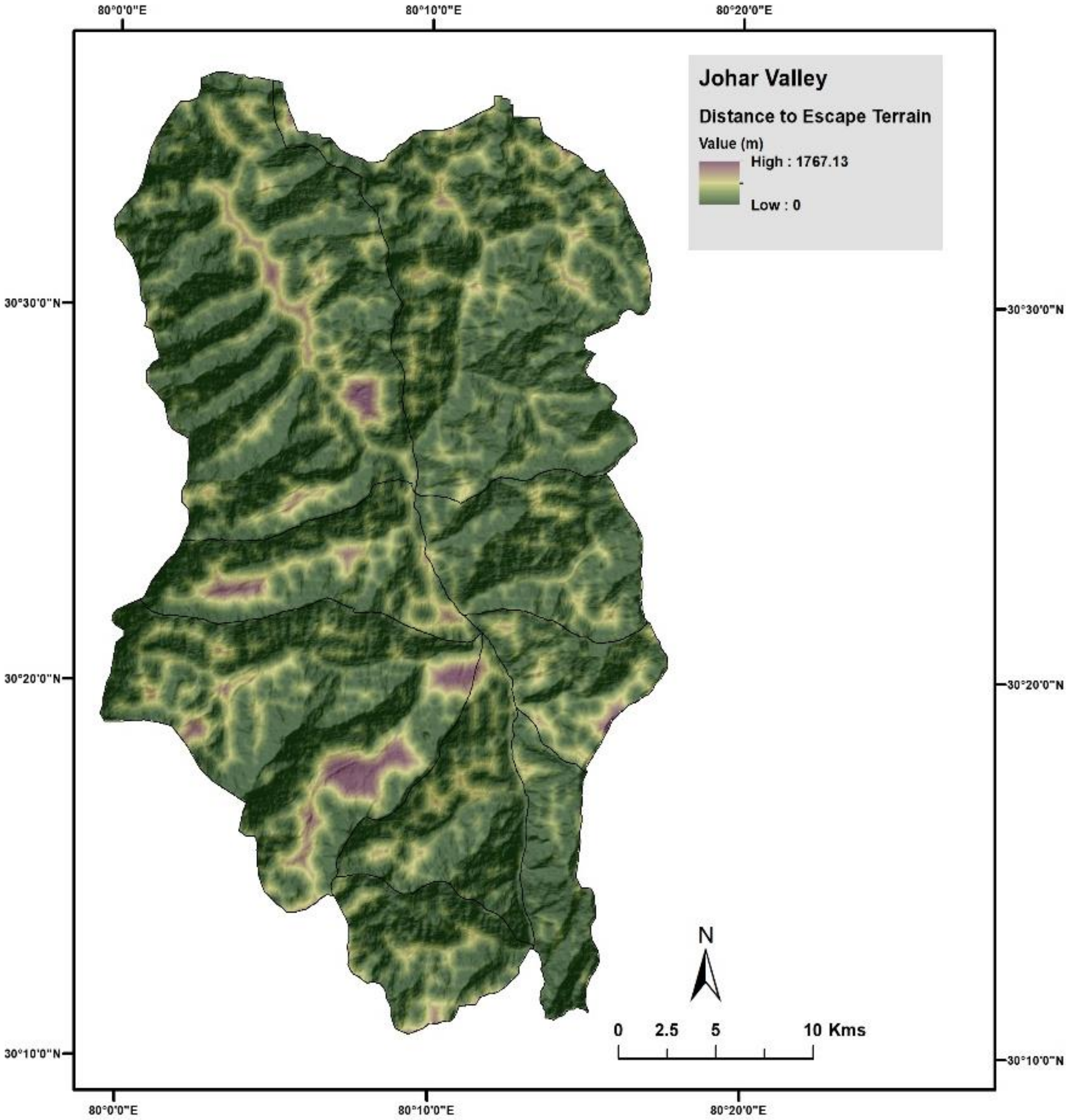

Figure 10 : Map of Johar valley showing distance to escape terrain

Chapter 3: Distribution pattern and population estimation

3.1 Introduction

Distribution pattern of a species is the manner in which the species is spatially arranged in an ecosystem. Providing information on spatial distribution of a species along with their population estimation is the first and basic requirement for their conservation. The purpose of studying distribution pattern is to provide spatially explicit information of the species with respect to their habitat for effective conservation planning, risk assessment of ecological impacts, endangered species management and prioritizing areas for conservation (Elith and Leathwick 2009; Franklin 2010; Elith et al. 2011). Distribution and abundance of a species are mainly influenced by availability of resources, seasonal variation and presence of predator or prey species (Boyce and McDonald 1999). Knowledge about the distribution pattern, thus, helps in understanding the species niche requirements which in turn leads to knowing their potential and most probable distribution in a geographic area (Villero et al. 2017). Mountainous regions with rugged terrains hinder the pursuit of proper ecological studies of the species inhabiting such areas. In-depth ecological studies on such species become difficult, time consuming and expensive. However, acquiring a sound baseline ecological information for most of these species, requires a good knowledge about their distribution a priori. Along with distribution, it is also important to estimate the population of species in a landscape for a baseline information (Gros, Kelly & Caro 1996; Suryawanshi, Bhatnagar & Mishra 2012; Shrotriya et al. 2015). A good idea about the estimated population of a species along with an accurately estimated suitable habitat provides much better insights for conservation of species in difficult terrains.

There have been several studies on the mountain ungulates of the IHR, mainly focusing on a local scale within protected areas (Sharma and Lachungpa 2003; Bhattacharya et al. 2010;

Namgail et al. 2009; Kandpal and Sathyakumar 2010; Sathyakumar et al. 2011). In recent years, use of models in predicting the spatial distribution of species (Boyce and McDonald 1999; Guisan and Zimmermann 2000; Pearce and Boyce 2006; Manly et al. 2007) have gained much interest. Species distribution models (SDM) are currently used for explaining the observed pattern of species occurrence using environmental or geographic information (Elith and Graham 2009). Such models use species presence records and spatially explicit environmental and ecological correlates to create a map of presence probability. Approaches to species distribution modelling include traditional regression techniques (e.g. generalized linear models and generalized additive models) to more recent techniques codified in software packages (e.g. Maximum Entropy or MaxEnt). Distribution models using rule based predictions provide a basic idea about the potential distribution of a species and is helpful for species information with very small sample sizes. However, recent work has shown that the presence-only model MaxEnt (Phillips, Anderson & Schapire 2006) also performs well with small sample sizes (Elith et al. 2011; Phillips et al. 2017). For a more accurate knowledge, MaxEnt is an important tool for generating distribution ranges for species. MaxEnt is helpful for predicting distribution of species with presence-only data especially for mountainous species without radio telemetry, where mostly the aforementioned kind of data is available. Hirzel et al. (2006) showed that the presence-only evaluators are fairly correlated to the presence/absence ones.

The conventional methods for wildlife data collection do not apply in mountainous regions. There are several caveats like terrain accessibility, climatic conditions and rarity/elusiveness of the concerned species. Thus, logically improvised methodologies need to be followed for obtaining data in such landscapes. Suryawanshi, Bhatnagar & Mishra (2012) derived a methodology called double observer survey method for obtaining the population estimation of mountain ungulates. This method is based on the capture recapture method for species population estimation and their method is by far the best suited for mountainous areas. But this method is only suitable for areas with good visibility ranges such as the Trans-Himalaya. For areas like the transition zones between the Greater and Trans-Himalaya, an adaptation from this method is required for proper population estimation of species. In this chapter, I attempted to estimate the distribution pattern, habitat suitability and population density of blue sheep, tahr, musk deer and livestock using an adaptation of the double observer survey method along with other methodologies.

Blue sheep has a wide distribution range in the southern and eastern Central Asian mountain ranges. It is distributed across China, Pakistan, India, Nepal, Tibet, Bhutan and Myanmar. In India, its distribution range includes parts of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Sikkim, and Arunachal Pradesh (Johnsingh and Manjrekar 2015). Despite such a wide distribution range, the documentation for blue sheep distribution in India is sparse and has been done in pockets. There is little or no documentation of distribution data from north east India. Previous literature available on blue sheep distribution include studies by Sharma and Lachungpa (2002) (Sikkim), Namgail (2009) (Ladakh and Spiti), Chanchani, Rawat & Goyal (2010) (Sikkim), Kandpal and Sathyakumar (2010) (Uttarakhand), Namgail (2010) (Ladakh), and Aryal et al. (2016) (Nepal). Tahr has a patchy distribution pattern and is found in India and Nepal. In India, it is distributed along the southern sides of Greater Himalaya in parts of Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Sikkim (Johnsingh and Manjrekar 2015). Distribution studies on tahr has been done by Sharma and Lachungpa (2002) (Sikkim), Shrestha (2006) (Nepal), Ale (2007) (Nepal), Kandpal and Sathyakumar (2010) (Uttarakhand). Musk deer has a distribution range in isolated pockets of India, Nepal, Bhutan and China. In India, musk deer has been reported to occur in parts of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh (Johnsingh and Manjrekar 2015). Studies focusing on distribution of musk deer has been done by Green (1986), Aryal (2005) (Nepal) and Lamsal et al. (2018) (Nepal). All these occurrence reports of the three wild ungulate species have been accounted mainly from protected areas. However, there remain several areas in the entire IHR with knowledge gaps which hinder a proper widespread estimation of distribution and population of these species.

Intensive studies and monitoring of wildlife have been done in the Terai region of Uttarakhand. But few studies (Green 1985; Vinod and Sathyakumar 1999; Kandpal and Sathyakumar 2010; Sathyakumar et al. 2011; Bhattacharya et al. 2012) have been done in the high altitude areas. The Trans-Himalayan region of Uttarakhand is dry and has sparse vegetation, similar to Ladakh and Tibetan plateau, in most of its extent. Animal abundances are rather low, constrained by the availability of food resources and suitable habitat. The unique parts of this state are the transition zones between the Trans-Himalayan and Greater Himalayan ranges which provide unique assemblages of flora and fauna as described in the previous chapter. The present study area in Askot landscape provides an opportunity to study distribution patterns along gradients of the Trans-Himalaya and Greater Himalaya. With the advent of pastoral practices and in the light of growing livestock abundances, the wild ungulates have shifted their niches in the area. Therefore, it becomes pertinent to find the distribution pattern and population of livestock along with the wild ungulates in order to assess the current scenario of interaction between them. Assessment of a baseline interaction pattern based on distribution would lead to future basis for further monitoring. This is the first attempt of scientific estimation of the current distribution pattern and population of wild and domestic ungulates from Johar valley.

3.2 Research questions and hypothesis

- How are wild and domestic ungulates distributed in Johar valley with respect to landscape features?
- What are the current patterns of abundances/population densities of wild ungulates and livestock in Johar valley?

Excluding human influence, distribution and abundance of species should be as per the carrying capacity of the habitat and extent. Species of the same trophic level, such as ungulates, are of fundamental interest in this context as their distribution pattern might get affected with the inclusion of human influences. The environmental conditions allowing species to compete or co-exist shapes the space use and space sharing of co-occurring species. Subsequently, population density of species will be reflected according to their distribution pattern in a region. My hypothesis for this chapter is that wild and domestic ungulates though co-occurring have differential distribution pattern based on topographic features which affects the detection probability and abundance of the wild ungulates.

3.3. Analysis

3.3.1. Distribution and habitat suitability

Geospatial analysis was done in GIS domain (ArcGIS 9.3) for blue sheep, tahr, musk deer and livestock. Species presence points (direct and indirect sightings) from the vantage point counts, trail walks and rapid mapping exercise methods as described in Chapter 2 were used for this analysis. The covariate layers used for SDM were DEM, slope, aspect, vegetation type, TRI, Bioclim layers (bio1, bio4, bio7, bio12 and bio15) and NDVI (May – September). NDVI values ranged from -1 to +1 where negative values indicated areas towards water or glacier with very less vegetation and values closer to 1 indicated areas with more vegetation. All layers except for the Bioclim were prepared at 30m resolution in Universal Transverse Mercator (UTM) Zone 44N projection. SDM was done with these variables using software MaxEnt ver. 3.4.1k (Phillips et al. 2006) which is a statistical machine learning algorithm based on maximum entropy principle (Elith et al. 2011). MaxEnt is one of the recent approaches which can be used under different conditions (Hernandez et al. 2006; Wisz et al. 2008) for proper distribution modelling, especially in difficult to survey mountainous regions. The framework for MaxEnt is based on occurrence/presence records (locations where the species has been found) together with environmental variables or constraints for a surrounding study area (Phillips et al. 2006; Phillips and Dudik 2008). The constraints, also defined in terms of 'features', require that the mean of each feature should match the sample mean. This formulation is equivalent to maximizing the likelihood of a parametric exponential distribution (Phillips, Dudik & Schapire 2004). An idealized data model is in which the study area is a finite grid of equal-sized cells, with occurrence records corresponding to grid cells randomly selected from those occupied by the species. Additionally, the primary goal of SDM is often to model and understand the environmental conditions inhabited by the species, rather than simply its geographic distribution. Both for this use and to better estimate the geographic distribution, it is important that the occurrence data represent a random sample of suitable conditions in the study area.

I ran the MaxEnt model using the feature classes linear, quadratic and hinge features to help smooth the variable responses and noise reduction (Elith et al. 2011; Merow, Smith &

Silander 2013). Hinge features provide at least as much flexibility in the fitted response to predictor variables as threshold features, while tending to reduce over-fitting to the training data. I used four regularization multipliers (1, 0.5, 0.25 and 2) for each species to select the most appropriate model according to the sample sizes of the species. Regularization multiplier is a modifiable parameter that adds new constraints to the model, thus used to evaluate the best potential combination of parameters teaming up with the feature classes (Morales, Fernandez & Gonzalez 2017). This is used to prevent overfitting of the model by controlling the intensity of the chosen feature classes (Elith, Kearney & Phillips 2010). 75% of the locations were used to train the model and rest 25% locations were used to test the accuracy level. A logistic output (Phillips and Dudík 2008) was enabled. I assessed the model performance by the mean AUC value (Area under the Receiver Operating Characteristic Curve; Hosmer and Lemeshow 2000). I calculated mean variable response curves and Jackknife of regularized training gain test to evaluate importance of each predictor and percent contribution and permutation importance, which were generated by the MaxEnt model analyses. I applied 10 percentile training presence logistic threshold to generate the species distribution maps. After the distribution raster layers were generated, I extracted the raster values for the training locations and applied a threshold based on the minimum raster value and then divided the layer into 3 classes – low, medium and high suitability and calculated area of each class. Since musk deer had the lowest number of presence locations, I also used rule based modelling to estimate potential distribution range for musk deer in order to compare the accuracy of the MaxEnt results. For rule based modelling I used DEM, slope, aspect, TRI and vegetation type layers and classified them according to musk deer preference.

3.3.2. Population estimation

Analysis for population estimation was done separately for two species viz., blue sheep and tahr. Musk deer did not have considerable number of observations to perform analysis for population estimation. I estimated the population density of the species using Program Distance version 6.0 (Thomas et al. 2010) using the point transect sampling framework. I used the direct observations from the vantage point count sampling for this analysis. A detection function was fitted to the observed distances and this fitted function was used to estimate the proportion of objects missed by the survey. I measured detection distances from the vantage point to each detected object. The detection function g(r) was the probability that an object at distance r from the point is detected, and assumed that g(0) = 1. Best fitted model selected was the one with the lowest Akaike Information Criterion (AIC) (Akaike 1973) value. I did size bias adjustment for cluster size using size bias regression method [ln(cluster size) against global detection function g(x)] at a significance level of alpha = 0.15. In both species cases, the test p value was greater than the specified significance level, so average cluster size was selected for analysis. No truncation of data was required. Since, tahr habitat had cliffs and ridges to serve as barriers for the ~360 degree visibility, I did adjustment for visible area for tahr using View shed tool in Spatial Analyst extension in ArcGIS 9.3. No adjustment for visible area was done for blue sheep. I recorded details of livestock number by direct count using the herders' information from the interviews. Since the herder and livestock numbers were fixed with differences of less than 100 animals in the three years, I used the absolute number as estimated population of livestock.

3.4. Results

3.4.1. Distribution pattern and suitable habitat

A total of 87 presence points (51 direct, 36 indirect) for blue sheep and 327 presence points (97 direct, 230 indirect) for livestock were obtained. Alongside, 22 presence points for tahr and 11 photo-capture locations of musk deer were recorded during the study period (Figure 11). Indirect evidences of tahr and musk deer were hard to collect because of their inaccessible terrain.

Blue sheep:

MaxEnt model used for blue sheep distribution was reliable as statistical estimation of accuracy showed 89% area under curve (AUC) for sensitivity vs specificity graph. 0.5 regularization multiplier was the most suitable for blue sheep to avoid overfitting of the model. Among the variables used to predict the distribution – Aspect, NDVI (July), bio 12 (precipitation seasonality), aspect and vegetation type were the most important factors with the highest percent contribution in blue sheep distribution modelling (Figures 14 & 15). The NDVI covariate showed an influence of negative values, with the peak indicating moderate dense vegetation (grasses, sedges and alpine scrub) during July which governed their distribution pattern. The relation showed a drop towards denser vegetation. This is the most productive month for nutritious grasses for foraging of the wild ungulates and the significance of precipitation alongside supported the result. The results also showed influence of vegetation classes subalpine and moist alpine pastures mostly in blue sheep distribution pattern and a preference towards the eastern aspects. The potential distribution range (Figure 12) and suitable habitat for blue sheep in Johar valley was found to be 442.23 km^2 which is ~46% of the study area. MaxEnt highest probability distribution of blue sheep is presented in Figure 13 categorizing distribution range area in low, moderate and high probabilities (Table 1). The threshold raster value for lowest category was found to be 0.074. A total of ~223.22 km^2 area was identified as its most suitable habitat combining the moderate and high classes which is ~15% of the study area.

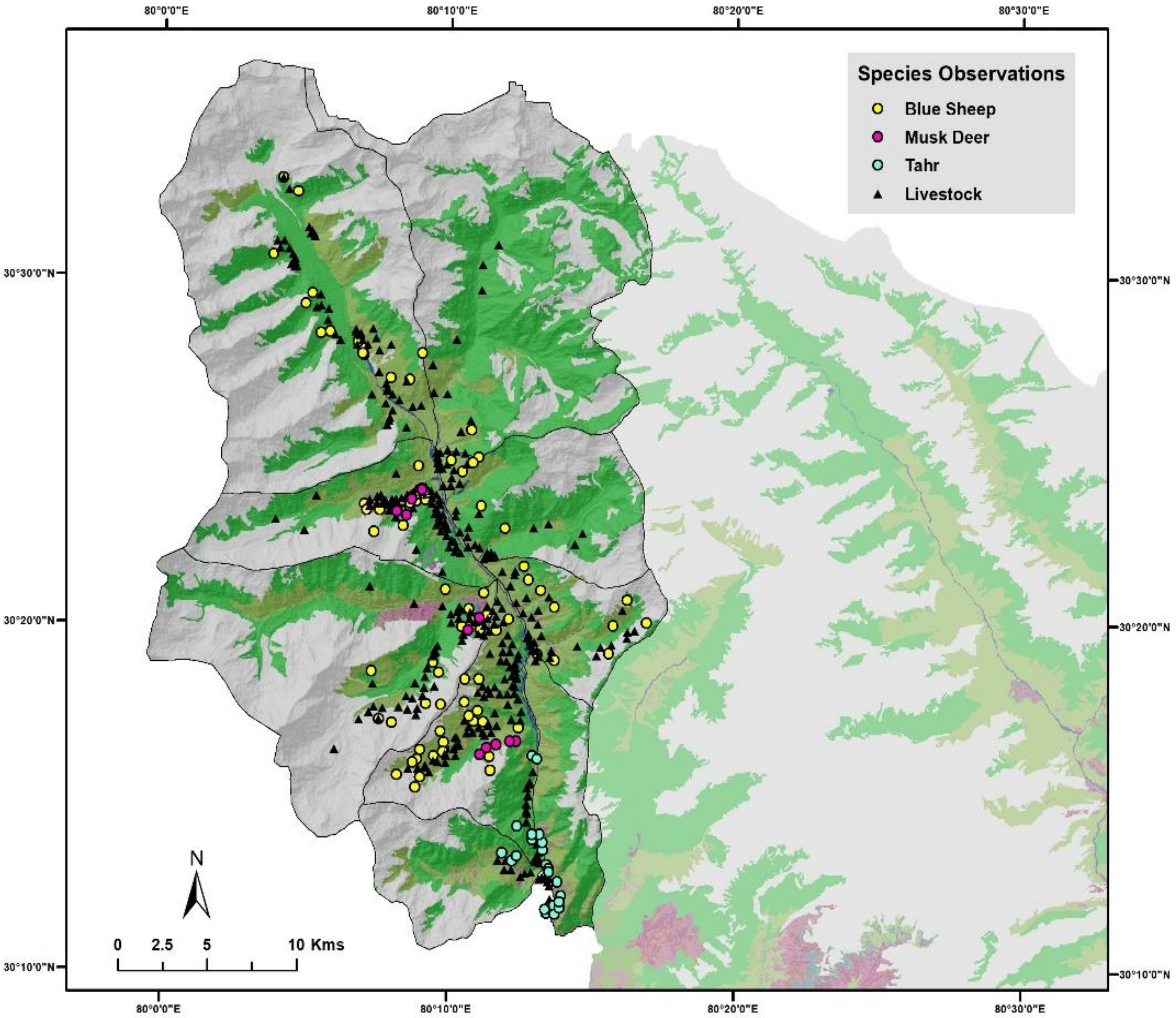

Figure 11 : Map of Johar valley showing presence point locations of blue sheep, tahr, musk deer and livestock

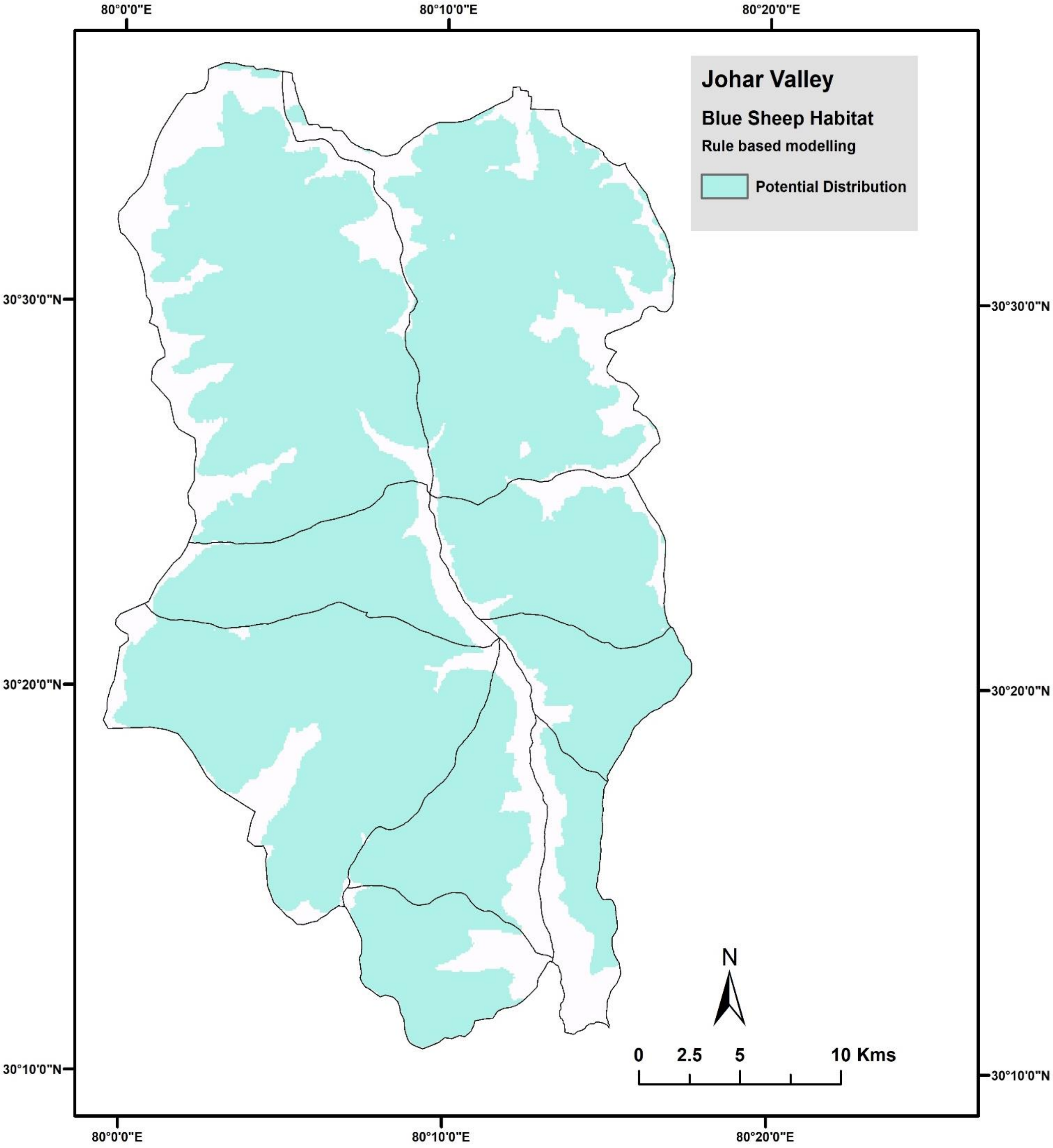

Figure 12 : Potential distribution map of blue sheep in Johar valley

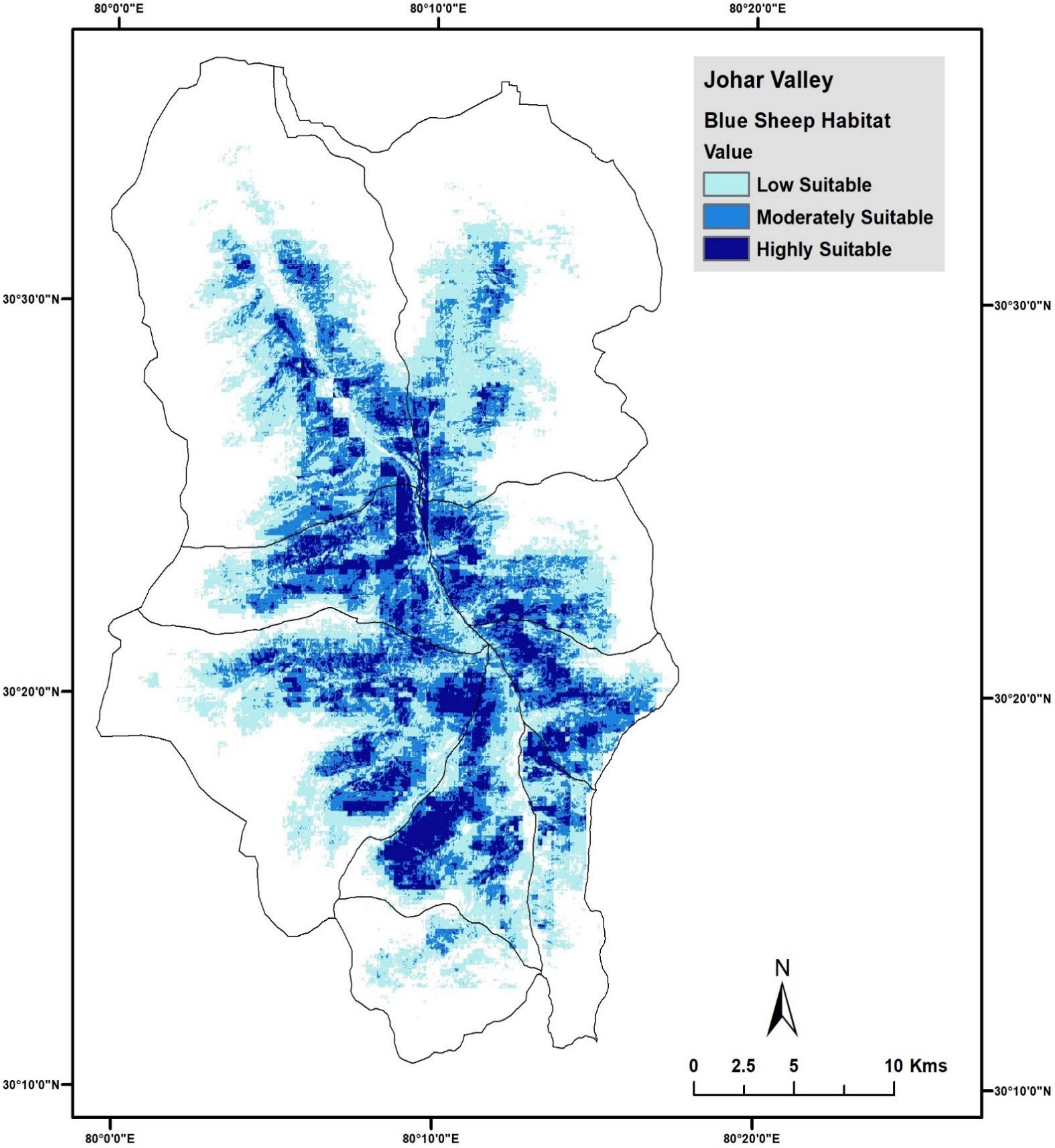

Figure 13 : Habitat suitability map of blue sheep in Johar valley showing low, moderate and high suitability areas

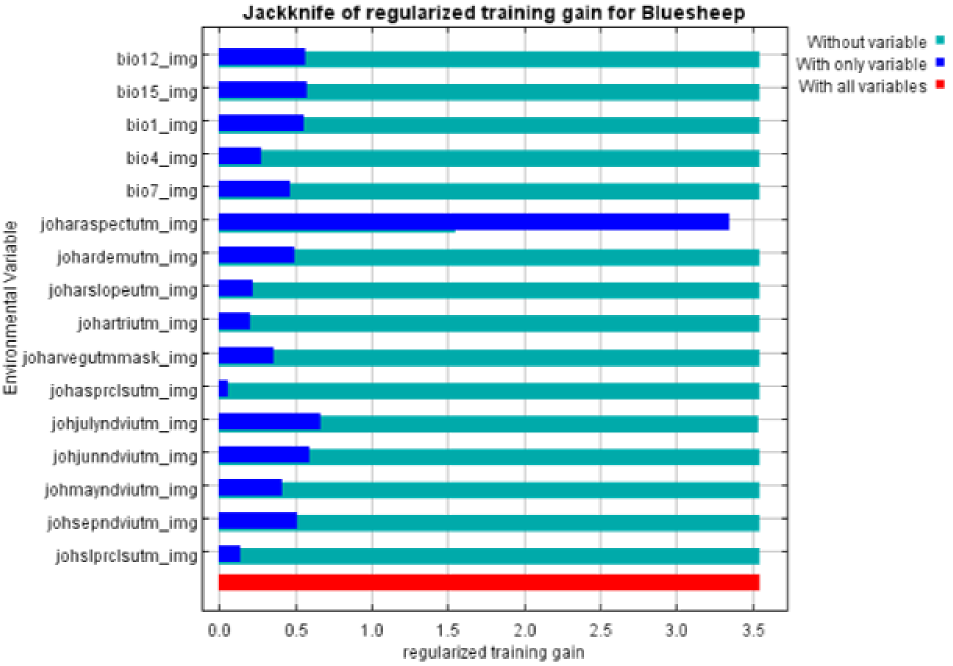

Figure 14 : Individual training gain of the variables used for prediction in Maxent distribution of blue sheep

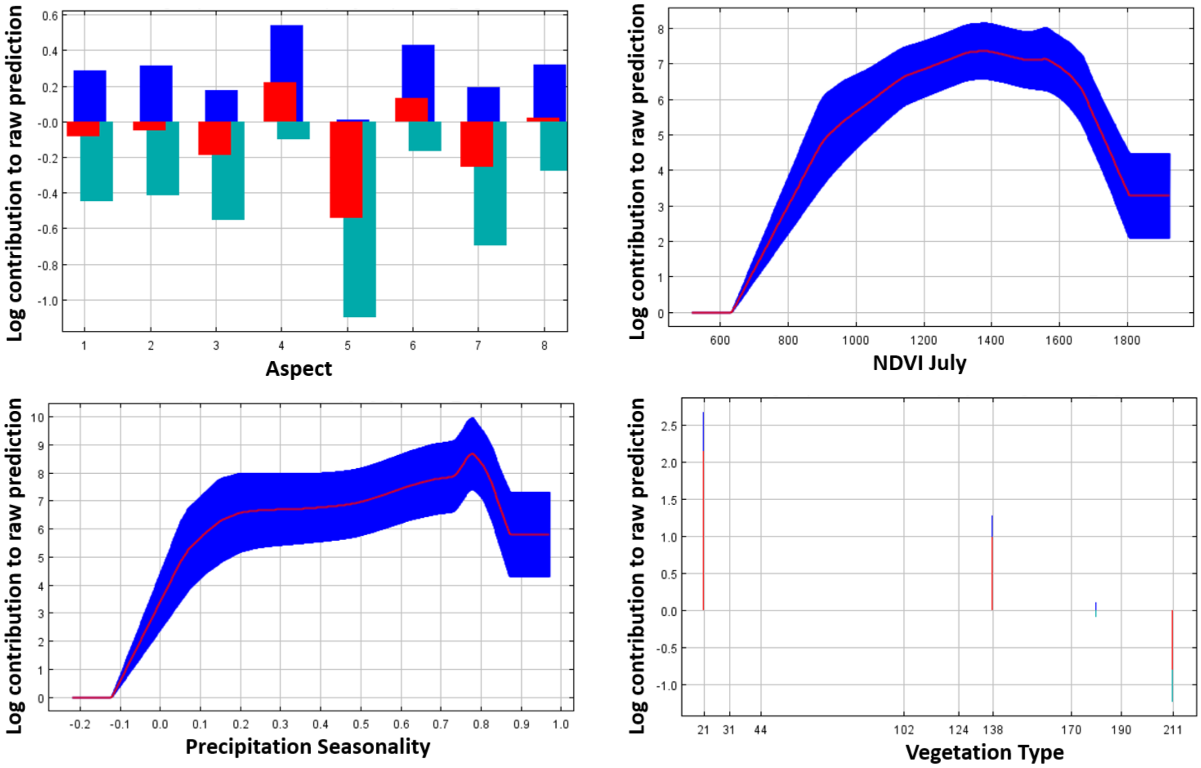

Figure 15 : Response curves of variables influencing distribution of blue sheep (a) Aspect (b) NDVI (July) (c) Precipitation seasonality (d) Vegetation type

Tahr:

MaxEnt model used for tahr distribution was reliable as statistical estimation of accuracy shows 93% area under curve (AUC) for sensitivity vs specificity graph. 0.5 regularization multiplier was the most suitable for tahr to avoid overfitting of the model. Tahr showed its distribution pattern in isolated patches in the Johar valley. The variables bio12 (precipitation seasonality), NDVI (May), Elevation and Aspect were the most important factors with the highest percent contribution influencing tahr distribution in the study area (Figures 18 & 19). The NDVI values governing tahr distribution showed a relation continuously towards the positive values, indicating influence of dense vegetation like subalpine areas and temperate forests. Tahr distribution also showed a positive relation with elevation, especially showing its peak at 2000 m – 3500 m, which is ideally the elevation range tahr inhabits. Tahr showed preference towards all aspects indicating its cliff dwelling nature. The significance of precipitation indicated the productive season for the forests. The potential distribution range (Figure 16) and suitable habitat for tahr in Johar valley was found to be 137.32 km^2 which is ~14% of the study area. Maxent highest probability distribution of tahr is presented in Figure 17 categorizing the distribution range area in low, moderate and high probabilities (Table 1). The threshold raster value for lowest category was found to be 0.08. A total of ~84km^2 was identified as its most suitable habitat combining the moderate and high classes.

