ECOLOGY AND MANAGEMENT OF THE ALPINE LANDSCAPE IN THE KHANGCHENDZONGA NATIONAL PARK, SIKKIM HIMALAYA

THESIS

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SANDEEP TAMBE

WILDLIFE INSTITUTE OF INDIA

CHANDRABANI, DEHRA DUN

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1.0 General Introduction

1.1 Alpine zone of the Himalaya: An introduction

"*The himalaya, the king of the mountains, five and three thousand leagues in extent at the circumference, with its ranges of eight and forty thousand peaks, the source of five hundred rivers, the dwelling place of multitude of mighty creatures, the producer of manifold perfumes, enriched with hundreds of magical drugs, like a cloud, the centre of the earth*." If anything could come remotely close to penning the magic of the Himalaya, this ancient hymn of sage Nagsena does. The alpine region of the Himalaya has exceptional ecological, cultural, economic and biodiversity values. Culturally this landscape is considered sacred by the Hindus and the Buddhists alike and is dotted with sacred temples, shrines and monasteries. Pastoralism, medicinal plants collection, nature tourism and pilgrimage are the main land use practices pervasive here. This zone forms the headwaters of the Himalayan rivers which sustain millions of humans who inhabit the Indo-Gangetic plains. Ecologically this area is of much interest due to adaptability of organisms to climatic extremes, vegetation processes, phytogeography and convergence of specialised life forms (Mani 1978).

Plant species richness and composition in the alpine meadows are governed by several factors such as glacial and avalanche actions, snow melt and deposition, soil depth and richness and resultant variation in the landscape diversity (Billings & Bliss 1959, Semwal *et al.* 1981). Generally, plant species diversity in the alpine regions decrease with increase in altitude but diversity of sites within each zone varies considerably (Kala *et .al.* 1998). The alpine vegetation exhibits a complex mosaic of succession due to micro-topographic variations and differences in the soil depth and nutrient status that varies with the degree of slope (Kikuchi & Ohba 1988). Although the growing season is very short (May to September) in the alpine zone, all species do not attain their maximum biomass at the same time. Most of the species complete their growth cycle rapidly within 3-5 months in order to ensure their survival. Unlike the alpine regions of the western Himalaya that have been studied in detail, very few quantitative studies have been carried out in the alpine meadows of the eastern Himalaya in general and the KNP in particular.

There are a number of important conservation issues in the Greater and trans-Himalaya today. Human landuse is pervasive in this landscape. Most of the national parks that presently exist have problems, and in many, adequate management machinery is yet to be established. Though large sized protected areas have been designated, the status of wildlife conservation within them is rather poor. The entire region undergoes pastoral and agro-pastoral landuse and the livestock population is growing. Many rangelands are overstocked. This has resulted in competition between livestock and wild herbivores, and many wild herbivore populations have consequently got depleted and even gone locally extinct (Mishra & Rawat 1998).

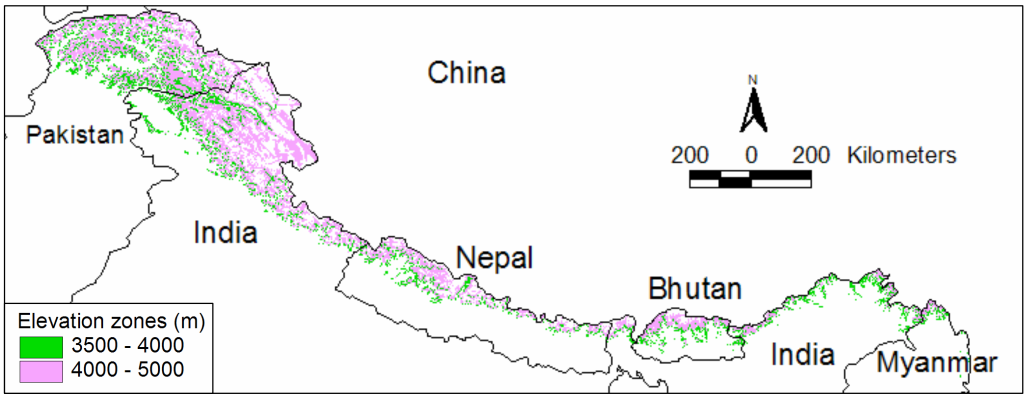
Concerns have been raised that the alpine zone is seriously threatened by human activities such as unsustainable harvesting, overgrazing, burning, hunting and poor stewardship, leading to loss of habitat or degradation in its quality. This has resulted in severe shortages of water, fodder, fuel, natural disasters and extinction of flora and fauna and also the resultant dying out of traditional practices.

1.2 Alpine zone of the eastern Himalaya

The alpine zone of the eastern Himalaya spans across eastern Nepal, Sikkim, Bhutan and Western Arunachal Pradesh. The *gumpas*, *chortens, shangrilas* and *beyuls* (hidden valleys) add a distinct mystical Buddhist identity to this landscape. This region also supports a large number of local and migratory pastoral communities who use the area for livestock grazing and collection of medicinal, aromatic and edible plants during summer (Singh & Chauhan 1997, Rai *et al.* 2000, Richard 2000). As per the ecosystem profile of the Eastern Himalaya region prepared by the Critical Ecosystem Partnership Fund (2005) this region is included in the 34 global biodiversity hotspots (Myers *et al.* 2000, Mittermeier *et al.* 2004) and includes several Global 200 eco-regions (Olson & Dinerstein 1998), two Endemic Bird Areas (Stattersfield *et al*. 1998), and several centers for plant diversity (WWF/IUCN 1995).

The alpine region in the eastern Himalaya differs considerably from the western Himalaya in terms of extent, terrain, climate, plant community composition, primary productivity, and history of ungulate grazing. The eastern Himalaya rise steeply from the Indian plains to the crest of the range in extremely short distances, while the western Himalaya in parts of Pakistan and northwest India are much wider. The alpine zone in the Himalaya becomes rather limited in extent and fragmented from west to east (Figure 1.1).

Figure 1.1: Map showing the variation in the extent and fragmentation of the alpine zone (3500 – 5000 meters) across the length (from west to east) of the Himalaya in the Indian subcontinent



The eastern Himalaya have a prolonged monsoon season from June to September and little precipitation is received from western disturbances in winter. The western Himalaya on the other hand has a short monsoon from July to August and a fairly long wet season from November to April (Miller 1987). The eastern Himalaya is more tropical in latitude and is geographically closer to the Bay of Bengal and to the monsoon winds (Figure 1.2, Figure 1.3). Consequently it has an oceanic climate, is more humid and exhibits higher seasonal primary productivity. The tree line is higher at 4,000 meters and the permanent snow line at 5,500 meters. The krummholtz and alpine scrub zone is also more extensive. It has a relatively recent history of extensive grazing and pristine areas with an insignificant history of grazing still exist. The recent geological origin, limited extent and fragmentation, steeper terrain and higher rainfall make them more fragile as compared to the western Himalaya.

The alpine zone of the state of Sikkim belongs to the biogeographic zone 2C - Central Himalaya according to Rodgers & Panwar (1988) and marks the extreme southern fringe of the Turkmenian subregion of the Palaearctic region (Mani 1978). It is surrounded by vast stretches of Tibetan plateau in the North, Chumbi valley and Kingdom of Bhutan in the East, Darjeeling district of West Bengal in the South and Nepal in the West. The alpine zone of Sikkim Himalaya differs from that of Western

Figure 1.2: Map showing the precipitation (mm) in the month of February originating from the west, across the extent of the Hindu Kush – Himalayan Region (Source: ICIMOD/MENRIS 2006)

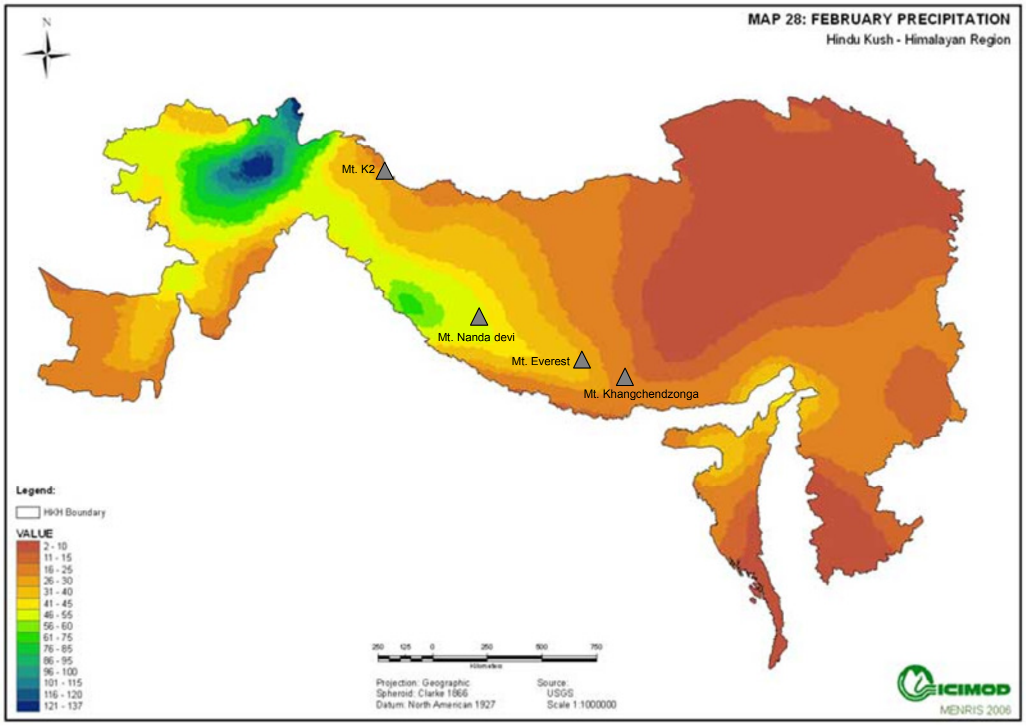
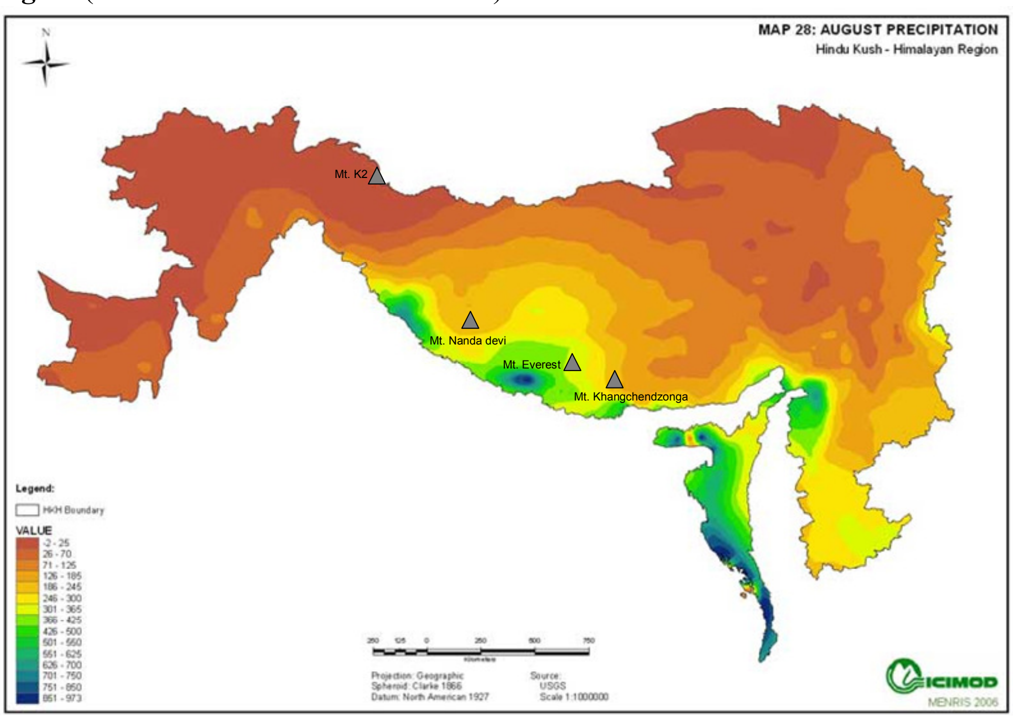


Figure 1.3: Map showing the precipitation (in mm) in the month of August originating from the south-east across the extent of the Hindu Kush – Himalayan Region (Source: ICIMOD/MENRIS 2006)



Himalaya in terms lower latitudes, sharper altitudinal gradient and higher rainfall. These alpine ecosystems are also of critical importance to millions of people in the lowlands as sources of freshwater, hydro-power, edible and medicinal plants and for the sustenance of local economies through large cardamom agro-forestry, animal husbandry, agriculture and nature tourism.

1.3 Conservation issues and information gaps

In 1975 with the merger of the kingdom of Sikkim with the Indian union, developmental activities increased and so did the human and livestock populations and tourist inflow (Lachungpa *et al*. 2003). In order to conserve the high altitude ecosystem, the Khangchendzonga National Park (KNP) was notified in 1977 and spreads over the North, West and South districts. The KNP lies between 27^o 30’ to 27^o 55’ N latitude and 88^o 02’and 88^o 37’ E longitude and spreads over 1,784 km^2 covering about 25% of the geographical area of the state. The alpine zone as used in this study includes the areas from where the Krummholtz thickets end and the alpine scrub begins and extends upto where the alpine meadows end and the subnival vegetation begins (broadly between 4,000 and 5,000 meters elevation). About 22% of the park with an extent of 390 km^2 falls within this zone.

This region also supports a large number of migratory pastoral communities who use the area for livestock grazing and collection of medicinal and aromatic plants during summer (Singh & Chauhan 1997, Rai *et al*. 2000). Concerns have been expressed that unsustainable grazing would lead to altered plant communities, lower range productivity and cause soil erosion (Singh *et al*. 1999). Loss of biodiversity is an inevitable result of these changes. Detailed studies on the above parameters are virtually lacking from the Sikkim Himalaya.

A total of 10 major research studies have been undertaken in and around KNP/KBR over the last 12 years covering the social, cultural, economic and ecological aspects Table 1.1.

Table 1.1: Details of major research studies undertaken in KNP/KBR recently

Study Title	Study Area	Researcher / Institute	Year
Livestock economics and its impact on the environment in North Sikkim	North Sikkim with Lhonak and Rangyong watersheds within KNP	Sonam Palzor, PhD Thesis, Centre for Himalayan Studies, University of North Bengal, W.B.	1990 - 1995
Impact of habitat disturbances on bird and butterfly communities along Yuksam–Dzongri trekking trail in Khangchendzonga Biosphere Reserve	Churong chu and Prek chu watersheds within KNP	Nakul Chettri, PhD Thesis, GBPIHED-Sikkim, University of North Bengal, W.B.	1996-2000
Grazing impact on plant diversity and productivity along a tourist trekking corridor in the Khangchendzonga Biosphere Reserve of Sikkim	Churong chu and Prek chu watersheds within KNP	H. Birkumar Singh, PhD Thesis, GBPIHED-Sikkim, University of North Bengal, W.B.	1996-2000
Economic benefits and conservation linkages from tourism development in the Sikkim Himalaya	Churong chu and Prek chu watersheds within KNP	Iyatta Maharana , PhD Thesis, GBPIHED-Sikkim, University of North Bengal, W.B.	1996-2000
Inventory of the biodiversity of the Khangchendzonga Biosphere Reserve	KNP fringe forests	Usha Lachungpa, Sikkim Forest Department	1999-2002
Vascular plant diversity of Kanchenjunga Biosphere Reserve, Sikkim	Whole of KNP including buffer areas	Debabrata Maity , PhD Thesis, BSI-Sikkim, Kalyani University, W.B.	1999-2004
Ethnographic research on Sikkim and Darjeeling Hills and archival research in India and England	Cultural landscape of KNP	Vibha Arora , PhD Thesis, University of Oxford, United Kingdom	2000-2004
Study of *Dzumsa* of Lachen as a part of a larger research project	Lachen and Thangu village, adjacent to KNP	Sophie Bourdet-Sabatier, Paris X Nanterre, France	2002-2004

Impact of anthropogenic pressures on the natural resources of Khangchendzonga Biopshere Reserve with particular reference to buffer zone	Buffer zone of KNP and fringe villages	Santosh Chettri , PhD Thesis, GBPIHED-Sikkim, Kumaun University, Nainital Uttaranchal	1999-2005
Carrying capacity study of Tista basin in Sikkim. Ten Volumes	Tista valley	Centre for Inter-disciplinary Studies of Mountain & Hill Environment, University of Delhi	2002-2006

Inspite of 30 years of its existence there are still major research gaps in the KNP. Broad areas where information is still lacking include structure and composition of vegetation, landscape characterization over large spatial scales, sustainability of pastoralism and ecology of pheasants and mammals.

1.4 The present study

Pastoralism is pervasive in the alpine zone of most of the protected areas of the country (Kothari *et al.* 1989). In Sikkim the villagers practice a mixed livelihood strategy earning their income from agriculture, horticulture and animal husbandry. Livestock such as yak, cow, sheep, horse, buffalo and goats are grazed in the forests and alpine meadows of the state. During the beginning of the 20th century the forests of the state were demarcated and the *Khasmahal* and G*oucharan* forests were specifically set aside to meet the fodder and firewood demands of the villagers. The population of Sikkim increased almost 15 fold in 110 years from 36,458 in 1891 to 5,40,851 in 2001 while the livestock (cattle, buffalo, yak, horse, sheep and goat) population stood at 2,99,020 in 2003 (Risley 1894, Anon 2001, Anon 2003). Consequently these forests were no longer able to meet the rapidly increasing demands of the villagers and soon even the fodder resources of the reserve forests were made use of.

In order to reduce this degradation the state government in a policy decision in 1995 banned the practice of open grazing in the reserve forests, plantation areas and perennial water sources of South and West Sikkim districts. As a consequence of the implementation of this ban, open grazing of cattle reduced considerably and more than 10,000 cattle and 500 agro-pastoralists were phased out from the sub-tropical and temperate forests of the state by 2003. Most of the yak herders were influential, which largely provided them with immunity from this eviction drive. Hence the numbers of yaks in the alpine forests reduced only to a limited extent. The ex-cattle herders and farmers then pressurized the forest department saying that, "*Yaks cause more damage than our cattle since they stay within the forests throughout the year. Moreover the yak herders are wealthy and own buildings in towns, if they are not evicted then we will also return to the forests with our cattle*." On the other hand the yak herder's contention was that, "*Our yaks do not come down below the tree line and hence cannot impact the forests, infact our yaks manure the alpine meadows and no wonder the alpine plants flower in greatest abundance around our yak-sheds. If you want to forcibly remove us then the forest department should buy our yaks and provide livelihood support to us*." The alpine zone being treeless has been traditionally given less importance by the forest departments, now faced with this dilemma and armed with insufficient information about this landscape, the park directorate was in an unenviable position.