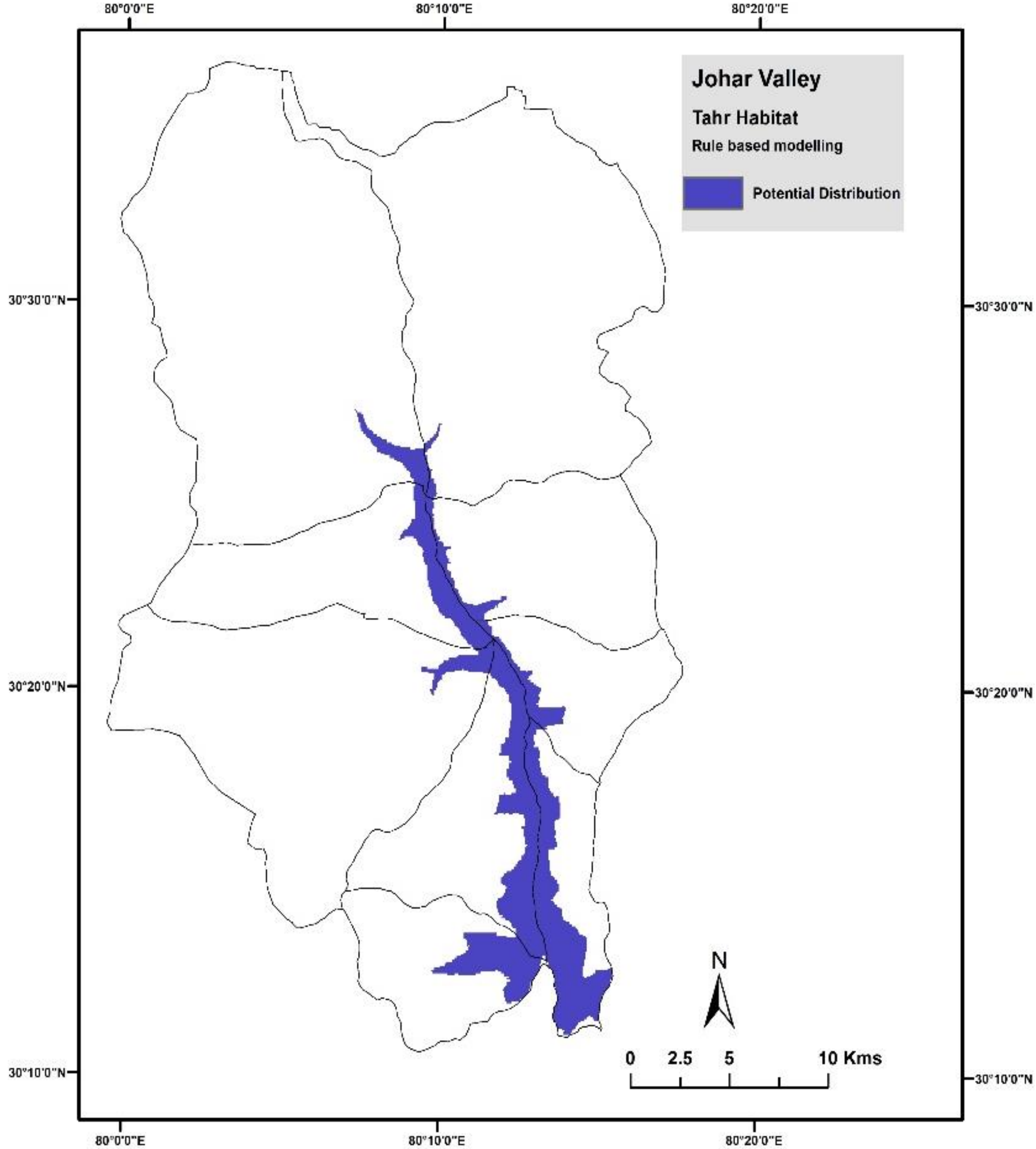

Figure 16 : Potential distribution map of tahr in Johar valley

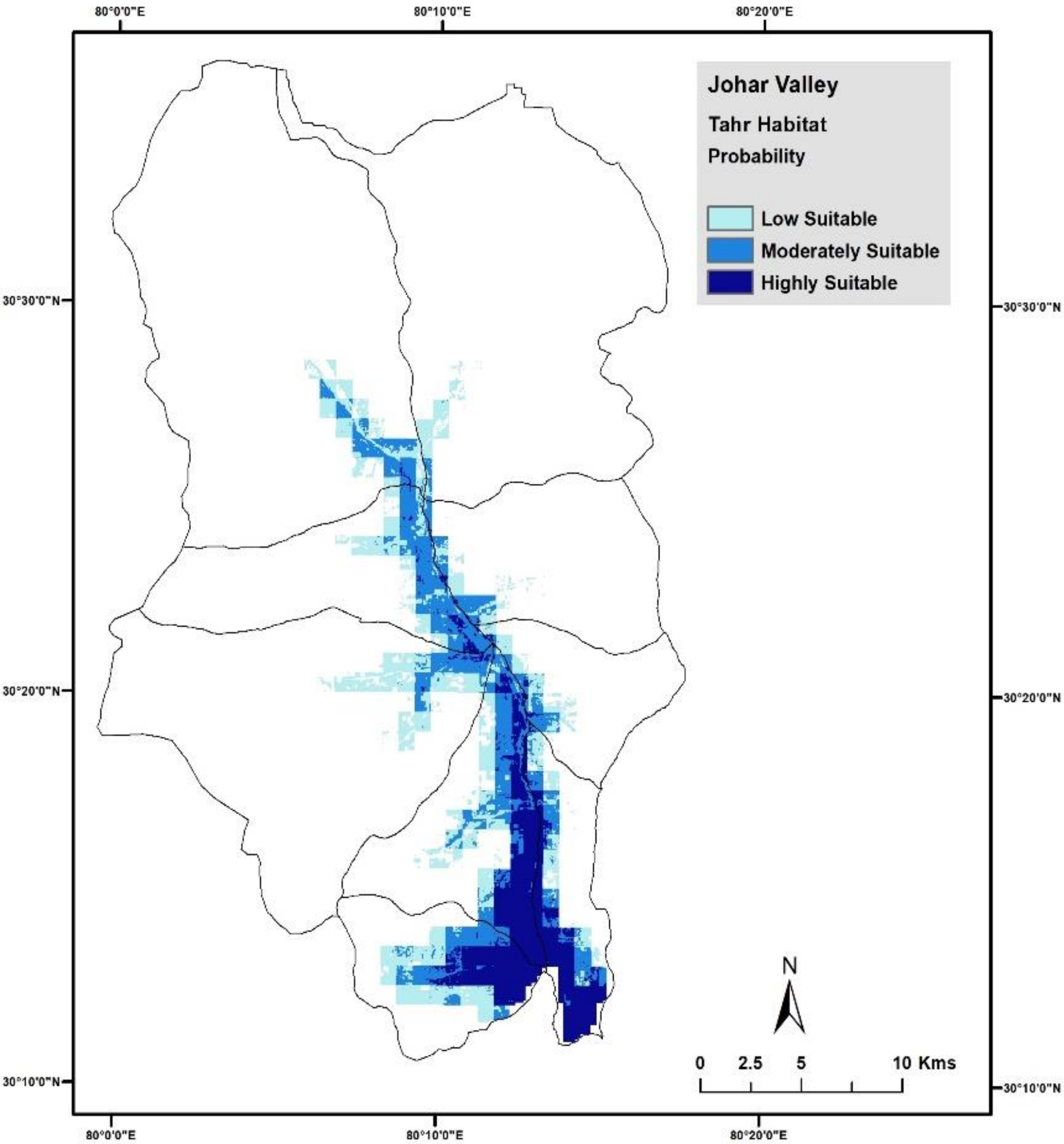

Figure 17 : Habitat suitability map of tahr in Johar valley showing low, moderate and high suitability areas

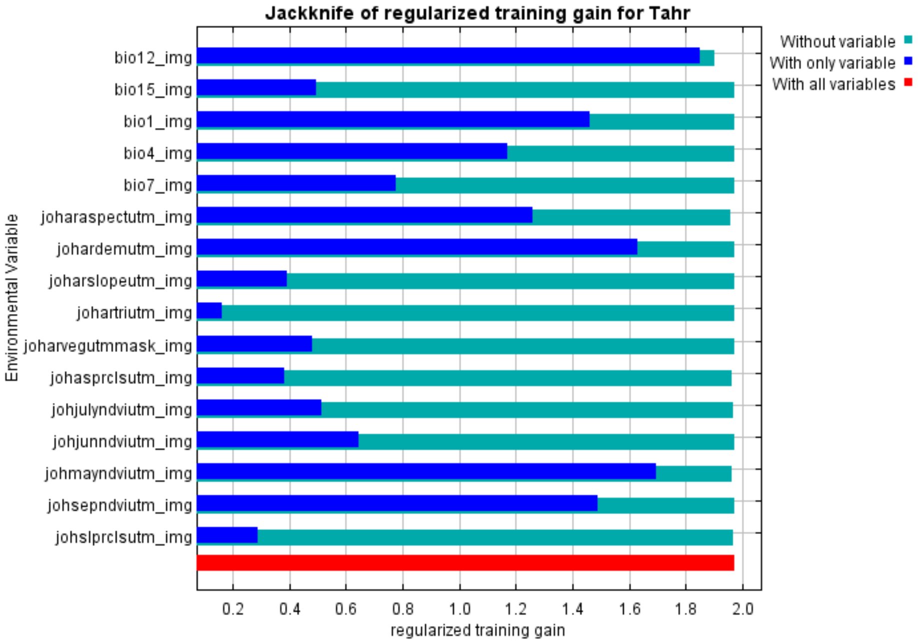

Figure 18 : Individual training gain of the variables used for prediction in Maxent distribution of tahr

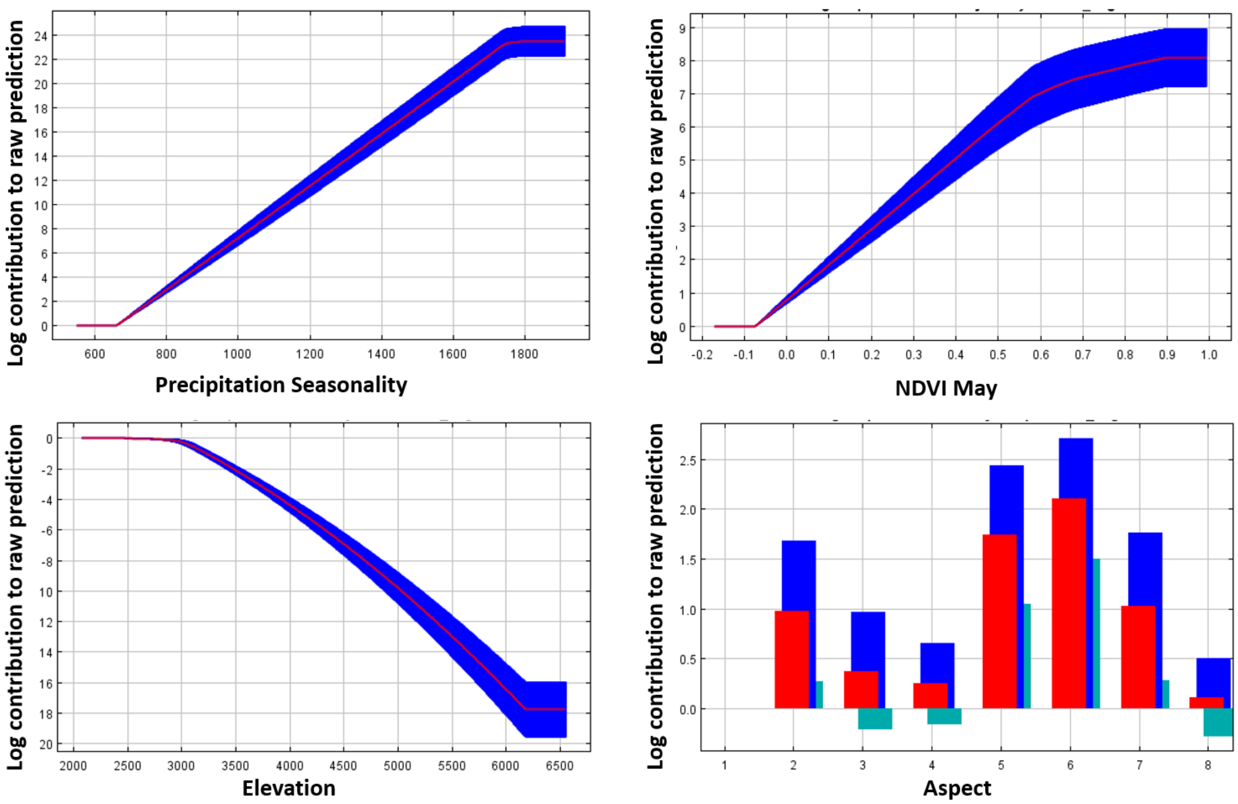

Figure 19 : Response curves of variables influencing distribution of tahr (a) Precipitation seasonality (b) NDVI (May) (c) Elevation (d) Aspect

Musk Deer:

Maxent model used for musk deer distribution was reliable as statistical estimation of accuracy shows 95% area under curve (AUC) for sensitivity vs specificity graph. 0.5 regularization multiplier was the most suitable for musk deer to avoid overfitting of the model. The factors affecting distribution of musk deer were NDVI (May), NDVI (July), temperature and aspect (Figures 22 and 23). The NDVI variables showed a relation towards the positive values showing the peak at moderate dense and dense vegetation areas. Musk deer showed preference in concurrence to its grazer-browser behavior where it preferred the vegetation in the summer as well as the monsoon season. Along with this, the northern and north-western aspects also influenced their distribution. The potential distribution range (Figure 20) and suitable habitat for musk deer in Johar valley was found to be 247.44km^2 which is ~26% of the study area. Maxent highest probability distribution of musk deer is presented in Figure 21 categorizing the distribution range area in low, moderate and high probabilities (Table 1). The threshold raster value for lowest category was found to be 0.014. A total of ~25 km^2 was identified as its most suitable habitat combining the moderate and high classes. The rule base modelling generated a high suitable area of 413 km^2 which skewed towards overestimation. The potential suitable habitat from both the rule based and MaxEnt models was at par with the ecology of the species showing the alpine scrub zones and birch fir zones as their most suitable habitat.

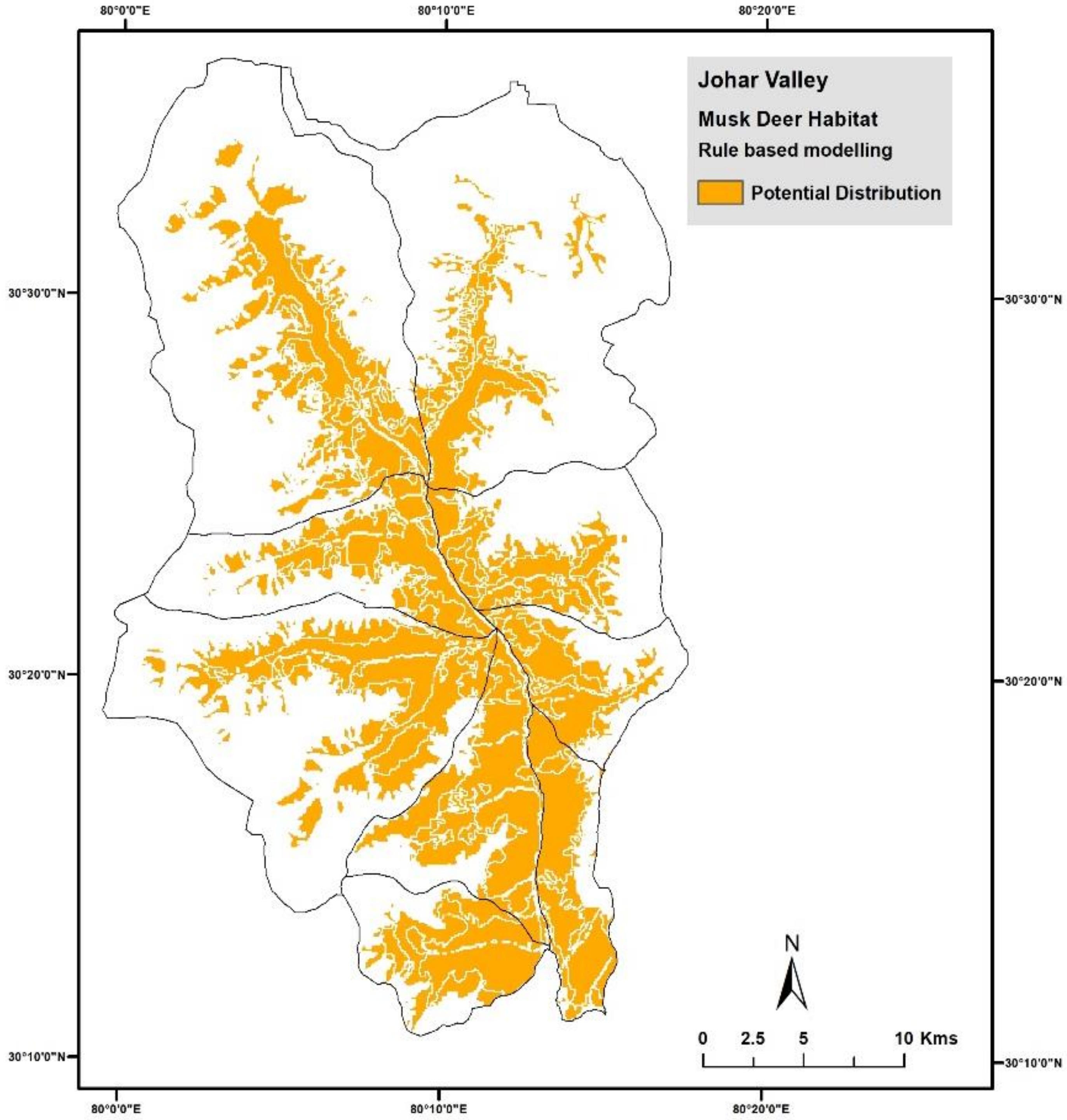

Figure 20 : Potential distribution map of musk deer in Johar valley generated by rule based modelling

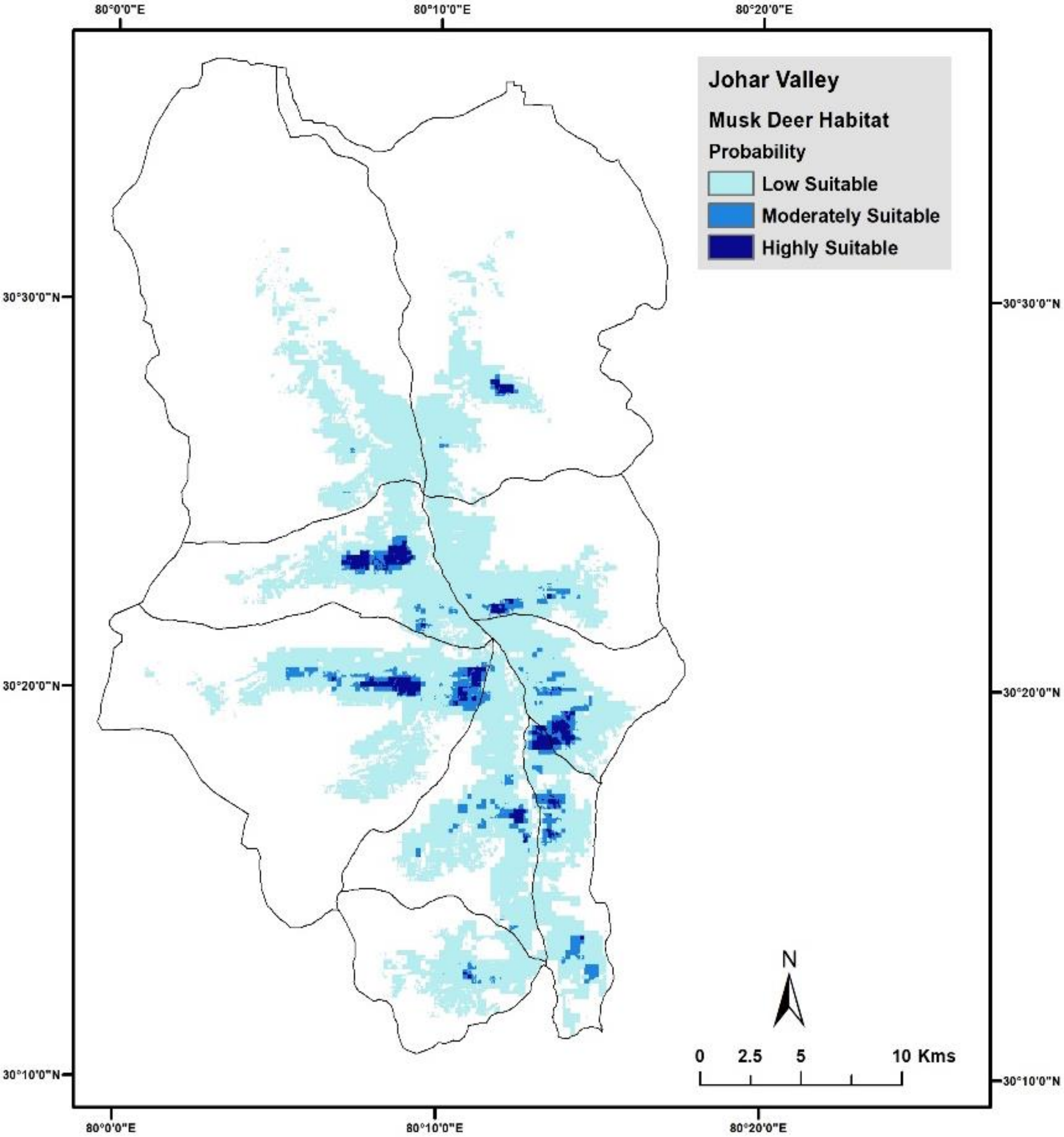

Figure 21 : Habitat suitability map of musk deer in Johar valley showing low, moderate and high suitability areas

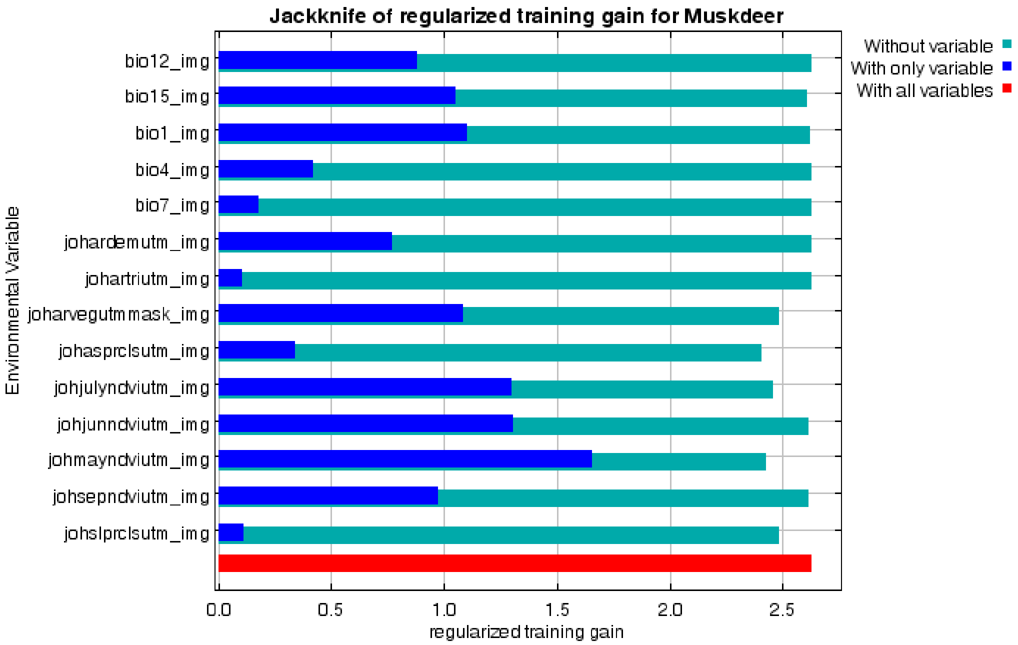

Figure 22 : Individual training gain of the variables used for prediction in Maxent distribution of musk deer

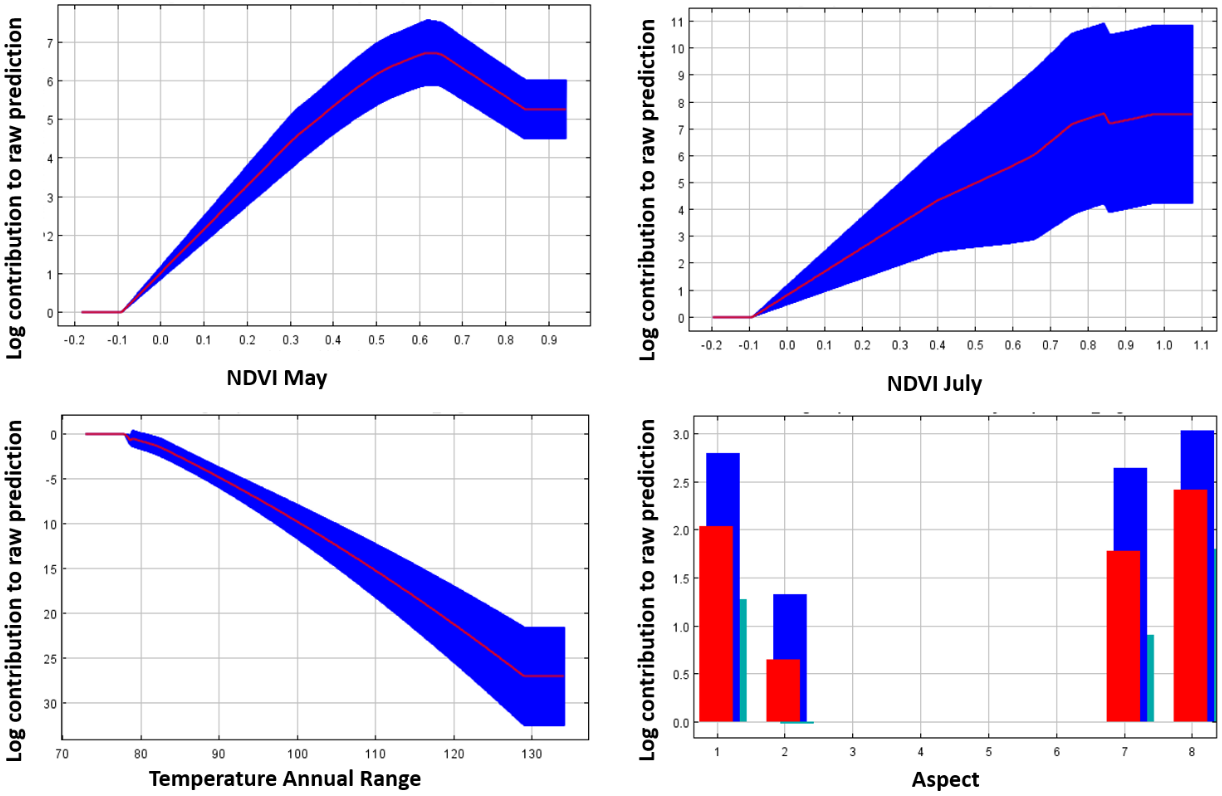

Figure 23 : Response curves of variables influencing distribution of musk deer (a) NDVI (May) (b) NDVI (July) (c) Temperature Annual Range (d) Aspect

Livestock:

Maxent model used for livestock distribution was reliable as statistical estimation of accuracy shows 91% area under curve (AUC) for sensitivity vs specificity graph. 0.25 regularization multiplier was the most suitable for livestock to avoid overfitting of the model. Among the variables used to predict the distribution – Aspect, NDVI (July), NDVI (May), and bio12 (precipitation seasonality) were the most important factors with the highest percent contribution in livestock distribution modelling (Figures 25 and 26). NDVI variables influencing livestock distribution showed relations towards positive values with the peaks indicating preference towards moderate and dense vegetation ranging from alpine pastures, subalpine areas and forests and also some areas near water sources. The preference of precipitation and vegetation during May and July was at par with the arrival of the pastoralists and most productive season for grasses respectively quite similar to the wild ungulate preferences. They also showed preference towards the northern aspects. The potential distribution range and suitable habitat for livestock in Johar valley was found to be 482.41 km^2 which is ~51% of the study area. Maxent highest probability distribution of livestock is presented in Figure 24 categorizing distribution range area in low, moderate and high probabilities (Table 1). The threshold raster value for lowest category was found to be 0.0049. A total of ~165.13 km^2 area was identified as its most suitable habitat combining the moderate and high classes which is ~17% of the study area.

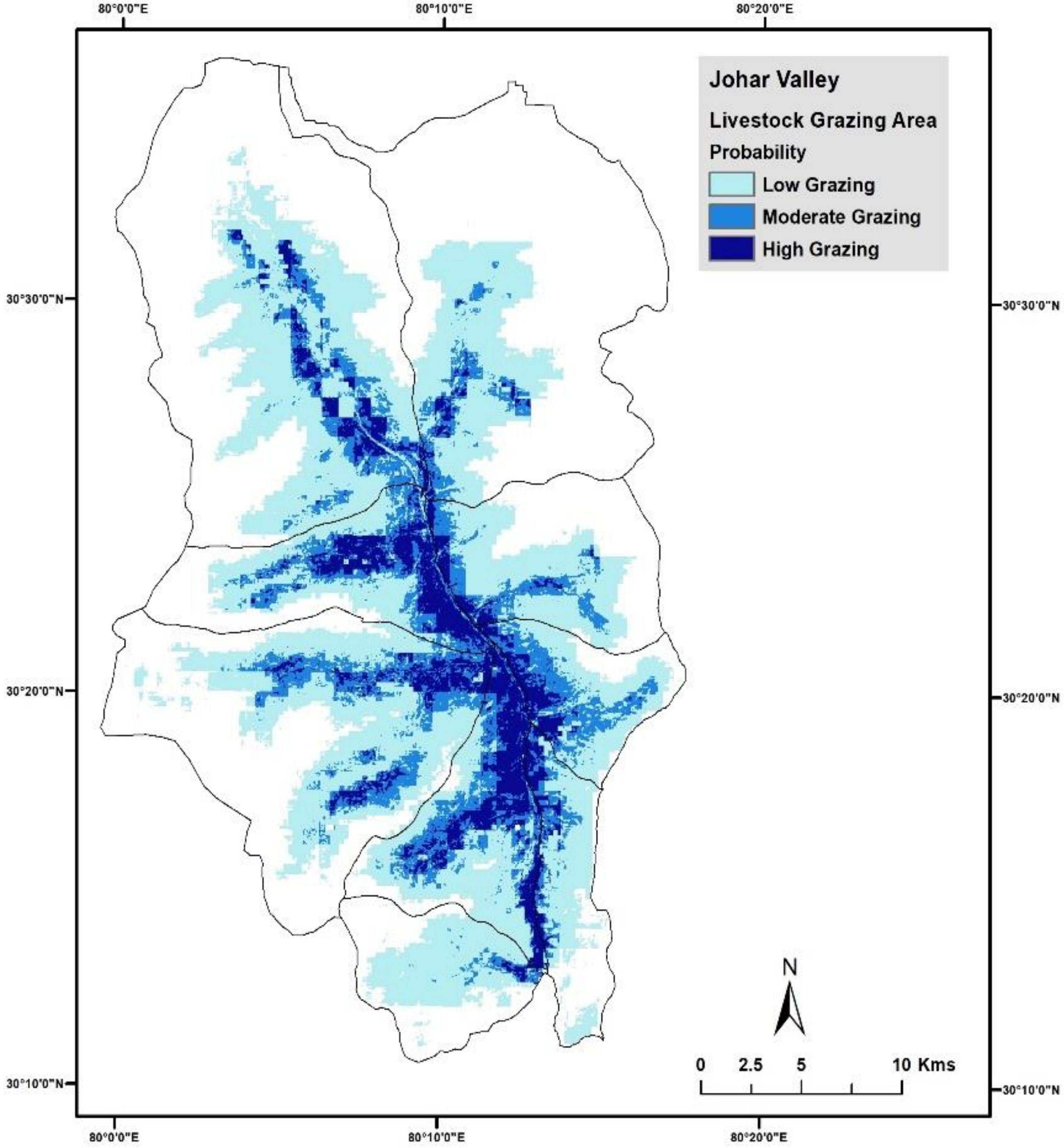

Figure 24 : Habitat suitability map of livestock in Johar valley showing low, moderate and high suitability areas

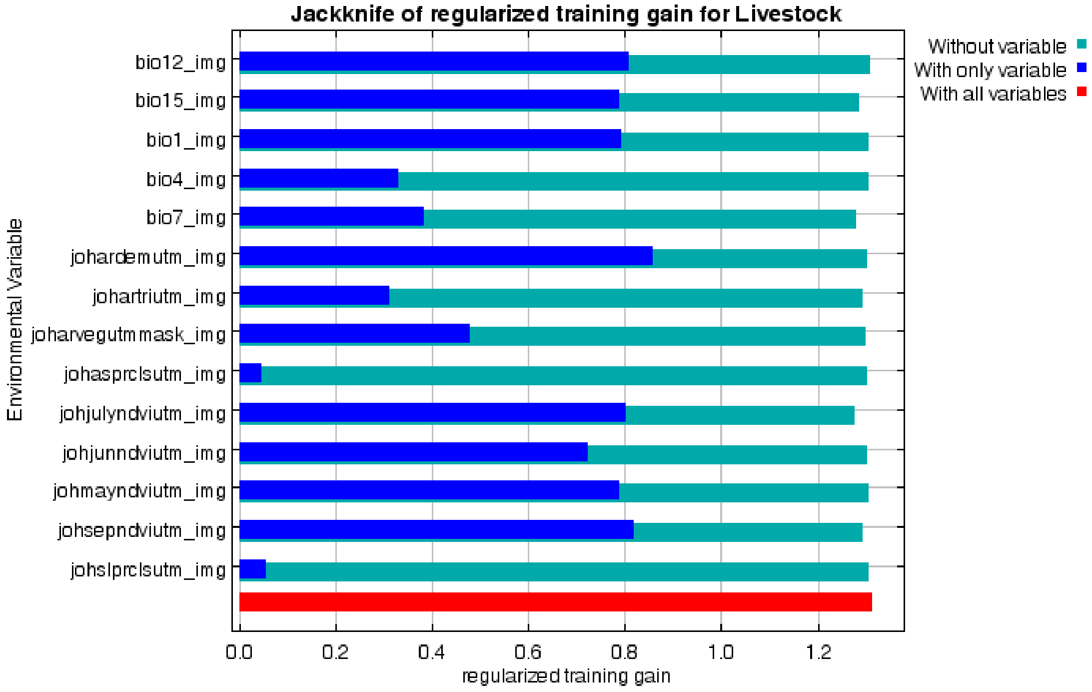

Figure 25 : Individual training gain of the variables used for prediction in Maxent distribution of livestock

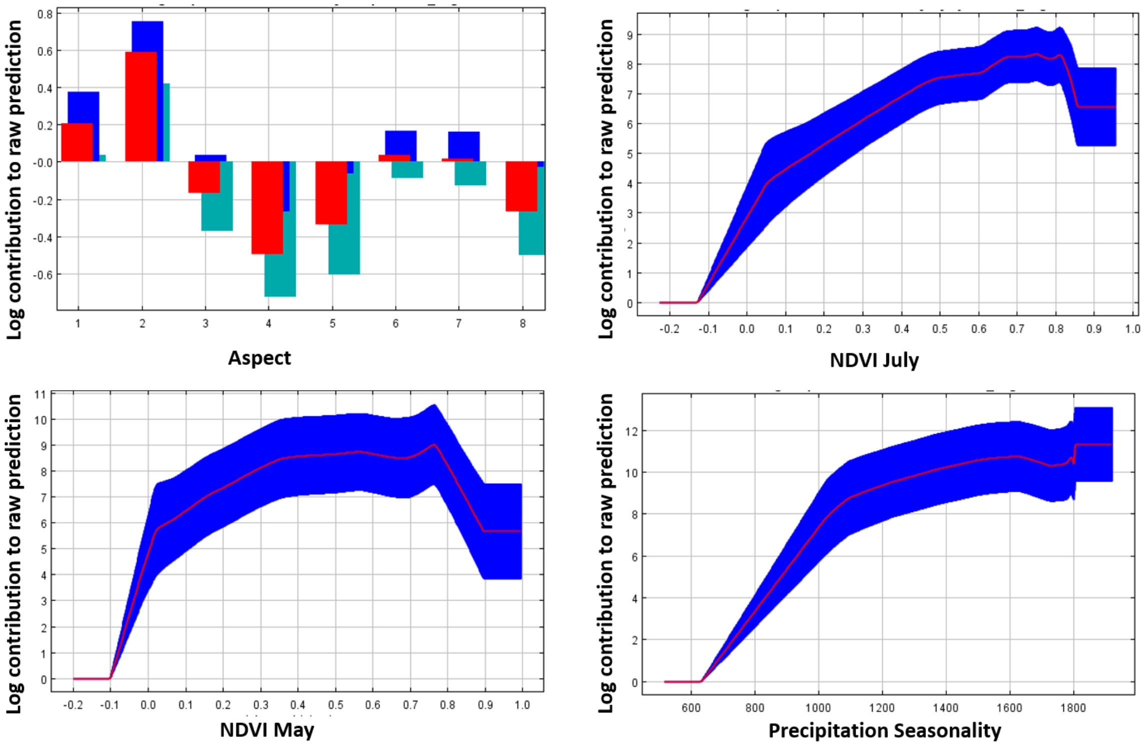

Figure 26 : Response curves of variables influencing distribution of livestock (a) Aspect (b) NDVI (July) (c) NDVI (May) (d) Precipitation Seasonality

Table 1: Results of habitat suitability modelling for blue sheep, tahr, musk deer and livestock

Species	**AUC**	**Regularization multiplier**	**Threshold**	**Unsuitable**	**Low**	**Moderate**	**High**	**Total suitable**
Blue sheep	89 %	0.5	0.074	510.77	219.01	147.07	76.15	442.23
Tahr	93 %	0.5	0.08	815.68	53.63	46.68	37.01	137.32
Musk deer	95 %	0.5	0.014	705.56	222.65	16.45	8.34	247.44
Livestock	91%	0.25	0.0049	470.59	317.28	100.46	64.67	482.41

3.4.2 Population size of wild ungulates and livestock

The best fitted model for blue sheep was Hazard rate key function with no adjustments (Figure 27). The number of intervals selected was four based on the observations. The estimated density of blue sheep was 0.99/km^2 (Table 2). The estimated population for blue sheep in Johar valley is 438 (305 – 624) individuals for a suitable area of 442.23 km^2. The best fitted model for tahr was Half normal key function with no adjustment (Figure 28). The number of intervals selected was three based on the number of observations. The estimated density of tahr was 0.32/km^2 (Table 2) and the estimated population of tahr is 44 (33 – 84) individuals for a suitable area of 137.32 km^2 in Johar valley. There are 45 herder groups in the entire study area with 15,845 livestock (goat and sheep) holding with a livestock population density of ~33/ km^2 for a pastoralism suitable area of 482.41 km^2 in Johar valley.