The genesis of this study lies in this conflict, wherein it was realized that a sound understanding of the ecology of the alpine meadows and pastoralism was needed to ensure effective management of these unique and fragile environments. It is with this objective that the present research study titled "Ecology and Management of Alpine Landscape in the Khangchendzonga National Park, Sikkim Himalaya" was initiated in 2004 which would evolve a long term conservation plan for the alpine zone of KNP. The study spans over a large spatial scale covering all the major watersheds of KNP and aims to bridge the knowledge gaps related to structure and composition of the alpine vegetation, alpine landscape characterization, sustainability of pastoralism, conservation strategy and co-management experiments. The purpose of the study is to provide a scientific basis for the long term conservation and sustainable and equitable use of the resources of the alpine zone of KNP to promote sustainable development in the state. The significance of the study is based in its ability to contribute in the formulation of a conservation plan for the alpine zone of KNP and a rational pastoral policy for the Sikkim Himalaya.

1.5 Objectives and questions

The study aims at finding the interrelationships between the alpine vegetation, landscape parameters and landuse patterns in the alpine zone of the KNP for evolving a long term conservation plan. The major objectives of the study along with the questions it seeks to answer are as follows:

- To assess the ecology of the alpine vegetation with respect to community composition, structure and fodder availability
    - What are the distinct vegetation types within the alpine zone?
    - What is the structure and composition of the alpine vegetation?
    - What is the fodder availability, key forage species and their nutrient status in these vegetation types?
- To study the spatial extent and recent changes in the alpine vegetation
    - What is the extent of each vegetation type?
    - What is the landscape status in terms of patchiness, disturbance and diversity?
    - What are the impacts of the anthropogenic factors on alpine vegetation?
    - Which vegetation types show maximum change temporally?
- To study the past and present livestock management practices and their impacts on the alpine landscape
    - What is the trend of livestock population over the years?
    - What are the impacts of these pastoral systems?
    - What are the incomes and benefit sharing from the pastoralism enterprise?
- To identify ecologically sensitive areas in the alpine zone to prepare a zonation plan based on
    - The spatial extent and seasonal variation of the grazing areas
    - The changes in the composition and structure of vegetation
    - Conservation status of sensitive species
- To evolve management strategies for the alpine zone of KNP
    - Planning zonation of the existing landuse practices
    - What co-management experiments are possible?
    - How to win the support of the local pastoralists?

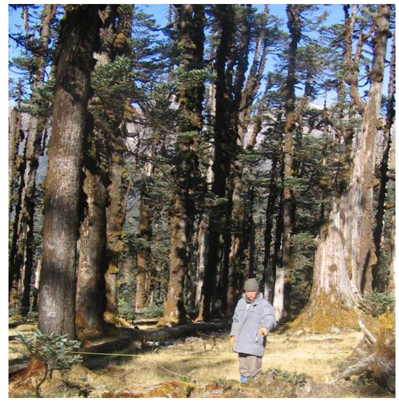
- How to get political support for implementing this plan?

1.6 Scope and organization

The present study has a broad watershed based approach and builds on the recent studies carried out in and around KNP. The doctoral research of Singh (1999) deals with the foraging characteristics of livestock and the grazing impact on the vegetation in the alpine zone. The vascular plant diversity of KNP and buffer zones was studied in detail by Maity (2002). The impacts of habitat disturbances on bird and butterfly communities along the Yuksam-Dzongri trekking trail were studied by Chettri (2000). While some socio-economic aspects of the fringe villages of KNP were studied by Chettri (2005). The present study covers the research gaps related to the structure and composition of the alpine vegetation, broad characterization of the landscapes in the alpine zone based on vegetation and the evolution and sustainability of pastoralism. Plate 1.1 provides glimpses of the study under progress. Pastoralism being the major landuse practice lies in the core of this study. The study also takes into account the social, cultural, economic, legal and political aspects of the various pastoral systems. A simple model to aid decision making by classifying various pastoral scenarios along the gradients of conservation and livelihood has also been attempted. Although the study covers the whole of KNP, more emphasis was given to the southern part of KNP in West Sikkim district and the adjacent reserve forests, as this region is at the core of the pastoral conflict, resolving which is a major thrust of this study (Figure 1.4). The major outcome of this study is the preparation of a conservation plan for the alpine zone of KNP based on the experiences gained from pilot interventions.

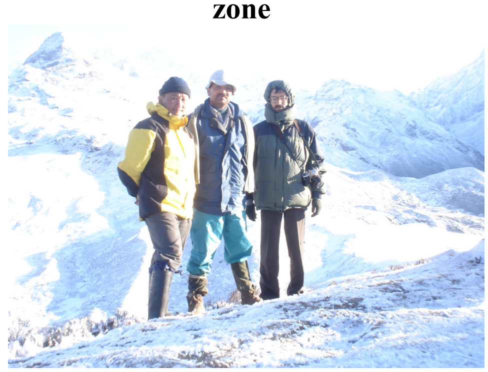
Plate 1.1: Process or methodology

Vegetation sampling in alpine zone



Vegetation sampling in the subalpine zone

Camping in the alpine meadows

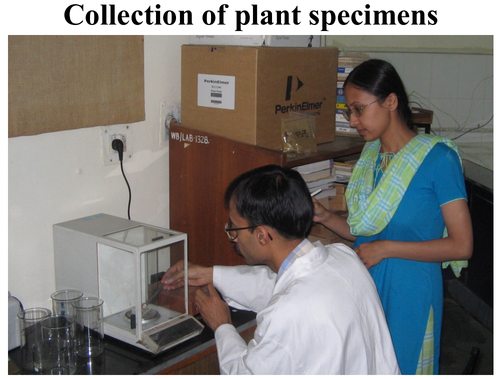


Expeditions in the KNP

Collection of key fodder plants

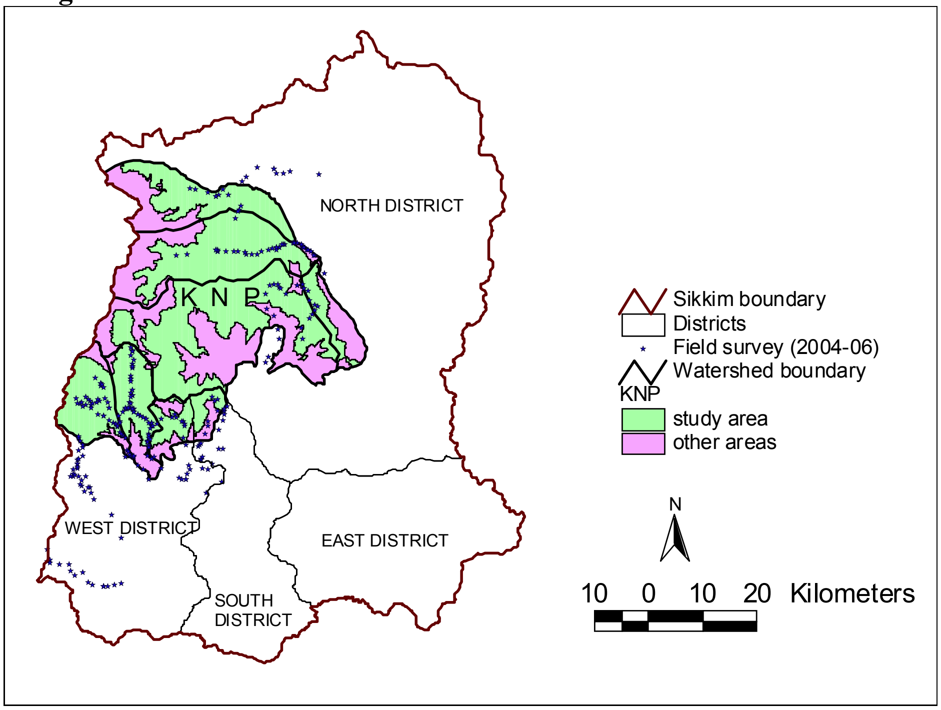
Collection of plant specimens

Village consultations



Forage analysis in WII laboratory

Figure 1.4: Field survey locations within various watersheds of KNP and adjoining reserve forests



The thesis has been organized into the following six chapters. Chapter 1 describes the problem at hand, the objectives, scope, challenges and limitations of the study. The introduction to the study area including the geography, climate, biological attributes, people and the park management is covered in Chapter 2. The spatial patterns in the alpine landscape and temporal change are dealt with in Chapter 3. Chapter 4 introduces the vegetation structure, composition, diversity, fodder availability and impacts of anthropogenic factors. The alpine vegetation forms the building blocks for the alpine landscape. The pastoral systems their origin, population trends, incomes, impacts and sustainability are dealt in Chapter 5. Finally the last chapter summarises the landuse zonation plan, experiences gained from participatory conservation experiments and emerging trends that are likely to play a vital role in the conservation and sustainable use of biodiversity in the KNP.

1.7 Challenges and limitations

The challenges to this study include a large study area in steep mountainous terrain undergoing rapid landuse change, where all travel is on foot alone. In addition most of the vegetation study had to be carried out in torrential rain in the monsoon months since the alpine plants are in a senescent stage during the winter months. Lastly the study had to be carried out with partly tight finances.

- **Geography:** Intensive study area of about 400 km^2 in the alpine zone, of KNP with an extensive study area of 1,000 km^2 including the adjacent reserve forests accessible by foot alone. Over their entire length, the Himalaya are the narrowest in Sikkim resulting in the topography being steep and rugged.

- **Climate:** The alpine vegetation here is best observed between mid June to mid August. The narrow window of two months for collection of vegetation and pastoralism related data also coincides with the peak monsoon season. Heavy rains result in frequent landslips, road blocks, bridges getting washed off and conditions are often difficult for audio-visual documentation.

- **Finances:** Except along two of the seven watersheds there is no accommodation available inside the KNP. Carrying camping gear, cooking equipment and kerosene is a must and hence support staff is needed. The porter rate influenced by tourism is Rs 200 per day. The conservative estimate of a 10 day field trip including travel, fooding and hiring of 5 porters is Rs 20,000. The total field expenditure of the study was to the tune of Rs 4.00 lakhs over a period of 3 years.

- **Lack of support from some villages:** While the study in general received whole hearted support of the people, in the villages of Lachen, Thangu and Muguthang the local village council was in general distrustful of the forest department and this resulted in a limited assistance in this portion of the study area.

The study was largely able to overcome all these hurdles but for the last one which resulted in a limited human dimension in the Lhonak watershed part.

2.0 Study Area: Khangchendzonga National Park

2.1 Introduction

The Himalaya is the youngest of the world's mountain chains and include all of the world's mountain peaks that exceed 8,000 meters in height (Sherpa *et al.* 2004). It is located at the intersection between the Palaearctic and the Oriental regions and bordering on five separate bio-geographical zones. These mountains form the watershed for the rivers flowing in northern India, and stop the northward flow of the monsoon clouds and are thus responsible for the abundant rainfall and the ensuing prosperity of the people living in the Indo-Gangetic plains. At present about 4.7% of the countries 3.3 million sq. km geographical area is under the protected area network. The Himalayan region covers The Himalaya and the trans-Himalaya covering ca. 12% of the countries 3.3 million km^2 geographical area in the six Indian states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, part of West Bengal and Arunachal Pradesh. The protected area network in the Greater and trans-Himalaya consists of 15 national parks and 60 sanctuaries covering 37,479.24 km^2 (based on data available in the National Wildlife Database of the Wildlife Institute of India).

Until the mid 19th century Khangchenjunga was considered to be the highest peak in the world, but calculations made by the Great Trigonometric Survey in 1849 indicated that Mount Everest was the highest and Khangchenjunga the third-highest. Khangchendzonga was first explored by J.D. Hooker in 1849, circumnavigated by Douglas Freshfield in 1899 and summited in 1955 by George Band and Joe Brown of a British expedition (Hooker 1851, Freshfield 1903, Evans & Band 1956). The British expedition honoured the beliefs of the Sikkimese, who hold the summit sacred, by stopping a few feet short of the actual summit.

As per the ecosystem profile of the Eastern Himalaya prepared by the Critical Ecosystem Partnership Fund (2005) this region is included in the 34 global biodiversity hotspots (Myers *et al.* 2000, Mittermeier *et al.* 2004) and includes several Global 200 eco-regions (Olson & Dinerstein 1998). It also has two Endemic Bird Areas (Stattersfield *et al*. 1998) and several centers for plant diversity (WWF/IUCN

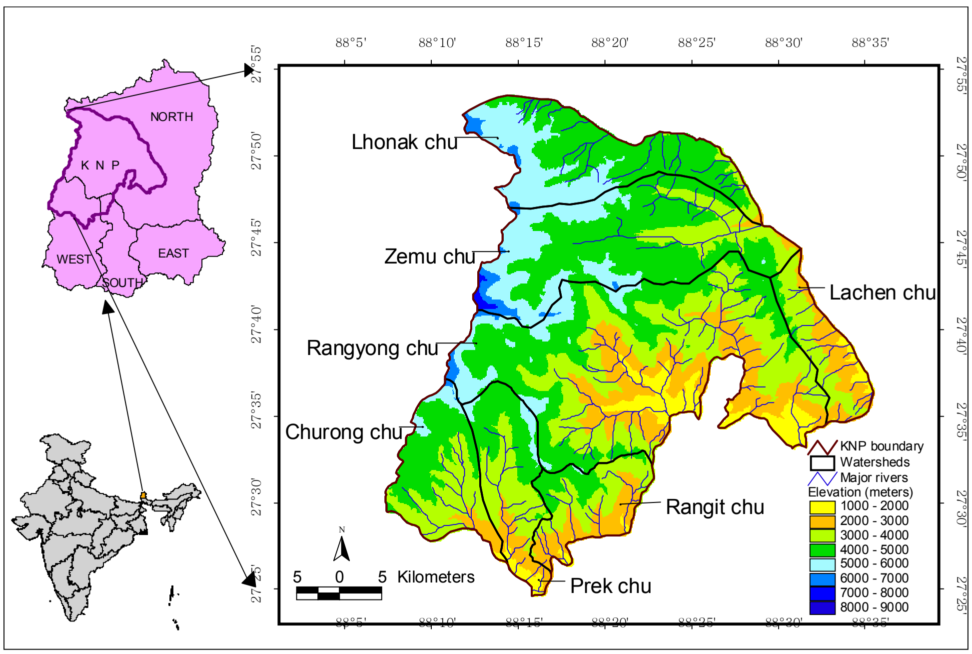
1995).

Sikkim is a small mountainous state in the Eastern Himalayan region extending approximately 114 km from north to south and 64 km from east to west, having a total geographical area 7,096 km^2. It is surrounded by vast stretches of the Tibetan plateau in north; chumbi valley and the kingdom of Bhutan in the east; Darjeeling district of West Bengal towards south and Nepal in the west. This land is drained by the mighty Tista River, which flows in the north-south direction (Lachungpa *et al*. 2003). Sikkim was an independent kingdom ruled by the Namgyal dynasty till 1975 before its merger with India as the 22^{nd} state. The administrative divisions in this least populous state of the country includes four districts (East, West, North and South), 9 sub-divisions, 8 towns and 166 Gram Panchayat units including the *Dzumsa* system of traditional governance. 81% of the geographical area of the state is classified as forestland and the forest cover is 46%. The protected area network comprising of the KNP and seven wildlife sanctuaries is 31% of the geographical area of the state, which is the highest in percentage terms in the country (Anon 1994; Anon 2003a). The state of Sikkim belongs to the biogeographical zone 2C - Central Himalaya (Rodgers & Panwar 1988) and marks the extreme southern fringe of the Turkmenian subregion of the Palaearctic region (Mani 1978).

The KNP is located on the (Sikkim) Indo-Nepal border between 27^o 30' to 27^o 55' N latitude and 88^o 02'and 88^o 37' E longitude and spreads over 1,784 km^2 covering about 25% of the geographical area of the state (Figure 2.1). It is the highest wildlife protected area of the country. It is part of the greater Khangchendzonga landscape providing biological connectivity with Kanchenjunga Conservation Area in Nepal, Barsey and Maenam sanctuaries in Sikkim and Singalila National Park in the Darjeeling district of West Bengal. It harbours four species of endangered mammals namely snow leopard (*Uncia uncia*), red panda (*Ailrus fulgens*), wild dog (*Cuon alpinus*) and particolored flying squirrel (*Hylopetes alboniger*). BNHS-Birdlife International also declared it as an "Important Bird Area" in 2004 (Islam & Rahmani 2004).

The climate here is characterized by a long monsoon followed by a long winter. The stunning variation in altitude of 7,400 meters in annual rainfall of 2,000 mm and the existence of nine major ethnic communities makes this park a unique natural and cultural heritage hotspot in the world. Most of the peaks, lakes, rivers and caves here are considered sacred and are visited by pilgrims. The alpine zone as used in this study broadly includes the areas between 4,000 and 5,000 meters elevation. Physiognomically it starts from where the Krummholtz thickets end and the alpine scrub begins and extends up to the subnival vegetation. About 22% of the park with an extent of 390 km^2 falls within this zone. Major direct economic benefits from the park include livestock production, nature tourism, pilgrimage and hydro-electricity.

Figure 2.1: Map of the study area (KNP)



The KNP with its geographical location and stunning variation especially in altitude and rainfall is a storehouse of many rare and endangered flora and fauna. It serves many other vital hydrological, environmental and recreational functions. The rich cultural mix of ethnic communities further adds another facet to its uniqueness. Large cardamom farming in the sub-tropical belt and livestock rearing in the temperate and alpine belt are the traditional livelihoods. Recently tourism in select villages has brought about local prosperity.

2.2 Material and methods

Various features such as contours, watersheds, glaciers, lakes, peaks and reserve forest boundary were digitized from the Survey of India (1:25,000 scale) topographic maps in ERDAS IMAGINE version 8.5 digital image processing software. Rainfall distribution and characterization of soil was mapped using maps prepared by the National Bureau of Soil Survey and Land Use Planning (Anon 2000). The trekking trails and locations were digitized using Survey of India (1:25,000 scale) topographic maps as well as primary ground truthing data collected during field survey. The population of the villages is as per the 2001 Census of India (Anon 2001). The major ethnic group in these villages was determined during the village meetings. The digital elevation maps (DEMs) were downloaded from the CGIAR-CSI GeoPortal (Jarvis *et al.* 2006). From the DEM the spatial analyst extension of ArcVIEW GIS version 3.2 was used to create contours and derive aspect and slope maps.

2.3 Physical features

2.3.1 Physiography

The Khangchendzonga massif presides over the physiography of Sikkim. It has five peaks, of which the true summit is 28,169 feet or 8586 meters. The huge massif of Khangchendzonga is buttressed by five great ridges running roughly in five directions. These ridges contain a host of peaks between 6,000 and 8,000 meters. On the east ridge in Sikkim, is Siniolchu (6,887 m), the west ridge culminates in the magnificent Jannu (Kumbakarna 7,710 m) in Nepal with its imposing north face. To the south are Kabru North (7,338 m), Kabru South (7,317 m) and Rathong peak (6,679 m). The north ridge, after passing through the minor subpeak Khangchendzonga North (7,741 m) contains The Twins (7,350 m) and Tent Peak (7,365 m), and runs up to the Tibetan border by the Jongsong la, a 6,120 meter pass. The fifth ridge running south east in Sikkim has the Pandim peak (6,691 m).