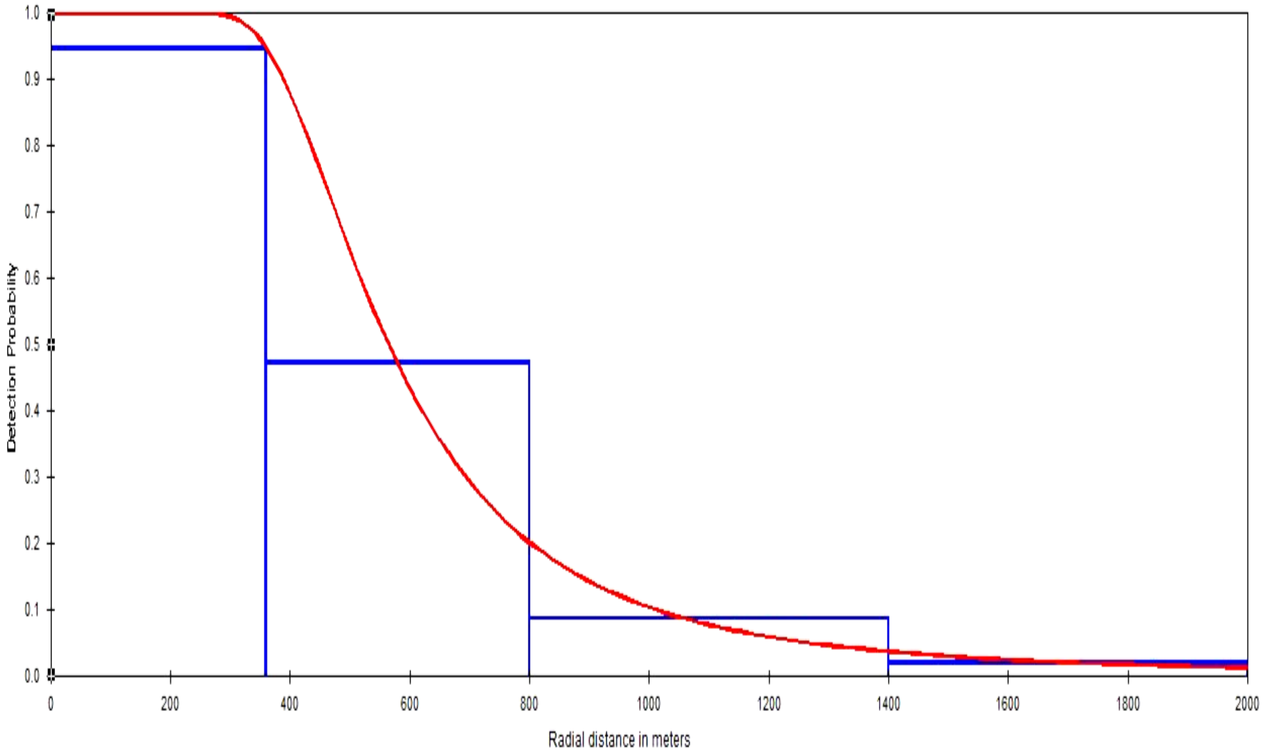

Figure 27 : Detection function (Hazard rate, no adjustment) fit to blue sheep data from point count survey

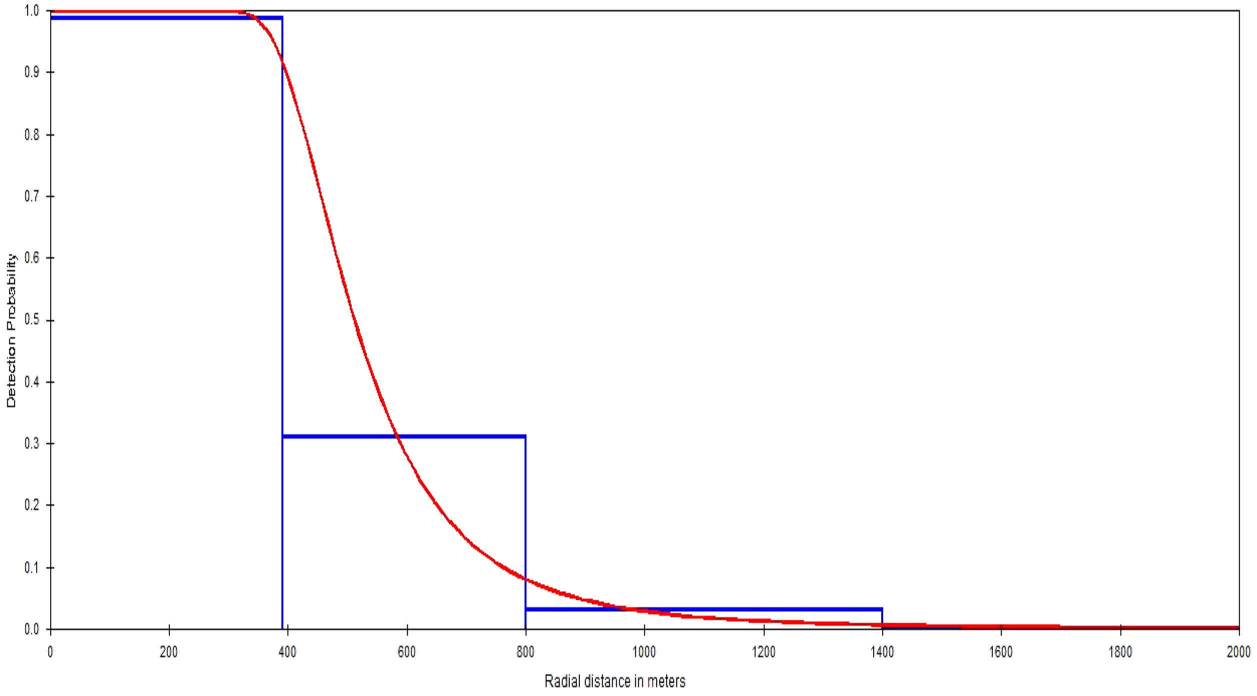

Figure 28 : Detection function (Half normal, no adjustment) fit to tahr data from point count survey

Table 2: Results of population estimation for blue sheep and tahr

Parameters	**Blue Sheep**	**Tahr**
Sampling Points	40	40
Sampling effort	520	520
Total no. of clusters observed	118	26
Individual Density (No. of animals/km^2)	0.99 (±0.17)	0.32 (±0.91)
Percent CV	18.06	27.96
95% confidence interval	0.69-1.41	0.24-0.61
Effective Detection Radius (in meters)	719.30 (±59.72)	585.99 (±66.75)
Percent CV	8.39	11.39
Average Cluster Size	8.85 (±0.62)	9.16 (±1.5)
Encounter Rate (No. of clusters seen/no. of samples)	0.18	0.38
Percent CV	1.02	0.81
Probability of a greater chi-square value, P	0.74	0.53
Population estimation	438 (305 – 624)	44 (33 – 84)

3.5. Discussion

Mountain ungulates owing to their ecology have huge geographic distribution ranges. Though their distribution range is huge, they are often found in selected pockets of their potential distribution ranges. Managing and monitoring mountain ungulates thus becomes tough for conservation planning in mountainous areas. An accurate distribution model helps in narrowing down their potential distribution ranges based on their most suitable habitat. In this regard, SDMs are effective to simulate species' current ranges from a limited set of known observations (Owens 2015). It is also important to know the factors controlling their distribution across a landscape which can help in monitoring them by devising species specific sampling methodologies.

From the present study, aspect, vegetation and precipitation turned out to be the most important factors affecting the distribution patterns of the wild and domestic ungulates. Blue sheep distribution showed a wide range covering 46% of the Johar valley and having 15 % of the study area as high suitable having a capacity to support around 440 individuals. Since, blue sheep was the most commonly seen species during the survey, the results reflected a near accurate distribution prediction. Previous studies had shown preference of blue sheep towards subalpine and alpine habitat types in the summer-monsoon season (Namgail et al. 2009; Namgail et al. 2010; Kandpal and Sathyakumar 2010). Our results reflected a similar pattern influencing their distribution. This also supported the importance of summer monsoon season, which is the season of production of the most nutritious grasses and foraging. Thus, blue sheep distribution was governed by their foraging behavior. The vegetation classes of subalpine and moist alpine pasture which influenced the most, supported this behavior. The less number of sighting records for tahr and musk deer may have overestimated their suitable area and underestimated the population in the valley. In case of tahr, this might also be an artefact of their ecology to live nearer to the cliffs and thus, the areas showing their pseudo absence might have actual presence of the species. Nevertheless, the potential range of ~14 % of the study area supporting a population of around 85 individuals, showed the distribution of tahr in the vegetation types subalpine, temperate grassy slopes and forests of *Kharsu (Quercus semicarpifolia)* and at areas with steep slopes which is at par with its preferred habitat known from literature (Prater 1980; Vinod and Sathyakumar 1999; Bhandari 2012; Johnsingh and Manjrekar 2015). Both MaxEnt and rule based modelling for musk deer gave a potential range of more than 20% of the study area and showed its distribution mainly in the subalpine and Krumholz zones. Thus, the Johar valley has a good potential of carrying a viable population of blue sheep and tahr and has a good potential habitat to support musk deer population. The results also reflected that Johar valley supports a variety of potentially suitable habitats for pastoralism practices which constitutes more than 50% of the study area. The July and May NDVI supports the time of their maximum movement for foraging as in July there is maximum nutritious forage available and May is the time of their arrival. The the important grazing areas during the foraging seasons for wild ungulates is occupied by livestock with a ratio of almost 1:33 individuals with livestock preferences of environmental conditions similar to the wild ungulates. These results provide a need for further studying habitat level resource selection patterns in areas where both wild and domestic ungulates thrive.

Spatial information about local populations of wild and domestic ungulates is important in the western Himalayas because of the knowledge gaps from lesser known areas. Blue sheep, tahr and musk deer are species of conservation concern for their respective habitats as well as their importance as prey species in the greater Himalayan region. Habitat loss and degradation due to landuse change and anthropogenic activities like pastoralism are the considered as major threats to these wild ungulates. Thus, to manage their population, managers need data in a spatial domain depicting side by side, the ecology of wildlife and their interaction with human activities. This can be achieved by generating accurate, high-resolution maps of seasonal habitats which can be updated with time (Walker et al. 2016). My study in this chapter, showcases the use and importance of spatial techniques as a tool in ecological research in mountainous regions for sampling mountainous species without radio-telemetry.

Chapter 4: Resource selection by wild and domestic ungulates

4.1 Introduction:

Long term conservation of a species requires an understanding of the species' ecology in terms of their distribution and the factors that influence them. In the previous chapter, I showed how the wild and domestic ungulates are distributed in space, their suitable habitat in Johar valley and population densities. Distribution of a species is dependent upon particular biotic and abiotic factors of their habitat which are termed together as resources. Hence, distribution and resource selection of a species are closely related entities. Resource selection occurs in a hierarchical manner starting broadly from the geographic range of species to selection of particular elements within the general features of their habitats within their home range (Manly et al. 2007). Ungulate species with overlapping distribution ranges and having similar ecological requirements are known to compete for these resources (Namgail 2001; Darmon et al. 2011). The alpine rangelands in Himalaya provide a wide range of habitat mosaics supporting diverse array of biodiversity and ecosystem services. In light of current landscape approach to conservation, it becomes important to assess the pastoralism pressure across a landscape and degree of competition of livestock with wild ungulates based on available resources for a proper monitoring/management plan. Previous studies in the Himalayan region have shown that wild ungulates tend to avoid areas which are heavily used by domestic livestock (Kala, Singh & Rawat 2002; Bagchi, Mishra & Bhatnagar 2004; Mishra et al. 2004; Namgail et al. 2007; Shrestha and Wegge 2008; Kittur, Sathyakumar & Rawat 2010). In the sub-alpine and alpine zones of the Greater Himalaya, optimal resources are confined to specific patches and available only for a short duration (June – September) (Bhasin 1988; Sharma, Rollefson & Morton 2003). Wild ungulates may be forced to forage in sub-optimal habitats due to livestock grazing in the limited optimal habitats. This might disturb their nutritional balance as they spend more energy avoiding the livestock grazed areas and consequently, they may be competitively excluded from better habitats (Schaller 1977; Mishra et al. 2004; Namgail et al. 2007). Wild ungulates like bharal, tahr and musk deer form the main prey base for the endangered snow leopard (*Panthera uncia*) (Schaller et al. 1987; Chundawat and Rawat 1994) especially in the alpine zones of the greater Himalaya. There is a considerable overlap in the distribution of these wild ungulates and snow leopard across the greater Himalayan region. Presence of these prey species indicates the occurrence of snow leopard and other predators. Estimation of resource selection is one of the powerful methods of identifying areas within a landscape that are highly used by a population of animals. It is generally assumed that if a species select certain habitat units or food resources disproportionately to their availability or 'patches' with certain characteristics, it improves their fitness, reproduction, or survival (McDonald et al. 2013). This justifies management actions on natural resources as well as monitoring population distributions of species. Thus, resource selection patterns of wild ungulates in the presence or absence of livestock grazing need to be analyzed in order to evolve site specific management strategies for effective conservation of these species.

Distribution pattern of a species is strongly influenced by the availability of habitat resources during various seasons and the presence of predator and prey species. According to the habitat selection theory (Hutchinson 1957; Orians and Wittenberger 1991), sympatric species with overlapping niches show behavioural characteristics that separate them spatially or temporally within the same range (Namgail 2001; Darmon et al. 2011). Prior knowledge about the distribution of various resources on which the species depend, leads to characterization of distribution and abundance of these species by resource selection functions (RSFs). A model based on RSF yields values proportional to the probability of use of a resource

(Boyce et al. 2002). RSF also helps in determining the probability of a habitat being used by the animal (Boyce and McDonald 1999). Various forms of distribution data like presence-absence, presence-only, use-availability and count data have been used for the development of specialized analytical techniques through machine learning (Aarts, Fieberg & Matthiopoulos 2012). Such studies have gained huge popularity in recent years inviting ecologists to better understand species ecology using these methods. New techniques in the mould of older ones are being developed to provide better interpretations by accounting for the major shortcomings such as sampling bias, data deficiency and other limitations (Warton and Shepherd 2010; Aarts, Fieberg & Matthiopoulos 2012; Renner et al. 2015). Such limitations are more acute in mountainous regions where terrain, accessibility, logistics and elusiveness of the species restrict movement of observers. For such terrains, information on species distribution mostly comes as occurrence data, i. e., locations where species have been observed. The presence-only data is without any corresponding information about species absence (Renner et al. 2015). A common approach for analyzing such data is randomly chosen background points or pseudo absences (Phillips and Elith 2013). Though there are several ways to model such data e.g., maximum entropy (MaxEnt) modeling of species distributions (Philips, Dud´ık & Schapire 2004; Philips, Anderson & Schapire 2006; Philips and Dud´ık, 2008; Elith et al. 2011), and the logistic regression model along with its various generalizations (Austin 2002; Elith et al. 2006) but most of them are limited by various shortcomings. These include model specification by not including prior construction of pseudo absences leading to problems in interpretation as the model parameters are functions of number of pseudo absences (Warton and Shepherd 2010). Since, resource selection criteria is different at different levels and there is no single correct level to study, multiscale studies are increasingly gaining importance (Levin 1992, Otin

1997). Point process model is one of the recent approaches to modelling resource selection that uses presence only data (Warton and Shepherd 2010; Aarts, Fieberg & Matthiopoulos 2012; Hooten et al. 2013; Johnson, Hooten & Kuhn 2013; Renner et al. 2015). This model addresses the weaknesses of randomly chosen pseudo-absences (Warton and Shepherd 2010) by focusing on the observed data. The model assumes the locations of point events to be independent and the intensity (expected number of presence per unit area) at those points can be modelled as a function of the explanatory variables. Thus it takes into account the locations of the organism from where it has been reported rather than where it occurs. This framework has been linked to the common approaches for fitting presence-only models over the past five years. The point process model provides advances to these models by having a criteria for choice of pseudo-absences, checking assumptions and accounting for observer bias for better ecological insights (Renner et al. 2015).

In this study, I used the point process framework to estimate the resource selection function of blue sheep and livestock. In this framework, the resource selection function is proportional to the expected density of observations (Aarts, Fieberg & Matthiopoulos 2012) which provide more accurate insights into relative patterns of species abundances in data deficient areas. This study is a first attempt to use the point process framework to estimate resource selection on a dataset not collected using radio-telemetry. Due to lack of considerable data (point locations) from tahr and musk deer inhabiting areas, resource selection for these species could not be generated through point process framework. I used the conventional approach which is Design I of Manly’s Resource Selection Function (Manly et.al. 2007) to calculate the habitat use vs availability for tahr, musk deer and livestock. Using blue sheep, tahr and musk deer as model species for different habitat zones, I aimed to estimate their resource selection probabilities and the factors that influence this in pastoralism influenced areas. I chose to see whether wild ungulates select resources based on topographic factors and avoid optimal habitats used by domestic livestock.

4.2 Research questions and hypothesis

- In presence of livestock, is there an avoidance of optimal resources by wild ungulates?
- Which factors other than presence of livestock govern the resource selection by wild ungulates in pastoralism influenced areas?

Competition for resources is likely within species of the same trophic level, such as large herbivores. The resource selection processes of wild ungulates are duly affected by environmental variables as well as presence of livestock. In the study area, optimal resources are available in restricted areas for both wild and domestic ungulates. Since livestock have a competitive advantage to select the optimal patches due to presence of humans, there should be a possible avoidance of these optimal areas by the wild ungulates. There should be utilization of topographic variables in the suboptimal patches so as to strike a balance between resource exploitation and predator avoidance. Thus, the hypothesis for this study is that a resource item for a species could be highly favoured but difficult to access hence, less utilized. Conversely, less favoured resources might comprise a large portion of used resources out of necessity if they are the only ones available to the species (Manly *et al.*, 2002). This pattern might lead to a probable shift or avoidance of optimal resource areas by the wild ungulates.

4.3 Analysis

4.3.1 Resource selection probability:

Blue sheep and livestock:

Presence-only data are a set of point locations $y = \{y1. . . yn\}$ in a continuous space A, where the locations (yi) are recorded as presences. Analysis of y is done as a point process, jointly modelling the number of presence points, n, and their locations (yi). A map of values in the space A for each k explanatory variables that were observed (values of these variables at yi) are denoted as $x = (xi1 . . . xik)$. Here, intensity at point yi (λi = expected number of presence points per unit area) is modelled as a log-linear function of covariates (k). The parameters of the model are stored in the vector $\beta = \{\beta 0, \beta 1 . . . \beta k\}$ (Cressie 1993).

$\log(\lambda i) = \beta 0 + \Sigma kj = 1\ xij\beta j$.

where λi = intensity at point yi

x = values of covariates

β = coefficient

The parameters of the model are stored in the vector $\beta = \{ \beta_0, \beta_1, . . ., \beta_k\}$.

Spatial locations of presence points (direct and indirect) of blue sheep and livestock and a background sample of random points (availability locations) were taken for point process analysis. The number of random points were chosen in point process framework using likelihood convergence method. Thus, 1000 random points were found suitable for our study area of ~950 km2 at an intensity of one point per km2. The 1000 random points were generated across the study area and labelled as zeroes to account for pseudo-absences. An intensity of random points of one point per km2 was considered for analysis to accommodate the comparable effort across point intensity for both species and avoid pseudo replication. We evaluated spatial independence within our observation points through Moran's I test (Moran 1950) for spatial autocorrelation. The results indicated a somewhat clustered pattern of our observation points, which may be due to random chance (Moran's Index = 0.03). Raster values of the topographic variables were extracted for both the presence and pseudo-absence locations. A binomial point process model was fitted to the binary data using the covariates at all of the used and available locations. The beta values for each covariate were estimated using the framework with a generalized linear model (GLM). The models were evaluated through Receiver Operating Characteristic (ROC) curve values, along with information theoretic approaches like Akaike Information Criterion (AIC) (Akaike 1974) and Bayesian Information Criteria (BIC) (Schwarz 1978). ROC was calculated using the package "pROC" in the R 3.5 (R core team 2017). We did not separate the training and test data as our sample size was small, but validation was done comparing with the whole dataset. Models with lowest AIC values were considered best fit models. However, the AIC values of the best fit models for both blue sheep and livestock had differences of less than two to determine the best model among them. For best model selection we used BIC values as they are better in situations where false positives are more misleading than false negatives. As we are more interested in minimizing the false positives in this case, BIC values provide better insights than AIC. The significant variables of the best fit model were used to generate maps of the predicted intensity of resource selection probability for both blue sheep and livestock. The intensity maps were generated using the map equation

Output = Beta1*Raster1 + Beta2*Raster2…+ Betan*Rastern

in the GIS domain with the coefficient values of the most significant variables of the best fit models for respective species. After the intensity raster layers were generated, we extracted the intensity values for the training locations and applied a threshold based on the minimum intensity value, then divided the layers of the respective species into five intensity classes: very low, low, moderate, high and very high. Area for predicted presence was calculated using moderate, high and very high classes. We first ran separate analyses with direct and indirect evidence presence points, which revealed insignificant differences in values to be considered for separate interpretation. We used both evidences combined for analysis to increase the spatial coverage of the dataset and incline towards more accurate results by increasing the number of unique observations. This did not alter the model for interpretation. All analyses for resource selection was done using the “Raster” (Hijmans 2016) and “spatstat” (Baddeley and Turner 2005) packages in R 3.5 (R core team 2017) and ArcGIS 9.3 (Esri Inc 2008).

Tahr, musk deer and livestock:

Due to lack of considerable data from tahr and musk deer inhabiting areas for point process framework, I used Design I of Manly’s Resource Selection Function (Manly et al. 2007) to estimate resource selection via the habitat use vs availability framework for these species and livestock. Design I was used as it does not need to identify individual animals and the resource units are assumed to be sampled for the entire study area. Thus, the estimations are made at a population level. I compared the number of individuals in each habitat type to the relative availability of the respective habitat type in the study area. Habitat use vs the proportion of available habitat was calculated using the package “adeHabitatHS” in R (Calenge 2019). Used habitats were considered as the areas, which were selected and received some investment by an animal. Proportion of available habitat was the quantity of the particular habitat type accessible to the species in the entire study area (Manly et al. 2007). Therefore, available resources were considered as the areas which can be potentially encountered and selected by the study species (Lele et al. 2013). Only direct sightings were considered for this analysis. I assessed resource availability digitally using GIS domain with the vegetation type layer (McClean et al. 1998; Mladenoff et al. 1999). The percentage use for each category was then compared to its respective availability to evaluate resource selection. I used the commonly employed ratio of percentage use divided by percentage available which is referred to as the forage ratio or selectivity index (Savage 1931; Manly 1972) as the resource selection index (w_i).

$w_i = o_i / \hat{\pi}i$

o_i = sample proportion of used units in category i;

$\hat{\pi}i$ = sample proportion of available units in category i;

This selection ratio gives the resource selection function (the relative probability of selection for category i). To estimate the resource selection probability function, I classified my point locations as used and a defined set of random locations in the study area as unused following Design I and Sampling protocol A (Manly et al. 2007). I extracted the point attributes such as the elevation, slope, aspect, TRI, DET and distance to water for the used and unused sites. I compared the available or unused locations with the used locations to evaluate resource selection probability function using the package “ResourceSelection” (Lele, Keim & Solymos 2019) in R. The analysis was based on the assumption that a resource unit category would be the next one selected if it was possible to make each of the types of resource unit equally available which would give the estimated probability. Following model selection and estimation of final RSF, I generated maps of the study area in GIS domain, which portrayed the predicted relative probability of selection for every possible resource unit. For mapping, the predicted values of the RSF were classified as low, moderate and high selection.

4.3 Results:

In this study I sampled 63% of the entire study area intensively. The rest of the study area was inaccessible for sampling. I used random and stratified random sampling approaches for collecting presence points of both direct and indirect evidences for three years (2015-2017) in the summer monsoon season. Along with this data we added questionnaire information from the herders as well and incorporated them in analysis which were considered by the model as unique observations. This was done to increase the spatial coverage of the dataset and incline towards more accurate results by increasing the number of unique observations. A total of 87 presence points (51 direct, 36 indirect) for blue sheep and 327 presence points (97 direct, 230 indirect) for livestock were obtained. Alongside, 22 presence points for tahr and 11 photocaptures of musk deer were recorded during the study period. Indirect evidences of tahr and musk deer were hard to collect because of their inaccessible terrain.

4.3.1 Blue sheep and livestock*:*

Best models with AIC difference of two were considered to explain variability of data (Table 3). In case of blue sheep, AIC values indicated that factors influencing resource selection were best modelled using vegetation type and distance to escape terrain as predictor variables (Figure 29, Table 4). Slope and terrain ruggedness had the least influence and was omitted from subsequent equations. Vegetation type showed a negative relationship with blue sheep presence (coefficient=-0.35, p<0.01) showing preference towards open vegetation types which included alpine grasslands, barren and snow covered areas. Escape terrain had a strong positive relation with blue sheep presence (coefficient=0.45, p<0.001) showing preference of blue sheep towards less steeper cliffs. Though aspect and elevation had low significance levels, the variables supported the ecological relations with the significant covariates. In case of livestock, resource selection was best modelled using vegetation type (coefficient=-0.36, p<0.001) and elevation (coefficient=-1.31, p<0.001) as variables. Slope and aspect, being the least significant variables were omitted. Both elevation and vegetation type showed negative relations (Figure 30, Table 5) with livestock presence showing preference of open vegetation at lower altitudes.

Table 3: AIC values of different models for blue sheep and livestock

Species		Model 1	Model 2	Model 3	Model 4
Blue sheep	N	990	990	990	990
	AIC	550.47	549.70	548.28 [a]	547.59 [a]
	BIC	584.75	579.09	572.77	567.18
Livestock	N	1234	1234	1234	1234
	AIC	1059.65	1057.90 [a]	1057.49 [a]	1060.42
	BIC	1095.48	1088.61	1083.08	1080.89

([a] MODELS WITH LEAST AIC VALUES)

Table 4: Coefficient and p values of different models for blue sheep

Predictors for Blue Sheep	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**
(Intercept)	-2.58 [a]	-2.56 [a]	-2.57 [a]	-2.56 [a]	-2.54 [a]
SE(Intercept)	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
Slope	0.33	0.11			
SE(Slope)	(0.25)	(0.15)			
Aspect	0.13	0.12	0.13		
SE(Aspect)	(0.12)	(0.12)	(0.12)		
Terrain ruggedness	-0.29				
SE(Terr rug)	(0.27)				
Vegetation type	-0.35 [b]	-0.34 [b]	-0.35 [b]	-0.34 [b]	-0.43 [b]
SE(Veg type)	(0.12)	(0.11)	(0.11)	(0.11)	(0.10)

Elevation	-0.23	-0.24	-0.24	-0.23	
SE(Elevation)	(0.14)	(0.14	(0.14)	(0.14	
Escape terrain	0.48 [a]	0.50 [a]	0.45 [a]	0.45 [a]	0.47 [a]
SE(Esc terr)	(0.11)	(0.11)	(0.09)	(0.09)	(0.09)
Pseudo R^2	0.11	0.10	0.10	0.10	0.09

([a] $p < 0.001$; [b] $p < 0.01$; [c] $p < 0.05$.)

Table 5: Coefficient and p values of different models for livestock

Predictors for Livestock	Model 1	Model 2	Model 3	Model 4
(Intercept)	-1.57 [a]	-1.57 [a]	-1.56 [a]	-1.53 [a]
SE(Intercept)	(0.10)	(0.10)	(0.10)	(0.10)
Slope	0.08			
SE(Slope)	(0.16)			
Aspect	0.10	0.10		
SE(Aspect)	(0.08)	(0.08)		
Terrain ruggedness	-0.30 [c]	-0.23 [c]	-0.23 [c]	
SE(Terr rug)	(0.17)	(0.10)	(0.10)	
Vegetation type	-0.36 [a]	-0.36 [a]	-0.36 [a]	-0.36 [a]
SE(Veg type)	(0.07)	(0.07)	(0.07)	(0.07)
Elevation	-1.33 [a]	-1.33 [a]	-1.31 [a]	-1.29 [a]
SE(Elevation)	(0.11)	(0.11)	(0.11)	(0.10)
Pseudo R^2	0.39	0.39	0.39	0.39

([a] $p < 0.001$; [b] $p < 0.01$; [c] $p < 0.05$.)

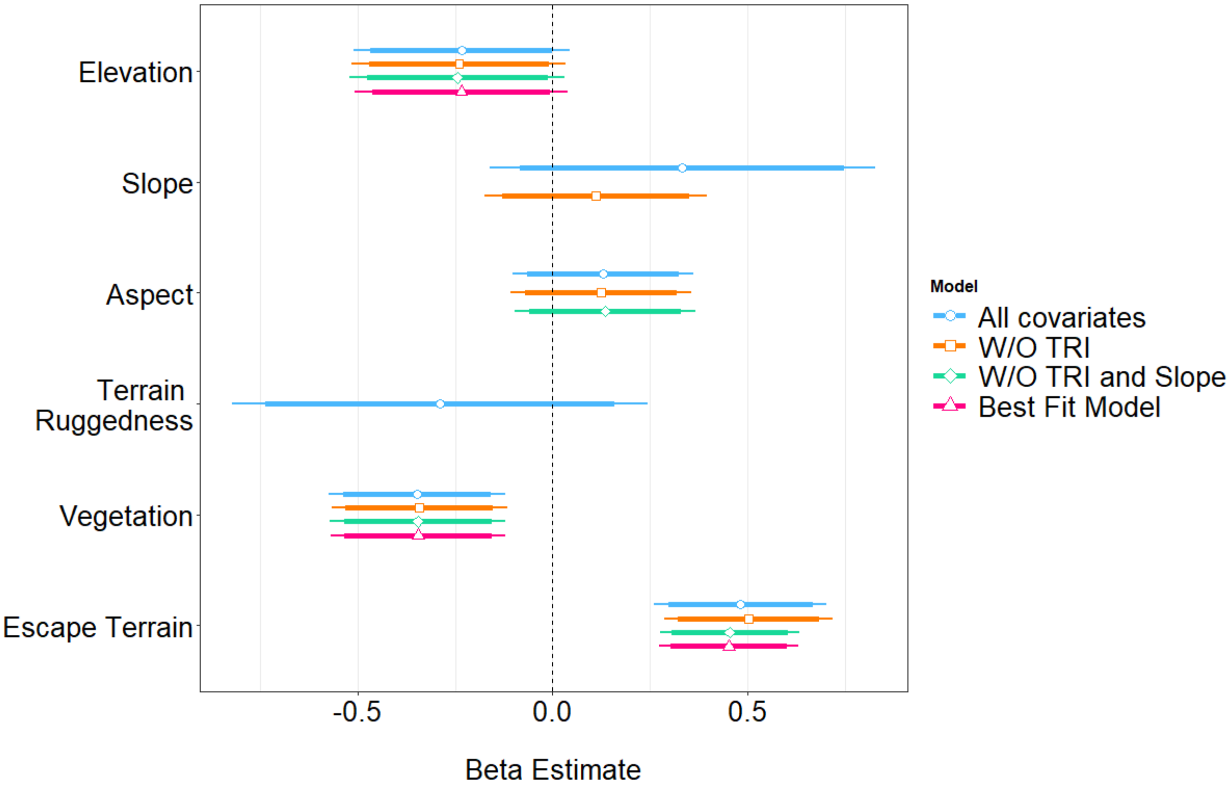

Figure 29 : Coefficient plot of blue sheep showing the best fit models with the covariates

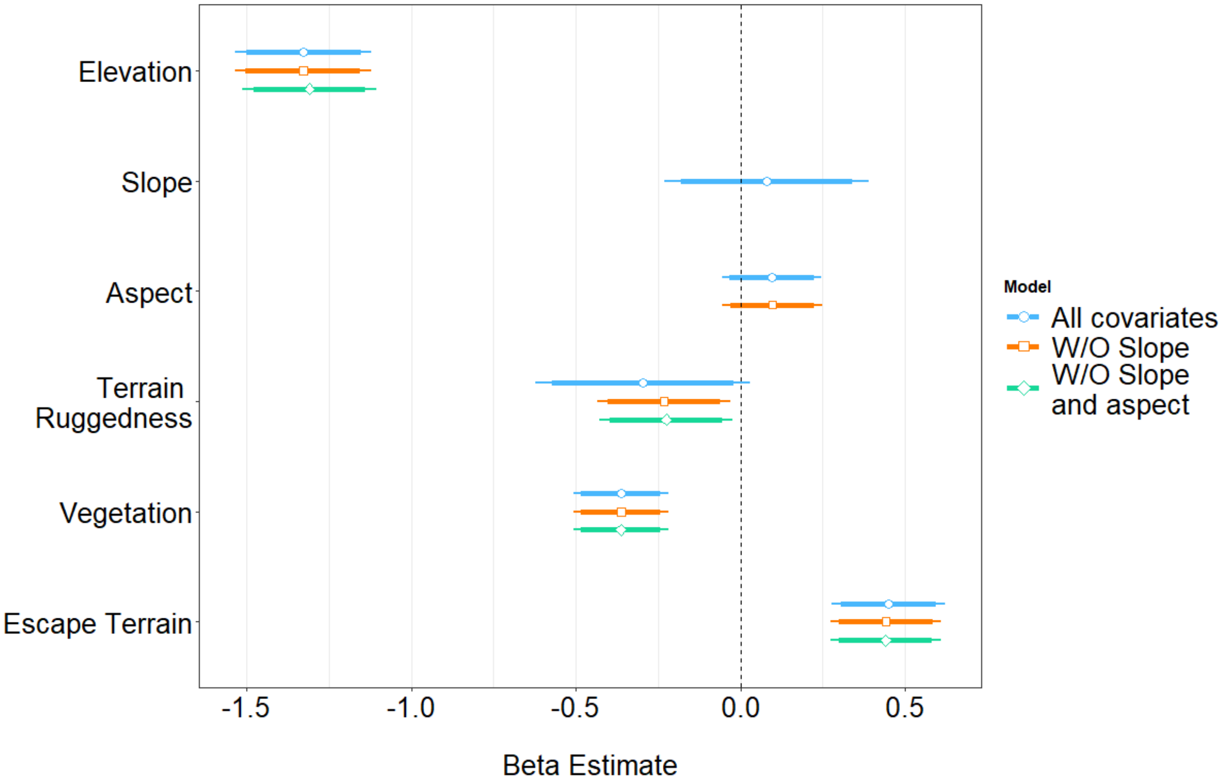

Figure 30 : Coefficient plot of livestock showing the best fit models with the covariates

An intensity map of resource selection probability for blue sheep (Figure 31) showed its predicted presence in areas with open vegetation representing the alpine grasslands. Their presence was predicted in a suitable area of ~660 km^2 which is 69% of the total study area. Their selection probability was in areas towards the alpine grasslands and valley floors on the southern aspect keeping a distance of 600m–1000m from the cliffs. There was no significant difference between the intensity maps of blue sheep generated separately with direct and indirect evidences (Figure 33a, 30b and 30c; Table 6). Livestock, being accompanied by humans, also showed presence probability (Figure 32) in areas with open vegetation but at lower altitudes with moderate terrain ruggedness away from cliffs mainly on the valley floors. Their high resource selection probability was predicted in an area of ~546km^2 which is ~57% of the total study area (Table 11).