Sikkim encompasses the Lesser Himalaya, Greater Himalaya, and the Tibetan marginal mountains. Although the trend of the greater Himalaya is to run across in an east-west direction, the two ridges demarcating Sikkim’s eastern and western sides, the Chola and the Singalila, follow a north-south pattern. Across the middle, another north-south ridge of lesser elevation separates the Rangeet Valley from the Tista Valley. Hence while the trend of the mountain system is broadly in the east-west direction, the chief ridges run in a more or less north-south direction. The Singalila range separates Sikkim from Nepal and forms the western boundary of KNP. It is dotted with the highest peaks in Sikkim reaching its peak at the summit of Mt. Khangchendzonga at 8,586 meters. The eastern face of this massif is drained by west-east running lateral glaciated valleys. Towards the south another lateral ridge originating from the Khangchendzonga massif runs southeast with the peaks of Pandim, Jopuno and Narsing. This middle ridge is drained by several south flowing rivers namely the Churong, Prek and Rangit and continues due south where it figures as the Maenam -Tendong ridge. Towards the north at Lhonak, the Tibetan marginal mountains or trans-Himalaya are found at 6000-7500 m and line the southern margin of the Tibetan Plateau. The Rangit and the Tista, which form the main channels of drainage, run nearly north south. These rivers flow through narrow gorges which gradually open up towards the top.

The elevation of KNP varies from about 1,220 to 8,586 meters within an aerial distance of just 42 kilometers. About 90% of the park lies above 3,000 meters and 70% above 4,000 meters making this a truly high altitude park (Figure 2.1). Along the whole length of the Himalayan system which stretches for about 3,000 km, in width it varies from as little as 80 km in Sikkim, to more than 300 km (Schaller 1977). Steep slopes coupled with heavy rainfall result in high surface runoffs and landslides. Consequently amongst all the Himalayan rivers, the Tista has the highest sediment yield of approximately 98 m^3/year/hectare of the catchment (Valdiya 1985).

2.3.2 Aspect and slope

The distribution of various aspect and slope categories derived from SRTM data is shown in Figure 2.2 and 2.3. The southern (Churong chu, Prek chu and Rangit chu; *Bhutia chu* = river) and south-eastern part (Lachen chu) of the park has its major valleys oriented north-south creating generally east and west aspects. While in the central (Rangyong chu) and northern (Zemu chu and Lhonak chu) portions of the park the valleys are east-west oriented creating mostly north and south aspects. In terms of relief the central and eastern parts of the park which are not dominantly sculptured by dominant valley glaciers are steeper as compared to the south-western and northern portions with glaciated valleys.

Figure 2.2: Map showing distribution of various aspect categories in KNP

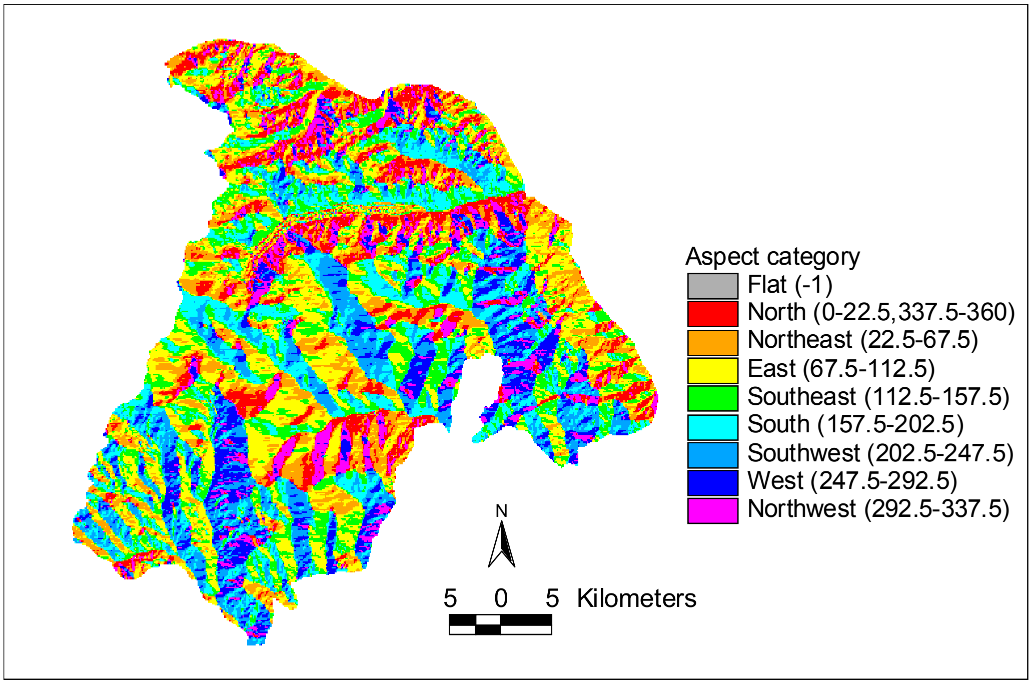
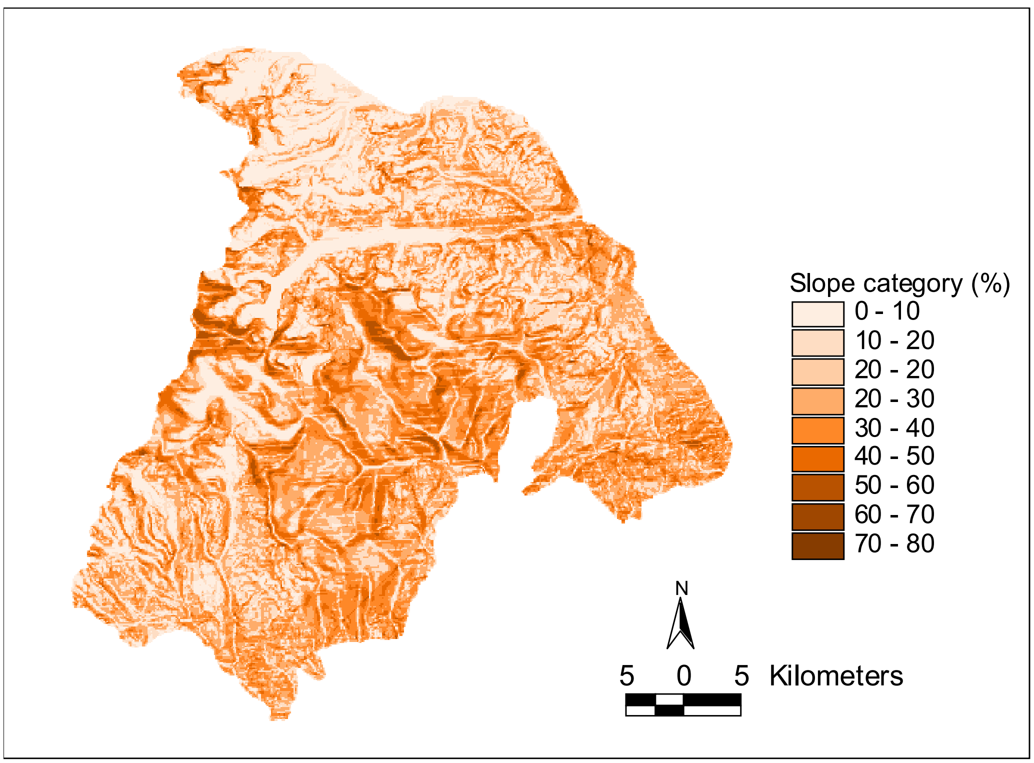


Figure 2.3: Map showing distribution of various slope categories (%) in KNP



2.3.3 Drainage and watersheds

The Khangchendzonga landscape forms the headwaters for seven major river systems namely Tista, Rangit, Torsa, Mahananda, Neora, Tamur and Sapt Koshi. The KNP is the source of two major river systems, the Tista and the Rangit. The Tista originates from the Tista Kangse glacier in the trans-Himalaya of Sikkim and cuts across the inner Himalaya before meeting the Brahmaputra in Bangladesh. While the Rangit originates from the various glaciers in the south-western part of KNP. For ease in understanding, the area of KNP is divided into seven watersheds or river sub-systems namely the Lhonak, Zemu, Lachen, Rangyong, Rangit, Prek and Churong (Figure 2.4, Table 2.1, Table 2.2). While the Rangit, Prek, Churong and Lachen rivers flow north-south, the others flow from west to east. These watersheds though located adjacent to one another show significant variation in physiography, climate and culture. In some watersheds the valley glaciers have melted and only the remnants remain, in others the valley glaciers are still active, while others which are steep and rugged were not sculptured dominantly by valley glaciers.

Figure 2.4: Map of major watersheds in KNP

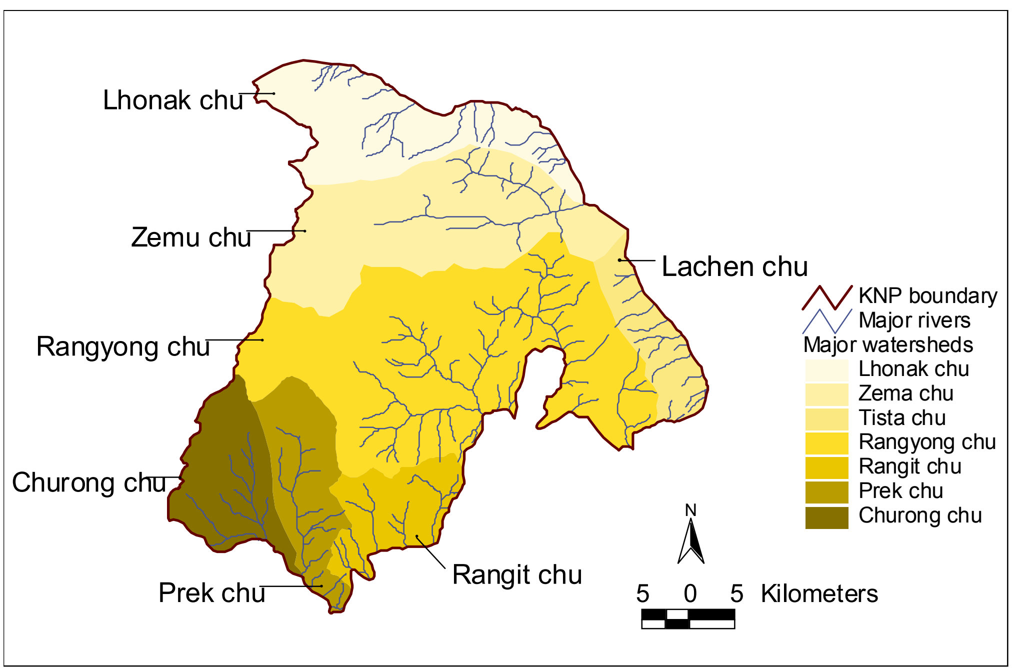


Table 2.1: Area (km^2) under various watersheds in KNP

Watershed	Major tributaries	Locations	Area (km^2)	% of KNP
Lhonak chu	Goma chu, Putung chu, Lungma chu	Rasum, Goma, Lungma	243	14
Zema chu	Thomphyak chu, Siniolchu glacier	Green lake, Yabuk, Talem	368	21
Lachen chu	Yuktu chu, Yel chu, Fim chu, Rokzang chu	Mensithang, Phimpu	95	5
Rangyong chu	Ringpi chu, Rukel chu, Umram chu, Talung chu	Tholung, Kisong	664	37
Rangit chu	Relli, Rungdung, Kaiyun	Relli, Rungdung, Jhyuare	118	7
Prek chu	Yangzee chu, Khola urar chu	Thangsing, Lamune, Gochela, Areylungchok, Lampokhri	144	8
Churong chu	Runzi chu, Tekep chu, Yangsaap chu	Boktok, Yangsaap, HMI Base Camp	152	9

Table 2.2: Relief characteristics of various watersheds in KNP

Watershed	Area	Highest Elevation	Lowest Elevation	Total Relief	Basin Length	Relief Ratio
	km^2	meters	meters	meters	meters	
Lhonak chu	243	7459	3100	4359	44065	0.10
Zema chu	368	8586	2700	5898	42697	0.14
Lachen chu	95	5064	1800	3264	27171	0.12
Rangyong chu	664	8476	1200	7276	31413	0.23
Rangit chu	118	5825	2200	3625	10747	0.34
Prek chu	144	6691	2200	4491	25626	0.18
Churong chu	152	7338	2200	5138	23953	0.21

2.3.3.1 Lhonak chu

This river originates as Goma chu from the North and South Lhonak glaciers and flows in the west-east direction before joining Zemu chu at Talem. A number of glacial lakes drain into this river which flows through a broad valley in the upper reaches formed by glaciers which have since then receded and only the remnants remain in the upper reaches (Smith & Cave 1911). The total area of this watershed is 243 km^2 and Goma chu, Putung chu, Lungma chu, Khora chu and Naku chu are its main tributaries. This is the only watershed, which is protected by ridges, which are more than 5,000 meters high on all sides. The two alpine passes namely the Theu la (5,235 meters) in the south-east and the Luna la (5,058 meters) towards the east connect it to the Zema chu and Lachen chu valley respectively. The Lhonak river valley forms a narrow gorge downstream where it meets the Zemu chu and together with these high ridges on all sides create a formidable barrier for the monsoon winds. This is the highest watershed of KNP with the elevation varying from 3,100 meters where the Lhonak meets the Zemu river to the top of Jongsang peak at 7,459 meters with the mean being 5,250 meters. The total relief is 4,359 meters, basin length 44 kilometers and the relief ratio 0.10. This is also the driest watershed with the annual rainfall varying from 750 mm to 1,575 mm with the mean being only 1,334 mm. The Lhonak chu also demarcates the northern boundary of the KNP and its right bank forms the only trans-Himalayan zone within this park. The flats along the middle and upper reaches of this river valley are important summer pastures for the yaks of the semi-nomadic *Dokpa* and *Bhutia* pastoralists who are based in Muguthang, Thangu and Lachen villages respectively. The Indo Tibet Border Police is also stationed here manning the international border with Tibet Autonomous Region of China. Administratively this watershed falls within the Chungthang subdivision of the North Sikkim district.

2.3.3.2 Zema chu

The 25 km long Zemu glacier forms the source of the Zemu river which flows in the west-east direction meeting the Lachen chu at Zema-1, which is also the road-head of this watershed. In its upper reaches it is fed by the Siniolchu, Simvo, Nepal Gap, Tent Peak and the Hidden glaciers. Other than these the Thomphyak chu and Lhonak chu are its major tributaries. The total area of this watershed is 368 km^2 with the Zemu glacier, which is the longest glacier in the Sikkim Himalaya being the dominant feature. The Kishong la (4,785 meters) towards the south east connects it to the Rangyong watershed. Since this valley is broad and open downstream, it is relatively moister compared to Lhonak, with the annual rainfall varying from 1,250 mm to 2,250 mm with the mean being 1,643 mm. The elevation varies from 2,700 meters at the confluence of the Zemu chu and the Lachen chu to the Khangchendzonga peak at 8,586 meters with the mean being 5,112 meters. The total relief is 5,898 meters, basin length 43 kilometers and the relief ratio 0.14. The upper reaches of this valley has extensive *Kobresia* sedge meadows which are free from livestock use for more than 30 years now. *Bhutias* are the major ethnic group here who reside in the Lachen village. This watershed falls within the Chungthang subdivision of North Sikkim district.

2.3.3.3 Lachen chu

The Lachen chu flows through a narrow valley first north-south between Zema and Chungthang and then east-west till it meets the Rangyong chu at Sangklang. The right bank which falls within the KNP is steep and rocky with a total area of only 95 km^2 making this the smallest watershed. Chyaga chu, Nathang chu, Yukti chu, Yel chu, Phim chu, Rolazong chu and Raman chu are the main tributaries. The annual rainfall varies from 1,250 mm to 2,250 mm with the mean being 1,812 mm. The upper reaches of this ridge has extensive *Kobresia* sedge meadows which are free from livestock use and provide important wintering habitat for ungulates. The elevation varies from 1,800 meters above Chungthang along Fim chu to 5,064 meters at Thepa la with the mean being 3,447 meters. The total relief is 3,264 meters, basin length 27 kilometers and the relief ratio 0.12. This watershed falls within the Chungthang subdivision of the North Sikkim district and the *Bhutias* and *Lepchas* are the main ethnic groups here. Lachen and Chungthang are the important villages adjacent to this watershed.

2.3.3.4 Rangyong chu

The Rangyong chu also known as the Talung chu flows east-west through a narrow valley and joins the Tista at Sangklang. The Talung, Tingchen Khangse, Tongshiong, South Simvo, Umram and Jumthul Phuk glaciers feed this river in the upper reaches. The Rukel chu, Umram chu, Passarum chu, Raviongrum chu, Ringpi chu, Rangli chu, Ringyong chu and Rani chu are the main tributaries. The Kishong la alpine pass (4,785 meters) connects this valley to the Zema chu watershed. The annual rainfall varies from 1,250 to 2,250 mm and with the mean being 1,866 mm. The elevation varies from 1,220 meters (lowest elevation in KNP) above Singhik village along Rani chu to the south peak of Mt. Khangchendzonga at 8,476 meters, with the mean being

4,173 meters. The total relief is 7,276 meters, basin length 31 kilometers and the relief ratio 0.23. This is the largest watershed within the national park with a total area of 664 km^2. The terrain is very steep with the Rangyong chu flowing through a gorge with near vertical faces. The upper reaches of this watershed has extensive *Kobresia* sedge meadows on steep slopes. This is also the stronghold of the *Lepcha* indigenous community who are the aboriginal inhabitants of the state. Consequently this watershed is rich in historical, cultural and religious values. The Ringpi chu valley has limited use by livestock mostly cows, yaks and sheep with the ownership concentrated with one household, otherwise this watershed is also free from livestock use. In the fag end of 2006 the local community got the Tholung-Kishong trek along the Ringpi chu valley approved by the state government. This watershed falls within the Mangan subdivision of the North Sikkim district.

2.3.3.5 Rangit chu

The Rangit chu originates from the Narsing glacier and the Laduwa chu, Relli chu, Rungdung chu and Kayum chu are the main tributaries. This watershed has a total area 118 km^2 and is very steep with the rivers flowing through gorges. This is the wettest watershed with the average annual rainfall being 2,250 mm. The elevation varies from 2,200 meters to the Narsing peak at 5,825 meters, with the mean being 4,176 meters. The total relief is 3,625 meters, basin length 11 kilometers and relief ratio 0.34. The upper reaches of this watershed have extensive *Kobresia* sedge meadows on steep slopes. The major ethnic groups living in scattered villages downstream of this watershed are the *Mangers, Gurungs* and the *Lepchas*. This watershed has seen limited use by the *Manger* and *Gurung* shepherds. This watershed has poor development infrastructure with no road connectivity as yet, irregular power supply and no tourism benefits. Consequently the human development indicators are also the weakest. In the fag end of 2006 the local community got the Narsing Himal trek approved by the State Government. This watershed spans across two districts and falls within the Gyalsing subdivision of West Sikkim district and Ravongla subdivision of South Sikkim district.

2.3.3.6 Prek chu

The Prek chu originates from the Onglaktang glacier and flows north-south before joining the Churong chu. Yangzee chu and Khola urar chu are the main tributaries.

The Prek chu valley opens up in the upper reaches and the total area of this watershed is 144 km^2. The annual rainfall varies from 1,750 to 2,250 mm and with the mean being 2,230 mm. The elevation varies from 2,200 meters to the summit of the Pandim peak at 6,691 meters, with the mean being 3,562 meters. The total relief is 4,491 meters, basin length is 26 kilometers and the relief ratio is 0.18. The immensely popular Yuksam – Dzongri - Gochela trek, which had more than 5,000 visitors in 2005, lies in this watershed. This watershed has also seen extensive use for livestock production traditionally by the *Gurung* shepherds and lately by the *Bhutia* yak herders and the free ranging *dzos* and horses used as pack animals in the tourism sector. *Limbus, Lepchas* and *Bhutias* are the major ethnic groups here who stay in Tshoka and Yuksam. This watershed falls within the Gyalsing subdivision of West Sikkim district.

2.3.3.7 Churong chu

The Churong chu originates from the Rathong glacier and flows north-south before meeting the Rangit river. Runzi chu, Tikip chu, Yangsaap chu, Boktok chu, Ome chu and Prek chu are the main tributaries. The Churong chu flows through a glaciated valley in the upper reaches and the total area of this watershed is 152 km^2. The alpine passes of Khangla and Boktok open into Nepal and have been used for trans-border trade since historical times. Due south, the Daphey bhir pass (4,631 meters) connects this watershed to the Rimbi chu watershed. The annual rainfall varies from 1,750 to 2,250 mm with the mean being 2,037 mm. The elevation varies from 2,200 meters to the Kabur North peak at 7,338 meters, with the mean being 4,591 meters. The total relief is 5,138 meters, basin length 24 kilometers and relief ratio is 0.21. This watershed has traditionally seen extensive use for livestock production by *Gurung* shepherds and lately by the *Bhutia* yak herders. The Himalayan Mountaineering Institute (HMI), Darjeeling has a training camp near the Rathong glacier, which is used for conducting training courses in mountaineering. The Yambong Singalila trek opened in 2005 as a part of the Singalila ecotourism promotion zone passes through the upper reaches of this watershed. This watershed falls within the Gyalsing subdivision of West Sikkim district. *Limbus* and *Bhutias* are the major ethnic groups here who stay in the villages of Chongri, Sindrabung and Yuksam.

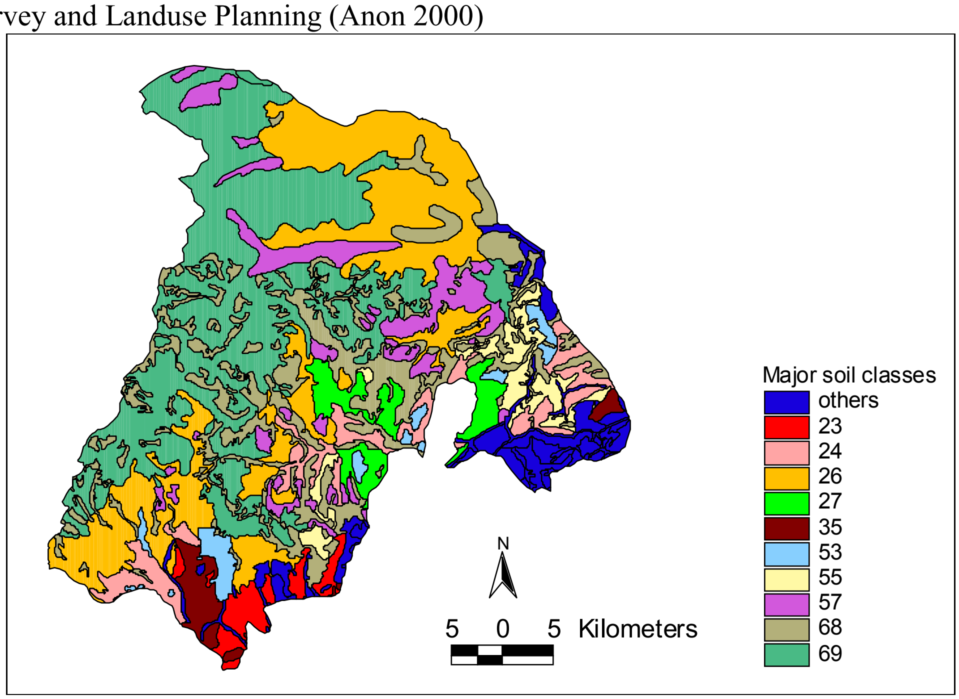
2.3.4 Soils

About 30% of the geographical area of KNP is under glaciers, ice sheets or perpetual snow cover. Loamy skeletal soils on high relief glaciated land and cliffs (slope > 50%) with severe erosion and moderate stoniness have a dominant cover of 53%. While coarse loamy soils, which are moderately shallow, excessively drained on steep to very steep slopes (slope >30%) cover about 11% of the total area of the park. Table 2.3 shows the distribution of the major soil classes and their extent while Figure 2.5 shows their distribution.

Table 2.3: Distribution of major soil classes in KNP (Source: National Bureau of Soil Survey and Land Use Planning (Anon 2000)

Soil unit	Soil classes	Area in km^2	% of KNP
69	Glaciers / ice sheet / perpetual snow cover	533.68	30.0
26	Loamy-skeletal, isofrigid Lithic Cryorthents	383.00	21.6
68	Loamy-skeletal, mesic Lithic Udorthents	300.70	16.9
57	Loamy-skeletal, mesic Lithic Udorthents	125.39	7.1
24	Loamy-skeletal, mesic Typic Haplumbrepts	93.73	5.3
27	Coarse-loamy, mesic Entic Haplumbrepts	61.42	3.5
55	Coarse-loamy, mesic Typic Haplumbrepts	58.91	3.3
23	Coarse-loamy, thermic Typic Haplumbrepts	40.79	2.3
35	Loamy-skeletal, thermic Entic Hapludolls	35.90	2.0
53	Coarse-loamy, mesic Cumulic Haplumbrepts	36.26	2.0

Figure 2.5: Map showing major soils of KNP (Source: National Bureau of Soil Survey and Landuse Planning (Anon 2000)

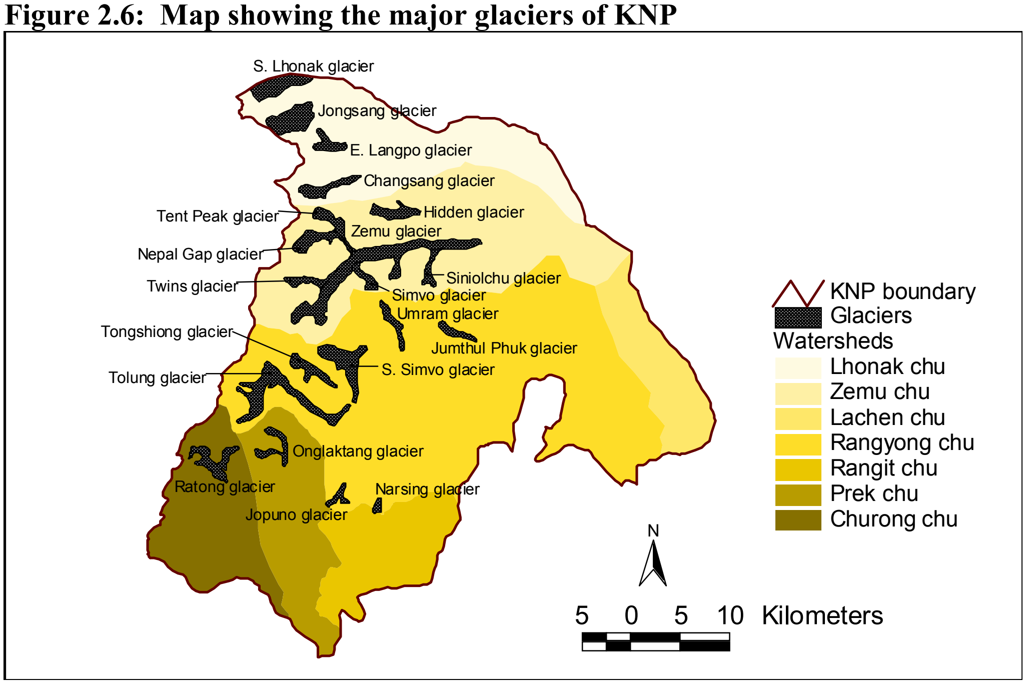


2.3.5 Glaciers and glacial lakes

As per the studies of the International Center for Integrated Mountain Development (ICIMOD), in Sikkim there are 285 glaciers altogether covering an area of 576.433 km^2 with an ice reserve of approximately 65 km^3 (ICIMOD 2004). The glaciers within the KNP generally flow in the west-east direction. The Zemu glacier is the largest and longest glacier in the Sikkim Himalaya, which occupies an area of around 107 km^2. The mean length of the glacier is around 25.7 km with an ice reserve of 22 km^3 (Anon 2005). Figure 2.6 shows the major glaciers in KNP.

Glaciers in western Himalaya receive more snow due to westerly disturbances while those in eastern Himalaya receive more moisture from the summer monsoon. In the western Himalayan region, the average annual winter precipitation is about 80% and 20% in summer season creating arid to semi-arid conditions. The situation is reverse in eastern and northeastern region where the average precipitation is 20% in winter and 80% in summer, resulting in humid conditions. The annual glacier melt is about 50% in the west, which decreases to about 10% in the northeast region (Anon 2005).

Figure 2.6: Map showing the major glaciers of KNP



There are altogether 313 glacial lakes throughout the Teesta basin of the Sikkim Himalaya covering an area of 21.5 km^2 (Anon 2005). Of these a total of 73 glacial lakes occur within the national park covering an area of about 3.34 km^2 (Table 2.4).

All the lakes within the KNP are above 4,000 meters and are classified as glacial lakes. The Prek chu and the Zema chu watersheds have the maximum number of 16 lakes each, while the Rangit chu watershed has just 2 lakes. In terms of area the Lhonak chu watershed contains 43% of the total area under lakes, primarily due to the presence South Lhonak tsho which has an area of 0.71 km^2 and is the largest lake in KNP.

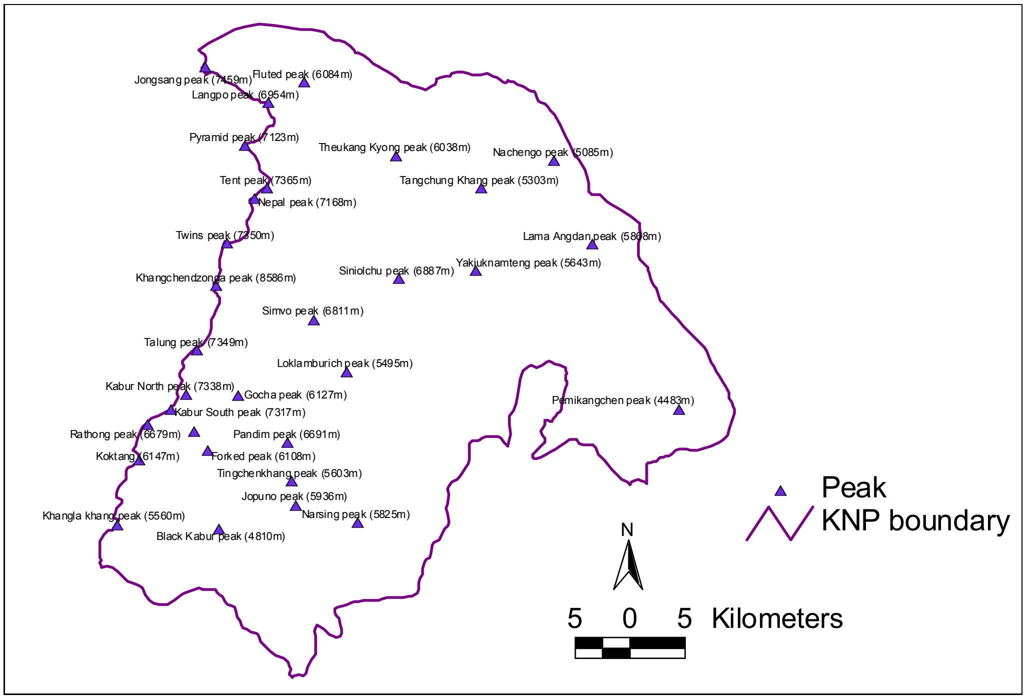
Table 2.4: Number and area of lakes in the various watersheds of KNP

Watershed	Number of lakes	Area of lakes in km^2	% of lake numbers	% of Lake area
Lhonak chu	11	1.43	15	43
Zema chu	16	0.41	22	12
Lachen chu	4	0.15	5	4
Rangyong chu	11	0.70	15	21
Rangit chu	2	0.07	3	2
Prek chu	16	0.28	22	8
Churong chu	13	0.31	18	9
Total	**73**	**3.34**	**100**	**100**

2.3.6 Mountain Peaks

There are 20 peaks, which are above 6,000 meters within the KNP. Out of these peaks 11 are between 6,000 to 7,000 meters, eight between 7,000 to 8,000 meters and one above 8,000 meters (Figure 2.7). The highest being Mt. Khangchendzonga, which towers at 8,586 meters and is the third highest peak in the world. Scaling of these high peaks is not permitted as they are considered the abode of the guardian deities. In 2006 the state government has opened four peaks within KNP between 5,000 to 6,000 meters elevation, namely the Frey's Peak, Lama Angden, Mt. Tinchenkang and Mt. Joponu for alpine expeditions.

Figure 2.7: Map showing the location and elevation of the major peaks of KNP



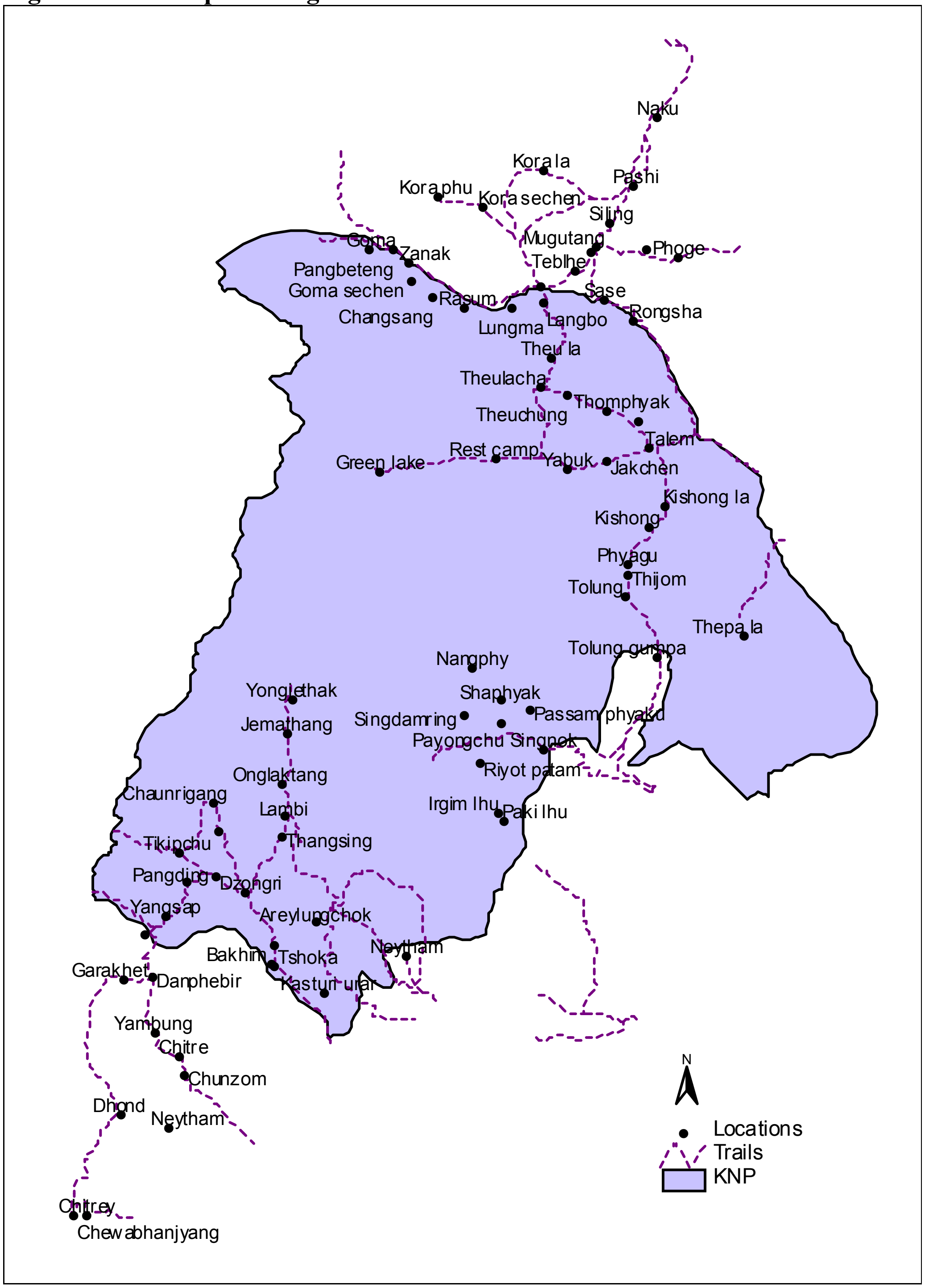
2.3.7 Trails and locations

The access to the various watersheds of KNP is along the river valleys, while inter valley connectivity is through alpine passes (Figure 2.8). Only the connectivity between Prek chu and the Rangyong watersheds is hazardous due to the inaccessible Talung glacier and fast flowing Rukel chu river. The Churong chu watershed provides trans-border connectivity with Nepal through the Boktok and Khangla alpine passes. While the Lhonak watershed provides connectivity with Tibet Autonomous Region of China through the Naku, Khora and Chorten Nymla passes.

2.4 The climate

The eastern Himalaya has a prolonged monsoon season from May to September and little precipitation is received from the western disturbances in winter. The western Himalaya, on the other hand has a short monsoon from July to August and a fairly long wet season from November to April (Figure 1.2, 1.3). In the pre-monsoon season from March to May, thunderstorms occur frequently in the eastern Himalaya and precipitation is heavy, increasing from March to May with the advance of the hot season. In the western Himalaya the pre-monsoon season is quite dry, except for occasional thunderstorms. The general climatic conditions in the east are semi-oceanic, but become increasingly continental westward (Miller 1987, Mani 1994).