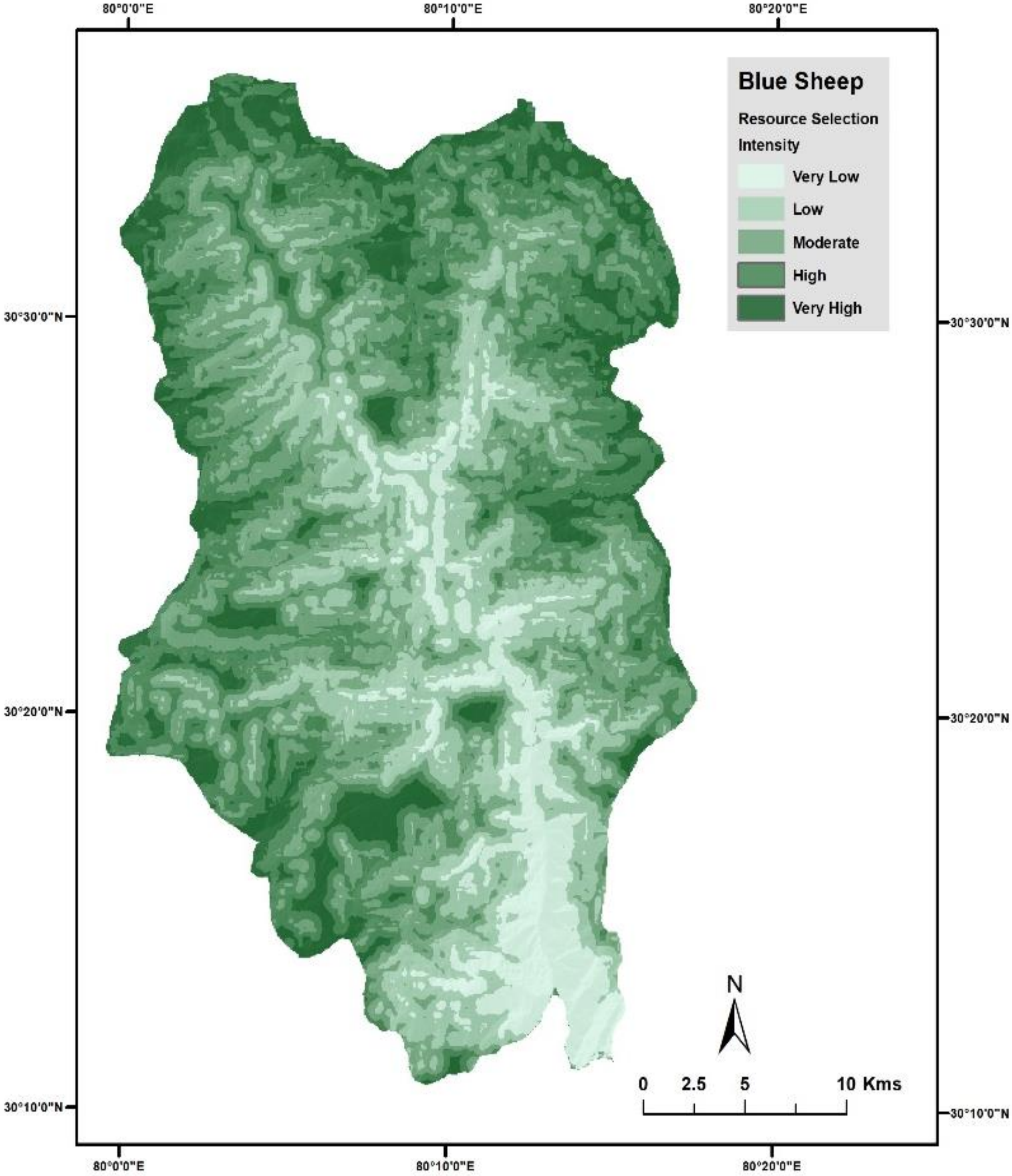

Figure 31 : Intensity map of resource selection probability of blue sheep

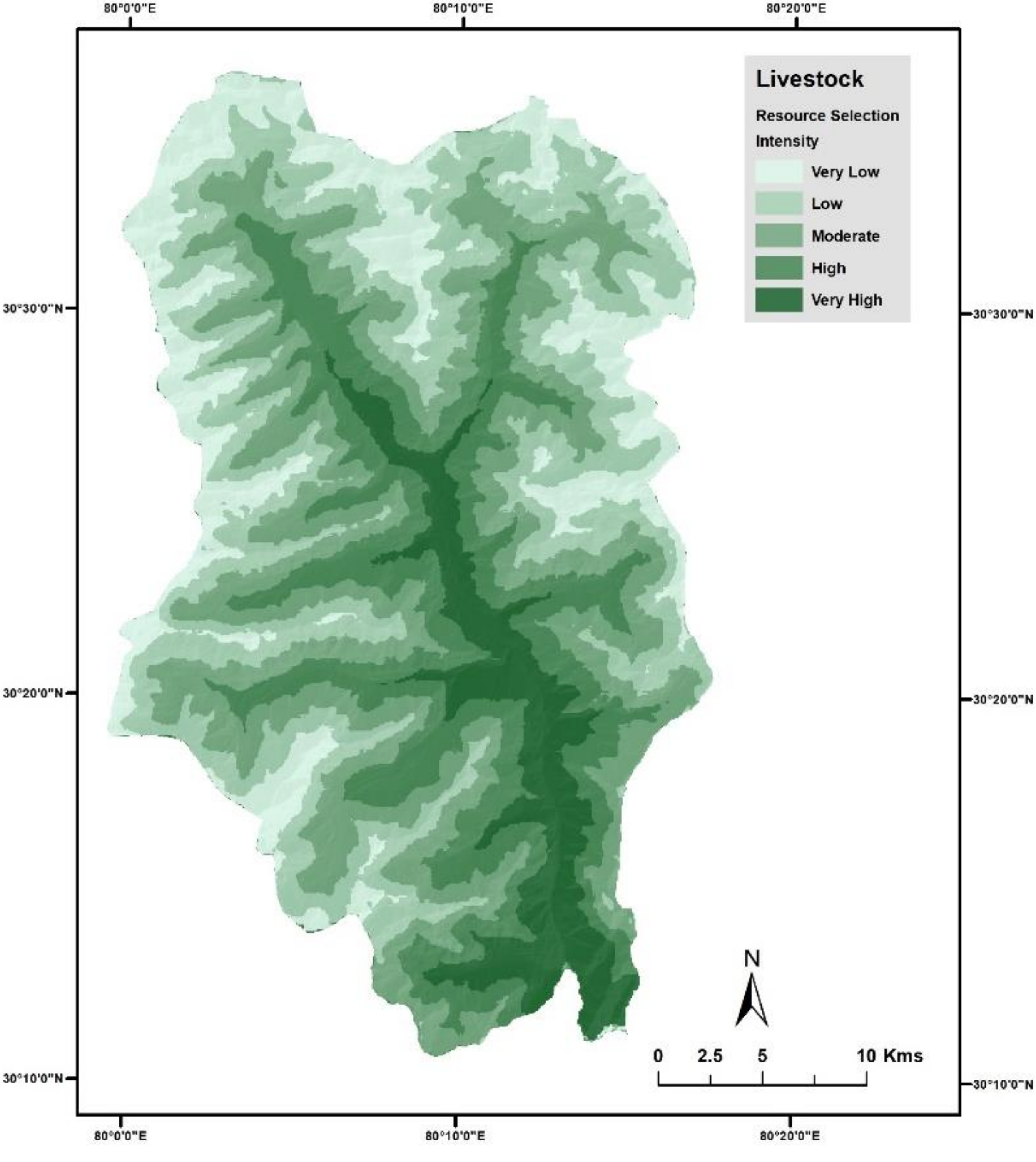

Figure 32 : Intensity map of resource selection probability of livestock

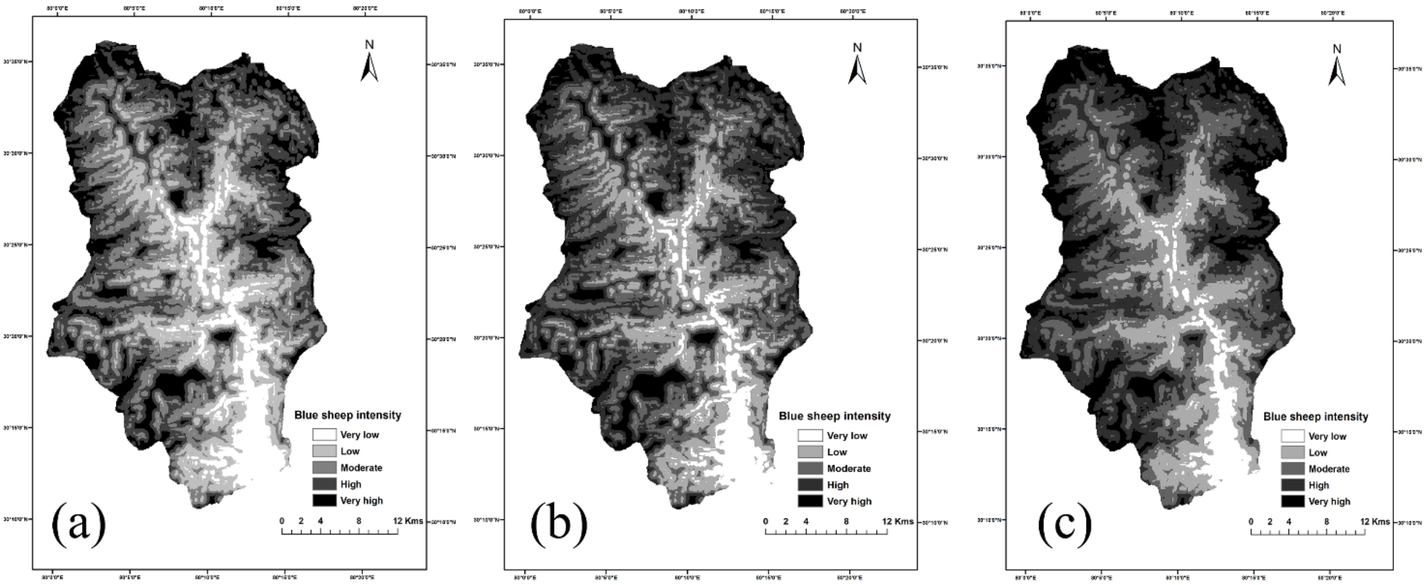

Figure 33 : Intensity map of blue sheep resource selection probability of (a) Combined (b) Direct and (c) Indirect evidences

Table 6: Coefficient and p values of blue sheep direct, indirect and combined observations

Predictors for Blue Sheep	Indirect data	Direct data	Combined data
(Intercept)	-3.02 [a]	-3.56 [a]	-2.56 [a]
Vegetation type	-0.28	-0.39 [c]	-0.34 [b]
SE(Veg type)	(0.15)	(0.17)	(0.11)
Elevation	-0.22	-0.25	-0.23
SE(Elevation)	(0.17)	(0.22)	(0.14
Escape terrain	0.32 [b]	0.60 [a]	0.45 [a]
SE(Esc terr)	(0.12)	(0.12)	(0.09)

([a] $p < 0.001$; [b] $p < 0.01$; [c] $p < 0.05$.)

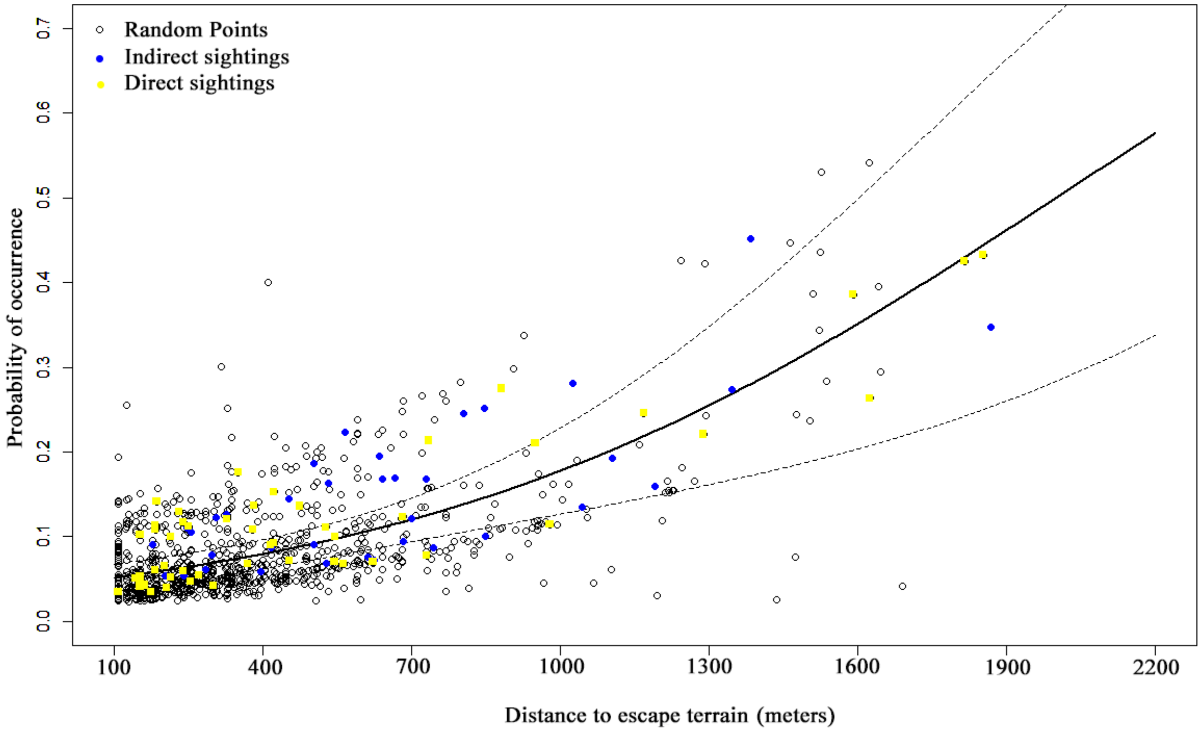

Figure 34 : Relation between distance to escape terrain and probability of occurrence of blue sheep

4.3.2 Tahr and musk deer vs livestock:

The results showed the probability that a resource unit in a particular category is used by the study species (resource selection function) as ratios of the observed to expected sample counts in different categories (Table 7). Tahr mostly preferred habitat types moru mix (wi = 62.65 ± 25.174), upper temperate grassy slopes (wi = 52.20 ± 5.4), *kharsu* oak *(Quercus semicarpifolia)* forests (wi = 41.76 ± 9.9) and Krumholtz zones of *Rhododendron campanulatum* patches (wi = 6.91 ± 2.02). Birch fir forests, *kharsu* oak, upper temperate grassy slopes and Krumholtz zones were utilized more than their available proportions (Figure 35). Musk deer utilized *Rhododendron campanulatum* patches (wi = 46.97 ± 13.87) and birch fir forests (wi = 7.89 ± 1.67) as their preferred habitats which were used more than their available proportions (Figure 36). Livestock utilized *Rhododendron campanulatum* bushes (wi = 4.23 ± 0.12), upper temperate grassy slopes (wi = 4.25 ± 0.14), alpine meadow (wi = 2.26 ± 0.01) and birch fir forests (wi = 2.46 ± 0.03) as their preferred habitat types. Rhododendron bushes, birch fir forests and alpine meadows were utilized more than their available proportions (Figure 37).

For the resource selection probability function of tahr and livestock, AIC was used as the objective criterion to determine the variables for inclusion in the RSF best fit models (Table 8). The best fit model with the lowest AIC value indicated that elevation, aspect and DET were the most influencing variables. The next best fit model indicated elevation and slope as the most influencing variables. The models showed a negative relation with elevation, DET and aspect and a positive relation with slope and TRI (Table 9). For livestock, the results showed that elevation, slope and DET were the most influencing variable for resource selection. The models showed a negative relation with elevation and slope and a positive relation with DET (Table 10). Using these estimates I generated the resource selection probability maps for tahr and livestock (Figure 38 & 39). Areas of relatively highest probability of use for tahr mainly occured along the steep slopes and rugged terrains in the landslide areas, nearer to the cliffs but not above 3500 m elevation. These are the areas where upper temperate grassy slopes, birch fir forests, kharsu forests and rhododendron bushes exist. The high resource selection probability area for tahr was ~185km^2 which was around 19% of the study area (Table 11). Livestock areas of high probability use were regions away from the cliffs, lower elevations and moderate slopes. Livestock high resource selection probability area was ~300 km^2, which is around 32% of the study area (Table 11).

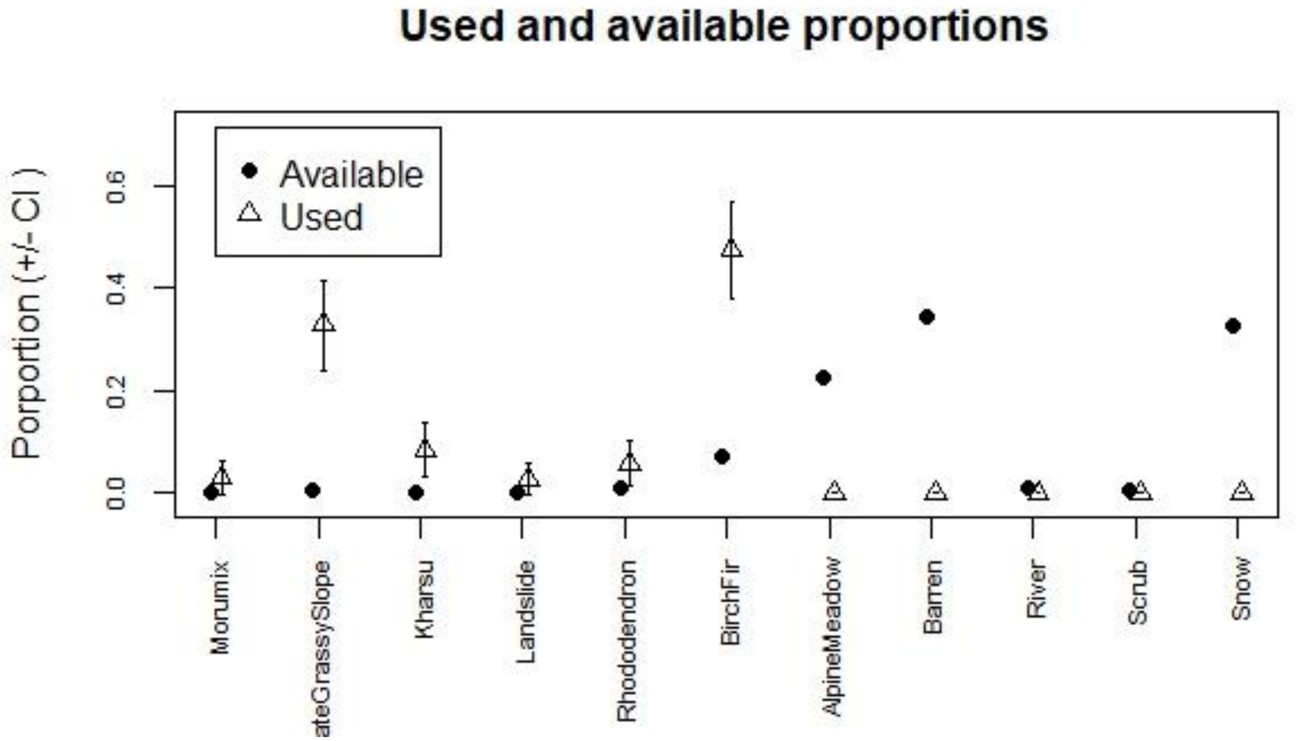

Figure 35 : Resource selection and utilization of tahr with respect to available habitat

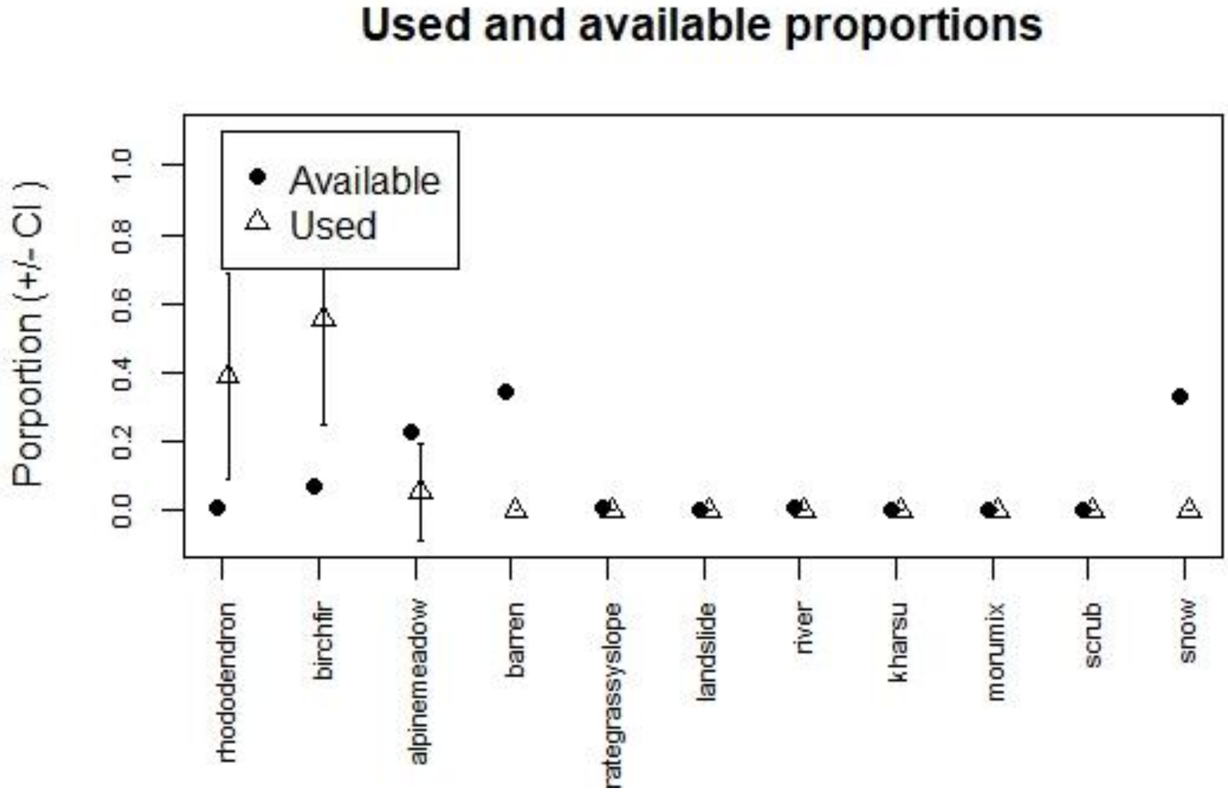

Figure 36 : Resource selection and utilization of musk deer with respect to available habitat

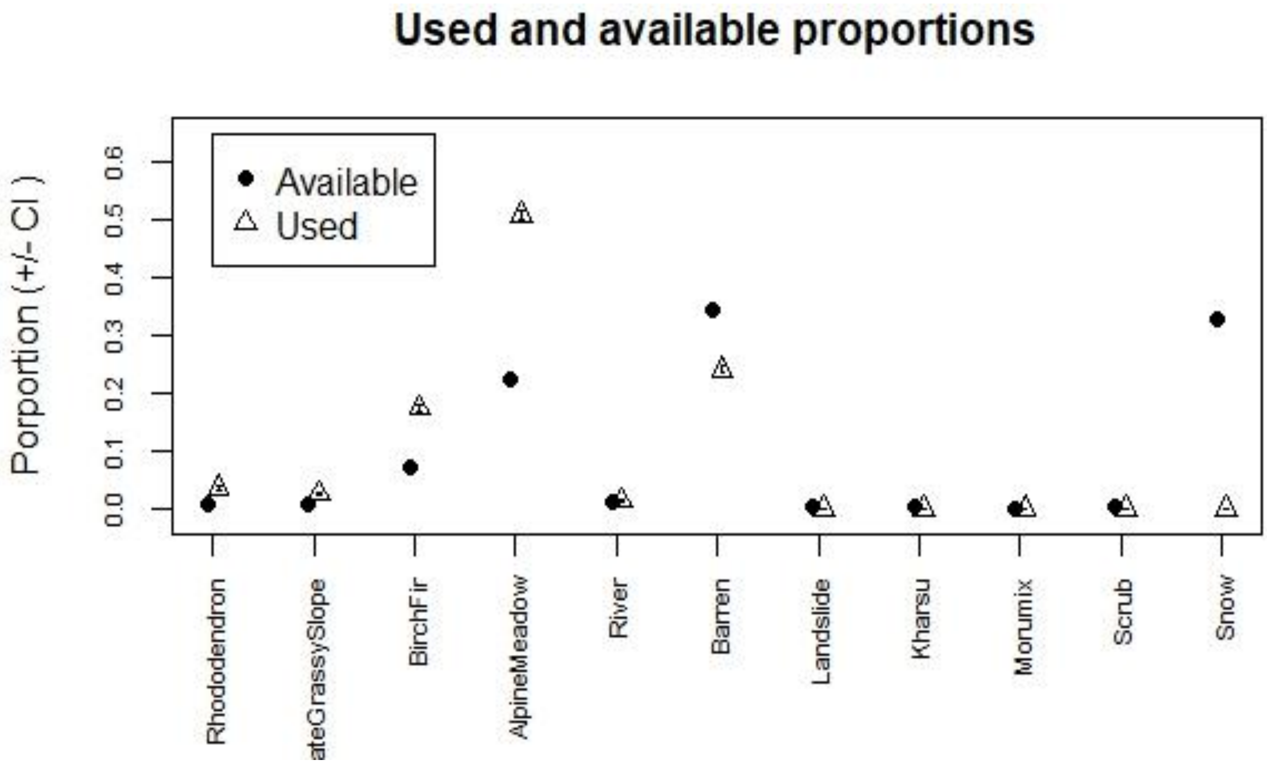

Figure 37 : Resource selection and utilization of livestock with respect to available habitat

Table 7: Selection index (wi values) of use vs availability for tahr, musk deer and livestock

Habitat type	Tahr (wi)	Musk deer (wi)	Livestock (wi)
Alpine Meadow	-	0.247	2.263
Barren	-	-	0.701
Upper temperate grassy slope	52.208	-	4.246
Landslide	10.040	-	-
River	-	-	1.304
Birch fir	6.739	7.899	2.465
Kharsu	41.767	-	-
Moru mix	62.650	-	-
Rhododendron	6.919	46.967	4.297
Scrub	-	-	-
Snow	-	-	-

Table 8: AIC values of different models for tahr and livestock

Species		Model 1	Model 2	Model 3	Model 4
Tahr	AIC	91.373 [a]	93.433 [a]	93.689	95.698
	BIC	97.92	97.8	96.96	101.2
Livestock	AIC	3604.05[a]	3606.54 [a]	3668.36	3668.92
	BIC	3627	3618	3684	3680

([a] MODELS WITH LEAST AIC VALUES)

Table 9: Coefficient and p values of different models for tahr

Predictors for tahr	Model 1	Model 2	Model 3	Model 4
(Intercept)	-35.009 [a]	-42.6670 [a]	-41.3008 [a]	-37.8049 [a]
SE(Intercept)	(8.72)	(4.80)	(2.67)	(1.95)
Slope	10.649	9.1521 [a]	7.9286 [a]	
SE(Slope)	(9.22)	(3.78)	(2.21)	
Aspect	-0.892 [c]	-0.4031		
SE(Aspect)	(0.38)	(0.31)		
Terrain ruggedness	-0.2022			1.5264 [a]
SE(TRI)	(1.59)			(0.32)
Elevation	-5.8555 [a]	-5.4274 [a]	-5.1164 [a]	-5.6578 [a]
SE(Elevation)	(1.44)	(1.55)	(0.80)	(1.12)
Escape terrain	-1.4828 [c]			
SE(DET)	(0.65)			

([a] $p < 0.001$; [b] $p < 0.01$; [c] $p < 0.05$.)

Table 10: Coefficient and p values of different models for livestock

Predictors for tahr	**Model 1**	**Model 2**	**Model 3**	**Model 4**
(Intercept)	-2.14 [b]	-2.59 [a]	-1.16 [b]	-1.09 [c]
SE(Intercept)	(0.66)	(0.23)	(0.44)	(0.43)
Slope	-0.79		-1.31	-1.42 [a]
SE(Slope)	(0.13)		(0.85)	(0.89)
Aspect	-0.18		-0.19	
SE(Aspect)	(0.10)		(0.13)	
Terrain ruggedness	0.49			
SE(TRI)	(0.30)			
Elevation	-2.79 [a]	-2.63 [a]	-3.47 [a]	-3.52 [a]
SE(Elevation)	(0.36)	(0.21)	(0.39)	(0.43)
Escape terrain	0.88 [a]	0.79 [a]		
SE(DET)	(0.13)	(0.09)		

([a] $p < 0.001$; [b] $p < 0.01$; [c] $p < 0.05$.)

Table 11: Resource selection probability areas in three categories for the study species

Species	Method	TSS threshold	Low	Moderate	High	Potential	High
Blue sheep	Point Process					659.18	
Livestock						545.97	
Tahr	Resource selection	18531.104	202.71	133.13	51.45	387.21	184.58
Livestock		13516.178	276.06	197.12	102.62	575.8	299.74

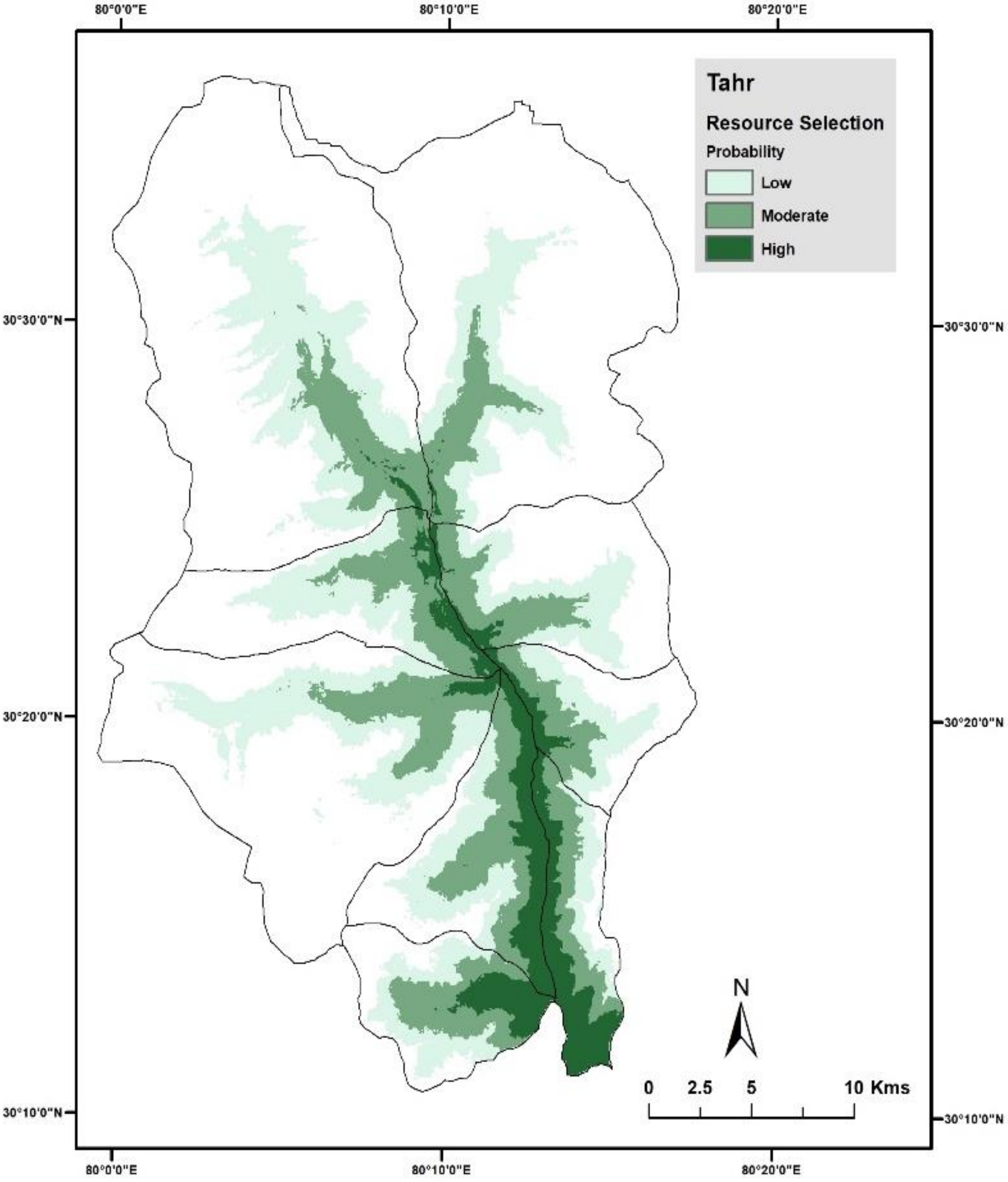

Figure 38 : Intensity map of resource selection probability of tahr

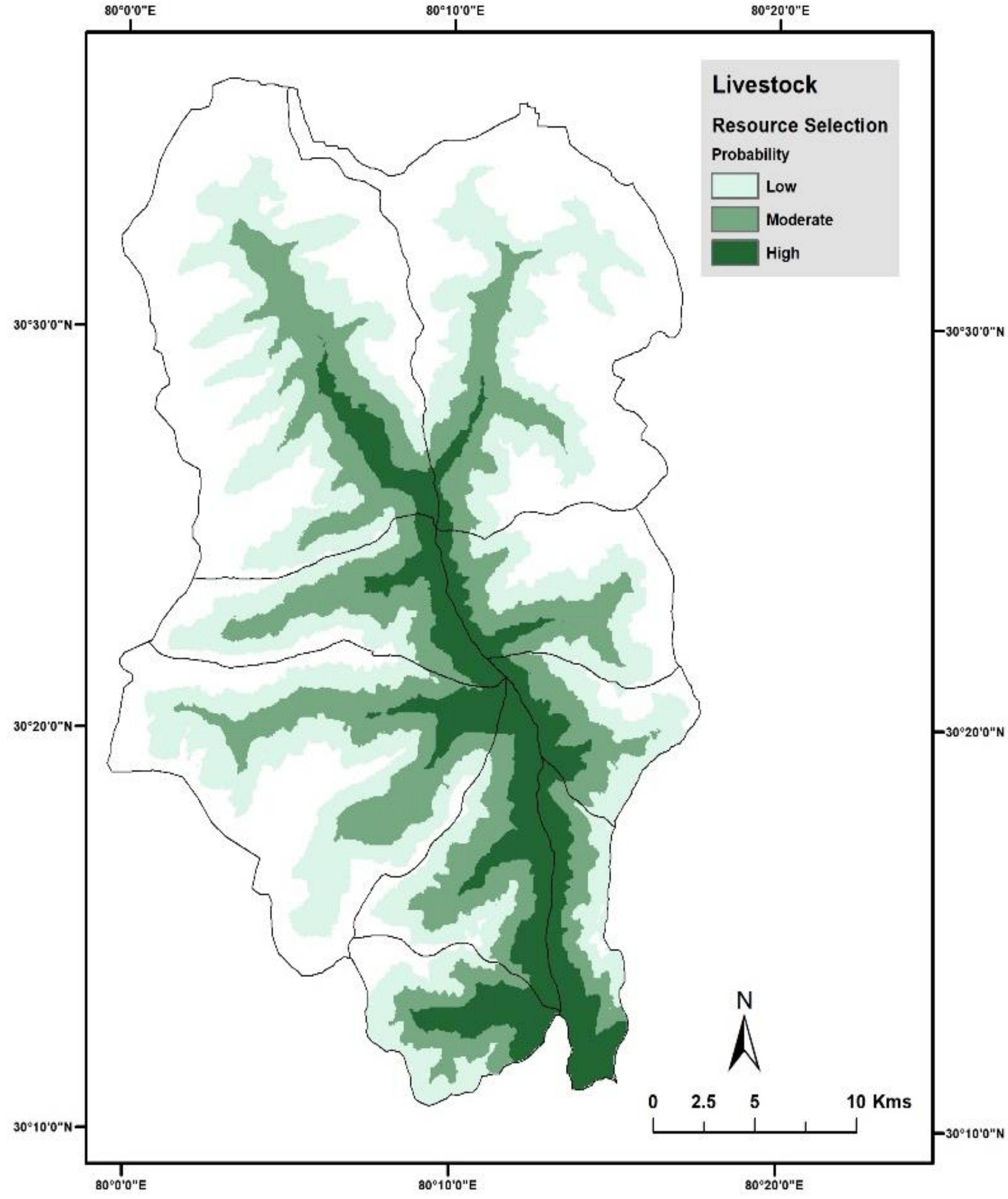

Figure 39 : Intensity map of resource selection probability of livestock

4.4 Discussion:

Wild ungulates tend to avoid competition by differential resource selection. The basis of this differential selection may be habitat, diet or anti-predator strategies (Namgail *et al.*, 2007). In most applications for estimating resource selection function, only relative probabilities rather than absolute probabilities can be used. As is the case with RSFs in general, the maps that predict high probability of use for certain areas do not necessarily define optimal habitats.