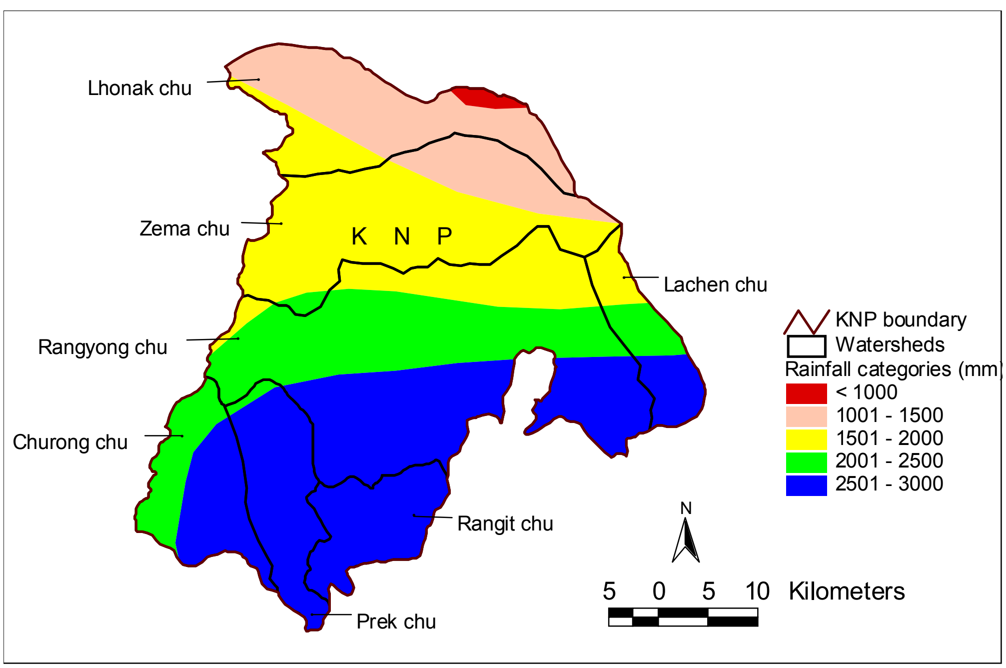
Figure 2.8: Map showing the foot trails and locations within the KNP



2.4.1 Rainfall and humidity

Most of KNP has a monsoon climate dominated by an extended wet season. The climate can be categorized as cold and wet, with the monsoons and winter being the two major seasons. The summer monsoon is prevalent from May to September and winter extends from November to March, with brief spells of spring and autumn during the months of April and October respectively. In the KNP the monsoon winds blowing from the southwesterly direction bring heavy precipitation, which is obstructed by successive west-east ridge formations, and consequently the precipitation decreases towards the north. The annual rainfall (Fig 2.9) decreases from 2,750 mm in the southeastern part to 750 mm in the north with the average being 2,143 mm (Anon 2000). July is the wettest month in most of the places. Lhonak and Chombo chu valley fall in the rain shadow with desert-like tundra, barely getting 1000 mm of annual rainfall. While within a watershed rainfall shows a declining trend with altitude (Figure 2.10). The relative humidity is high (>70%) throughout the year and in the subalpine (cloud-forest) zone, mist precipitation results in a still higher relative humidity (Figure 2.11).

Figure 2.9: Map showing the mean annual rainfall categories in KNP (Source: National Bureau of Soil Survey and Land Use Planning (Anon 2000)



2.4.2 Temperature

The mean minimum and mean maximum temperatures vary inversely with altitude with January being the coldest month and August the warmest (Figure 2.12 and 2.13).

Figure 2.10: Monthly variation in rainfall (in mm) in the three altitudinal zones, Yuksam (1500 m), Tshoka (3000m) and Dzongri (4000m) (Source: Chettri 2000)

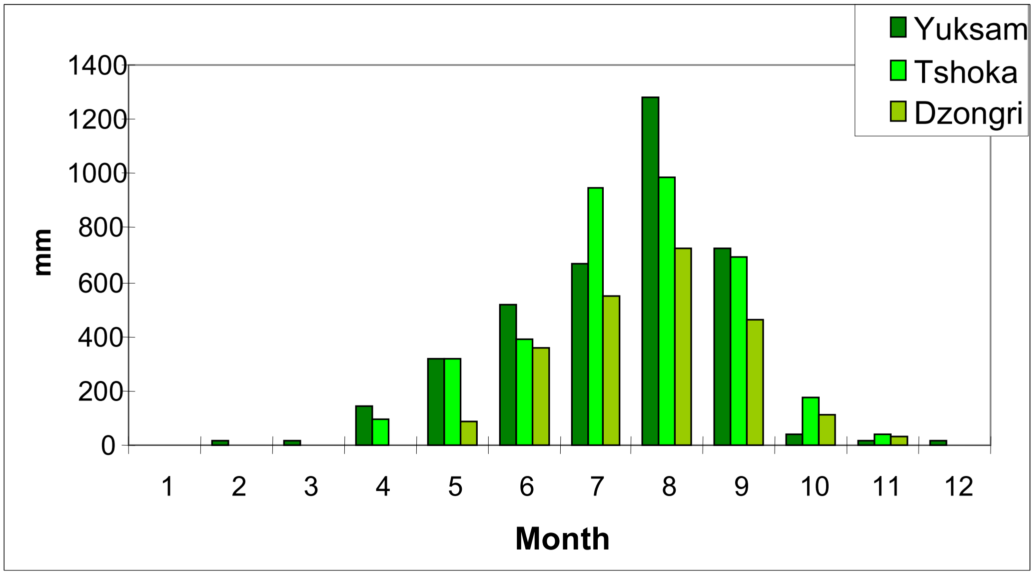


Figure 2.11: Monthly variation in relative humidity (in %) in the three altitudinal zones, Yuksam (1500 m), Tshoka (3000m) and Dzongri (4000m) (Source: Chettri 2000)

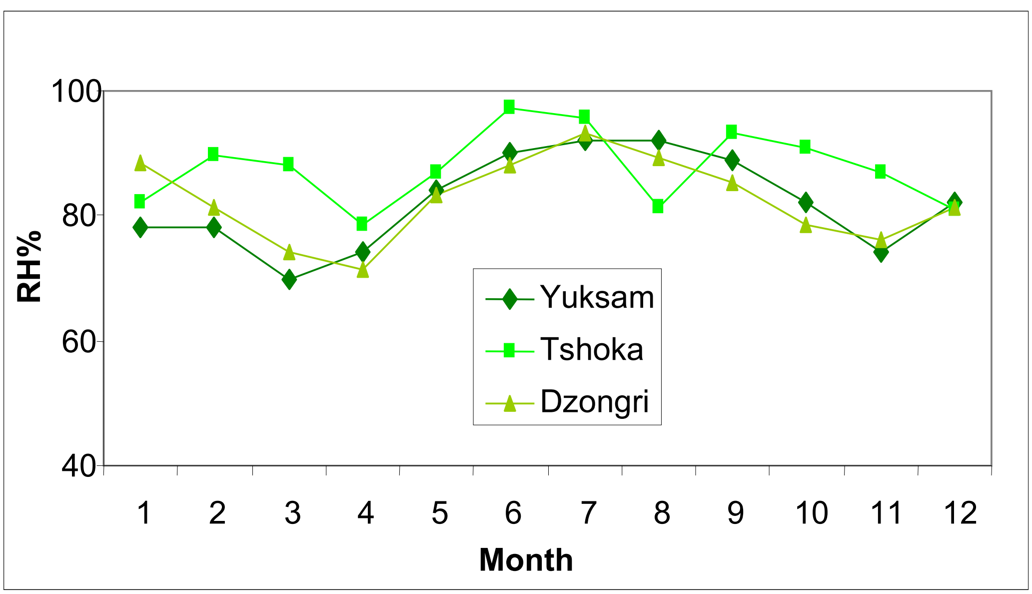


Figure 2.12: Monthly variation in mean minimum temperatures (in °C) in the three altitudinal zones, Yuksam (1500 m), Tshoka (3000m) and Dzongri (4000m) (Source: Chettri 2000)

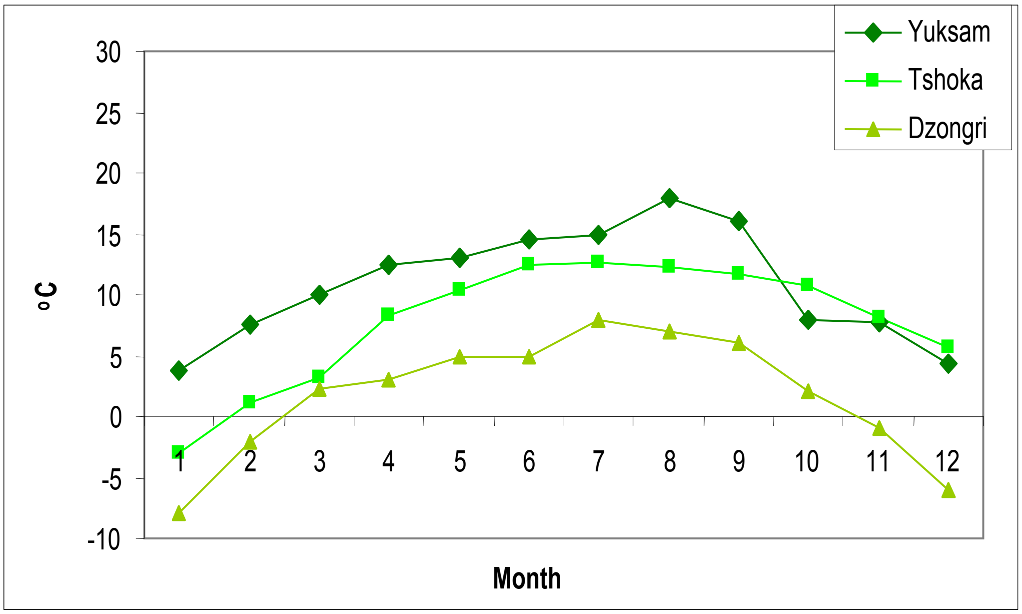
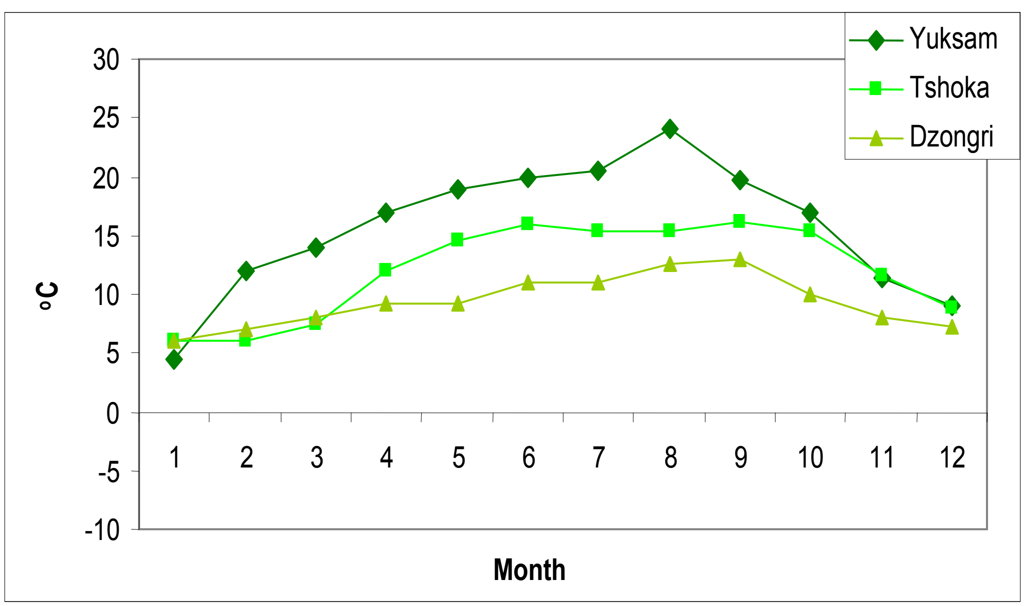


Figure 2.13: Monthly variation in mean maximum temperatures (in °C) in the three altitudinal zones, Yuksam (1500 m), Tshoka (3000m) and Dzongri (4000m) (Source: Chettri 2000)



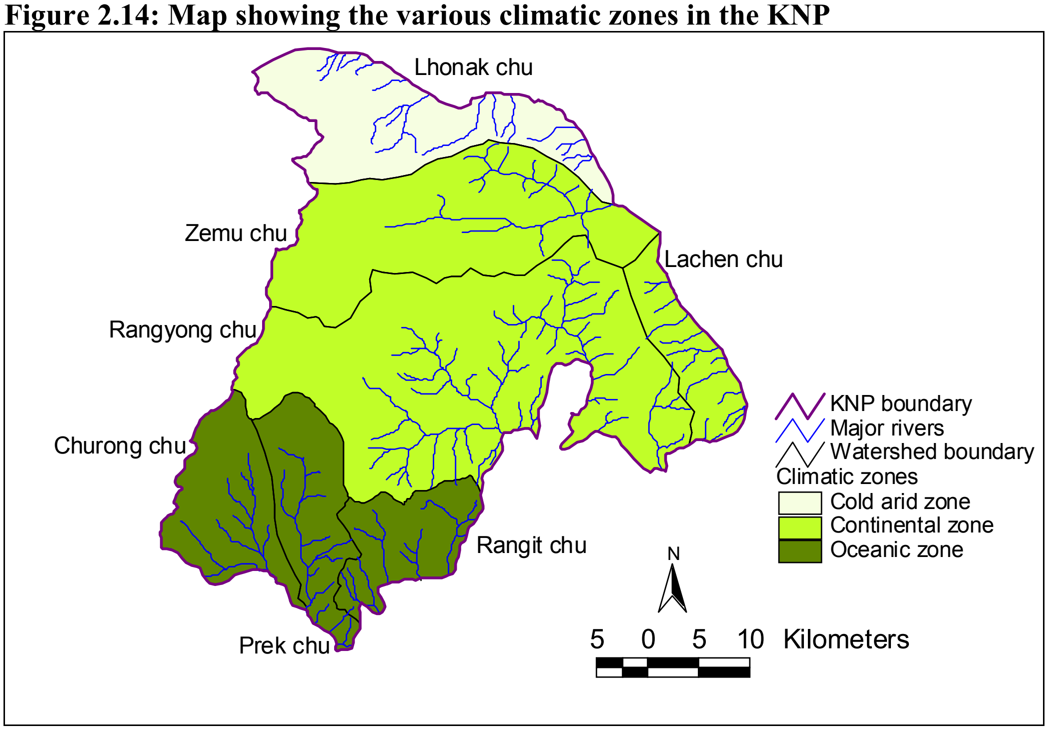
2.4.3 Climatic zones

The southern watersheds directly facing the westerly monsoon winds having an oceanic climate. Subsequently the successive west-east running ridges obstruct these moisture laden winds resulting in the central watersheds having a continental climate. While the northern most Lhonak watershed being a cold, arid, highland has a distinct trans-Himalayan character (Table 2.5, Figure 2.14).

Table 2.5: Distribution of mean annual rainfall and climatic zonation of the various watersheds of the KNP

Watershed	Area (km^2)	Mean annual rainfall (mm)	Climatic zone
Lhonak chu	243	1,334	Cold arid zone
Zema chu	368	1,643	Continental zone
Lachen chu	95	1,812	Continental zone
Rangyong chu	664	1,866	Continental zone
Rangit chu	118	2,250	Oceanic zone
Prek chu	144	2,230	Oceanic zone
Churong chu	152	2,037	Oceanic zone

Figure 2.14: Map showing the various climatic zones in the KNP



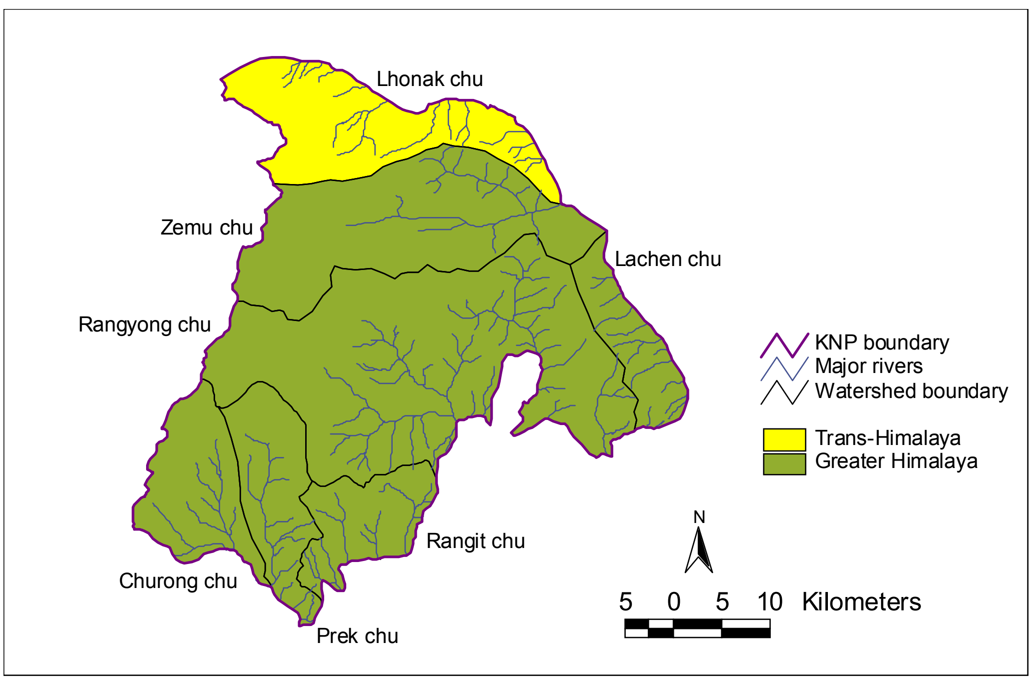
2.4.4 Greater and Trans-Himalaya

The river valleys in KNP provide a conduit for the monsoon winds blowing from the south east to progress inside. The Lhonak watershed which is contiguous with the Tibetan plateau in the extreme north and guarded by high ridges on all sides with an average elevation of 5,250 meters receives a scanty annual rainfall of 1,334 mm. It is the highest, least moist and is located in the extreme north closest to the Tibet Autonomous Region of China (Figure 2.15). Also it harbors characteristic trans-Himalayan floral elements and is categorized under the trans-Himalaya. Though only 14% of the total area of KNP is under this category, it adds another dimension to its natural and cultural diversity (Table 2.6).

Table 2.6: Area and watersheds under Greater and trans-Himalaya in the KNP

S. No.	Himalaya category	Watershed name	Area (km^2)	% Area
1	Trans Himalaya	Lhonak chu	243	14%
2	Greater Himalaya	Zema chu, Lachen chu, Rangyong chu, Rangit chu, Prek chu, Churong chu	1541	86%

Figure 2.15: Map showing the location of Greater and trans-Himalaya in the KNP



2.5 Biological attributes

Sikkim is widely acknowledged as amongst the most significant biodiversity hot spots of the country with a bewildering density of biodiversity in just 0.2% of the geographical area of the country. It harbours an estimated 5,000 species of flowering plants including 36 species of *Rhododendrons*, 11 species of oaks, 11 species of conifers, 550 species of orchids, 30 species of *Primulas*, 20 species of bamboos, 484 species of medicinal plants and 175 species of wild edible plants. The faunal wealth consists of about 144 species of mammals, 550 species of birds, 600 species of butterflies, 33 species of reptiles, 16 species of amphibians and 48 species of freshwater fishes (Hajra & Verma 1996, Lachungpa *et al.* 2003). KNP constitutes about 25% of the geographical area of Sikkim.

2.5.1 Forest types

According to the classification by Champion and Seth (1968) for the states of Assam (including NEFA, Nagaland, Sikkim and Bhutan) and West Bengal, there are 18 forest types in KNP with four figuring in the alpine zone. These are $8B/C_1$ East Himalayan sub-tropical wet hill forest, 11B/C1(a,b,c) East Himalayan wet temperate forest, 12/C3(a,b) East Himalayan moist temperate forest, 12/DS1 Montane bamboo brakes, 12/DS2 Himalayan temperate parkland, 12/DS3 Himalayan temperate pastures, 12/1S1 Alder forest, 13/C6 East Himalayan dry temperate coniferous forest, 13/C6/E1 Larch forest, 13/C7 East Himalayan dry juniper/birch forest, 13/1S1 *Hippophae / Myricaria* scrub, 14/C2 East Himalayan sub-alpine birch/fir forest, 14/DS1 Sub-alpine pasture, 15/C1 Birch/*Rhododendron* scrub, 15/C2/E1 Dwarf *Rhododendron* scrub, 15/C3 Alpine pastures, 16/C1 Dry alpine scrub, 16/E1 Dwarf juniper scrub.

2.5.2 Flora

Floristic study by Maity and Maiti (2007) indicates that the Khangchendzonga Biosphere Reserve (KBR) contains 1580 species of vascular plants comprising of 106 pteridophytes, 11 gymnosperms and 1463 species of angiosperms. The angiosperms are represented by 1,207 species of dicots and 256 species of monocots, distributed under 598 genera and 138 families. The gymnosperms have 5 families in 9 genera and 11 species. The dominant families are Asteraceae, Rosaceae, Orchidaceae, Poaceae, Scrophulariaceae, Ericaceae and Primulaceae.

2.5.3 Mammals and birds

Four species of endangered mammals namely snow leopard (*Uncia uncia*), red panda (*Ailrus fulgens*), wild dog (*Cuon alpinus*) and particolored flying squirrel (*Hylopetes alboniger*) and five species listed in the vulnerable category are found in KNP. KNP is a part of the Endemic Bird Area (EBA) - Eastern Himalaya. Due to the size and altitude elevations in this EBA, birds recorded are from at least four biomes. Thus this EBA has at least 127 bird species of conservation concern including seven globally threatened and restricted range species, 24 species of Biome-5 (Eurasian High Montane), 67 of Biome-7 (Sino-Himalayan Temperate Forest), 26 of Biome-8 (Sino Himalayan Subtropical Forest) and three listed in Biome-9 (Islam & Rahmani 2004). Amongst birds there are four species in the vulnerable category. Plate 2.1 depicts some key wildlife of the subalpine and alpine zones. As per the Wildlife Protection Act 1972, there are 16 schedule I species and 8 in part II of schedule II (Table 2.7). Butterflies of the Snow Apollo genus *Parnassius* of the Swallowtail (*Papilionidae*) family are reported from the alpine areas.

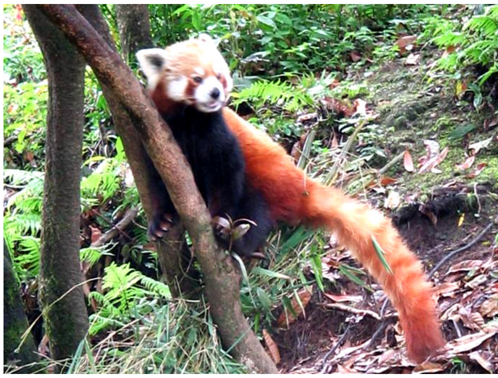
Table 2.7: Large mammals and birds of KNP along with their global and legal conservation status (** sighted during current study)*

Common Name	Scientific Name	Local Name	Global Threat Status (IUCN)					WPA-1972
			Critical	Endangered	Vulnerable	Near Threatened	Least Concern	Schedule
HERBIOVRES								
Barking Deer	*Muntiacus muntjak*	Mirga					LC	III
Bharal / Blue Sheep*	*Pseudois nayaur*	Ban bheda					LC	I
Himalayan Goral	*Naemorhedus goral*	Goral				NT		III
Himalayan marmot*	*Marmota himalayana*						LC	II Part II
Himalayan Musk Deer*	*Moschus chrysogaster*	Kasturi				NT		I
Himalayan Tahr*	*Hemitragus jemlahicus*	Jharal			VU			I
Serow*	*Capricornis sumatraensis*	Tahr			VU			I
Wild boar	*Sus scrofa*	Banel					LC	III
CARNIVORES								
Asiatic Black Bear	*Ursus thibetanus*	Bhalu			VU			II Part II
Clouded Leopard	*Neofelis nebulosa*	Ningalo chituwa			VU			I
Common leopard	*Panthera pardus*	Chituwa					LC	I

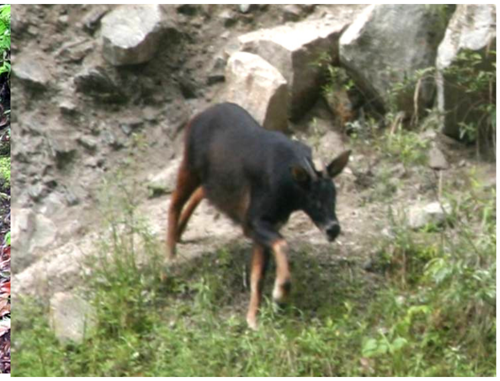
Common Name	Scientific Name	Local Name	Global Threat Status (IUCN)					WPA-1972
			Critical	Endangered	Vulnerable	Near Threatened	Least Concern	Schedule
Dhole / Wild dog	*Cuon alpinus*	Ban kukur		EN				II Part I
Leopard Cat	*Prionailurus bengalensis*	Ningalo					LC	I
Red fox	*Vulpes vulpes*	Lekh shyal					LC	II Part II
Red Panda	*Ailurus fulgens*	Kundo		EN				I
Snow Leopard	*Uncia uncia*	Hiun chituwa		EN				I
Tibetan wolf	*Canis lupus*	Buanso					LC	I
Yellow-throated Marten	*Martes flavigula*	Malsapro					LC	II Part II
OTHER MAMMALS								
Assamese Macaque*	*Macaca assamensis*	Baander			VU			II Part I
Common Langur*	*Semnopithecus entellus*	Dhedu				NT		II Part I
Common Otter	*Lutra lutra*	Onth				NT		II Part II
Himalayan Palm Civet	*Paguma larvata*	Kaala					LC	II Part II
Indian Crested Porcupine	*Hystrix indica*	Dhumsi					LC	IV
Orange-Bellied Himalayan Squirrel	*Dremomys lokriah*						LC	II Part II
Particolored Flying Squirrel	*Hylopetes alboniger*	Raj-pankhi		EN				II Part II
KEY AVIFAUNA								
Beautiful Nuthatch	*Sitta formosa*				VU			IV
Blood Pheasant*	*Ithaginis cruentus*	Chilime					LC	I
Chestnut-breasted Partridge	*Arborophila mandellii*				VU			IV
Hill-Partridge	*Arborophila torqueola*	Peura					LC	IV
Himalayan Griffon*	*Gyps himalayensis*						LC	I
Himalayan Monal*	*Lophophorus impejanus*	Danphe					LC	I
Kalij Pheasant*	*Lophura leucomelanos*	Kalij					LC	I
Lammergeier or Bearded Vulture*	*Gypaetus barbatus*						LC	IV
Lesser Kestrel	*Falco naumanni*				VU			IV
Rusty-bellied Shortwing	*Brachypteryx hyperythra*				VU			IV
Satyr Tragopan*	*Tragopan satyra*	Munal				NT		I
Snow Partridge*	*Lerwa lerwa*	Larewa					LC	IV
Tibetan Partridge	*Perdix hodgsoniae*						LC	IV
Tibetan Snowcock*	*Tetraogallus tibetanus*						LC	I

Adapted from CEPF 2005, Islam & Rahmani 2004, Chettri 2000, IUCN 2006, Anon 2003b

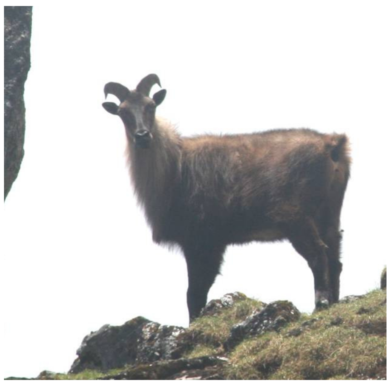
Plate 2.1: Some key wildlife of the sub-alpine and alpine zones



Red panda (state animal)

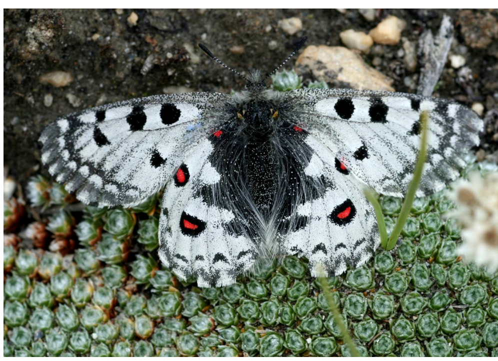


Serow



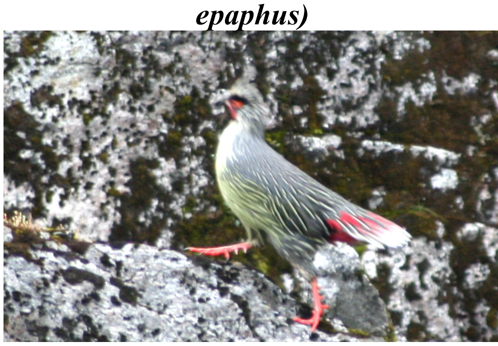
Himalayan tahr

Blue sheep



Common red apollo *(Parnassius epaphus)*

Lammergier or Bearded vulture



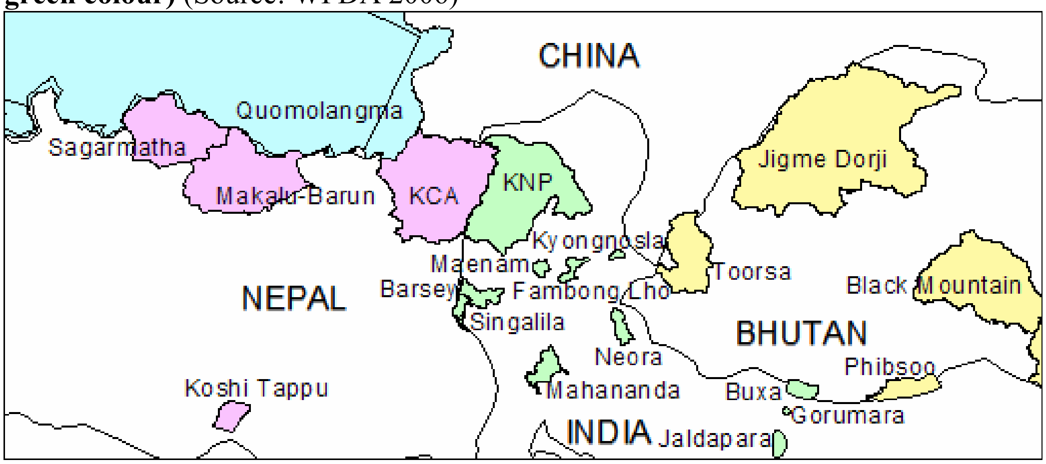
Blood pheasant (state bird)

Red fox

2.6 The trans-boundary landscape

The KNP is located in the western half of Sikkim due west of the Tista river and is contiguous with the Kanchenjunga Conservation Area of Nepal and linked through biological corridors to the Barsey and Maenam Sanctuaries, while due north lie the vast tracts of the Tibetan plateau (Figure 2.16). The Khangchendzonga landscape spans across international borders and shares this trans-boundary trait with 169 other such complexes of two or more adjoining protected areas that are divided by international boundaries (Sandwith *et al.* 2001).

Figure 2.16: The protected area landscape around KNP including ones in Nepal (in pink colour), China (in blue colour), Bhutan (in yellow colour) and India (in green colour) (Source: WPDA 2006)



The Singalila ridge runs north-south on a rocky spur separating the Indian state of Sikkim on the east and Nepal on the west. This is an open, porous border and since ages movement of people, livestock, wildlife and lately tourists has been going on. This ridge separates the districts of Ilam, Panchthar and Taplejung of Nepal with the districts of Darjeeling, West Sikkim and North Sikkim of India. This ridge is also studded with some of the highest and majestic snow peaks including Mt. Khangchendzonga (8,586 meters). Trade with Ilam and Panchtaar districts of Nepal takes place mostly through the temperate and sub-alpine passes below 3,500 meters while trade with Taplejung district of Nepal and Tibet takes place through the high altitude alpine passes. The high passes viz., Boktok la and Khang la are open only during summer. Sir J. D. Hooker in his Himalayan Journals recounts how salt used to be smuggled into Sikkim from Tibet after crossing four high passes, all above 15,000 feet, covering one-third of the circuit of Khangchendzonga and taking more than a month (Hooker 1851).

The Singalila ridge is not only an international border but also a development divide. Though the ecological and socio-cultural fabric on either side of the border is the same, the economic progress on both sides is disparate. On the Nepal side the people are primarily engaged in farming and livestock production with limited infrastructure, communication, education and health facilities. While Sikkim is a fast developing state with even remote villages boasting of good road connectivity, electricity, drinking water, schools, hospitals, and subsidies on rural infrastructure, essential food items and kerosene oil. Hence it is economical for the people residing in the border villages of Nepal to access goods and services from the border towns of India. This demand for household provisions from Nepal is met from India in barter trade with mostly dairy products.

To the extreme north-west the trans-Himalayan Lhonak valley separates Sikkim from the Tibetan Autonomous Region of China. The Lhonak valley served as the summer pastures for the nomadic herders from Sikkim and the Khambajong province of Tibet during the early twentieth century (Smith & Cave 1911). However after the Sino-Indian war in 1962, the international border was sealed and currently there are 9 *Dokpas* families in Muguthang hamlet who lead a semi-nomadic life of herding ca. 1,000 yak.

Limbus, Gurungs, Sherpas and *Bhutias* are the main ethnic groups who share family ties across the border. Alpine lakes in Singalila are a source of pilgrimage during the summers, when the snow has melted and the passes accessible. Important lakes for pilgrimage are Tingmvo in Nepal and Laxmi, Majur and Doodh Pokhri in Sikkim. In terms of sacred sites for the pilgrims in Sikkim which are approachable by road the healing hotsprings of Legship, Borong and Polok and sacred caves in Labdang, Sopakha and Rimbick in South and West Sikkim are big attractions. Similarly the Kali Goddess temple at Pathibara in Taplejung and the Changtapu temple in Panchthar are the main pilgrim attractions in Nepal.

2.7 Cultural profile

2.7.1 Sacred landscape

Guru Padmasambhava a Buddhist scholar and saint of the 8th century A.D, eulogized as the second Buddha is considered to have blessed and sanctified Sikkim. He introduced the Tantrayana Buddhism to Sikkim and is said to have hidden holy books in various caves to be discovered in future times. Nearly every mountain, hilltop, prominent rock, mountain pass, crevasse, valley, old tree, lake, river and stream seems to be the abode of some supernatural being. The mountain deity inhabiting the peak of Mt. Khangchendzonga is considered to be their chief and his worship is an important aspect of rituals everywhere among Sikkimese Buddhists. The area south of Mt. Khangchendzonga in West Sikkim is referred to as '*Beyul Demazong'* or the sacred, hidden land, and has the highest concentration of powerful sacred sites and hidden treasures within Sikkim (Figure 2.17). Khangchendzonga literally means five repositories of God's treasure, namely that of salt, gold and turquoise, holy books, arms, medicines and different types of seeds. It is believed that these treasures will be made available to the Sikkimese people in times of need. In the center of this sacred land is Tashiding with four miraculous caves in the four cardinal directions namely Dechen phu, Khandu Sang phu, Bas phu and Lhari Nying phu where one can attain extraordinary powers (Kumar 1995, Balikci-Denjongpa 2002). Table 2.8 tabulates the key events in the history of KNP.

During Panglhabsol festival, Buddhist monks perform rituals and prayers in the name of the Khangchendzonga guardian deity. The monks and the devotees trek upto 'Dhaplha Gang' at Dzongri in KNP to offer prayers and rituals to the Khangchendzonga deity for good harvest, free the whole country and world from disease, hunger, famine and war. Offerings are made to the protector deities but this is no longer possible if the land and water are desecrated. Village level activities on land and water resources are permitted, but any large-scale disturbance in the Yuksam region would destroy the hidden spiritual treasures or *ters*. Any major perturbation to the river system would disturb the protector deities of the 109 sacred lakes. Indeed, the very cultural fabric of Sikkimese society is dependent on the conservation of this entire sacred landscape (Ramakrishnan 1996). In 1997 the Rathong chu hydel project in Yuksam was shelved midway as it was feared that it would hurt the sentiments, religion and interests of the Sikkimese people.

Similarly the sacred valley of Tholung-Kishong in the heart of KNP in North Sikkim constitutes the nerve centre of Lepcha social life and epitomises Sikkimese Buddhism of nationalist practice. It comprises an uninhabited tract of mountainous forests adjacent to the wish-fulfilling pilgrimage site of the Tholung temple that preserves the sacred treasures of the former Buddhist Kingdom of Sikkim. This landscape comprises a monastery, a sacred grove, a sacred hot spring, and some sacred caves that are used by monks to meditate in seclusion. Tholung is located at an altitude of 2,500 meters and impregnable mountains bound the Tholung sacred grove and the temple on all sides. Beyond Tholung, there are some sacred caves and sacred springs where it is believed that Padmasambhava meditated and hid some sacred treasures for discovery in the future (Arora 2006).