Blue sheep: This study revealed that vegetation type was an important variable in predicting the resource selection by both blue sheep and livestock. The results reflected upon raster values of the 12 selected vegetation categories. From this study, I inferred blue sheep's preference towards alpine grasslands (moist and dry), barren and snow covered areas. The negative relation indicated selection of open alpine areas with herbaceous vegetation type which coincide with the diet and foraging patterns of both blue sheep and livestock. In summers, both species are hugely dependent on alpine grasses and other associated plant species which mainly grow on the warmer aspects (Kala et al. 2002). The analysis reveals that though blue sheep continue to use the same habitat after arrival of migratory livestock, they separated selecting different variables or resources based on topographic features. Blue sheep selected warmer aspects in moderately rugged terrains to forage on the grasses, and also showed preference to remain at an optimal distance from the escape terrain. The preference to remain towards the cliffs is an artefact of their behavioural trait (Namgail 2009; Johnsingh and Manjerakar 2015). According to the results, they prefer to remain within a distance of 600 m - one km to exploit the alpine meadows. Since, summer - monsoon is the main foraging season for blue sheep, it is most likely to prefer the optimal habitat patches other than the steep cliffs. It was also suggested in Namgail (2001) and Namgail et al. (2004) that there is less forage available in the cliffs so blue sheep have to move out of such escape terrain to feed on the grasses, thus compensating their safety. The above mentioned studies have shown that in a Trans Himalayan landscape, blue sheep tend to remain closer to the cliffs (within 250 m). Escape terrain, like the other covariates is a function of topography which varies across different Himalayan zones. In a greater Himalayan landscape the foraging sites are the places where alpine grasses grow, which are quite far for from the steep cliffs. Thus, blue sheep need to have a balance between food acquisition and predator avoidance while feeding outside the escape terrain. I analysed the relation of distance to escape terrain with the direct and indirect evidences and found that most observations were within a distance of 1000m and 600m from the cliffs respectively (Figure 34). Use of an escape terrain during foraging season is a strategy to maintain a balance between exploiting resources and avoiding predation. A study by Wegge (1979) has reported blue sheep feeding in open habitats and resting in rugged terrains. Due to presence of livestock, blue sheep prefers to avoid proximity to the optimal patches resulting in selecting an optimal distance to escape terrain. We found this threshold distance to be 600–1000m from the cliffs. This also explains the negative relation with elevation (Figure 27) as blue sheep is found to prefer areas closer to the alpine meadows in the summer-monsoon season. Previous studies on blue sheep tied with my results led to infer a probable shift of habitat preference from known preferred habitats of the species due to avoidance of the optimal areas. It also seems from the results that blue sheep has some kind of selective advantage for resources of their choice because of their ecology in rugged terrains. Advantage with the topographical factors for blue sheep allows the species to use some habitat and utilize those resources which otherwise would not have been possible due to presence of livestock.

Tahr: Tahr is known to mostly utilize habitats between 1800m to 3500m preferring open and sparsely wooded rugged slopes and landslide zones (Johnsingh and Manjrekar 2015). It mainly prefers extremely precipitous terrains with steep cliffs, scrubs and forests (Prater 1980) and have been mostly encountered between 2800 – 4400 m in previous studies in the western Himalaya (Sathyakumar 1994; Vinod and Sathyakumar 1999). From the results I found that tahr, owing to their ecological traits selected the steep slopes nearer to the cliffs and landslide zones of the right bank of the Gori River which are inaccessible to the pastoralists. 70 % of the observations were obtained from the right bank of the river. Most of the villages and pastoralist zones are situated at the left bank of the river. The preferred resources in these areas were upper temperate grassy slopes, kharsu-oak forests, birch fir forests and Krummholtz zones which serve as good forage and resting areas for tahr. This goes at par with the species' known habitat choices of low tree cover and scrubs amongst the open grassy slopes, steep cliffs and rocks (Caughley 1969; Prater 1980). Their preference for *kharsu* oak forests also complements their known preference for dense forests on steep slopes. Interestingly, all these preferred habitat types were utilized more than their availability. A preferred habitat type is used more than it becomes more available because the targeted species learns to use it in a more effective way (Boyce et al. 2002). This might be because tahr distribution is restricted to certain patches in the valley as shown in the previous chapter. My results in this chapter revealed only 19% of the study area as its high resource selection probability area complementing the previous results. There are optimal patches for tahr in the livestock grazing areas as well but tahr with its selective topographical advantage mostly choose areas devoid of human presence. Thus, topography and ecological traits keeps tahr naturally separated from livestock. The species, thus, has a visible segregation of habitat depending upon their preferences for different habitat covariates which agree with their ecological traits.

Musk deer: In the greater Himalayan region, musk deer mainly inhabits upper temperate, subalpine, alpine meadows and scrub regions (Illyas 2015; Syed and Illyas 2015).They occur between 2000 m till the tree line and prefer oak-rhododendron mixed forests (Green 1985). In my study, musk deer photo captures showed that they mostly preferred the Krummholtz zones followed by birch fir forest habitat types in the valley. Himalayan musk deer tends to remain in dense cover by day and use open habitat at night, when it is usually more active (Green 1985; Johnsingh and Manjrekar 2015; Illyas 2015). The dense scrub and undergrowth of the study area serve as good escape cover for the species as they do not stray far away in the open. Previous studies have also shown that resource selection of musk deer is influenced by altitude, shrub and herb density and distance to human habitation (Illyas 2015). Thus, musk deer remains separated from livestock in terms of resource selection and temporal activity.

Livestock: Livestock, accompanied by pastoralists, preferred areas at comparatively lower elevations than blue sheep and tahr with moderately rugged terrain, mainly on the valley floors. These are areas convenient for pastoralists for establishing their campsites and feasibility of grazing along with the presence of grasses. These highly suitable areas were along the valley floors and low altitude alpine patches interspersed with Krummholtz zones and grassy slopes, the optimal areas preferred by pastoralists because of nutritious grasses for their livestock. This makes the resource selection probability area for livestock more than the wild ungulates. This supports our results that blue sheep are shifting to a rugged topography at a threshold distance to their escape terrain although there is a chance of selection of the optimal areas.

Feeding activity patterns showed a temporal segregation between blue sheep, tahr, musk deer and livestock. Tahr and blue sheep are active mainly in the early mornings and late afternoons with a resting period during midday (Johnsingh and Manjrekar 2015). Musk deer is mostly nocturnal or crepuscular which makes it difficult to sight as well as survey. All the photo captures of musk deer were at dusk and late evening showing a temporal separation from livestock as they are active at early mornings and afternoon till dusk. Thus, they remain segregated from livestock due to their behavior and activity patterns. Livestock accompanied by humans foraged according to the convenience of the pastoralists. Thus temporally the wild and domestic ungulates were separated from each other in terms of resource selection.

The advantage of point process in this study is the choice of background points or pseudo-absences according to the objective of the study. In RSF designs explained by Manly et al. (2007), available resource units are sampled for the entire study area or unused resource units are considered as available units. Point process framework provides a platform to systematically select our background or available points in accordance with the species presence points. This gives more specificity to the intensity prediction. Another advantage of this method is its relation to the common approaches for RSF estimation. These models are a generalization of the weighted distribution models mostly used, like generalized linear models and MaxEnt (Johnson et al. 2013; Renner et al. 2015). This can be readily implemented by animal ecologists inferring about relative patterns in species abundances taking sampling biases into account. Earlier studies (Bagchi et al. 2004; Namgail et al. 2007; Suryawanshi et al. 2009) mainly explained resource selection through dietary patterns. Other habitat association studies (Namgail et al. 2007; Shrestha and Wegge 2008) explained RSF through GLMs with the entire study area as available habitat. My study focuses on the spatial basis of selection probability. I used background points to provide a more accurate association with the habitat variables and the species presence points rather than a generalized proportional probability layer. I used point process framework to model resource selection probability of blue sheep and livestock via intensity function. Instead of a probability, I estimated the expected abundance of species presence throughout the study area, using intensity as a function of the covariates (Renner et al. 2015). This is the first study where point process model is used to model resource selection function of terrestrial mammal species without radio-telemetry data. The main aim of studying mountain ecosystems is to provide better management decisions to practitioners and managers. These insights include spatial layers relating to the ecology of the species. A sound knowledge of spatial factors based on preferred resources of species, facilitates prioritization for these management strategies.

Chapter 5: Influence of Pastoralism

5.1 Introduction

Animal husbandry has been an inherent part of livelihood for the people of the Himalayan region (Sundriyal 1995). Alpine meadows, which comprise the major type of rangelands in the IHR, have provided grazing lands for livestock of the local communities during the summer-monsoon season since centuries (Farooquee and Rao 1999). At the higher reaches, livestock grazing is mainly practiced by transhumant or nomadic pastoralists who exploit the seasonal resources in the marginal environments of the alpine pastures (Nautiyal et al. 2003). These pastoralists follow a migratory cycle between the pastures of the upper reaches and lowlands throughout the year (Bhasin 2013). Since centuries, a pastoral ecosystem has tried to maintain a balance between the different habitats, flora, fauna, livestock and the herders in a rangeland (Dong, Yi & Yan 2016). The pastoralists through their techniques of mobility, herding, grazing reserves and use of fire have maintained the vegetation composition, carbon sequestration and the overall habitat of the Himalayan rangelands (Seid, Kuhn & Fikre 2016). Some of the pastoral communities of the IHR are *Gujjars*, *Bakarwals, Kinnauras*, *Kaulis* and *Kanets* of north India, *Bhotiyas* of Garhwal and Kumaon, *Monpas* of Arunachal Pradesh, *Bhutias* of Sikkim and *Changpas* of Ladakh. (Bhasin 2013)

The *Bhotiya* community of the high altitudes of Kumaon region of Uttarakhand has also a repository of centuries' old traditional knowledge and practices (Negi 2017; Negi et al. 2018). Earlier, these people were involved in trade between borders of India and Tibet, but due to the Sino-Indian conflict in 1962, the trade was terminated (Farooque 1998). These indigenous people have been involved in agriculture, internal trade of medicinal plants and pastoralism since then. In Johar valley, over the years the traditional practices of agriculture have also faded with the out-migration of younger generation, advent of development and tourism. However, pastoralism has remained with certain modifications from the traditional ways. The contemporary pastoralists of the Johar valley (*Shaukas* and *Anuwals*) are particular people whose only source of income is through livestock grazing. Most of these people reside in villages of the lower reaches of the valley and spend their life seasonally migrating from the upper (3000 m – 4500 m) to the lower (1200 m – 1900 m) regions to graze their livestock. Each group of herders consist of 2 to 3 people, their dogs and livestock. The livestock mainly consists of sheep and goat and most individuals of the herd is the property of the respective pastoralist. In addition to that, the local people who migrate to their residences on the high altitudes in the summer season, take services from these pastoralists for grazing their own livestock. Each village has designated alpine pastures within their village boundary and the pastoralists pay a royalty amount (per sheep and per goat) to the village for grazing their livestock in these pastures. The fee is 5 rupees per animal and with a herd of about 500 - 600 animals it amounts to ~3000 rupees per herder group. Due to their migration throughout the year, the pastoralists have detailed information regarding the flora, fauna and natural resources of the Johar valley. From the herders' point of view, a good pasture is characterized by presence of nutritious palatable species, absence of invasive and unpalatable species, and an extensive area that could support larger herds.

Changes in internal and external situations in the IHR has restricted the traditional pastoral practices in recent times (Seid, Kuhn & Fikre 2016). This has led to livestock pressure over the rangeland habitats and their biodiversity. Physiographical changes in the landscape of the Johar valley due to natural disturbances like landslides, flashfloods, erratic weather, etc. have led to inaccessible conditions to reach certain alpine patches which were used previously (Personal Communication with Pastoralists). Also, there used to be connections between the valleys from where the herders could travel across the valleys. These connections have also been lost due to climatic factors. This has resulted in overstocking of livestock in the limited number of pastures. With the increase in livestock numbers over the years, the capacity of the fragmented patches to support them has decreased. A study by Negi (2010) showed that the number of livestock (sheep and goat) in the Johar valley was 10075. The 2012 livestock census revealed that the number of livestock in entire Munsiyari Tehsil was 50108 (Uttarakhand Livestock Department Board http://www.uldb.org/cen.htm). According to my estimation in 2017 from the results of Chapter 3, the current livestock number in Johar valley was 15845. Thus, there has been an increase in the livestock numbers in Johar valley. Alongside, there has been the advent of a new livelihood option in the valley in the last 10 years called *kidajadi* or collection of *Cordyceps sinensis* which is a caterpillar fungus with high medicinal and thus economic value (Laha, Badola & Hussain 2018). Most people of this valley are engaged in this trade because of comparatively more earnings than the traditional practice of agriculture. The alpine patches of respective villages used for livestock grazing have been earmarked for this purpose from April to June every year and herders are not allowed during this period. This process involves digging the ground for searching the fungus which in turn might lead to destruction of the alpine habitat taking a toll on the growth of nutritional forage. Due to the clash with *Cordyceps* collection time, the pastoralists come all at the same time during late June or early July and stay till September. There has also been a loss of the traditional sustainable way of pastoral practices with introduction of young pastoralists replacing the aged ones. Earlier there also used to be ceremonial exclusion of particular patches in alternate years for better growth of the grasses (Negi 2010) but this practice has also faded over the years.

The alpine meadows in many parts of the Greater Himalaya have been overused and degraded (Negi et al. 1993). Studies have shown that uncontrolled grazing on the steeper slopes reduces water holding capacity of the soil, creates channels or paths on hill slopes which remove huge quantities of soil during the rains (Rawat 1998). Over grazed areas also show a decrease in grasses and increase of unpalatable species (Rawat and Uniyal 1993). A study conducted by Shah (1988) has shown that the alpine meadows of Kashmir have faced considerable vegetation loss due to excessive grazing and wide presence of weeds. Overstocking is also considered an insurance against losses due to predation, disease and unfavorable climatic conditions. Alongside, the fragmentation and degradation of habitat due to natural and anthropogenic factors has also lead to reduced number of pastures for wild ungulates to forage. It has also been established from previous studies that extensive grazing by migratory livestock negatively affects the abundance of ungulates (Sathyakumar et al. 1993; Bhatnagar et al. 2006). Hence, it becomes important to assess the current situation of pastoralism influence on the ecology of wild animals. For that it becomes important to know the intensity of influence of pastoralism on wild ungulates and the ecosystem. This will lead us to suggest conservation implications keeping in mind the situation of both the pastoral traditions as well as ecology of wild ungulates. It becomes important to consider the traditional and current aspects of pastoralism in a landscape in order to come up with a proper management plan.

In the previous chapters, I have assessed the amount of suitable habitat available for proper distribution and optimal resource selection for both wild and domestic ungulates. In this chapter, I attempted to assess the effect of livestock grazing on wild ungulates and the amount of overlap of livestock in suitable habitat areas of wild ungulates.

5.2 Research questions and hypothesis

- What is the degree of livestock intensity influencing distribution of wild ungulates and pastoralism areas
- What is the degree of overlap between high suitable and resource selection probability areas of wild ungulates and livestock

My hypothesis for this chapter is that fragmentation of habitat due to various factors leads to less or smaller grazing pastures with high livestock use intensity which can cause higher overlap of livestock grazing areas with suitable habitats of wild ungulates. Thus, grazing pressure might exist in the Johar valley to the extent of management of livestock or excessive competition with wild ungulates

5.3 Analysis

5.3.1 Influence of livestock intensity

I collected GPS locations along the boundaries of each of the 30 alpine patches and mapped them in Google Earth. I generated a spatial layer of the alpine patches and calculated the area of each alpine patch in GIS domain. I calculated the number of livestock per alpine patch area and generated a layer of livestock use intensity in each patch using the equation

Livestock use intensity = Number of livestock in one alpine patch / area of the alpine patch

I then compared the naïve distribution (potential distribution without livestock presence), habitat suitability (distribution including livestock presence) and resource selection probability layers of the three wild ungulates with the livestock use intensity. For this, I used the distribution ranges and resource selection probability layers of the three wild ungulates and livestock and did a union analysis in GIS domain respectively. Union analysis calculates the geometric intersection between two layers where the output features have attributes of the input features that they overlap. I used the union between the high and very high classes for interpreting the results. Thus, I got the overlap zones of distribution and resource selection between blue sheep - livestock, tahr - livestock and musk deer - livestock. These overlap zones represented the high overlap areas between wild ungulates and livestock. I calculated the amount of area overlapped by livestock use in the distribution and resource selection probability areas of the three wild ungulates.

5.4 Results

There were 30 alpine patches with 33 herder groups holding a livestock population of 15845 (Figure 40). The results depicted, that different sizes of alpine patches showed different levels of grazing intensity (Figure 41, Table 12). The smaller patches showed higher intensity of grazing as compared to the larger patches.

Table 12: List of alpine patches in Johar valley with grazing intensities

Grazing Intensity	Alpine Patch	Patch Area (sq.km.)	Livestock Present	Livestock Intensity
High	Milam	3.682	400	108.624
High	Milam	3.583	400	111.642
High	Martoli	4.831	560	115.908
High	Bilju	5.982	700	117.012
High	Milam	3.205	400	124.818
High	Bugdiyar	6.238	800	128.246
High	Milam	2.938	400	136.144
High	Milam	2.085	300	143.902
High	Milam	1.893	300	158.457
High	Martoli	6.196	1000	161.403
High	Milam	3.017	500	165.729
High	Nahar Devi	3.489	600	171.964
High	Milam	2.827	500	176.855
High	Milam	1.668	300	179.862
High	Laspa	3.244	600	184.943
High	Martoli	3.484	720	206.636
High	Milam	2.295	500	217.895
High	Martoli	4.257	1040	244.311
High	Laspa	2.382	700	293.817
Low	Burphu	28.818	700	24.290
Low	Milam	10.378	500	48.177
Low	Milam	7.345	400	54.462
Low	Tola	39.189	2600	66.346
Low	Rilkot	7.404	500	67.532
Low	Milam	6.779	500	73.752
Low	Martoli	7.531	560	74.364
Low	Laspa	4.748	400	84.251
Low	Milam	4.611	400	86.757
Low	Ganghar	33.016	3000	90.866
Low	Laspa	5.249	500	95.260

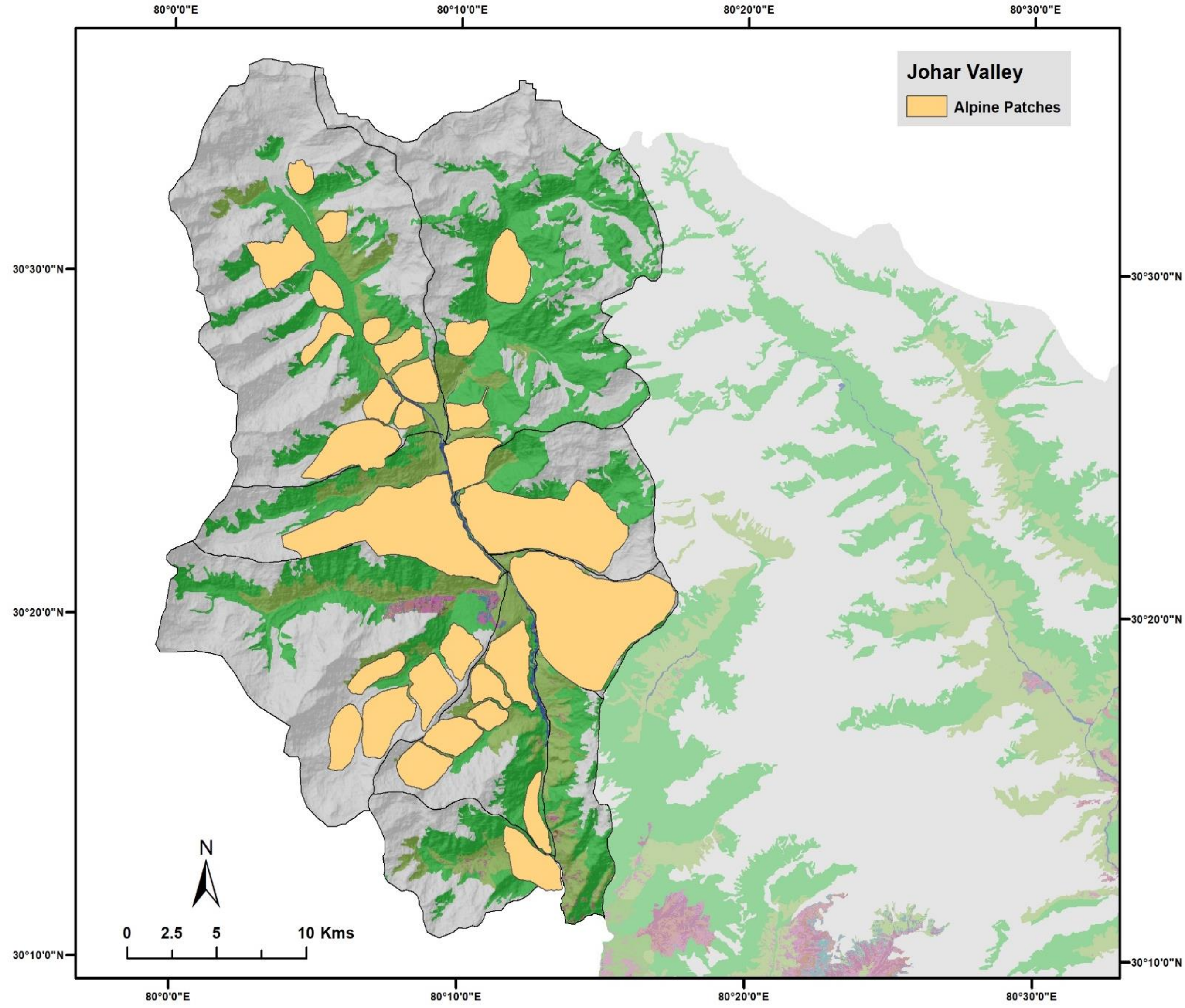

Figure 40 : Map of Johar valley showing the sampled alpine patches

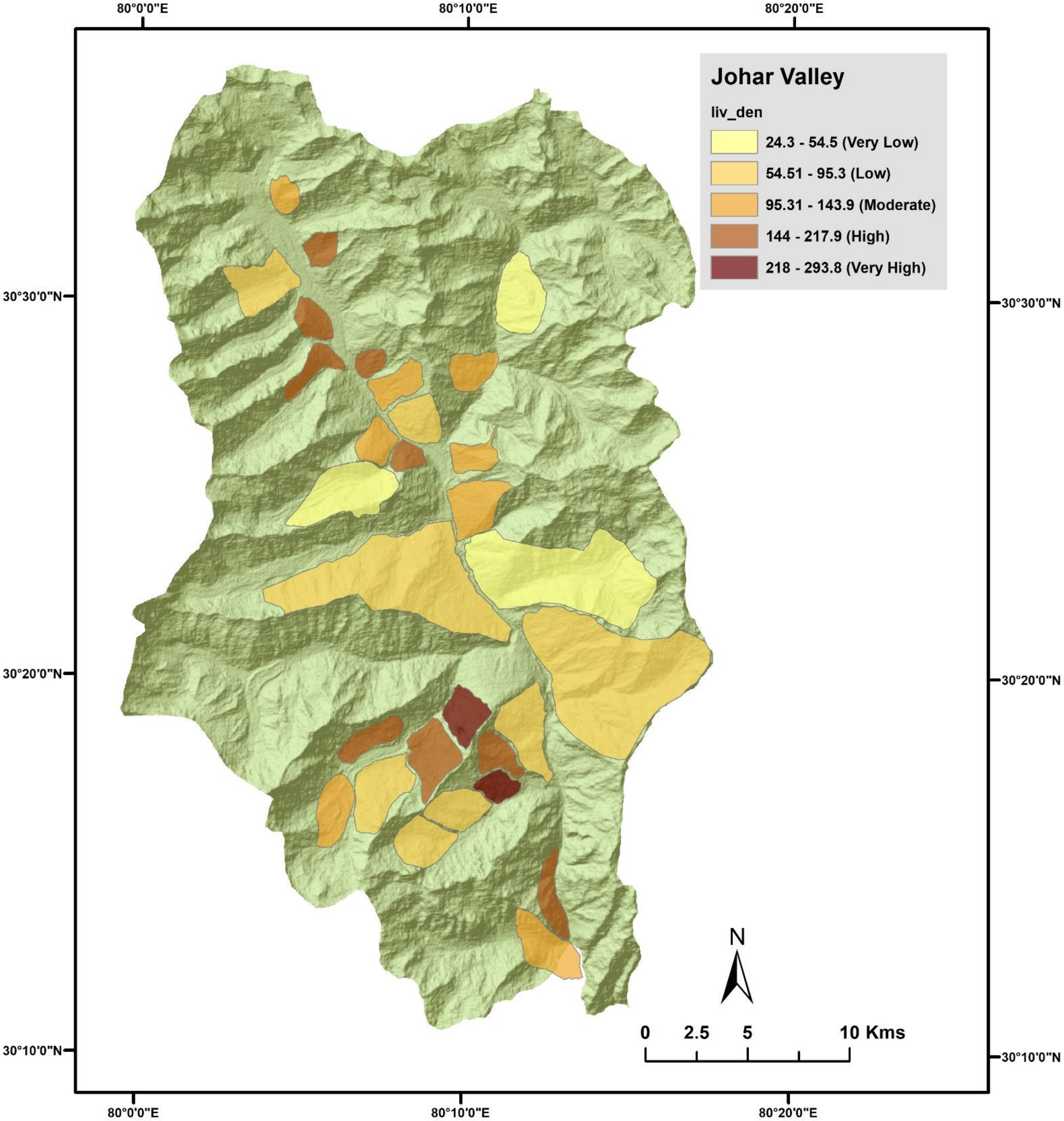

Figure 41 : Map of Johar valley showing livestock grazing intensity in the sampled alpine patches

5.4.1 Influence of livestock intensity

When the naïve distribution and suitable habitat of blue sheep were compared with the livestock use intensity areas, the results revealed that the moderate, high and very high intensity zones overlapped with the high suitable habitats of blue sheep (Table 13). The suitable habitat of blue sheep showed a decrease in area from the naive distribution when livestock intensity was included. The results showed a reduction of blue sheep habitat from 70% to 47% (Figure 42). Livestock grazing areas overlapped with 49% (~ 110 km^2) of the highly suitable habitat area of blue sheep (Figure 43). The results also showed that livestock grazing areas overlapped 39 % (~ 259 km^2) of the blue sheep resource selection probability area (Figure 44, Table 14). In case of tahr, the results revealed that the moderate and high livestock intensity zones coincided with the high suitable habitats of tahr. However, the results revealed that tahr habitat remained the same in area after inclusion of livestock intensity (Figure 45). The results showed that livestock grazing areas overlapped with 59% (~ 50 km^2) of the highly suitable habitat of tahr (Figure 46, Table 13). Livestock grazing areas had an overlap of 100 % (~ 185 km^2) with the tahr resource selection probability area (Figure 47, Table 14). In case of musk deer, the results revealed that the high and very high intensity zones coincided with high suitable habitats of musk deer. There was a reduction of musk deer habitat from 43% to 26% when livestock intensity was included (Figure 48, Table 13). Livestock grazing areas had an overlap of 68% (~ 17 km^2) with the highly suitable habitat of musk deer (Figure 49).

Table 13: Overlap of livestock use area with suitable habitat of wild ungulates

Species	Overlap area	% overlap
Blue sheep & livestock	110.47	49
Tahr & livestock	49.99	36
Musk deer & livestock	17.14	7

Table 14: Overlap of livestock use area with resource selection probability area of wild ungulates

Species	Overlap area	% overlap
Blue sheep & livestock	259.37	39
Tahr & livestock	51.25	28

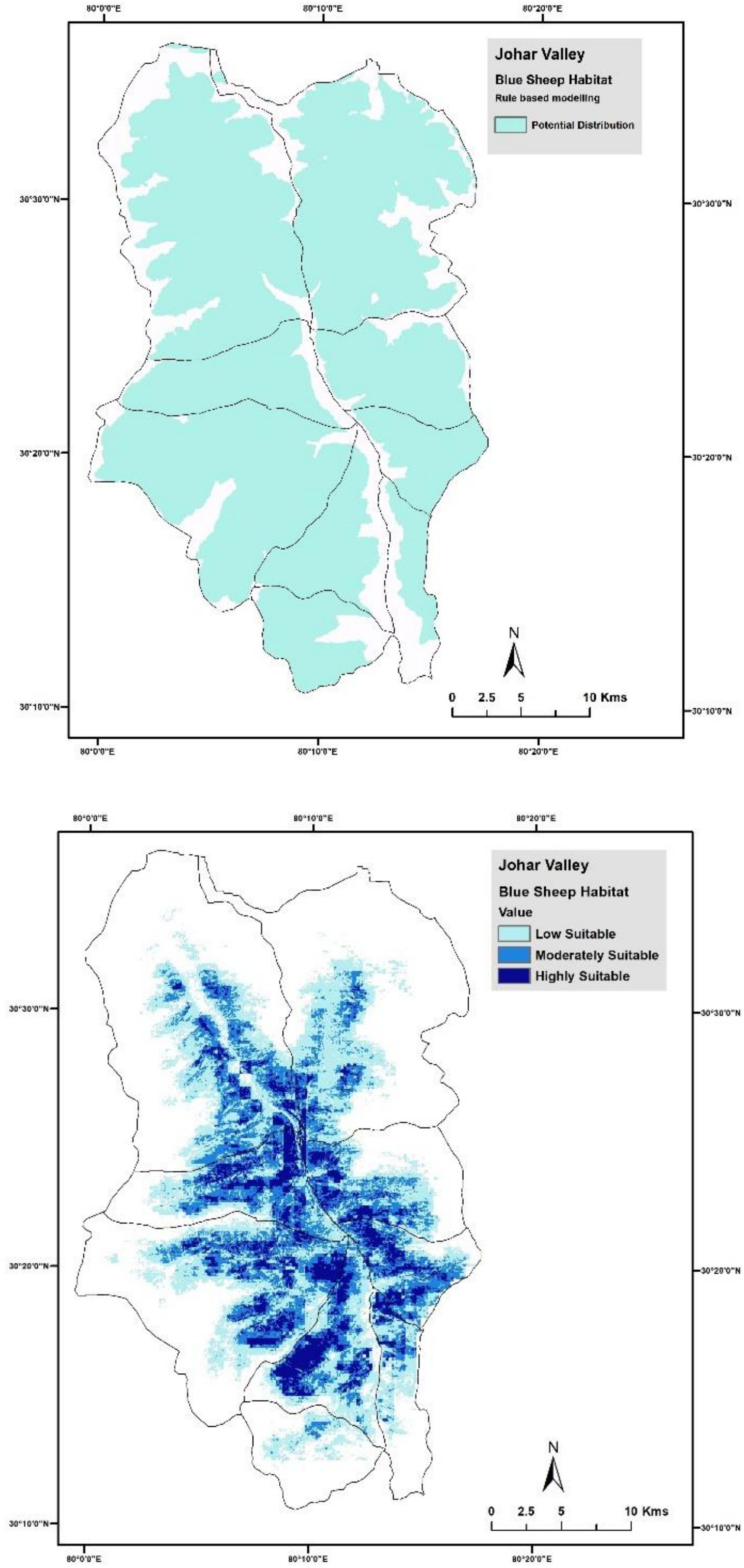

Figure 42 : Map of Johar valley showing (a) potential habitat of blue sheep without inclusion of livestock and (b) suitable habitat after inclusion of livestock

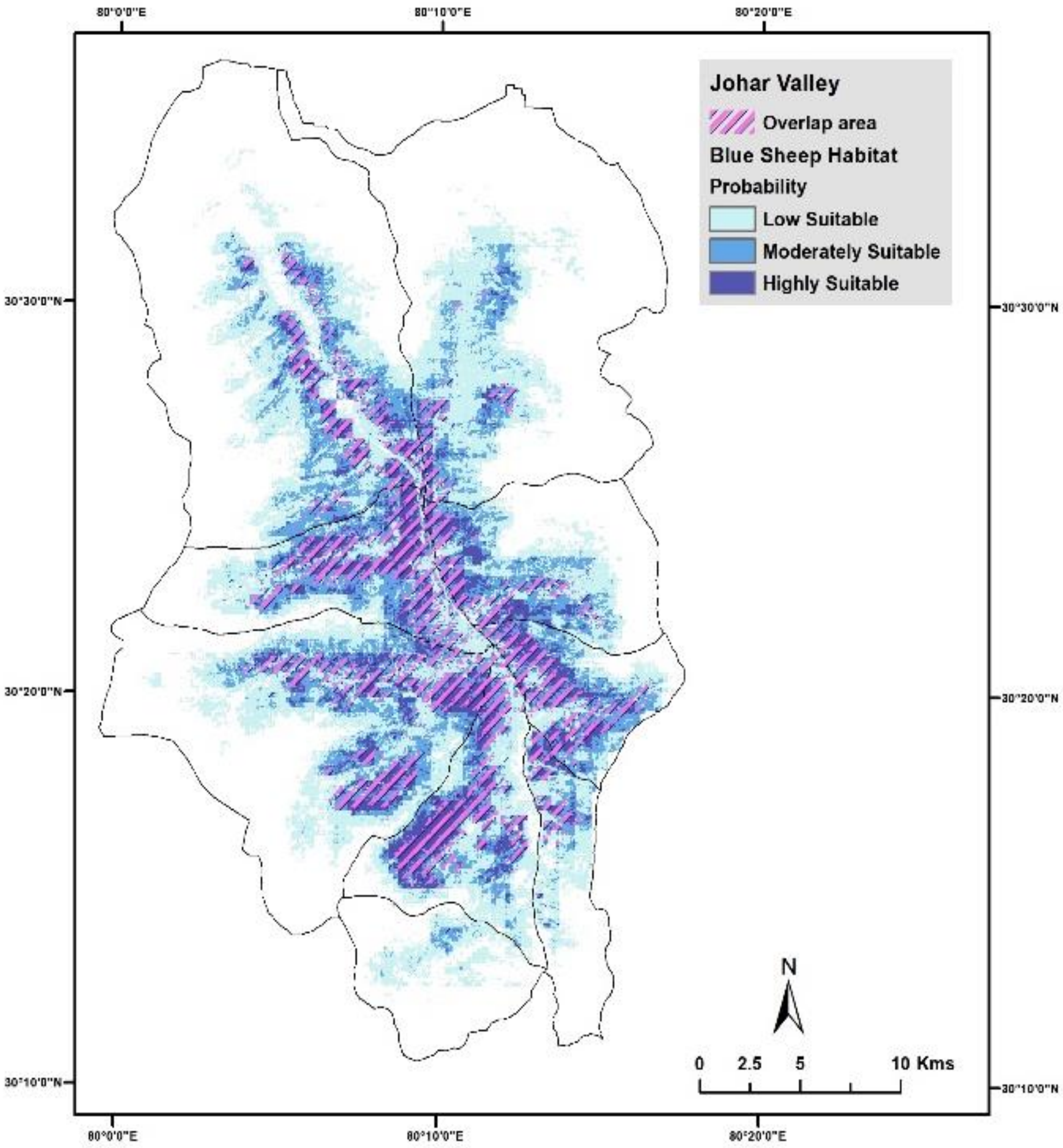

Figure 43 : Map of Johar valley showing overlap of distribution between livestock grazing areas and blue sheep suitable habitat

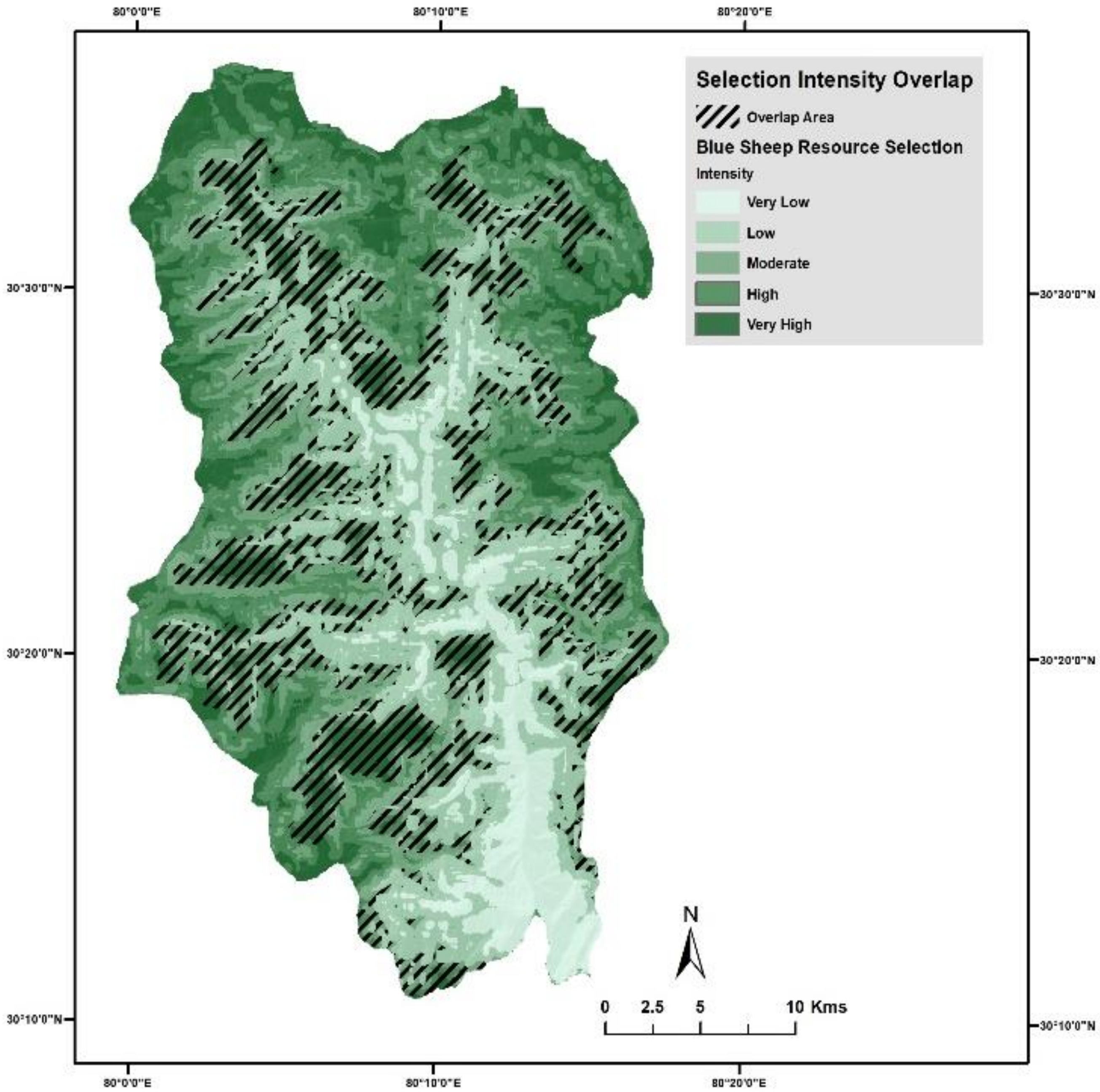

Figure 44 : Map of Johar valley showing overlap of probable resource selection areas between livestock and blue sheep

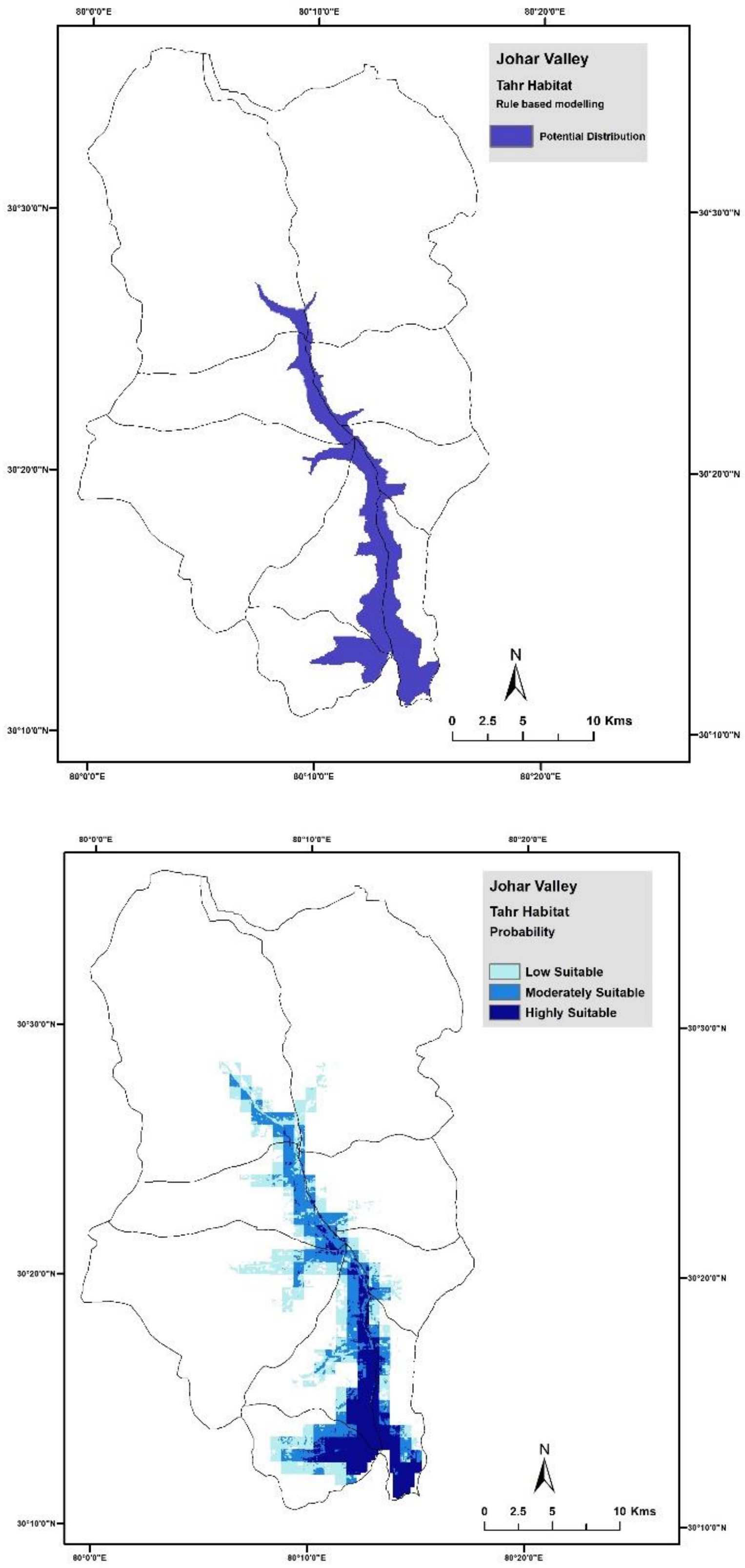

Figure 45 : Map of Johar valley showing (a) potential habitat of tahr without inclusion of livestock and (b) suitable habitat of tahr after inclusion of livestock

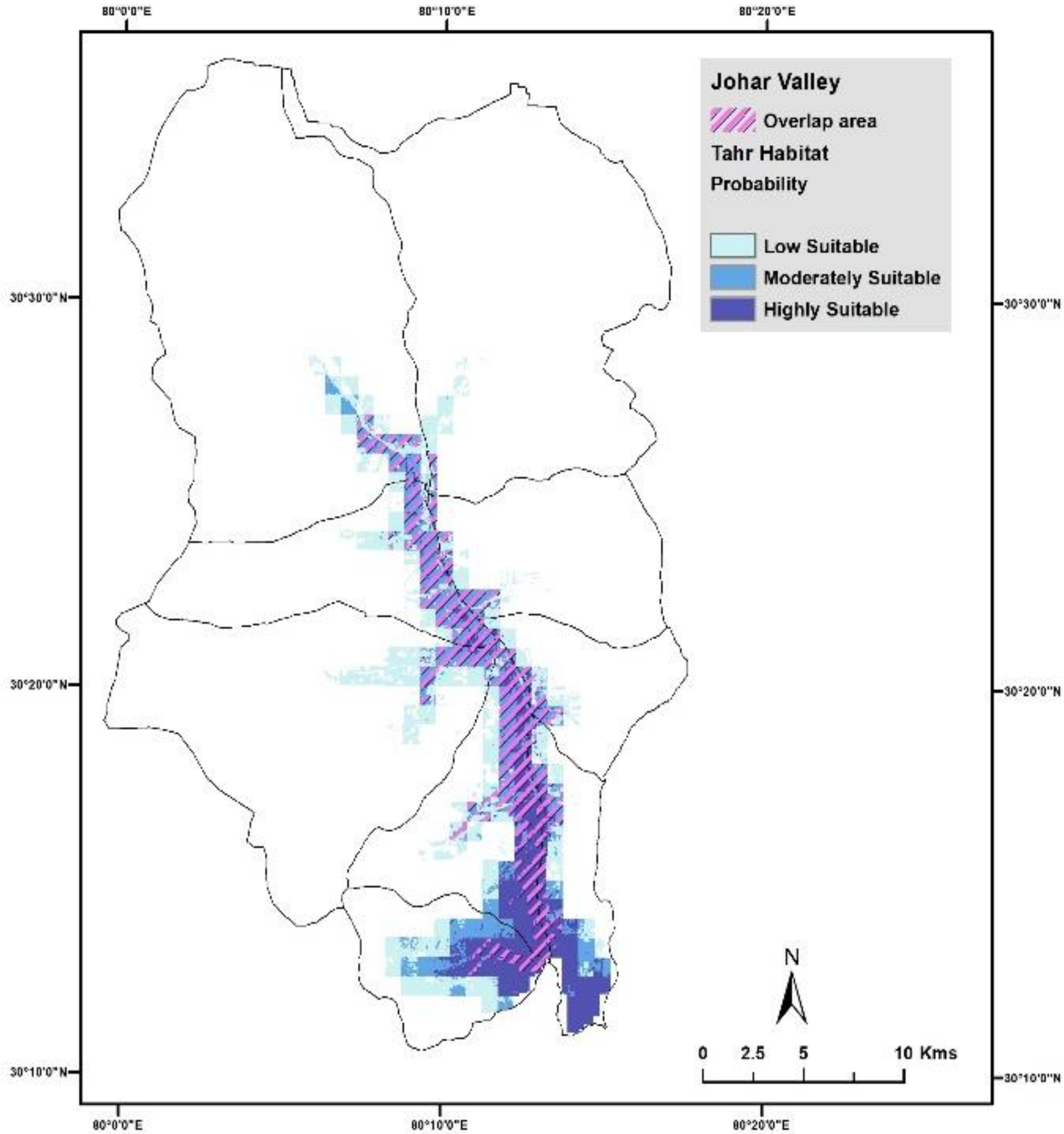

Figure 46 : Map of Johar valley showing overlap of distribution between livestock grazing areas and tahr suitable habitat

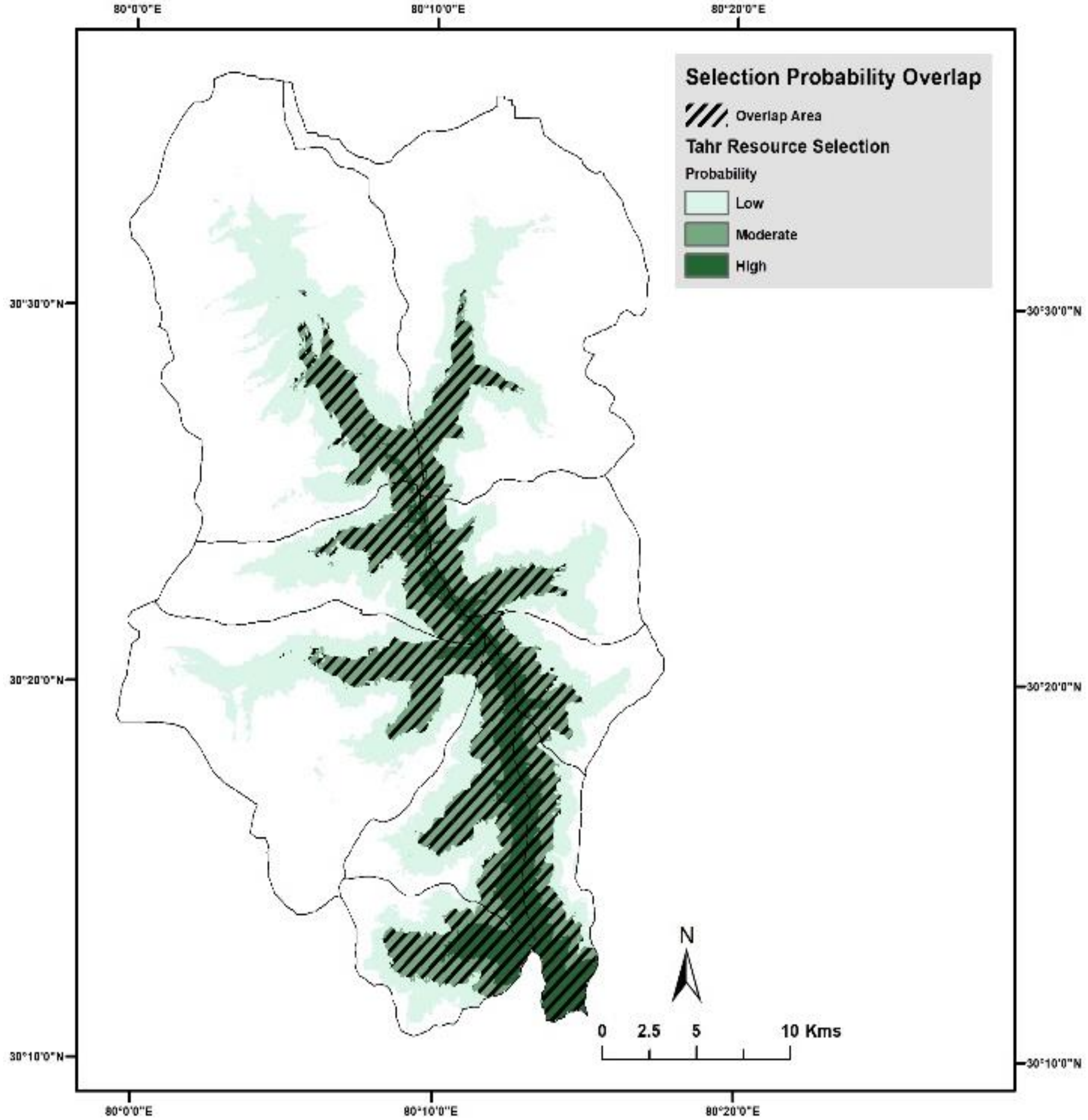

Figure 47 : Map of Johar valley showing overlap of probable resource selection areas between livestock and tahr

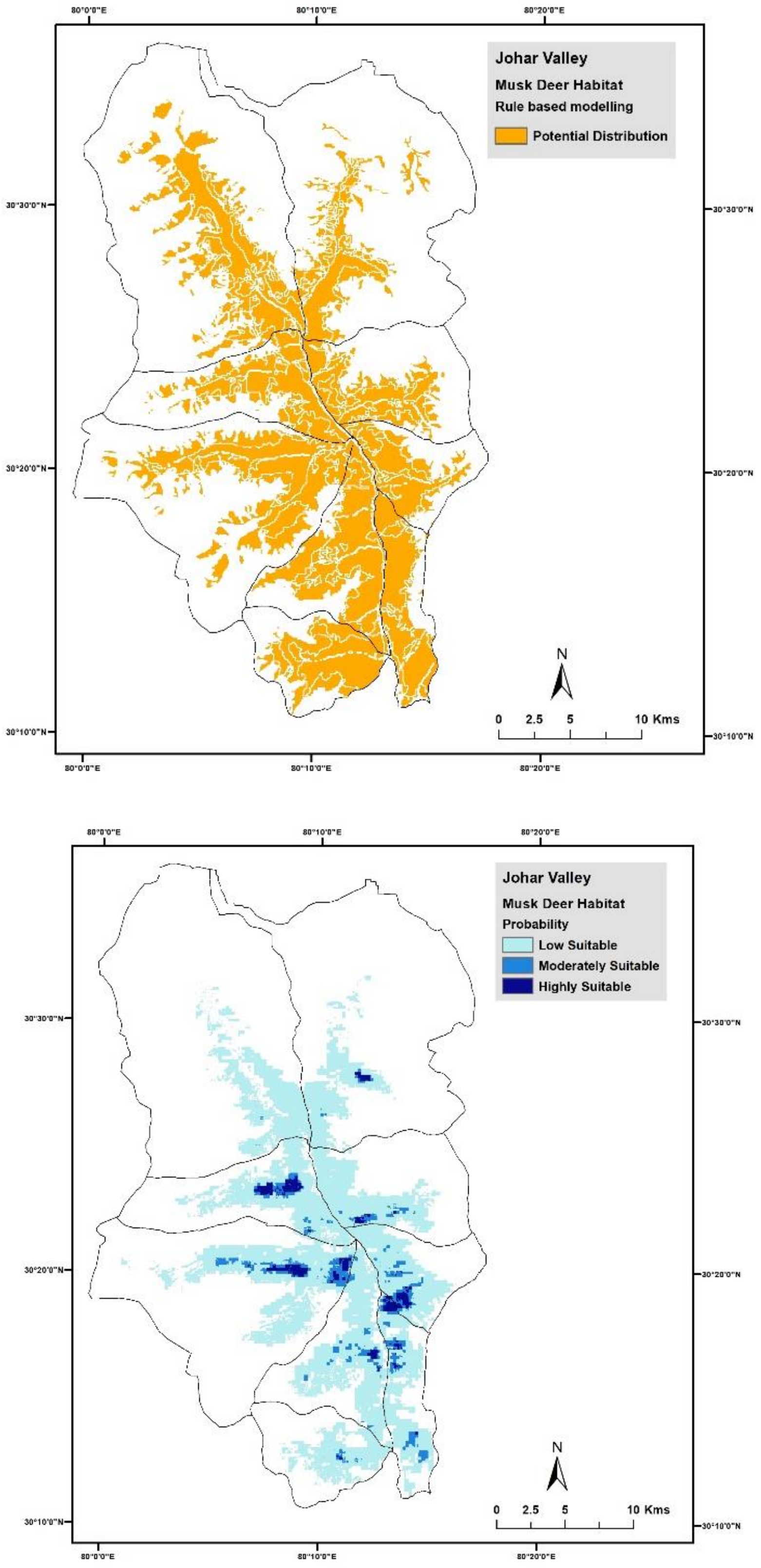

Figure 48 : : Map of Johar valley showing (a) potential habitat of musk deer without inclusion of livestock and (b) suitable habitat of musk deer after inclusion of livestock

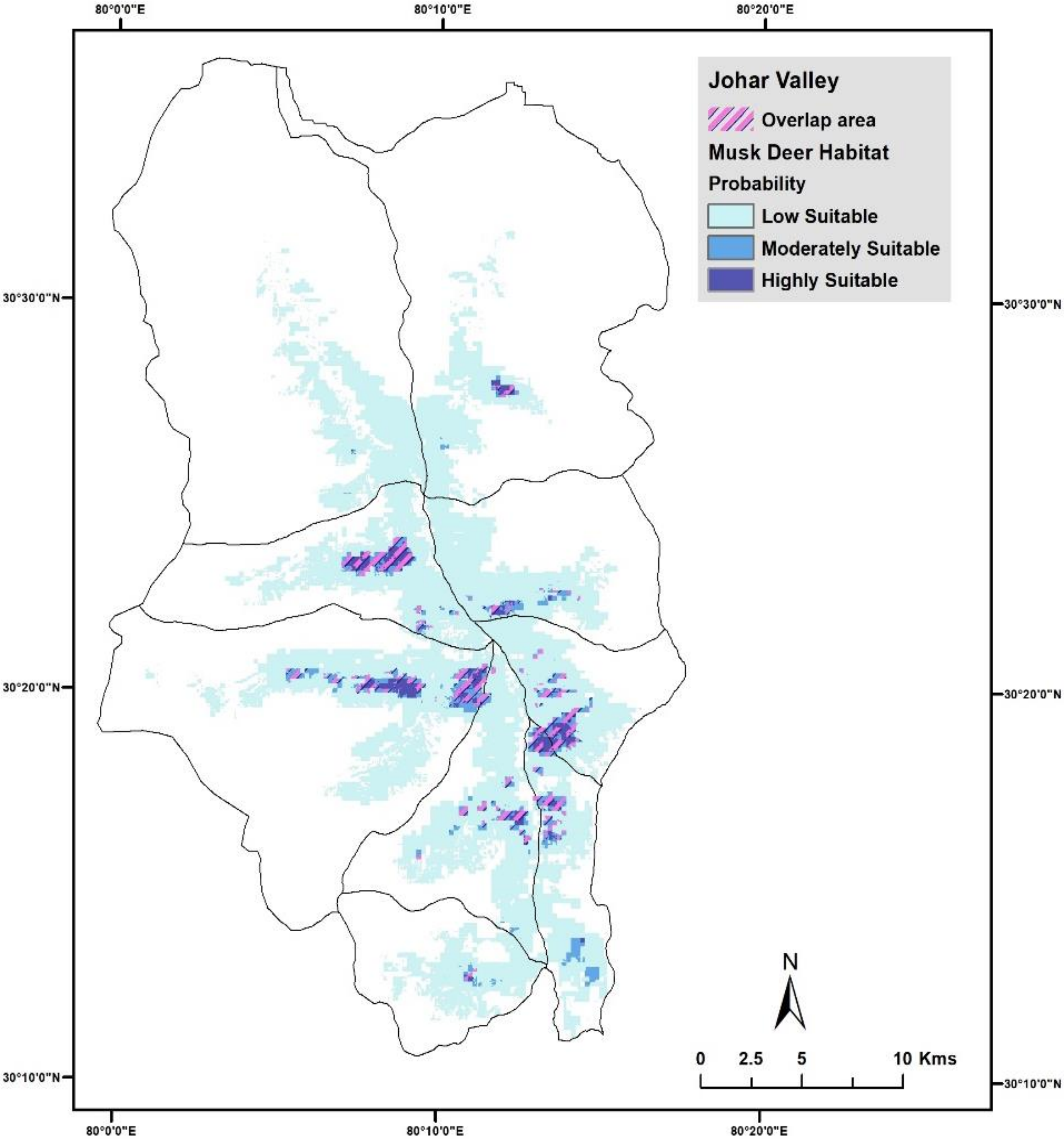

Figure 49 : Map of Johar valley showing overlap of distribution between livestock grazing areas and musk deer suitable habitat

5.4 Discussion

High niche overlap along with the physical presence of herders and their livestock converts into competition when the resources are limited and in case of wild ungulates. Rawat and Adhikari (2005) showed that in the summer season, most alpine meadows are heavily grazed by livestock leading to low abundances of wild animals in the Western Himalaya. My results suggested that there is a considerable amount of overlap between high intensity areas of livestock use and high suitability and selection probability areas of all the three study species in Johar Valley. The areas of high intensity use of livestock are those pastures with good quality nutritious grasses selected by pastoralists. Combining the results from the previous chapters, it is imperative that presence of livestock, affects the distribution and resource selection patterns of the wild ungulates. This is reflected in the results by a reduction in their distribution range.

The results from my previous chapters suggested that blue sheep avoid the optimal grazing patches by selecting different topographical features when livestock is present. Blue sheep migrated to the higher elevations in the few areas with alpine and subalpine vegetation which were devoid of livestock. A similar pattern has been observed by Ahmad et al. (2016) in Markhors. Shrestha and Wegge (2008) suggested that high stocking densities of livestock might lead to competition with blue sheep. My results concurred with previous studies suggesting that blue sheep mainly used suboptimal areas with low or no livestock density during the summer-monsoon season. However, with the exclusion of livestock, they might prefer the optimal patches. Musk deer, on the other hand, seemed to use livestock areas to a relatively larger extent. It is possible that its cryptic habits using alpine and sub-alpine scrubs mainly at night, might facilitate their coexistence with livestock (Ahmad 2014). Areas with good shrub cover, used by livestock, provide both forage and escape cover to species like musk deer (Green 1987) and thus, effect of livestock intensity on this vegetation might affect the ecology of musk deer in such areas. A study by Kala, Singh & Rawat, (2002) showed that due to the effect of livestock grazing, plant species richness and diversity was low in Great Himalayan National Park in Himachal Pradesh than Valley of Flowers National park in Uttarakhand which had no livestock grazing. The exclusion of livestock might facilitate habitat improvement for musk deer in Johar valley. Tahr seemed to be the least affected and though there is an overlap, they used the high livestock intensity areas to a lesser extent. This pattern might be due to the use of precipitous terrain by tahr and thus spatially segregating themselves from livestock.

My results also revealed that the smaller patches had very high intensity of use by livestock than the larger patches. This may be an artefact of use of single patches by single herder groups which is preferable to them rather than sharing the larger pastures with other herder groups which might reduce the forage availability as well the monetary rate. My findings suggest that there is less chance of sustaining wild ungulates in these patches due to livestock presence. Management authorities need to limit the amount of livestock grazing within high altitude rangelands to check the increasing livestock intensity and further degradation of the alpine meadows. Larger patch sizes allow adequate spatio-temporal separation between wild ungulates and livestock. This tied along with lower pressure of tourism and managed pastoral practices might lead to an increase in wild ungulate abundance and lesser avoidance of optimal patches by them. However, any management decisions have to be taken, keeping in mind the traditional aspect of pastoralism in the Himalayan region. This can be achieved by participatory interventions with the current pastoralist community of the Johar valley.

Chapter 6: Synthesis and Conservation Implications

6.1 Background

Concerns related to development in the IHR revolve around managing local resources in such a way as to conserve and enhance environmental values and promote socioeconomic development. It is essential to have a comprehensive knowledge about the ecology of species and the influence pastoral practices on them across the IHR at a landscape level in order to fill the research gaps. There are many areas in the IHR which are lesser known and no scientific ecological study has been conducted. For such areas, a baseline study providing an information base against which we can monitor and assess the progress of an activity and its effectiveness during implementation is essential. Baseline data is the standard information present or developed, on the basis of which further study is pursued and compared. Though mountain ecosystems are difficult for conducting large scale scientific studies, the advancement of sampling & analytical tools/ techniques in recent years in the field of remote sensing, radio telemetry and genetics have paved the ways for more accurate ecological information from such areas. Spatial information about local populations of wild and domestic ungulates is important. To manage and monitor wildlife population, managers need data in a spatial domain depicting ecology of wildlife and their interaction with human activities. Thus, a dynamic spatial information in the form of accurate, high-resolution maps which can be updated with time is the need of the hour. Wild ungulates tend to avoid competition by differential resource selection patterns, shifting from limited optimal patches to sub optimal areas. Advantage with topographical factors for wild ungulates allows it to use some habitat and utilize those resources which otherwise would not have been possible due to presence of livestock. Thus, information about the importance of foraging behavior of wild ungulates is essential for their survival and monitoring interventions.

6.2 Ecological insights

My study explored the current ecological situation of three wild ungulates belonging to different habitat types and their interactions with livestock in the Johar valley. In the third chapter, I studied the current distribution status of the study species with and without livestock in Johar valley. Blue sheep, inhabiting the exclusively the subalpine, alpine and transition zones showed a wide distribution probability in the valley without livestock. However, due to almost similar body size and diet patterns with the livestock, inclusion of the livestock parameter reduced their distribution range considerably. It can be said that blue sheep was the most affected with the presence of livestock. Himalayan tahr, residing mainly in areas with steep cliffs in the subalpine and temperate zones had isolated pockets as their distribution range. They were ecologically separated from the livestock based on their body size, diet and habitat type and hence, not much affected by their presence. This is because, the pastoralists do not use tahr inhabiting areas for grazing their livestock and these areas are inaccessible for humans in the context of Johar valley. Musk deer also showed distribution pattern in isolated pockets of alpine scrubs and subalpine zones. Though their distribution was affected by inclusion of livestock, the species being mainly elusive and nocturnal temporally separated from the domestic ungulates. However, data on musk deer was sparse and the conclusion can be definite if more camera trapping can be done in the area. Livestock preferred similar environmental covariates with the wild ungulates in their suitable distribution ranges revealing the hint of competition with them. All species preferred covariates concurring with their foraging behavior which was the nutritious vegetation of the monsoon season. My results gave an idea regarding the current population status of the study species.

In the fourth chapter, I tried to evaluate the resource selection patterns of blue sheep, tahr and livestock. The study revealed that though blue sheep selected similar vegetation types as those of livestock, they shifted their niche based on other topographic factors. This led to selection of probable suboptimal grazing patches. Interestingly, converse to studies from the Trans-Himalaya, I found that blue sheep maintained an optimal distance of 600 m -1000 m from their escape terrain which is far from the optimal distance maintained by the species (maximum 250 m) in the Trans-Himalaya. Thus, blue sheep had a tradeoff between food and safety and though they avoided the optimal patches, remained closer to foraging patches which are not available closer to the cliffs. On the other hand, tahr having different diet and topographic preferences remained separated from livestock in terms of resource selection as well.

In the fifth chapter, I tried to explain the influence of livestock intensity on these ecological aspects. I found that the distribution and resource selection patterns of blue sheep was affected the most due to livestock intensity and areas which were highly preferred by blue sheep overlapped with high livestock use intensity areas. This caused a probable competition between the two species leading to avoidance of the preferred patches by blue sheep. Musk deer also showed a similar pattern but they were separated temporarily as mentioned before. Himalayan tahr was least affected by livestock intensity though their distribution and resource selection ranges overlapped the most. However, because of topography, tahr ecologically separated themselves from livestock. The smaller alpine patches had the highest livestock use intensities in the Johar valley.

My study revealed that livestock intensity is an important factor which should be considered while studying the ecology of mountain ungulates in different habitat types. Though some species might not be affected directly, the habitat which they reside in might get affected. It is important to conserve the rangeland habitat harboring these mountain ungulates and prevent them from being overused by livestock. My study also showcases the use of recent analytical techniques for sampling mountainous species without radio telemetry. These advanced techniques are important to accurately interpret results of data deficient studies with small sample sizes as in the case of montane landscapes. My study provides a baseline ecological information regarding mountain ungulates in the Johar valley which was not available previously. My study also depicts the current status of livestock and their grazing intensity in the valley. Previous status of livestock was available in 2010 and my study updates this information.

6.3 Conservation implications

Distribution and resource selection patterns of the three wild ungulates in my study, can be used to infer the relationship between the animal’s space use and its environmental niche. In this regard, a sound knowledge of spatial factors facilitates prioritization for management strategies. My study will help inform monitoring and planning efforts focusing on identifying and protecting important habitat resources in the IHR. The spatial information represented in the distribution, resource selection, livestock intensity and overlap maps in this study can serve as a tool for directing efforts towards planning managed pastoral practices in the Johar valley. My predictive maps, when applied appropriately, can also help identify areas across Indian Himalayan landscapes with a high potential of being good blue sheep, tahr and musk deer habitat. Identification of such areas will assist with large-scale land-use planning, management and recovery efforts for threatened species (Boyce and McDonald 1999; Boyce and Waller 2003). The coefficients and predictive maps generated from my study can also serve to generate hypotheses for future research and direct population inventories across areas where relatively little is known about the distribution of mountain ungulate species. Areas with more number of direct and indirect evidences of species like Martoli, Ganghar and Laspa and areas which are not used by livestock can be started as future conservation and control sites. I recommend that these models and maps, and results from similar applications, be used as baseline information for future research. According to Mladenoff et al. (1999), observations from further research and inventory efforts can be used in an integrative fashion to assess and update resulting maps. According to my conclusion, I suggest that land managers use distribution maps and treat the overlapped areas as conservation priority areas.