Figure 2.17: An artist's impression of the sacred landscape of Khangchendzonga (Phu is sacred cave, Illustration by Peter Lepcha)

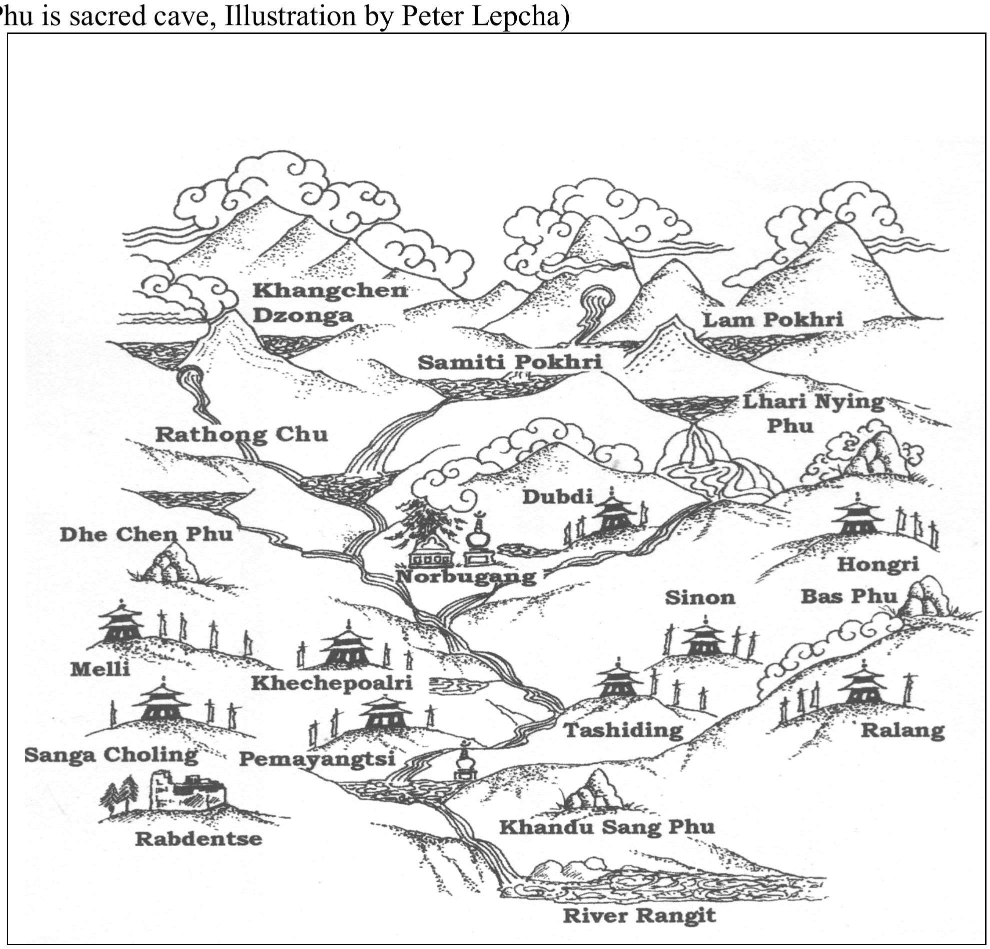


Table 2.8: Key events in the history of KNP

8th Century A.D.	It is believed that Guru Padmasambhava, the revered Buddhist sage blessed the Khangchendzonga landscape of Sikkim
1642	Three learned lamas coronate Phuntshok Namgyal as the first religious king (*Chogyal*) of Sikkim at Norbugang in Yuksam
1851	Sir J. D. Hooker, world-renowned naturalist explored the Khangchendzonga region
1902	Reserve forests of the state demarcated vide C.M.3-3-1902
1933	Earthquake damaged the monasteries at Dubdi, Khecheopalri, Sanga Choeling and Norbugang
1953	Livestock in KNP include one yak herd of the king (*Chogyal)* and *Gurung* shepherds in West Sikkim and nomadic *Dokpa* herders in Lhonak valley of North Sikkim
1954	The creation of the base camp near Rathong glacier of the Himalayan Mountaineering Institute (HMI), Darjeeling initiated by Sherpa Tenzing Norgay
1961	Religious expedition to Dharma Dhoka (Ney Pemathang) took place
1969	Tibetan refugees settled at Tshoka within KNP by the king
1973	Massive forest fire destroyed extensive patches of old growth temperate and subalpine forests in West Sikkim
1975	Sikkim merged as the 22nd state of the Indian union
1977	KNP notified by the state government
1980	First Tourist lodge "Dzongrila" opens in Yuksam in West Sikkim
1982	Livestock production of yaks started increasing in West Sikkim
1985	Tourism started growing in Yuksam
1985	Musk Deer poachers from Nepal arrested by the forest department
1989	Pagala Pokhri and Tinkune lake outburst in West Sikkim
1996	Biodiversity Conservation Network and Sikkim Biodiversity and Ecotourism project of The Mountain Institute and GBPIHED initiated
1996	Respecting local cultural sentiments the state government stalls the Rathong chu hydro electric project
1997	Area of KNP increased to 1,784 km^2
2000	Khangchendzonga Biosphere Reserve notified with KNP as the core zone and a buffer of 836 km^2 of reserve forests
2000	New Singalila round trekking trail opens from Uttarey village
2000	NBSAP planning process initiated in Rathong chu substate site
2002	Russian scientists nabbed at Yuksam by Khangchendzonga Conservation Committee (KCC) NGO while trying to smuggle moths, butterflies and beetles from KNP
2003	JFMCs and EDCs formed in the villages adjacent to KNP
Source: (Adapted from Tambe *et al.* 2003)	

2.7.2 Ethnic groups and demography

Inspite of being a small state the Sikkimese society is ethnically diverse with different lifestyles, cultures and religion existing in harmony with one another. Sikkim has five major ethnic groups namely *Lepcha, Bhutia, Limbu, Nepalese* and plainsmen of Indian origin. These include no less than twenty-five communities (Singh 1993) which are 1) *Lepcha*, 2) *Bhutia*, 3) *Limbu* or *Tsong*, 4) *Mangar*, 5) *Rai*, 6) *Gurung*, 7) *Tamang*, 8) *Thami*, 9) *Yakha*, 10) *Kagatey*, 11) *Sherpa*, 12) *Drukpa*, 13) *Tibetan*, 14) *Newar*, 15) *Brahmin*, 16) *Chhetri*, 17) *Thakuri*, 18) *Sunuwar*, 19) *Majhi*, 20) *Bhujel*, 21) *Kami*, 22) *Damai*, 23) *Sarki*, 24) *Bihari* and 25) *Marwari*. Hinduism and Buddhism are the main two religions. Most of the Nepali groups follow Hinduism and the *lingua franca* of the state is Nepali. The population of the former Buddhist Kingdom of Sikkim is predominantly Hindu (68%), the Buddhists comprise a large community (27%), Christians comprise a small minority (about 3%) and Muslims are present in insignificant numbers (Lama 2001).

The villages adjacent to KNP are located in the altitude zone of 800 – 4,500 meters in the districts of West, North and South Sikkim. As per the census of India, 2001 there are 29 revenue blocks with 9,482 households and a total population of 29,199 living adjacent to KNP (Table 2.9, Figure 2.18). As can be seen from Figure 2.19 the maximum population of the fringe villages adjacent to KNP is in North Sikkim district. Only the Tibetan refugee's settlement of Tshoka in Yuksam forest block which has 7 households is inside the KNP (Tambe *et al.* 2003). The highest village inhabited by the semi-nomadic Dokpa yak herders is at Muguthang in Lachen forest block at 4,500 meters. Chungthang is the most populous revenue block with 36% of the population concentrated here followed by Lachen and Yuksam. The scheduled tribes mainly the Limbu, Lepcha and Bhutia are a majority in the revenue blocks located in the south west, east and north while the other backward classes mainly the Gurung and Manger are clustered in the south east (Figure 2.20). In 2004 of these 29 revenue blocks, only 8 namely Yuksam, Meli, Singrangpung, Dhupidara, Narkhola,Yuksam forest block, Lachen and Lachen Forest Block had major impacts in the sub-alpine and alpine zone of KNP. Sex ratio is just 66 females per 100 males due to the presence of a large workforce of migratory workers especially in Chungthang and Lachen revenue block.

Figure 2.18: Population map of revenue blocks adjacent to KNP

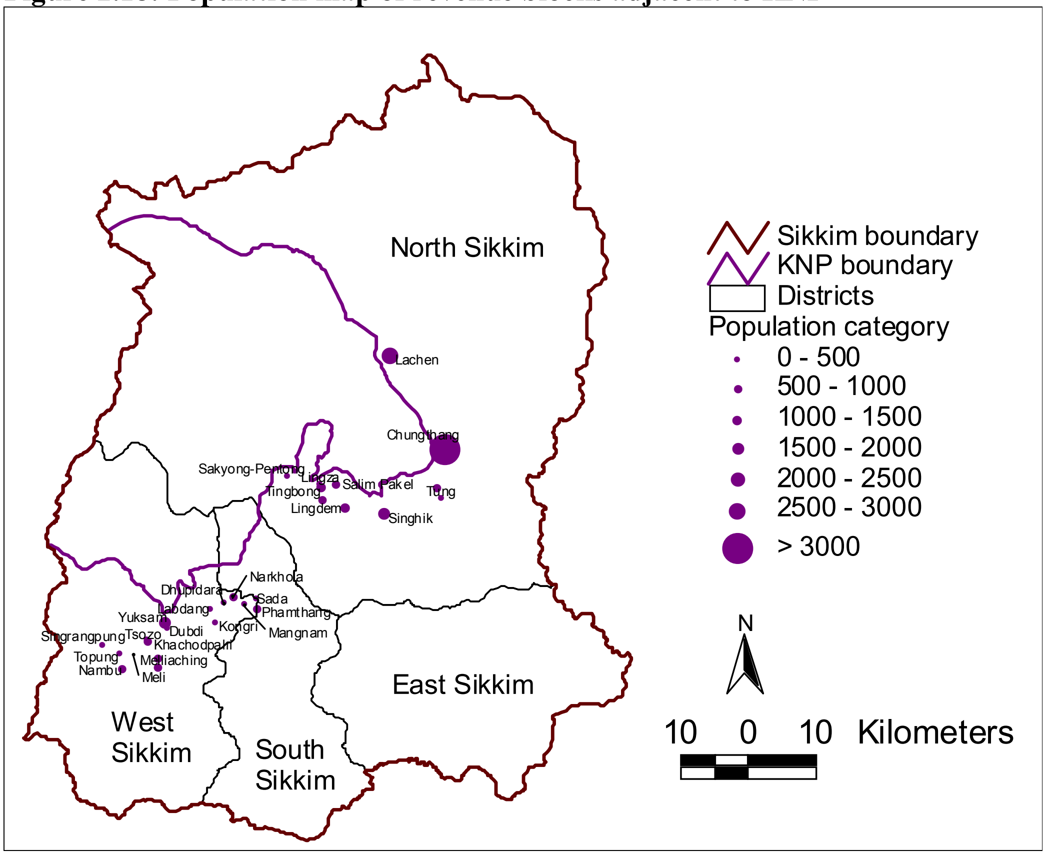


Figure 2.19: District wise distribution of population and households of the revenue blocks adjacent to KNP

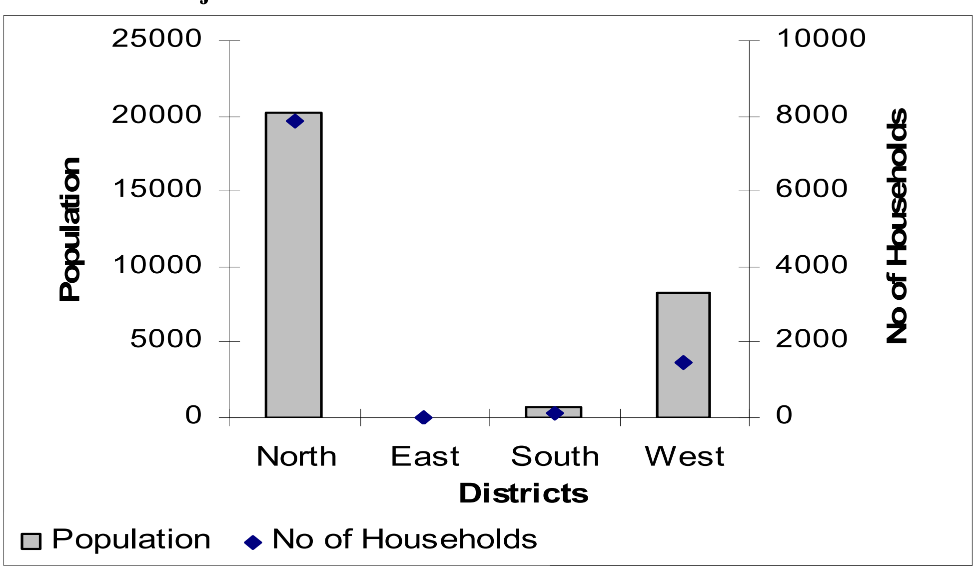
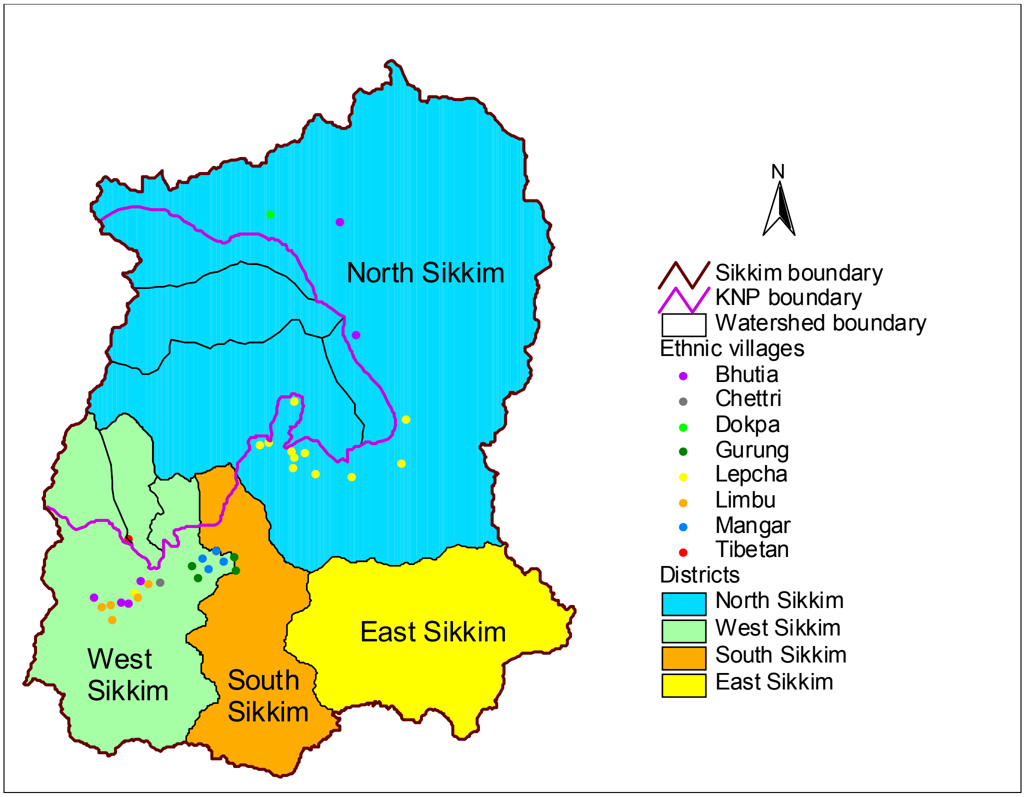


Table 2.9: Number of households, population, male population and major ethnic groups in the revenue blocks adjacent to the KNP

Revenue block	District	No. of households	Total population	Male population	Major ethnic group	Status
Dubdi	West	69	402	217	Limbu	ST
Yuksam*	West	364	1,951	1,043	Bhutia	ST
Tsozo	West	89	476	270	Limbu	ST
Khachodpalri	West	114	556	269	Limbu	ST
Meli*	West	116	623	332	Bhutia	ST
Melliaching	West	109	589	293	Bhutia	ST
Topung	West	52	286	154	Limbu	ST
Singrangpung *	West	47	227	125	Bhutia	ST
Nambu	West	146	859	436	Limbu	ST
Kongri	West	71	442	239	Gurung	OBC
Labdang	West	80	456	241	Gurung	OBC
Dhupidara*	West	76	493	247	Mangar	OBC
Narkhola*	West	82	510	269	Mangar	OBC
Mangnam	West	64	380	199	Mangar	OBC
Yuksam forest block*	West	9	29	18	Tibetan	ST
Sada	South	24	156	82	Gurung	OBC
Phamtam	South	98	601	305	Gurung	OBC
Lachen*	North	1,609	2,923	2,158	Bhutia	ST
Shipgyer	North	166	695	389	Lepcha	ST
Tung	North	52	201	108	Lepcha	ST
Lachen Forest Block*	North	12	32	19	Dokpa	ST
Chungthang	North	4,897	10,502	7,116	Lepcha	ST
Singhik	North	412	1898	1,002	Lepcha	ST
Salim Pakel	North	132	615	307	Lepcha	ST
Lingthem	North	210	1161	614	Lepcha	ST
Lingdem	North	97	542	301	Lepcha	ST
Tingbong	North	164	1001	516	Lepcha	ST
Lingzah-Tolung	North	80	397	203	Lepcha	ST
Sakyong-Pentong	North	41	196	117	Lepcha	ST
Total		**9,482**	**29,199**	**17,589**		

** High impact revenue blocks*
ST = Scheduled Tribe, OBC = Other Backward Classes

Figure 2.20: Map showing the location of major ethnic villages in and around KNP



2.7.3 Traditional landuse practices

The landuse practices in Sikkim evolved with the immigration of various ethnic groups who made this state their home at different periods of history. The Lepchas and the Limbus were the aboriginal inhabitants of the state. There were other ethnic groups like Rais, Gurungs, Mangers and Tamangs who were also the early inhabitants of Sikkim. The Bhutias started immigrating in the 13th century from Tibet, the Nepali influx started from the late 18th century and the plainsmen from India after the merger in 1975. Traditionally the Lepchas and the Limbus were the hunter-gatherers and shifting cultivators, Gurungs the sheep herders, Bhutias the yak herders and traders and Chettri and Bahuns the cattle rearers and farmers. The population of Sikkim was only 36,458 in the year 1891, but by 2001 it had increased by almost 15 times to 5,40,851. (Risley 1894, Choeden 1995, Ghulati 1995, Anon 2001, Balikci-Denjongpa 2002).

Presently these mountain communities follow a diversified livelihood strategy linked to farming, pastoralism and lately tourism. Overall settled mixed farming is the most common livelihood strategy. Agriculture (41%) and cattle rearing (22.3%) are the main occupations. The main source of income in the villages located between 1,500 to 2,100 meters adjacent to KNP is large cardamom farming, while in higher elevation villages like Chongri, Tshoka, Lachen, Thangu, and Muguthang it is livestock production. In the sub-alpine and alpine zones of KNP, livestock production, collection of medicinal and aromatic plants and lately tourism are the main landuse practices. In 2004 there were about 1,629 yaks, 469 milch cow-yak crossbreeds, 1,141 sheep, 150 cows and 316 horses and *dzos* owned by 99 families using the national park. These livestock generated incomes of about Rs 112 lakhs annually.

Recently trekking tourism which is a thrust area of the state government is fast catching up as a major landuse in the alpine zone of KNP. The Yuksam-Dzongri-Gochela trek is the most popular in KNP and had about 4,700 visitors in 2005.