I posit that conservation of threatened and important prey species in Himalayan rangelands depends on managed pastoral practices and community participation. Garcia et al. (2012) suggested that most harmful effects of grazing arise from improper management of very high grazing pressure areas. In this regard, in the Johar valley, managed pastoral practices can include exclusion of particular pastures from the priority areas for livestock grazing and cohesion of pastoralist groups for sharing of pastures instead of individual pastures. Those areas can be dealt with by the management for managed pastoral practices and inclusion of pastoralist communities to maintain a biodiversity information flow and help in conservation of wildlife. Pastoralists have a detailed knowledge of the rangeland biodiversity and climate. This knowledge can be used in the Johar valley as well as other rangeland areas of the IHR to assess to conserve and monitor the biodiversity. Pastoralists can be provided with incentives to maintain a steady information on the population and behavior of wild ungulates as well as other species of conservation importance and in turn the health of the overall ecosystem.

I posit that a large patch size and low livestock intensity is the recipe for coexistence with wild ungulates. Rather than abandoning pastoralism entirely, the rejuvenation of traditional practices and indigenous knowledge is important to secure sustainable livelihoods for millions of pastoralists and to maintain rangeland biodiversity and ecosystem services (Seid, Kuhn & Fikre 2016). The key to that is to connect the fragmented patches and improvise pastoral practices in the area. Ecologically, sites with better conservation status are those which represent the full range of alpine habitats (and microhabitats), without human induced habitat degradation. Management authorities need to rationalize livestock grazing within high altitude landscapes in order to pursue conservation objectives and check further degradation of the alpine meadows in the Himalaya. My study provides helpful insights for managing rangelands at a landscape scale, which can be tied with microhabitat level dietary patterns, yielding a more all-encompassing approach to proper conservation measures in the future. My study calls for a regular landscape level assessment of grazing pressure, wildlife abundance and status of meadows in the IHR.

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Details of peer-reviewed journal of published paper

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1.	Zoological Studies	Biological Research Center, Academia Sinica, Taiwan	1810-522X

Details of Conferences attended

1. **Bhattacharya, A.,** Habib, B., Mondal, I. & Shrotriya, S. (2016). **Predicting Species Occurrence in a Mountainous Landscape using Species Distribution Modelling.** In National Symposium on Recent Advances in Remote Sensing and GIS with special emphasis on Mountain Ecosystems and Annual Conventions of Indian Society of Remote Sensing and Indian Society of Geomatics. Dehradun, India: Indian Institute of Remote Sensing, 07 – 09 December, 2016. (Oral)

2. **Bhattacharya, A.,** Habib, B & Rawat, G. (2018). **In search of the greener side: Do wild ungulates avoid optimal grazing habitats due to pastoralism in Himalayan rangelands?** In Conservation Asia Conference, Society for Conservation Biology, Asia Section. Bishkek, Kyrgyzstan: American University of Central Asia, 6 – 10 August 2018. (Oral)

3. **Bhattacharya, A.** and Habib, B. 2019. **Developing distribution and habitat suitability maps of key mammal species in a Western Himalayan Landscape, India.** In International Congress for Conservation Biology. Kuala Lumpur, Malaysia: Kuala Lumpur Convention Centre, 21 – 25 July 2019. (Oral)

ISRS

CERTIFICATE OF PARTICIPATION

This is to certify that Dr. / Mrs. / Mr. / Ms. Ankita Bhattacharya (Reg. No. 652) of WII, Dehradun has presented a (oral) paper titled "Predicting Species Occurrence in a Mountainous Landscape Using Species Distribution Modelling" in the National Symposium on "Recent Advances in Remote Sensing and GIS with Special Emphasis on Mountain Ecosystems" & Annual Conventions of Indian Society of Remote Sensing & Indian Society of Geomatics held during December 7 - 9, 2016 at Dehradun, India.

Organising Secretary

Date: December 9, 2016

Place: IIRS, Dehradun

American University of Central Asia

CONSERVATION ASIA 2018

Society for Conservation Biology
Asia Section

CERTIFICATE OF PARTICIPATION

This is to acknowledge that

Ankita Bhattacharya

participated in this conference and gave a talk titled

In search of the greener side: Do wild ungulates avoid optimal grazing habitats due to pastoralism in Himalayan rangelands?

Prof. Zheenbek Kulenbekov
American University of Central Asia

Antony J. Lynam

Antony J. Lynam Ph.D
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Certificate of Presentation

We confirm that **Ankita Bhattacharya** presented an oral presentation entitled:

Developing distribution and habitat suitability maps of key mammal species in a Western Himalayan Landscape, India

the 29th International Congress for Conservation Biology

"Conservation Beyond Boundaries: Connecting Biodiversity with Communities, Government and Stakeholders"

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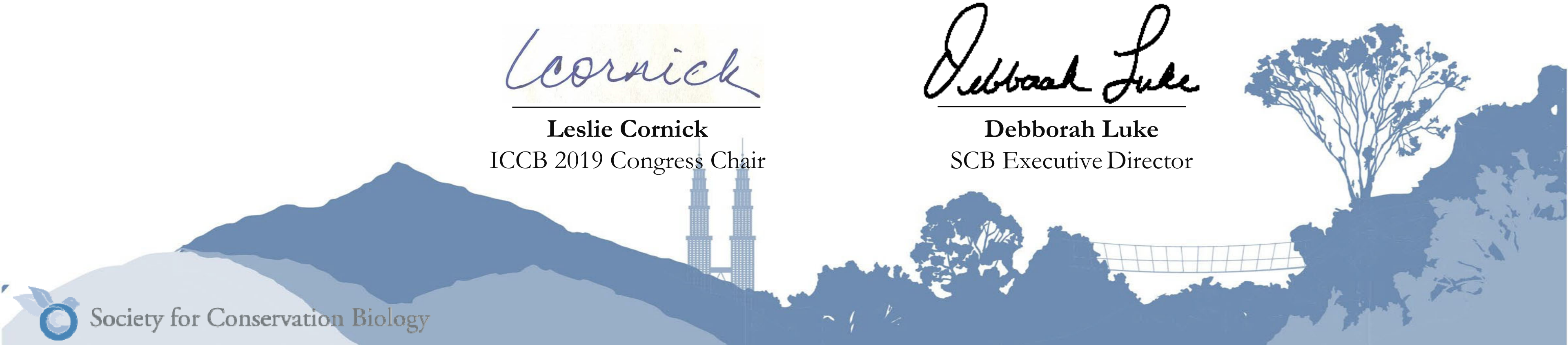

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Blue Sheep Resource Selection in Alpine Grasslands of a Western Himalayan Landscape – A Point Process Approach

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In-depth knowledge of distribution and factors influencing it is important for species conservation and management. Many forms of such data have led to the development of new analytical techniques for better interpretation. For mountainous terrains with certain limitations, species data are obtained in the presence-only form. The point process model is one of the recent approaches for modelling such data, taking care of pseudo-absences and spatial independence. For conservation in regions with limited resources and species with similar ecological requirements, it is important to properly assess the extent of competition extent between wild and domestic species. We attempted to use point process framework to estimate the function of resource selection in blue sheep (*Pseudois nayaur*) in areas influenced by pastoralism in a western Himalayan region. Our study is the first attempt to use this framework to estimate resource selection on a dataset not collected using radio-telemetry. Spatial locations of blue sheep and livestock and a background sample of random points with six topographic covariates were used to model resource selection probability via intensity function. Blue sheep showed its predicted presence in areas with open vegetation coinciding with alpine meadows, influenced by southern aspect keeping a threshold distance of 600–1000 m from cliffs (escape terrain). Livestock, also showed presence probability in open vegetation, but at lower altitudes, mainly on valley floors. Our results suggest that though blue sheep continued to use the same habitat type after livestock arrival, they selected different resources based on topographic factors. Livestock were in areas where it was convenient for pastoralists to establish campsites and where nutritious grasses were present, making it feasible to graze. Thus, we argue that the probable shift in habitat for blue sheep from optimal areas occurs due to livestock presence, which might disturb their nutritional balance. Our study provides helpful insights for managing rangelands, which when tied with dietary patterns will give a better idea for proper conservation measures in the future.

Key words: Uttarakhand, Johar valley, Pastoralism, *Pseudois nayaur*, Mountain ungulates.

BACKGROUND

Long term conservation of a species requires an understanding of the population genetics and ecology of that species through in-depth analysis of their distribution and the factors that influence that distribution (Franklin 2010; Zhai et al. 2017). Distribution of a species is dependent upon particular biotic and abiotic factors of their habitat, which together are considered resources. Hence, distribution and resource selection of a species are closely related entities. Resource selection occurs in a hierarchical manner, starting broadly from the geographic range of species to selection of particular elements within the general features of their habitats

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within their home range (Manly et al. 2002). Ungulate species with overlapping distribution ranges and similar ecological requirements are known to compete for these resources (Namgail 2001; Darmon et al. 2011). Various forms of distribution data like presence-absence, presence only, use-availability and count data have been used for development of specialized analytical techniques through machine learning (Aarts et al. 2012). Such studies have gained huge popularity in recent years, inviting ecologists to better understand species ecology using these methods. New techniques in the framework of older ones are being developed to provide better interpretations by accounting for the major shortcomings such as sampling bias, data deficiency, and spatial independence and other limitations (Warton and Shepherd 2010; Aarts et al. 2012; Renner et al. 2015).

Such limitations are more acute in mountainous regions where terrain, accessibility, logistics and elusiveness of the species restrict movement of observers. For such terrains, information on species distribution mostly comes as occurrence data, *i.e.*, locations where species have been observed. The presence-only data lacks any corresponding information about species absence (Renner et al. 2015). A common approach for analysing such data is randomly chosen background points or pseudo absences (Phillips and Elith 2013). Though there are several ways to model such data, *e.g.*, maximum entropy (MaxEnt) modelling of species distributions (Phillips et al. 2006; Phillips and Dudík 2008; Elith et al. 2011), and the logistic regression model along with its various generalizations (Austin 2002; Elith et al. 2006), most of them are limited by various shortcomings. These include model specification by not including prior construction of pseudo absences, leading to problems in interpretation as the model parameters are functions of the number of pseudo absences (Warton and Shepherd 2010). The point process model is one of the recent approaches to modelling that uses presence-only data (Warton and Shepherd 2010; Aarts et al. 2012; Hooten et al. 2013; Johnson et al. 2013; Renner et al. 2015). This model addresses the weaknesses of randomly chosen pseudo-absences (Warton and Shepherd 2010) by focusing on the observed data. This model assumes locations of point events to be independent, and the intensity (expected number of presence per unit area) at those points can be modelled as a function of the explanatory variables. Thus it takes into account the locations of the organism from where it has been reported rather than where it occurs. This framework has been linked to the common approaches for fitting presence-only models over the past five years. The point process model provides advances to these models by having the criteria for choice of pseudo-absences, checking assumptions and accounting for observer bias for better ecological insights (Renner et al. 2015). In this study, we used this framework to analyse the resource selection function of a mountain ungulate in an upland valley of Western Himalaya, which is heavily grazed by migratory livestock during summer-monsoon season. Blue sheep (*Pseudois nayaur*) is a widely distributed mountain ungulate forming the main prey base for the endangered Snow leopard (*Panthera uncia*) (Schaller et al. 1987; Oli et al. 1993; Chundawat and Rawat 1994). There is a considerable overlap in the distribution of these two species across the Himalayan region, and thus presence of one species indicates the occurrence of other.

The alpine rangelands in Himalaya provide a wide range of habitat mosaics supporting unique arrays of biodiversity and ecosystem services. Transhumant pastoralism is one such service that has thrived here for centuries (Bhasin 2013). In the last few decades, changes in livestock holdings, loss of traditional grazing patterns and knowledge systems (Farooquee and Nautiyal 1999) have greatly affected the wildlife, especially the wild ungulates (Bagchi et al. 2004; Mishra et al. 2004; Namgail et al. 2007). In light of current landscape approaches to conservation, it is becoming important to assess the pressures of pastoralism across a landscape and degree of competition of livestock with wild ungulates based on available resources for a proper monitoring/management plan for rangelands. Previous studies in the Himalayan region have shown that wild ungulates tend to avoid areas that are heavily used by domestic livestock (Kala et al. 2002; Bagchi et al. 2004; Mishra et al. 2004; Namgail et al. 2007; Shrestha and Wegge 2008; Kittur et al. 2010). In the sub-alpine and alpine zones of the Greater Himalaya, optimal resources are confined to specific patches and available only for a short duration (June–September) (Bhasin 1988; Sharma et al. 2003). Wild ungulates may be forced to forage in sub-optimal habitats due to livestock grazing in the limited optimal habitats. By sub-optimal we mean habitats which are more rugged and which require more energy consumption by the species. This might disturb their nutritional balance as they spend more energy avoiding the livestock grazed areas, and consequently they may be competitively excluded from better habitats (Schaller 1977; Mishra et al. 2004; Namgail et al. 2007). Thus, resource selection patterns of wild ungulates in the presence or absence of livestock grazing need to be analysed to evolve site specific management strategies for effective conservation of these species. Estimating resource selection is one powerful methods for identifying areas within a landscape that are highly used by a population of animals. It is generally assumed that if a species selects certain habitat units or food resources disproportionately to their availability or 'patches' with certain characteristics, it improves their fitness, reproduction, or survival (McDonald et al. 2013). This justifies actions to manage natural resources targeting such characteristic patches and monitor population distributions of species in these areas.

Species distribution patterns are strongly influenced by the availability of habitat resources during various seasons and the presence of predator and prey species. According to the habitat selection theory (Hutchinson 1957; Orians and Wittenberger 1991), sympatric species with overlapping niches show behavioural characteristics that separate them spatially or temporally within the same range (Namgail 2001; Darmon et al. 2011). Prior knowledge about the distribution of various resources on which the species depend allows people to characterize the distribution and abundance of these species by resource selection functions (RSFs). RSF yield values are proportional to the probability of use of a resource and helps in determining the probability that a habitat is being used by the animal (Boyce and McDonald 1999; Boyce et al. 2002). This study aimed to find the resource selection probability of blue sheep and the factors that influence this in areas influenced by pastoralism. We chose to determine whether, in presence of livestock, wild ungulates selected resources based on topographic factors and avoided optimal habitats. We also chose to see which factors govern the resource selection probability of blue sheep in pastoralism influenced areas. Under given topographic conditions and pastoralism activities, a resource item for a species could be highly favoured but difficult to access, and hence less utilized. Conversely, less favoured resources might comprise a large portion of used resources out of necessity if they are the only ones available to the species (Manly et al. 2002). This pattern might lead to a probable shift or avoidance of better resource areas by the wild ungulates. We estimated the resource selection through point process model. Here, the resource selection function is proportional to the expected density of observations (Aarts et al. 2012), which provides more accurate insights into relative patterns of species abundances in data-deficient areas. This study is a first attempt to use the point process framework to estimate resource selection on a dataset not collected using radio-telemetry.

MATERIALS AND METHODS

Study area

The ~950 km^2 study area forms the upper catchment of the Gori River, referred to as the Johar Valley. It lies between 80° to 81°5'E Longitudes, and 29°5' to 30°N Latitudes in Uttarakhand state of Western Himalaya (Fig. 1a b c). The valley covers an elevation range of 1918–6727 m and falls in the Biogeographic Province 1C under the Trans-Himalayan biogeographic zone of India (Kumar et al. 2017). This forms a transition zone of biogeographical elements of western

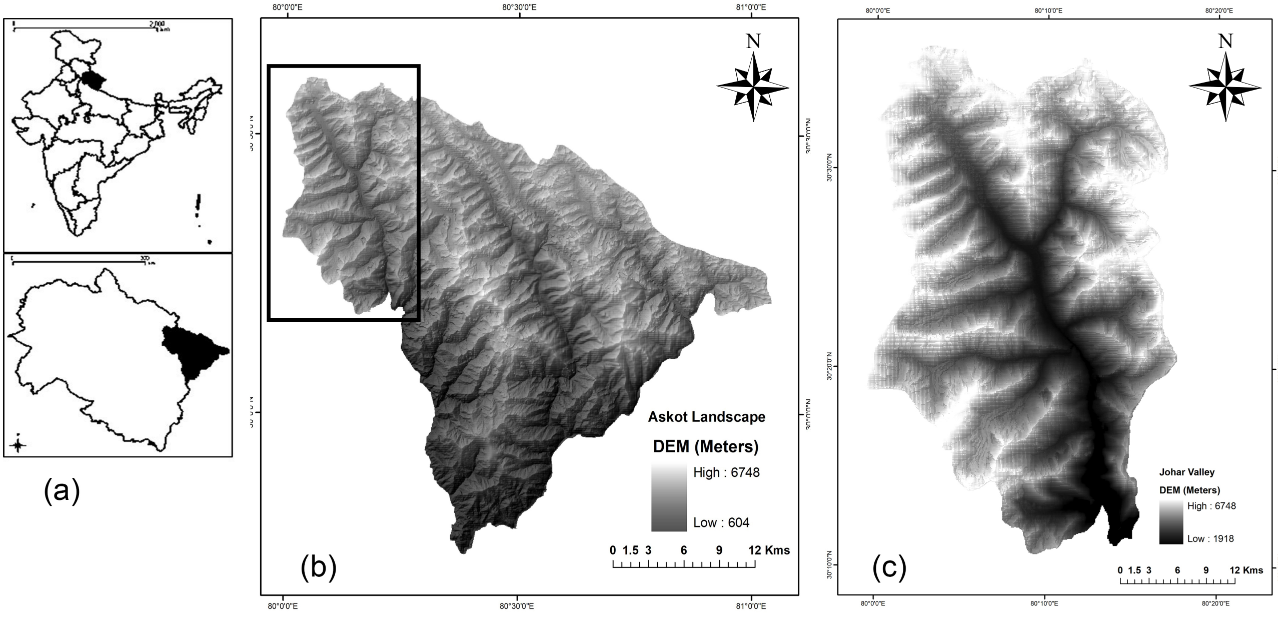

Fig. 1. Study area map showing (a) Location of Askot landscape in India and Uttarakhand; Digital Elevation Model (DEM) of (b) Askot landscape and (c) Johar Valley.

Himalaya and the Tibetan plateau. The variation in altitude creates habitats with sub-alpine and alpine birch (*Betula utilis*) forests associated with alpine shrubs and sciophytic herbs, Krummholz zones of *Rhododendron campanulatum* and *Juniper* scrub, widespread moist (Greater Himalayan area) and dry (Trans Himalayan area) alpine habitats (locally known as *bugyals*), beyond which lie the glaciers and cold desert merging with the Tibetan plateau (Government of India 2011; Negi 2010). Major ungulate species include Himalayan goral (*Naemorhedus goral*), Himalayan tahr (*Hemitragus jemalhicus*), Himalayan musk deer (*Moschus chrysogaster*) and blue sheep. These rangelands provide livelihood opportunities for the local communities in the form of high value medicinal herbs such as caterpillar fungus (*Ophiocordyceps sinensis*) and grazing resources for domestic livestock (sheep and goat) during the summer monsoon months. The main pastoralist community is *Bhotiya*, who seasonally migrate to the higher pastures (Sharma et al. 2003). The prominent fodder plants in the alpine habitats are *Danthonia* spp. and *Festuca* spp., several species of *Stipa* spp., *Carex* spp., *Selinum* spp., etc. These are important nutritious foraging grounds for both wild and domestic ungulates (Kala et al. 2002; Suryawanshi et al. 2009). The subalpine zones of birch forests and Krummholz zones serve as good cover for the wild ungulates. The movement of pastoralists with their livestock continues between sites in a regular pattern (Sharma et al. 2003).

Field Methodology

Prior to the field visit, the entire study area was divided into 38 large grids 5 × 5 km using Arc GIS 9.3 (Esri Inc 2008). The grid size was chosen in a way to incorporate the average daily movement distance (Garland 1983) of blue sheep (2.9 ± 0.5 km) to avoid sampling duplicates across grids. The grids were placed for sampling feasibility, maintaining the optimal distance between spatial replicates to avoid autocorrelation. Random and stratified random sampling approaches were used to conduct the study for three years (2015–2017) during the summer-monsoon season (May–September).

Direct observations

During the field study, vantage points with maximum visibility were selected in each grid depending on accessibility and logistics. Maximum visibility was ensured by visiting each sampling grid and surveying for elevated locations with ~ 360-degree visibility of the surroundings. Point counts of 10 minutes each were conducted from each vantage point with binoculars (10 × 50). Twenty out of the 38 grids were sampled with 40 vantage points (two in each grid), and thirteen repeated point counts were done at each vantage point per day at an hour's interval (6 am to 6 pm). Along with this, pre-existing trails of two to 11 km ($n = 24$) en route to the vantage points and sampling grids were surveyed for direct evidence. Two trails per day were sampled and the trails were walked in the mornings (6 am to 9 am) and evenings (3 pm to 6 pm). There were three replicates of trail sampling in three years. To avoid inter-observer bias, all field observations were made by a single observer. When encountered, species type (blue sheep or livestock), projected sighting locations, date and time were recorded. Only sheep and goat were considered as livestock for the study.

Experienced and reliable pastoralists ($n = 45$) were interviewed with open-ended semi structured questionnaires regarding locations of blue sheep as observed and remembered in the past five years. These are the only pastoralist groups that graze their livestock every year in pre-determined alpine patches and have over 20 years of experience in the study area. Probable areas were surveyed to accumulate sighting locations from the pastoralist community. Twenty-three sighting locations were recorded from the herders, out of which direct sightings were obtained in 14 of the locations (~60%). Based on this, we considered the herders' locations to be correct. The information collected from the herders contributed to around 17% ($n = 9$) of the direct data in the study. This information was included as direct evidence in the analysis.

Indirect observations

Thirty alpine pastures (regular encampments) and areas *en route* to these, which are used for livestock grazing, were sampled for pellet enumeration of blue sheep and livestock (sheep and goat). The area of each pasture ranged from ~2 to 200 km^2. Random circular plots each of 10 m in radius ($n = 304$) and separated by at least 300 m were placed across the selected pastures as well as adjoining areas and areas en route to these pastures. Previous studies suggested that belt transects are relatively more prone to missed groups error of pellets than circular plots for large ungulates (Neff 1968). The smaller plot may have a greater proportion of perimeter pellet groups, making its inclusion or exclusion a topic for discussion. Also in order to capture the richness of the species present, smaller plots would need to be much more numerous, but this process would be too time consuming. The disadvantage of using larger plots is the chance of missing pellet groups (Smith 1968; Noor et al. 2010). The optimal size for plots was found to be ~10 m in radius (Smith 1968). Since the study area terrain was not suitable for a systematic sampling, we placed the circular plots (10-m) randomly, covering all possible habitat types. Information on the number of pellet groups, species, and locations was recorded. Blue sheep pellets were recognized in areas devoid of livestock presence and seen visiting their previously observed presence locations in those areas. Blue sheep pellets were distinguished from pellets of other wild ungulates by their size and shape. Distinguishing blue sheep pellets from those of livestock (sheep and goat) was confusing initially. However, after careful study and consultation with experienced herders, this problem was resolved. We further collected blue sheep pellets in zip lock bags for future verification.

Analytical methods

Preparation of geospatial layers

Vegetation/land use data on western Himalaya were acquired from a vegetation type map of India from the Biodiversity Information System portal of the Indian Institute of Remote Sensing (http://bis.iirs.gov.in) at a resolution of 23.5 m (Roy et al. 2015). We clipped the vegetation categories according to our study area. The vegetation data have 20 classes for our study area, from which we selected the most relevant for the study species and clubbed the least relevant categories as miscellaneous. Twelve categories were generated for the final layer which were moist alpine pasture, wet grasslands, dry alpine scrub, barren land, snow, *Rhododendron*, sub alpine, dry deciduous scrub, dry evergreen scrub, Himalayan moist temperate, agriculture and miscellaneous. These classes were ordered and ranked starting from open to closed vegetation types. The openness rank for each of the 12 vegetation categories were Snow - 1, Barren land - 2, Moist alpine pasture - 3, Wet grasslands - 4, Dry alpine scrub - 5, *Rhododendron* - 6, Sub alpine - 7, Dry deciduous scrub - 8, Dry evergreen scrub - 9, Himalayan moist temperate - 10, Agriculture - 11 and Miscellaneous - 12. These ranks were then standardized using standard normal transformation to be used as a continuous variable in the study. Digital Elevation Model (ASTER 30 m DEM) was acquired from Ecological Mapping Atlas of Askot Landscape, Uttarakhand, India (WII-BCRLIP 2015). Raster layers of the aspect, slope and terrain ruggedness index (TRI) were derived from DEM. We considered steep cliffs as escape terrain for blue sheep based on the terrain of the study area. To generate an escape terrain layer, slope was classified into two classes (0–45 and 45–80 degrees) and slopes above 45 degrees were considered steep cliffs (Namgail et al. 2004; Ahmad et al. 2016). Euclidean distances from the steep cliffs (slopes > 45 degrees) were calculated at 100 m intervals (maximum distance 2 km) to generate a distance from escape terrain (DET) raster layer. This was done as blue sheep sighting from nearest escape terrain varied from 100–2000 m during the study. Based on the average daily movement distance of blue sheep, we used DET intervals of 100 m from the steep cliffs so that the results are not skewed towards a particular DET category. From point locations (direct and indirect) of blue sheep and livestock collected during the field study, we extracted the raster values of the topographic layers (Vegetation type, DEM, slope, aspect, TRI and DET). These variables are known to influence resource selection in these species (Namgail 2001; Suryawanshi et al. 2009; Johnsingh and Manjrekar 2015). All geospatial analysis was done in GIS domain (Arc GIS 9.3, Esri Inc 2008) and all raster layers were resampled to a resolution of 30 m.

Resource selection probability

Presence-only data are a set of point locations $y = \{y_1 \dots y_n\}$ in a continuous space A, where the locations (y_i) are recorded as presences. Analysis of y is done as a point process, jointly modelling the number of presence points, n, and their locations (y_i). A map of values in the space A for each k explanatory variables that were observed (values of these variables at y_i) are denoted as $x = (x_{i1} \dots x_{ik})$. Here, intensity at point y_i (λ_i = expected number of presence points per unit area) is modelled as a log-linear function of covariates (k). The parameters of the model are stored in the vector $\beta = \{\beta_0, \beta_1 \dots \beta_k\}$ (Cressie 1993).

(1) $\log(\lambda_i) = \beta_0 + \sum_{j=1}^{k} x_{ij}\beta_j$.
where λ_i = intensity at point y_i
x = values of covariates
β = coefficient

Spatial locations of presence points (direct and indirect) of blue sheep and livestock and a background sample of random points (availability locations) were taken for point process analysis. The number of random points were chosen in point process framework using likelihood convergence method. Thus, 1000 random points were found suitable for our study area of ~950 km^2 at an intensity of one point per km^2. The 1000 random points were generated across the study area and labelled as zeroes to account for pseudo-absences. An intensity of random points of one point per km^2 was considered for analysis to accommodate the comparable effort across point intensity for both species and avoid pseudo replication. We evaluated spatial independence within our observation points through Moran's I test (Moran

1950) for spatial autocorrelation. The results indicated a somewhat clustered pattern of our observation points, which may be due to random chance (Moran's Index = 0.03). Raster values of the topographic variables were extracted for both the presence and pseudo-absence locations. A binomial point process model was fitted to the binary data using the covariates at all of the used and available locations. The beta values for each covariate were estimated using the framework with a generalized linear model (GLM). The models were evaluated through Receiver Operating Characteristic (ROC) curve values, along with information theoretic approaches like Akaike Information Criterion (AIC) (Akaike 1974) and Bayesian Information Criteria (BIC) (Schwarz 1978). ROC was calculated using the package "pROC" in the R 3.5 (R core team 2017). We did not separate the training and test data as our sample size was small, but validation was done comparing with the whole dataset. Models with lowest AIC values were considered best fit models. However, the AIC values of the best fit models for both blue sheep and livestock had differences of less than two to determine the best model among them. For best model selection we used BIC values as they are better in situations where false positives are more misleading than false negatives. As we are more interested in minimizing the false positives in this case, BIC values provide better insights than AIC. The significant variables of the best fit model were used to generate maps of the predicted intensity of resource selection probability for both blue sheep and livestock. The intensity maps were generated using the map equation

$$(2)\ \text{Output} = \text{Beta}_1{*}\text{Raster}_1 + \text{Beta}_2{*}\text{Raster}_2 \ldots + \text{Beta}_n{*}\text{Raster}_n$$

in the GIS domain with the coefficient values of the most significant variables of the best fit models for respective species.

After the intensity raster layers were generated, we extracted the intensity values for the training locations and applied a threshold based on the minimum intensity value, then divided the layers of the respective species into five intensity classes: very low, low, moderate, high and very high. Area for predicted presence was calculated using moderate, high and very high classes. We first ran separate analyses with direct and indirect evidence presence points, which revealed insignificant differences in values to be considered for separate interpretation (Table S1). We used both evidences combined for analysis to increase the spatial coverage of the dataset and incline towards more accurate results by increasing the number of unique observations. This did not alter the model for interpretation. All analyses for resource selection was done using the "Raster" (Hijmans 2016) and "spatstat" (Baddeley and Turner 2005) packages in R 3.5 (R core team 2017) and ArcGIS 9.3 (Esri Inc 2008).

Since the covariate vegetation type was used as a continuous variable for vegetation openness in the point process model, we conducted a post hoc test to validate the results. We conducted Design I of Manly's Resource Selection Function (Manly et al. 2002) to estimate resource selection via the habitat use vs availability framework for blue sheep and livestock. Design I was used as it does not need to identify individual animals and the resource units are assumed to be sampled for the entire study area. We compared the number of individuals in each vegetation type to the relative availability of the respective vegetation type in the study area. Habitat use vs the proportion of available habitat was calculated using the package "adeHabitatHS" in R 3.5 (Calenge 2016). Used habitats were considered as the areas, which were selected and received some investment by an animal. The proportion of available habitat was the quantity of the particular vegetation type accessible to the species in the entire study area (Manly et al. 2002). Therefore, available resources were considered as the areas that the study species may select (Lele et al. 2013). The percentage use for each category was then compared to its respective availability to evaluate resource selection. We used the commonly employed ratio of percentage use divided by percentage available, which is referred to as the forage ratio or selectivity index (Savage 1931, Manly 1974) as the resource selection index (wi).

$$(3)\ wi = oi / \pi\hat{i}$$

where oi = sample proportion of used units in category i
$\pi\hat{i}$ = sample proportion of available units in category i

A resource item for a species could be highly favoured but difficult to access, and hence, less utilized. Conversely, less favoured resources might comprise a large portion of resources used out of necessity if they are the only ones available to the species (Manly et al. 2002). The selection index mainly indicates a high preference for a particular habitat unit that is highly used.

RESULTS

In this study, 63% of the entire study area was sampled intensively, and the rest of inaccessible for sampling. A total of 87 presence points (51 direct, 36 indirect) for blue sheep (Fig. S5) and 327 presence points (97 direct, 230 indirect) for livestock (Fig. S6) were obtained. The survey effort consisted of a total of 40 sampling points with 520 point count replicates for 5200 minutes (single season) along with 149 km of trail walk for 4172 minutes per season (three seasons) and 304 pellet plots of 315 m^2 each (single season).

Factors influencing resource selection

Best models with AIC differences of two or less were considered to explain variability in the data. In the case of blue sheep factors influencing resource selection, the best models were generated using vegetation openness and DET as predictor variables (Fig. 2, Table 1). Slope and TRI had the least influence and was omitted from subsequent equations. Vegetation openness showed a negative relationship with blue sheep presence (coefficient = -0.35, $p < 0.01$), showing preference towards open vegetation types, including alpine grasslands, barren and snow covered areas. The post hoc test complimented this result (Fig. S2, Table 3), revealing that blue sheep mostly preferred alpine meadows that were used more frequently than they were available. Escape terrain had a strong positive relation with blue sheep presence (coefficient = 0.45, $p < 0.001$) showing preference of blue sheep towards less steep cliffs. Though aspect and elevation had low significance levels, the variables supported the ecological relationships with the significant covariates. In the case of livestock, resource selection was best modelled using vegetation type (coefficient = -0.36, $p < 0.001$) and elevation (coefficient = -1.31, $p < 0.001$) as variables. Slope and aspect, the least significant variables, were omitted. Both elevation and vegetation openness showed a negative relationships (Fig. 3, Table 2) with livestock presence, showing preference for open vegetation at lower altitudes. The post hoc test for livestock also complimented these results (Fig. S3, Table 3), showing that alpine meadows were their most preferred habitat type.

Resource selection probability

An intensity map of resource selection probability for blue sheep (Fig. 4a) showed its predicted presence in areas with open vegetation representing the alpine grasslands. Their presence was predicted in a suitable area of 659.18 km^2 which was 69% of the total study area. Their selection probability was in areas towards the alpine grasslands and valley floors on the southern aspect keeping a distance of 600–1000 m from the cliffs. There was no significant difference between the intensity maps of blue sheep generated separately with direct and indirect evidence (Fig. S1 a b c). Livestock, accompanied by humans, also showed presence probability (Fig. 4b) in areas with open vegetation but at lower altitudes with moderate terrain ruggedness away from cliffs, mainly on the valley floors. Their presence was predicted in an area of 545.97 km^2 which was ~57% of the total study area. An overlap map of livestock intensity areas with blue sheep intensity areas showed an overlap area of 259.37 km^2 which was ~39% of blue sheep resource selection probability area (Fig. 5).

DISCUSSION

Wild ungulates tend to avoid competition through differential resource selection patterns. The basis of this differential selection may be habitat, diet

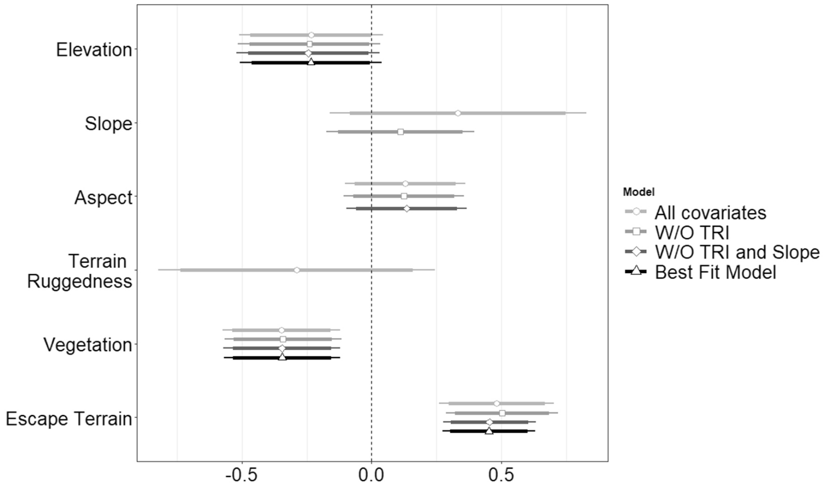

Fig. 2. Coefficient plot of covariates used in the point process model of blue sheep.

or anti-predator strategies (Namgail et al. 2007). In most applications for estimating resource selection function, only relative probabilities rather than absolute probabilities can be used. This study reveals that vegetation openness is an important variable for predicting the resource selection by both blue sheep and livestock. Our results reflected the openness value of the selected vegetation categories. We inferred that blue sheep have a preference towards alpine grasslands (moist and dry) and barren and snow covered areas in our study. The negative relation indicated a preference for open alpine areas with herbaceous vegetation type,

Table 1. Coefficients and *p* values of point process models with different combinations of covariates for blue sheep

Predictors for Blue Sheep	Model 1	Model 2	Model 3	Model 4	Model 5
(Intercept)	-2.58 ***	-2.56 ***	-2.57 ***	-2.56 ***	-2.54 ***
SE	(0.13)	(0.13)	(0.13)	(0.13)	(0.13)
Slope	0.33	0.11			
SE	(0.25)	(0.15)			
Aspect	0.13	0.12	0.13		
SE	(0.12)	(0.12)	(0.12)		
Terrain Ruggedness	-0.29				
SE	(0.27)				
Vegetation Openness	-0.35 **	-0.34 **	-0.35 **	-0.34 **	-0.43 ***
SE	(0.12)	(0.11)	(0.11)	(0.11)	(0.10)
Elevation	-0.23	-0.24	-0.24	-0.23	
SE	(0.14)	(0.14)	(0.14)	(0.14)	
Escape Terrain	0.48 ***	0.50 ***	0.45 ***	0.45 ***	0.47 ***
SE	(0.11)	(0.11)	(0.09)	(0.09)	(0.09)
N	990	990	990	990	991
AIC	550.47	549.70	548.28	547.59	549.09
BIC	584.75	579.09	572.77	567.18	563.79
Pseudo R^2	0.11	0.10	0.10	0.10	0.09
ROC	0.716	0.715	0.715	0.717	0.701

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

Table 2. Coefficients and *p* values of point process models with different combinations of covariates for livestock

Predictors for Livestock	Model 1	Model 2	Model 3	Model 4
(Intercept)	-1.57 ***	-1.57 ***	-1.56 ***	-1.53 ***
SE	(0.10)	(0.10)	(0.10)	(0.10)
Slope	0.08			
SE	(0.16)			
Aspect	0.10	0.10		
SE	(0.08)	(0.08)		
Terrain Ruggedness	-0.30	-0.23 *	-0.23 *	
SE	(0.17)	(0.10)	(0.10)	
Vegetation Openness	-0.36 ***	-0.36 ***	-0.36 ***	-0.36 ***
SE	(0.07)	(0.07)	(0.07)	(0.07)
Elevation	-1.33 ***	-1.33 ***	-1.31 ***	-1.29 ***
SE	(0.11)	(0.11)	(0.10)	(0.10)
Escape Terrain	0.45 ***	0.44 ***	0.44 ***	0.55 ***
SE	(0.09)	(0.09)	(0.09)	(0.07)
N	1234	1234	1234	1234
AIC	1059.65	1057.90	1057.49	1060.42
BIC	1095.48	1088.61	1083.08	1080.89
Pseudo R^2	0.39	0.39	0.39	0.39
ROC	0.843	0.842	0.842	0.841

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

which coincides with the diet and foraging patterns of both species. In summers, both species are hugely dependent on alpine grasses and other associated plant species that mainly grow on the warmer aspects (Kala et al. 2002). The analysis reveals that, though blue sheep continue to use the same area after migratory livestock arrive, they separated, selecting different variables or resources based on topographic features. Blue sheep selected warmer aspects in moderately rugged terrains to forage on the grasses, and also showed a preference to remain a moderate distance from the escape terrain. The preference to remain towards the cliffs is an artefact of a behavioural trait (Namgail et al. 2009; Johnsingh and Manjerakar 2015). According to our results, they prefer to remain 600–1000 m from the cliffs to exploit the alpine meadows. Since the summer monsoon season is the main foraging season for blue sheep, it is most likely to prefer the lesser rugged habitat patches other than the steep cliffs. It was also suggested in Namgail (2001) and Namgail et al. (2004) that there is less forage available in the cliffs, so blue sheep have to move out of such escape terrain to feed on the grasses, thus compromising their safety. The above mentioned studies showed that blue sheep in a Trans Himalayan landscape tend to remain closer to the cliffs (within 250 m). Escape terrain, like the other covariates, is a function of topography, which varies across different Himalayan zones. In a greater Himalayan landscape, the better foraging sites are the places with alpine grasses, which are quite far from the steep cliffs. Thus, blue sheep need to balance food acquisition and predator avoidance while feeding outside the escape terrain. We analysed the relation of DET with our direct and indirect evidences and found that most observations were within a distance of 1000 m and 600 m from the cliffs, respectively (Fig. S4). Use of an escape

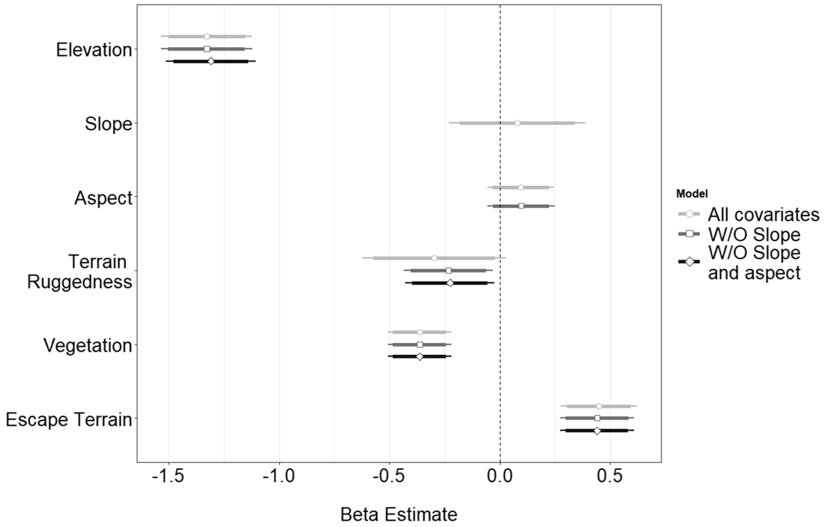

Fig. 3. Coefficient plot of covariates used in the point process model of livestock.

Table 3. Selection index (Wi values) of use vs availability for blue sheep and livestock

Habitat Type	Blue sheep Wi	SE	Livestock Wi	SE
Moist Alpine	1.813***	0.116	2.263***	0.012
Barren	0.736**	0.068	0.701*	0.007
Dry Alpine Scrub	2.254	1.001	4.246	0.140
Dry Evergreen Scrub	0.000	0.000	0.000	0.000
Agriculture	0.000	0.000	0.000	0.000
Wet Grassland	2.336***	0.280	2.465***	0.029
Sub Alpine	0.000	0.000	7.430	0.330
Himalayan Moist Temperate	0.000	0.000	0.000	0.000
Rhododendron	1.711	0.760	4.297	0.122
Dry Deciduous Scrub	0.000	0.000	0.000	0.000
Snow	0.450**	0.058	0.000	0.000

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

terrain during foraging seasons is a strategy to exploit resources and avoid predation. A study by Wegge (1979) reported blue sheep feeding in open habitats and resting in rugged terrains. Due to presence of livestock, blue sheep avoid close proximity to the optimal patches, resulting in selecting an optimal DET. We found this threshold distance to be 600–1000 m from the cliffs. This also explains the negative relation with elevation (Fig. 2), as blue sheep are found to prefer areas closer to the alpine meadows in the summer-monsoon season. Previous studies on blue sheep tied with our results led us to infer a probable shift in habitat preference from known preferred habitats of the species. It might seem from the results that blue sheep have a selective advantage for feeding on resources of their choice because of their ecology in rugged terrains. Advantage with the topographical factors for blue sheep allows the species to use some habitat and utilize those resources that otherwise would not have been possible due to presence of livestock.

Livestock, accompanied by pastoralists, preferred areas at lower elevations than blue sheep, with moderately rugged terrain, mainly on the valley floors. These are areas convenient for pastoralists to establish campsites and are feasible for grazing. Presence probability of livestock overlapped with ~39% of the high intensity area for predicted blue sheep presence (Fig. 5). These highly suitable areas were along the valley floors and low altitude alpine patches interspersed with Krummholz zones and grassy slopes, the optimal areas preferred by pastoralists because they have nutritious grasses for their livestock. This makes the resource selection probability area greater for livestock than ungulates. This supports our results that blue sheep are shifting to a rugged topography at a threshold distance to their escape terrain, although there is a chance of selecting the optimal areas.

Our analysis suggests that, to avoid pastoralist occupied areas, blue sheep select resources in more rugged areas that are less disturbed and inaccessible to humans. Whether the selected areas are really sub-optimal foraging sights for the wild ungulates is difficult to predict. Moreover, RSF maps that predict high probability of use for certain areas do not necessarily define them as optimal habitats. This is because there is not much information on these areas, because they are inaccessible. Nevertheless, we can suggest from our results a definite segregation of resource selection patterns, with blue sheep taking refuge in topographic covariates instead of coveting nutritious factors. In

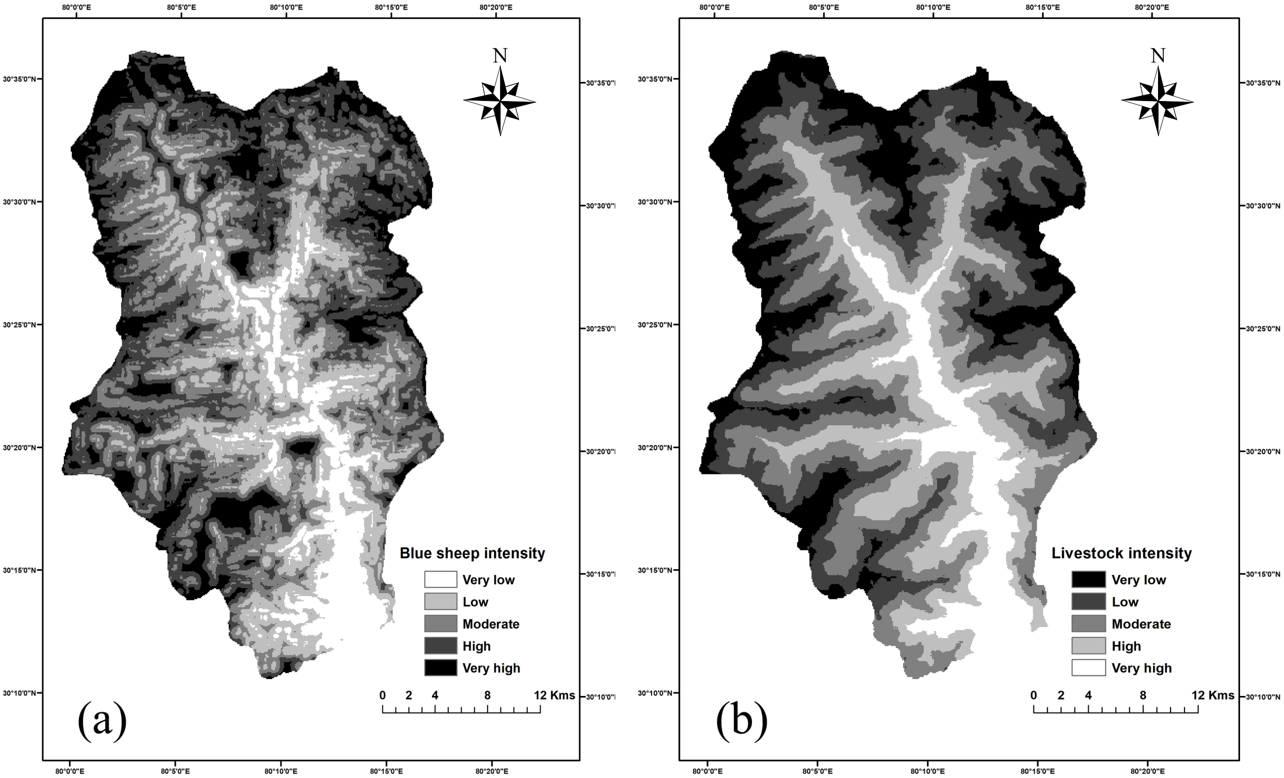

Fig. 4. Map showing intensity of resource selection probability of (a) Blue sheep (Output = 0.47 * Distance to escape terrain raster layer – 0.43 * Vegetation type raster layer) and (b) Livestock (Output = 0.55 * Distance to escape terrain raster layer – 1.29 * Elevation raster layer – 0.36 * Vegetation type raster layer).

greater Himalaya, both blue sheep and the pastoralists exploit the seasonal abundance of grazing resources that are available in marginal environments. Nutritional quality of forage during the summer is suggested to be a mediator of both blue sheep and livestock survival during the remainder of the year (Cincotta et al. 1991). Competition is expected among sympatric ungulates when shared resources are in short supply (Pianka and Huey 1978). As alpine meadows are less abundant, exploitative competition is likely to occur. We propose that, through the pattern of resource selection, blue sheep avoid optimal pastures, which can alter their foraging and dietary pattern. Suryawanshi et al. (2009) showed this avoidance through diet estimation and foraging availability of blue sheep in Trans-Himalaya. Livestock has a competitive advantage due to the presence of humans who lead them to optimal grazing pastures. They remove large amounts of forage from pastures, reducing its availability for wild ungulates (Bagchi et al. 2004; Suryawanshi et al. 2009), thus imposing resource limitations. This might lead to their exclusion from better habitat patches, in turn affecting their ecology. Our results suggest that blue sheep might prefer the resources in the optimal patches used by livestock as these patches have high nutritional content and require less energy expenditure. Our model predicts that blue sheep will avoid optimal grazing areas in the presence of livestock, suggesting a segregation of resource selection patterns.

The advantage of using the point process in this

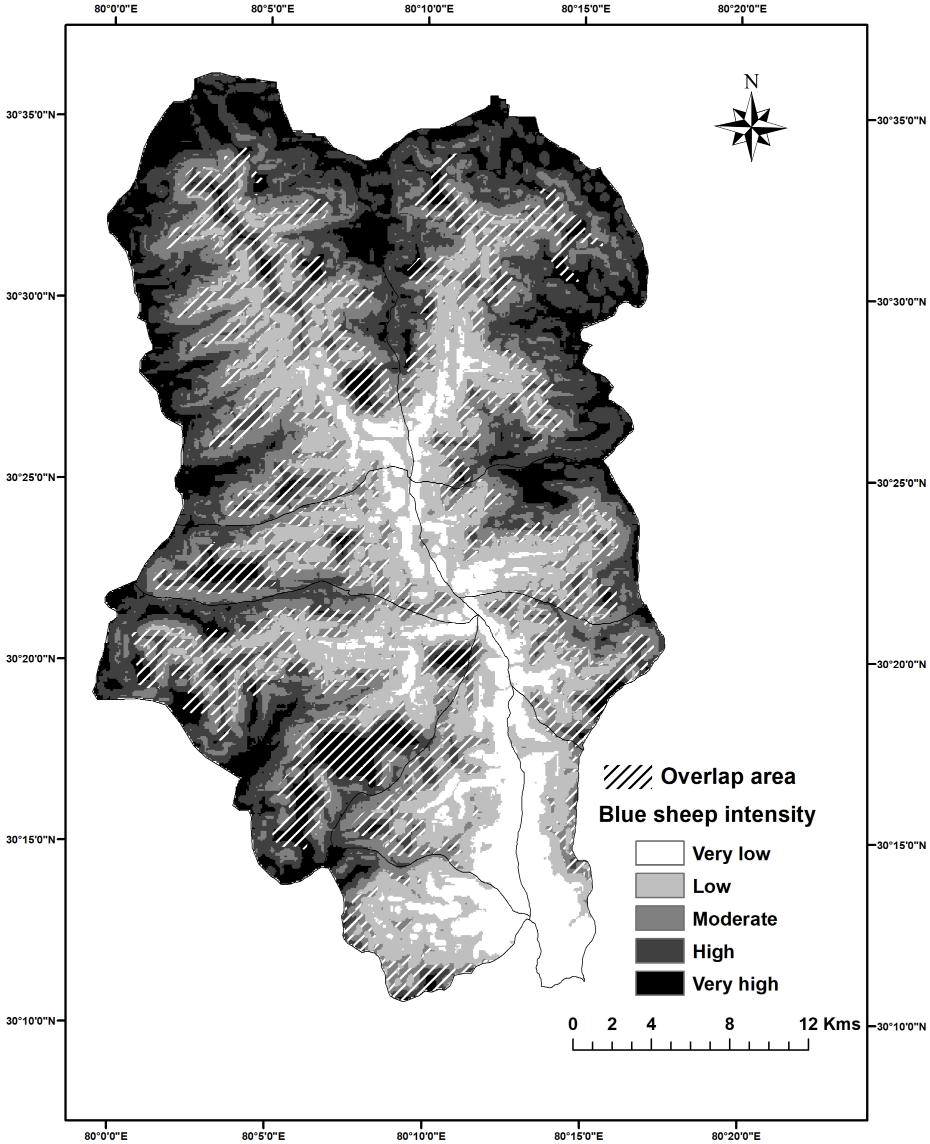

Fig. 5. Map showing overlap of resource selection intensity between livestock and blue sheep.

study is the choice of background points or pseudo-absences according to the objective of the study. In the RSF designs explained by Manly et al. (2002), available resource units were sampled for the entire study area or unused resource units were considered as available units. The point process framework provides a platform to systematically select our background or available points in accordance with the species presence points. This gives more specificity to the intensity prediction. Another advantage of this method is its relation to the common approaches for RSF estimation. These models are a generalization of the frequently-used weighted distribution models, like GLM and MaxEnt (Johnson et al. 2013; Renner et al. 2015). This can be readily implemented by animal ecologists inferring about relative patterns in species abundances taking sampling biases into account. Earlier studies (Bagchi et al. 2004; Namgail et al. 2007; Suryawanshi et al. 2009) mainly explained resource selection through dietary patterns. Other habitat association studies (Namgail et al. 2007; Shrestha and Wegge 2008) explained RSF through GLMs with the entire study area as available habitat. Our study focuses on the spatial basis of selection probability. We used background points to provide a more accurate association with the habitat variables and the species presence points rather than a generalized proportional probability layer. We used the point process framework to model the resource selection probability of blue sheep and livestock via intensity functions. Instead of a probability, we estimated the expected abundance of species presence throughout the study area, using intensity as a function of the covariates (Renner et al. 2015). This is the first study in which the point process model is used to model the resource selection function of terrestrial mammal species without radio-telemetry data.

CONCLUSIONS

The main aim of studying mountain ecosystems is to inform better management decisions for practitioners and managers. These insights include spatial layers relating to the ecology of the species. Resource selection patterns can be used to infer the relationship between an animal's space use and its environmental niche. A sound knowledge of spatial factors facilitates prioritization for management strategies. Our study will help inform monitoring and planning efforts focusing on identifying and protecting important habitat resources in the Himalayan region. Our spatial information represented in the resource selection and overlap maps can serve as a tool for directing efforts towards planning managed pastoral practices in the Johar Valley. Managed pastoral practices can include exclusion of particular pastures from the priority areas for livestock grazing and cohesion of pastoralist groups for sharing of pastures instead of individual pastures. Our predictive maps, when applied appropriately, can also help identify areas across Himalayan landscapes with a high potential of being good blue sheep habitat. Identification of such areas will assist with large-scale land-use planning, management and recovery efforts for threatened species (Boyce and McDonald 1999; Boyce and Waller 2003). The RSF coefficients and predictive maps from the study can also serve to generate hypotheses for future research and direct population inventories across areas where relatively little is known about the distribution of blue sheep or other species. We recommend that these models and maps, and results from similar applications, be used as baseline information for future research. According to Mladenoff et al. (1999), observations from further research and inventory efforts can be used in an integrative fashion to assess and update RSF and resulting maps. According to our conclusion, we suggest that land managers use distribution maps and treat the overlapped areas as conservation priority areas. We posit that conservation of threatened and important prey species in Himalayan rangelands depends on managed pastoral practices and community participation. Those areas can be dealt with by the management for managed pastoral practices and inclusion of pastoralist communities to maintain a biodiversity information flow and help in conservation of wildlife. Our study provides helpful insights for managing rangelands at a landscape scale, which can be tied with microhabitat level dietary patterns, yielding a more all-encompassing approach to proper conservation measures in the future.

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Supplementary materials

Fig. S1. Intensity map of blue sheep resource selection probability of (a) Combined (b) Direct and (c) Indirect evidences. (download)

Fig. S2. Resource selection and utilization of blue sheep with respect to available habitat. (download)

Fig. S3. Resource selection and utilization of livestock with respect to available habitat. (download)

Fig. S4. Relation between distance to escape terrain and probability of blue sheep occurrence. (download)

Fig. S5. Observation points of blue sheep recorded in Johar Valley. (download)

Fig. S6. Observation points of livestock recorded in Johar Valley. (download)

Table S1. Coefficient and *p* values of blue sheep direct, indirect and combined observations. (download)

MONGABAY
NEWS & INSPIRATION FROM NATURE'S FRONTLINE IN INDIA

Mongabay Series: Beyond Protected Areas

Livestock grazing drives blue sheep in the Himalayas to forage in sub-optimal areas

by Neha Jain on 7 July 2020

- *In the summer, nutritious grasses growing in Himalayan valleys and* *moderately rugged terrains far away from cliffs are ideal for foraging mountain ungulates such as blue sheep.*

- *A new study finds that pastoralists' presence and their foraging livestock in these areas overlaps with blue sheep, pushing the sheep into more rugged areas. At the same time, they maintain a safe distance from predators and livestock.*
- *These areas are sub-optimal for foraging, which could affect their nutritional balance as they spend more energy to avoid livestock grazed areas.*
- *By providing training and incentives to pastoralists, some optimal foraging areas could be maintained livestock-free for the blue sheep.*

Blue sheep, locally known as bharal, are wild mountain ungulates which are, in fact, more closely related to goats than sheep. They reside in the

Himalayas and are the main prey base for endangered snow leopards in the region. During the summer-monsoon season, blue sheep graze on alpine grasses found in valleys where pastoralists also migrate to graze their livestock.

A new study (http://zoolstud.sinica.edu.tw/Journals/59/59-11.pdf) by researchers from the Wildlife Institute of India has analysed resource use patterns of blue sheep in the presence of livestock in Johar valley in Uttarakhand. The study shows that while blue sheep forage in the same habitat after livestock arrival, they shift to grazing in more rugged terrain to avoid humans and livestock.

High-intensity areas predicted for blue sheep overlap 39 percent with the probability of the presence of livestock, according to the study.

“Since resources are limited and patchily distributed in the alpine regions, an overlap of 39 percent is an indication of a resource conflict,” said doctoral student Ankita Bhattacharya and lead author of the study. “Presence or overlap of livestock in these areas provides insights on managing pastoral practices in selected regions to aid conservation of blue sheep.”

For centuries, the alpine rangelands of Johar valley and other valleys have been used seasonally by agro-pastoral communities such as the Bhotiya and Gaddis for grazing their livestock, noted Bhattacharya and scientist Gopal S. Rawat, who is a co-author. These practices, known as transhumant pastoralism, were not a threat because of the low livestock population, said Bhattacharya, but over the past few decades, livestock holding has grown and overgrazing shows a decrease in grasses and increase of unpalatable species.

The alpine habitat of the Johar Valley, Uttarakhand. Photo by Ankita Bhattacharya.

“In need of livelihood improvement, more and more numbers of livestock are increasing day by day causing overstocking and overgrazing," explained Bhattacharya. "Overstocking is also an insurance against losses due to predation and unfavourable climatic conditions. Thus, degradation of habitat, substitution of optimal foraging patches with less nutritious patches, risk of predation as well as hunting are the major problems faced by the ungulates due to overstocking and overgrazing."

Predicting blue sheep and livestock resource selection

The research team carried out field observations of blue sheep and livestock in 63 percent of their study area in Johar valley (elevation range of 1918—6727 metres), located in the upper catchment of the Gori river. Studying animals in the Himalayas is challenging because of the harsh terrain, elusive nature and rarity of species, said Bhattacharya and co-author Nilanjan Chatterjee, who is also a doctoral student. Although recent studies have relied on radio-telemetry, which involves attaching a radio transmitter to animals and tracking their movement through radio signals, it is more suited to a smaller study area and has other limitations. Consequently, the team used a point-process framework to model the resource selection probability of blue sheep and livestock.

“This model estimates the species distribution focusing on the presence-only observed data and accordingly selects the number of pseudo-absence points required for the analysis," explained Chatterjee.

“Through this approach, we tried to model the intensity of the occurrence points using environmental factors."

Blue sheep or Bharal in Gangotri National Park, Uttarakhand. Photo by Nilanjan Chatterjee.

Livestock and blue sheep both preferred open vegetation, with the former in lower altitudes and valley floors and the latter in alpine meadows. Their results suggest that blue sheep tend to avoid optimal patches of grazing, usually in moderately rugged areas and valley floors, due to the presence of pastoralists and livestock and they maintain a distance of 600 to 1000 metres from cliffs — their escape terrain from disturbances such as predators and in this case livestock presence.

"An interesting behaviour of mountain ungulates like blue sheep is their strategy for predator avoidance," Bhattacharya observed. "These animals have specialised limbs which help them climb steep slopes or cliffs in case of predation. These steep cliffs (slopes above 45 degrees) are termed as escape terrain."

Read more: The thrills and spills of snapping snow leopard pictures in the high Himalayas (https://india.mongabay.com/2018/06/interview-the-thrills-and-spills-of-trapping-snow-leopard-pictures-in-the-high-himalayas-motivates-tashi-ghale/)

Blue sheep shift to more rugged, less disturbed terrains to avoid livestock. The researchers believe these are sub-optimal foraging areas because nutritious grasses are patchily distributed and far away from cliffs.

"This shift affects the quality of grazing for blue sheep" because "nutritious grasses grow for a limited period in the summer monsoon season and are important for lactation and maintaining other physiological functions of the mountain ungulates," said Bhattacharya and Bilal Habib, lead scientist and senior author of the study.

"Availing forage in the optimal patches requires less energy expenditure and easy availability of nutritious fodder, thus a natural choice," they added.

A pastoralist's tent in Johar Valley, Uttarakhand. Photo by Ankita Bhattacharya.

Pastoralist communities key to maintaining biodiversity

The spatial map of the probable optimal resource-rich areas preferred by blue sheep can help manage rangelands and pastoral practices in the region. Bhattacharya highlights the importance of pastoralists' traditional knowledge of alpine meadows and fauna, which can help greatly in monitoring biodiversity in Himalayan rangelands.

"Awareness, training and incentives for the pastoralists can help to use their knowledge to maintain a biodiversity information flow regarding mountain ungulates," Bhattacharya said, adding that some of the optimal pastures can be avoided entirely for mountain ungulates to access exclusively. But this will "require incentives and active participation of the pastoral communities, local stakeholders, state forest departments and organisations studying wildlife conservation," she acknowledged.

Subhash R. Lele, a Prof-Associate Chair at the University of Alberta, Canada, who was not connected with this research, said that the study is interesting and important for wildlife management. He also pointed out two issues, which could have an impact on management decisions.

First, he explained was that the method assumes that the resources at the random locations from the study area represent the resources blue sheep would have used if they were not differentiating between resources. “This assumption can be violated, for example, if the species under study exhibits grouping behaviour or if they have high fidelity to the area where they were born or many other mechanisms that have nothing to do with selection of the resources,” said Lele, suspecting that blue sheep are gregarious.

Second, while the study uses “relative risk” to determine how much the probability of selection by blue sheep has changed because of grazing by livestock, he said “absolute probability” can give a more accurate sense of the impact of grazing on blue sheep.

He explained with two examples: “In the first situation, probability of selection of a resource unit without grazing is 0.8 and with grazing, it is reduced to 0.4. The relative change due to grazing is of factor 2.

Consider an alternative situation where the probability of selection without grazing is 0.1 and it is reduced to 0.05 with grazing. The relative change is of factor 2 again. However, from the management perspective, the first situation is likely to have a much more serious impact on the survival of the species than the second situation where the area was already quite bad and it became slightly worse due to grazing."

This study can be tied with radio telemetry for better insights in more-detailed future studies on the ecology of blue sheep, said the researchers.

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Banner image: Livestock grazing in the Johar Valley, Uttarakhand. Photo by Ankita Bhattacharya.

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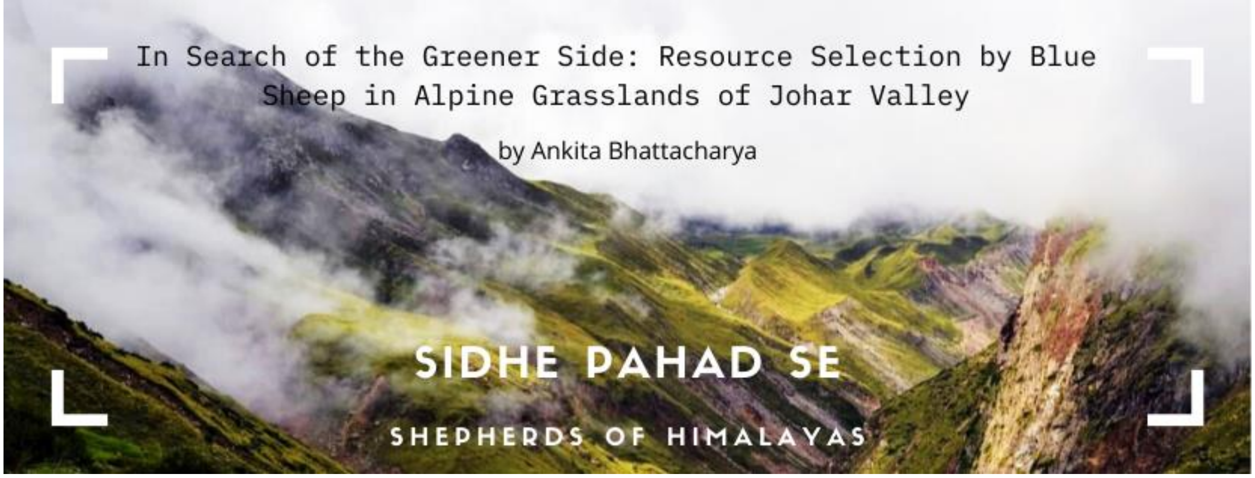

In Search of the Greener Side: Resource Selection by Blue Sheep in Alpine Grasslands of Johar Valley, Western Himalaya

By Ankita Bhattacharya

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In the Indian Himalayan Region (IHR), rangelands include the Trans-Himalayan zone and the alpine meadows of the Greater Himalayan zone. These rangelands provide a wide range of habitats supporting unique arrays of biodiversity and ecosystem services. Transhumant pastoralism is one such service that has thrived in the Himalayan region for centuries. But in the last few decades, changes in livestock holdings, loss of traditional grazing patterns, and knowledge systems have greatly affected the wildlife, especially the wild ungulates. Mountain ungulates play a crucial role in maintaining the Himalayan rangeland ecosystem by shaping the vegetation structure, plant species composition, nutrient cycling, and forming prey base for carnivores. In light of current landscape approaches to conservation, it is thus important to assess the pressures of pastoralism across a landscape and degree of competition of livestock with wild ungulates based on available resources for a proper monitoring/management plan for rangelands. With this motivation, the study was carried out to investigate the effect of various topographical and environmental factors along with pastoralism on the resource selection by Blue sheep (*Pseudois nayaur*) in the Johar Valley, using the novel Point Process Model.

Naming Paradox

Blue Sheep is a widely distributed mountain ungulate from the steppes of Trans-Himalayas to Alpine meadows of Greater Himalayas. But their name can be deceptive as Blue sheep is neither blue nor a sheep. Their coat is gray to pale brown, changing a bit between summer and winter. It is more closely related to Goat than Sheep. The typical diet of Blue sheep consists of mainly grasses and herbs during summer and dried grass and lichens in the winters. It also forms an important part of a diet for various carnivores species in the Himalaya, especially, the Snow Leopard (*Panthera uncia*).

Blue sheep (Pseudois nayaur), picture credit @ Naitik Patel

Jewel of Askot Landscape: Johar Valley

The study on Blue sheep was carried out in ~950 km^2 of the upper catchment of the Gori River, referred to as the Johar valley, between 80° to 81°5'E Longitudes, and 29°5' to 30°N Latitudes in Uttarakhand state of Western Himalaya. It forms a part of the Askot Conservation Landscape in the Pithoragarh district. The valley forms the transition zone between the biogeographical elements of western Himalaya and Tibetan plateau covering an elevation range of 1918 m–6727 m. The variation in altitude creates habitats like sub-alpine and alpine birch forests, Krummholz zones of *Rhododendron campanulatum* and *Juniper* scrub, widespread moist (Greater Himalayan area) and dry (Trans Himalayan area) alpine habitats (locally known as *bugyals*), beyond which lie the glaciers and cold deserts merging with the Tibetan plateau. It harbors major ungulate species like Himalayan Goral (*Naemorhedus goral*), Himalayan Tahr (*Hemitragus jemlahicus*), Himalayan Musk Deer (*Moschus chrysogaster*) and Blue Sheep.

Landscape of the Johar valley

Sharing the Pastures

Apart from supporting a wide range of biodiversity, these rangelands provide livelihood opportunities for the local communities in the form of high-value medicinal herbs such as caterpillar fungus (*Ophiocordyceps sinensis*) and grazing resources for domestic livestock (sheep and goat) during the summer monsoon months. The main pastoralist community is Bhotiya, who live transhumance life, seasonally migrating to the alpine meadows from the valleys in search of better pastures for their herd. The prominent fodder plants in the alpine habitats are *Danthonia* spp. and *Festuca* spp., several species of *Stipa* spp., *Carex* spp., *Selinum* spp., etc. These rangelands are important nutritious foraging grounds for both wild and domestic ungulates in the summer, making it a battleground for resources. The seasonal abundance of highly nutritious forage during summer-monsoon months is suggested to be important for the survival of Blue sheep as well as livestock for the reminder year. Lesser the number of meadows, greater the competition for the resources. The livestock holds clear the advantage over Blue sheep due to the presence of pastoralists, who can guide them to nutritious grazing ground, driving away any competition.

Herds of livestock in the alpine meadows of the Johar valley

The search for the greener side

With the increasing resource competition, the important questions to answer are: how Blue sheep are adopting and distributing themselves in these habitats? What are the various factors governing their distribution and resource selection in the Johar valley?

To address the above questions, the resource selection function for Blue Sheep was estimated using the point process framework in this study. This model estimates the species distribution focusing observed data (as in this case presence-only data) and accordingly selecting the number of pseudo absence points required for the analysis. Further the expected number of Blue sheep presence per unit area at these points is modelled as a function of the important factors i.e. explanatory variables. These variables are elevation, terrain ruggedness, vegetation, aspect, slope, distance to escape terrain/ steep cliffs which are important to govern the selection of a particular site by Blue Sheep for grazing. The combination of direct observations, pseudo absence points, and explanatory variables generated in the GIS domain was considered during the analysis using the point process model to estimate the probability of the presence of Blue Sheep, Livestock, and their overlap in the area of interest.

The results of the study revealed that Blue Sheep prefers alpine grasslands (moist and dry), barren, and snow-covered areas. They also select the warmer aspects in moderately rugged terrains to forage on the grasses, and also showed a preference to remain a moderate distance (600 m – 1000 m) from the escape terrain. Livestock, accompanied by pastoralists had a competitive advantage and preferred areas at lower elevations than Blue Sheep, with moderately rugged terrain, mainly on the valley floors. It is observed that the probability of area occupied by the Livestock is overlapped with ~39% of the predicted suitable area for the presence of the Blue Sheep. It is also observed that if given a choice, Blue Sheep will always prefer the valley floors and low altitude alpine patches interspersed with Krummholz zones and grassy slopes. But to avoid the pastoralists and Livestock, they are selecting the resources in more rugged areas that are less disturbed and inaccessible to humans, making compromise on the nutritious grass for the safety of topographic features.

Various habitats in the Johar valley

Making meadows Blue Sheep friendly

The estimation of the distribution of Blue Sheep and factors affecting their resource selection with respect to livestock can be used to formulate the conservation plan for the rangeland by managing the pastoral practices in the Johar Valley. Some of the identified optimal pastures from the Johar valley can be excluded from the pastoral areas for the Livestock, providing exclusive access to Blue Sheep. With the proper application of the point process model, it can be further used to identify areas across Himalayan landscapes with a high potential of being a good habitat for Blue Sheep. These areas can be further treated as the priority areas for habitat conservation with the active participation of pastoral communities and local stakeholders.

Sharing the meadows with the pastoralists

Link to the research paper: http://zoolstud.sinica.edu.tw/Journals/59/59-11.html

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Ankita Bhattacharya

Books and television played a major role in tweaking my curiosity for the animal world. During my Bachelor's and Master's degree in Zoology from the University of Calcutta, my interest grew owing to educational tours to some of the protected areas in India and motivational teachers. Needless to say, it didn't take much convincing for me to choose a career for which I am passionate about. I have worked as a research scholar at the Wildlife Institute of India on the distribution and status of mammals in Uttarakhand and Himachal Pradesh. I am a huge admirer of the mountain ecosystems and currently pursuing my Ph.D. on mountain ungulates from Wildlife Institute of India. My interest is particularly in high altitude camera trapping and species distribution modelling. Alongside I am fond of food, music, reading, and travelling.