2.8 Socio-economic setting

According to the "Human development report of Sikkim", the state has recorded several significant gains in human development after merging with India in 1975 such as in education, health and medical facilities, economic growth, infrastructure development etc. (Lama 2001). The growth indicators published by the Department of Information and Public Relations (Table 2.10) also provide evidence of this rapid transformation (Anon 2006).

The average land holding is 3.01 ha in North Sikkim, 2.28 ha in West Sikkim and 2.22 ha in South Sikkim (Anon 2002). The quality of life as well as economic indicators of North Sikkim fare much better compared to the other districts (Anon 2005c). Landholding per household in the buffer villages of KNP range from 0.2 ha to 162 ha. In the villages adjacent to KNP average male literacy (55%) was higher than females (47.6%) but is much lower compared to the state average of 75%. The villages adjacent to KNP in North Sikkim are relatively well off and the average annual income per household here varies from Rs 30,825 in Pentong to Rs 74,565 in Lachen (Chettri *et al.* 2003, Krishna *et al.* 2002).

Table 2.10: Trend of growth indicators of Sikkim over the last 12 years (1994-2006)

Growth Indicators	Units	2005-06	1993-94
Per capital income (at current price)	Rs.	26,851	9,300
GSDP (at current price)	Rs.	80,557	40,270
Infant mortality rate	Per 1000	33	46
Literacy rate	%	75	53.47
Daily wage	Rs.	85	20
College	Nos.	11	5
Government schools	Nos.	782	264
Forest cover	%	45.97	43.95
JFMC/EDC committees	Nos.	205	0
Milk production	Lakh ltrs	39	16
Domestic tourist arrivals	Nos.	2,51,744	70,365
Foreign tourist arrivals	Nos.	16,523	7,360
Power generation	MU	165	65.81
Revenue from power	Rs. in crores	27.1	4.17
Consumer cooperative societies	Nos.	574	253
Cereals production	MT	93,000	89,000
Annual plan outlay	Rs. in crores	511.1	120
State revenue (2004-05)	Rs. in crores	228.31	48.44

2.8.1 Livelihood strategy

The farming sector includes large cardamom agro-forestry, subsistence agriculture, animal husbandry and collection of non timber forest produce (NTFP). The farming strategy includes growing food crops, cash crops, fodder trees, vegetables and livestock rearing. The farming practices include agro-forestry, mono-cropping, multiple cropping and rotational cropping. Amongst these cropping forms, mono-cropping is the most common (81.8%), followed by mixed cropping (13.6%) and shifting cultivation (4.5%). The rainfed fields are planted with maize, potato and soyabean, while the steep fields have an under-storey of large cardamom (*Ammomum sublatum)* crop under the shade of Alder (*Alnus nepalensis)* trees which is the primary revenue earner of the village. Village wise average produce per household of large cardamom varies from 70 kg in Chungthang to 140 kg in Sakyong, Upper Dzongu. The cardamom fields and the adjoining forests are also a source of various edible fruits, seeds, leaves, flowers, tubers and mushroom. Vegetable grown include potato, green peas, cabbage, cauliflower and radish. The kitchen garden is used for growing fruit trees like papaya, guava, banana, mandarine orange, sugarcane, yams, tubers, vegetables and fodder trees. Fodder trees mainly *Ficus hookeri* (Nebaro), *Saurauia napaulensis* (Gogun), *Prunus cerasoides* (Paiyun) and *Thysanolaena maxima* (*Amliso* grass) are grown to meet their fodder requirements during winter. Livestock like cow, yak, cow-yak crossbreed, horse, sheep, goat, poultry and pig are reared mainly for milk, butter, cheese, meat, wool, draught power and for carrying trekking tourism loads. The level of dependence for fodder, firewood and NTFP on the buffer zones of KNP is high and ranged from 50% to 75% (Chettri *et al.* 2003, Krishna *et al.* 2002, Singh *et al.* 2005).

The tourism sector has witnessed a rapid growth, with the arrivals of domestic tourists increasing three fold and overseas tourists by two fold over the last decade (Anon 2006). New alpine destinations like passes, lakes and treks which were earlier offbounds for tourism have been recently opened. Conducted tours in jeeps as well as mountain trekking on foot is prevalent. Income opportunities to the local community lie in providing boarding, lodging, transport, farm produce, provisions and manpower for trekking. Villages which benefits from tourism e.g. Yuksam, Tshoka, Lachen and Thangu show higher per capita income.

2.9 The park management

2.9.1 Land tenure and state policy

India has a federal system of governance with the forests, environment and wildlife sector placed in the concurrent list. This implies that both the state and union government can legislate, but in case of overlap, the union laws will prevail. The *dejure* land tenure status of the study area is reserve forests which constitute KNP were demarcated in 1902 and were free from all rights and concessions. The KNP which corresponds to a strict nature reserve under the IUCN protected area category was carved out of such reserve forests on 26^{th} August, 1977 vide Notification No: 43(9)Home/77 with an initial area of 850 km^2 under the provisions of the Wildlife (Protection) Act, 1972. The park comprises notified reserve forests which are free from rights and concessions and protected under the Sikkim Forests, Water Courses, Road Reserve (Protection and Preservation) Act 1988. The final notification wherein the area was increased to 1784 km^2 vide Notification No: 1/KNP(WL)/F/27 dated 19^{th}

May,1997 on account of its intact continuous tract of mountain land reserved for conservation of native wildlife with many rare and endangered species (Lepcha 1997). Any activity within the park has to be in consonance with the provisions of the Wildlife (Protection) Act, 1972. Since the status of land is forest land, any diversion for non-forestry purpose has to also follow the mandatory provisions of the Forest Conservation Act, 1980.

The hon'ble Supreme Court of India in its WP No 202/95 dated 14/02/2000 has "restrained states from ordering even the removal of dead, diseased, dying or wind fallen trees and grasses from national parks and sanctuaries." Hunting of wildlife, destroying its habitat, cutting trees or shrubs, livestock grazing, collecting firewood, fodder or NTFP, constructing any infrastructure for non-forestry purposes are all banned under these strict national laws. Other than tourism no other livelihoods are legally permitted with the national park. Even anyone entering the national park has to obtain a permit from the park directorate. There is one village of Tibetan refugees within the park at Tshoka (3,000 m) with 7 households who have land tenure rights for 13 acres granted by the king (*Chogyal*) of Sikkim in 1969.

In 1996 the state government took a policy decision of banning grazing in the reserve forests in the South and West districts of the state, in plantation areas and water sources. This ban was opposed by the herders and in a response to a plea filed by them the Sikkim high court reaffirmed the grazing ban as it was as per the provisions of the existing acts vide its judgment dated 14/05/1999.

The state government also viewed with concern the depletion of medicinal plants and NTFP excluding bamboos, grasses, plants used as food and cardamom from the forest areas of Sikkim. With a view to encourage regeneration of areas that are facing depletion of these resources the state government banned the collection of all medicinal plants for commercial purpose, for a period of five years vide order No. 13/F/Env & WL. Dated 6th Sept, 2001. This ban was further extended by another five years in 2006.

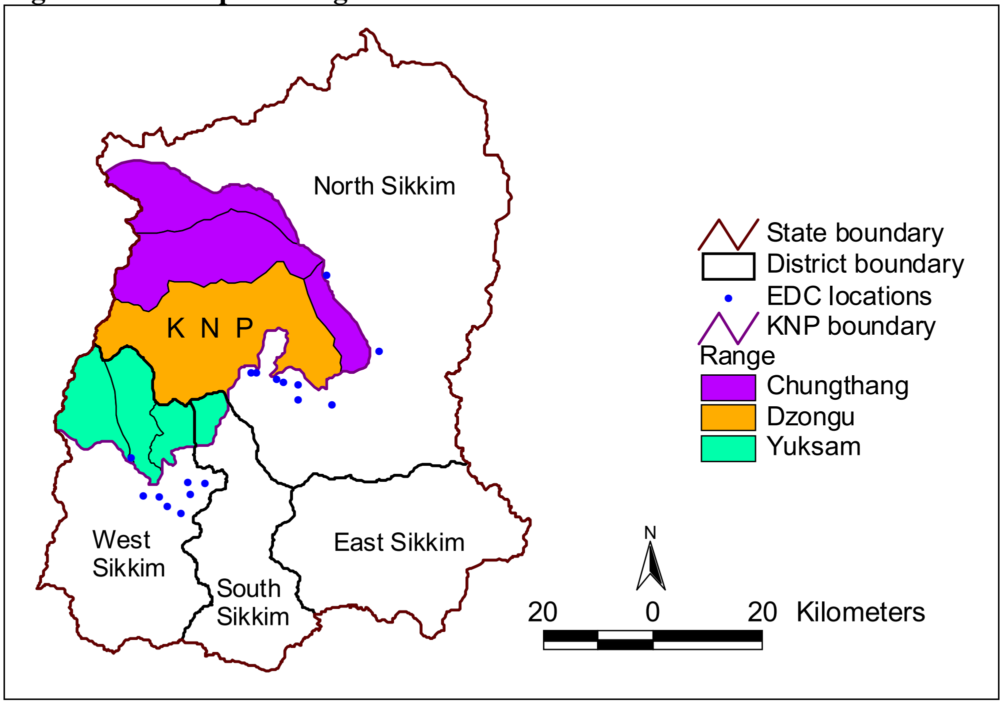
The *defacto* land tenure shows a marked difference from what is envisaged in the state policy or *dejure* land tenure. Livestock production in the alpine rangelands of

KNP, mostly sheep rearing in the Churong chu, Prek chu and Rangit chu watersheds and yak rearing in the Lhonak chu watershed was prevalent since historic times (Hooker 1851, Smith & Cave 1911). The pastoralists used the alpine resources after paying nominal grazing fees to the territorial wing of the forest department. In the absence of permanent presence of the forest department within the park, pastoralists, travel companies, security forces, tourism department and the Himalayan Mountaineering Institute, Darjeeling used the park resources as per their needs. In the absence of a long term scientific management plan for KNP, conservation management continues to be short term. However with the initiation of joint forest management the local community jointly with the forest department is now exercising more control over the park's resources.

2.9.2 Administrative setup

The KNP spans across three districts with a major chunk of 77% in North Sikkim, 20% in West Sikkim and just 3% in South Sikkim (Figure 2.21). It covers four subdivisions namely Chungthang, Mangan, Ravongla and Gyalsing. Administratively the park is divided into three ranges namely Yuksam in West Sikkim and Dzongu and Chungthang in North Sikkim. The park is under the administrative control of the wildlife wing of the Forest Department headed by a Director who reports to the Chief Wildlife Warden. He is assisted by one additional director, one joint director and two field directors one each for North and West Sikkim districts and 2 assistant conservator of forests. The field staff includes 7 daily wages staff, 12 forest guards, 4 block officers (foresters) and 3 range officers manning 1,784 km^2 of rugged, high altitude terrain. On an average there is one forest guard for 150km^2 of the park and the field staffs are posted and stay outside the park. Without adequate field staff and their physical presence inside, the park is managed mostly remotely. Hence effective "on ground" management was lacking and the park management was able to implement mostly procurement and sub-contracting related activities related to afforestation and infrastructure creation. It was unable to effectively carry out activities related to wildlife protection, conflict resolution, regulating tourism and pastoralism, wildlife census and monitoring and evaluation. In 2003, 17 Ecodevelopment Committees, 8 in Yuksam range, 7 in Dzongu range rand 2 in Chungthang range were formed. Now the park directorate has more outreach and presence on the ground.

Figure 2.21: Map showing the administrative units within the KNP



2.9.3 Conservation programmes

The funding support for the conservation programmes of the park directorate is received from the Ministry of Environment and Forests, Government of India though three centrally sponsored schemes. These schemes are "Assistance to states for development of national parks and sanctuaries", "Assistance for management action plan of Khangchendzonga Biosphere Reserve" and the "National afforestation programme under the forest development agency". The average annual grant of these three schemes from 2002-2003 to 2004-2005 amounts to Rs. 129 lakhs. The thrust areas of the park management are habitat improvement, afforestation and infrastructure development with ecodevelopment, protection, awareness and research receiving limited attention. The state government bears salary, office and travel costs of the personnel.

3.0 LANDSCAPE COMPOSITION, CONFIGURATION AND CHANGE

3.1 Background

Vegetation mapping is a primary requirement for various management and planning activities at the local, regional and global level. It has assumed greater importance in view of the shrinkage and degradation in forest cover (Singh *et al.* 2002). Remote sensing with multi-spectral and multi-temporal data collection systems allows the work of data collection and integration more quickly and effectively (Blamont & Méring 1987). Digital image processing of satellite sensed data involves image rectification, enhancement, multispectral classification, evaluating separability, accuracy assessment and GIS integration (Lillesand & Kiefer 2000). Remotely sensed images are also used for detecting changes in vegetation over space and time. Temporal change detection is a technique to detect the location, amount and trend of change.

Recent developments in satellite remote sensing and a geographic information system (GIS) coupled with user oriented computer programs allow the use landscape ecological principles for biodiversity characterization at landscape level more efficiently (Roy *et al.* 1999). Landscape analysis at broad spatial scale is becoming increasingly important for biodiversity conservation. Characterization of habitats, their configuration and fragmentation, on the other hand provide reliable information on biodiversity distribution patterns. Hence habitat characterization at the landscape level is a major issue for investigation by landscape ecologists (Roy & Tomar 2000).

A number of landscape metrices have been developed to measure various landscape characteristics including fragmentation and heterogeneity. Despite the increased use of spatial analysis and available measures, experts have not yet reached an agreement on how to measure patterns of fragmented landscapes and, thus, unambiguous translation of experimental findings into conservation or management guidelines is hampered (Bogaert 2003). Also the source of fragmentation is often not easy to ascertain with it often being multicausal, exhibiting thresholds and time lags and affected by the scale of observation and system history (Bissonette & Storch 2002).

The objective of this study was to find out the spatial extent of the various vegetation types and analyze the recent changes in the vegetation in the alpine zone and near the tree line or krummholtz zone using digital image processing techniques. The research questions were related to delineation of the broad vegetation types, their extent, spatial pattern and temporal change dynamics.

3.2 Material and methods

3.2.1 Approach

The study area was surveyed in summer and winter seasons in 14 field visits spanning 125 days over a 3-year period from 2004 to 2006. A total of 161 ground reference points using a GPS along with the attribute data like location and vegetation type were recorded. A hand-held Garmin, etrex (summit) model, 12- channel was used for this purpose. To get clear panoramic views of the landscape, winter surveys were also conducted. Simultaneously about 200 digital photographs of the landscape were also taken to assist in the visual interpretation during classification.

3.2.2 Digital image processing and GIS

The Shuttle Radar Topographic Mission (SRTM) produced by NASA originally, has provided high quality digital elevation data (DEMs). The SRTM 90m DEM was downloaded from the CGIAR-CSI GeoPortal (Jarvis *et al.* 2006). The SRTM 90m DEM's have a resolution of 90m at the equator, and are provided in mosaiced 5 degree x 5 degree tiles for easy download and use. This data has been generated by not-for-profit institutions with the objective of supplying accessible and useful information to developing country organizations and use for scientific, non-commercial purposes is encouraged. The data file srtm_54_07.zip with latitude tile of 25^0 N – 30^0 N and longitude of 85^0 E – 90^0 E with the centre point latitude 27.50^0 N longitude 87.50^0 E was downloaded from this website and unzipped. The data is projected in a Geographic (Lat/Long) projection, with the WGS84 horizontal datum and the EGM96 vertical datum. This file which is in Geotiff format is imported to image format in ERDAS and reprojected to Polyconic/WGS84 projection. The study area was subset from this image and exported to grid format. In Arcview GIS version 3.2 the surface option of the spatial analyst extension was used to create contours and derive aspect and slope. The DEM of the study area was also prepared in virtual GIS and various other thematic layers draped on it to provide a realistic visualization of the study area. The SRTM elevation data had a northward shift in the Zemu watershed relative to the LANDSAT image which was corrected.

For remote sensing study panchromatic and multispectral satellite images were used followed by image rectification, enhancement, hybrid classification and smoothening with adequate ground truthing to map broad vegetation types. Images from both IRS (Table 3.1) and LANDSAT (Table 3.2, Table 3.3) satellites were studied.

Table 3.1: Characteristics of Indian Remote Sensing Satellite IRS-IC

Image characteristics	**Sensor**	
	LISS-III	**PAN**
Acquisition date	13th Jan, 2002	9th Nov, 2002
No of scenes	1	3
Scanner type	Push Broom	Push Broom
No of bands	4	B/W
Spectral resolution (in µ meter)	B1: 0.52 - 0.59 B2: 0.62 - 0.69 B3: 0.77 - 0.86 B4: 1.55 - 1.70	0.5 - 0.75
Radiometric resolution	7 bits	6 bits
Spatial resolution	23 / 70 meters	10 meters
Temporal resolution	24 days	5 days
Swath width	142 km /148 km	70 km

Source: Anon 1994

The source for the LANDSAT data set was the Global Land Cover Facility, www.landcover.org and were downloaded in the GeoTIFF format from the geoportal http://glcfapp.umiacs.umd.edu.

Table 3.2: Characteristics of LANDSAT satellite images

Satellite	L 2	L 7
Sensor	MSS multi-spectral	ETM+ multi-spectral
Date	23rd Jan, 1977	26th Dec, 2000
Spectral Range	0.5 - 1.1 μm	0.45 - 2.35 μm
Bands	1, 2, 3, 4	1, 2, 3, 4, 5, 7
Scene Size	185 x 185 km	185 x 185 km
Citation	NASA Landsat Program, 1977	NASA Landsat Program, 2000

Table 3.3: Radiometric characteristics of LANDSAT satellite images

Satellite	Spectral resolution		Band	Spatial resolution
		(μm)		(meters)
Landsat 1-3	**MSS**			
	Band 1:	0.50 - 0.60	Green	60
	Band 2:	0.60 – 0.70	Red	60
	Band 3:	0.70 – 0.80	Near IR	60
	Band 4:	0.80 – 1.10	Near IR	60
Landsat 7	**ETM+**			
	Band 1:	0.450 – 0.515	Blue	30
	Band 2:	0.525 – 0.605	Green	30
	Band 3:	0.630 – 0.690	Red	30
	Band 4:	0.760 – 0.900	Near IR	30
	Band 5:	1.550 – 1.750	Mid IR	30
	Band 6:	10.40 – 12.5	Thermal	60
	Band 7:	2.080 – 2.35	Mid IR	30
	Band 8:	0.52 – 0.92	Pan	15

The decision to use either LANDSAT or IRS image for vegetation classification is based on a number of parameters as indicated in Table 3.4.

Table 3.4: Comparison of LANDSAT and IRS images

Parameters	LANDSAT-7 ETM+ Image	IRS-IC LISS III Image
Spectral range	5 spectral bands	3 spectral bands
Spatial resolution	30 meters	23 meters
Georeferencing	Georeferenced image available	Individual georeferencing has to be carried out
Ease in change detection	Old images of MSS sensor available from 1970s onwards	Oldest image available is 1980s onwards
Costs incurred	Freely available in geoportal	Needs to be purchased from NRSA

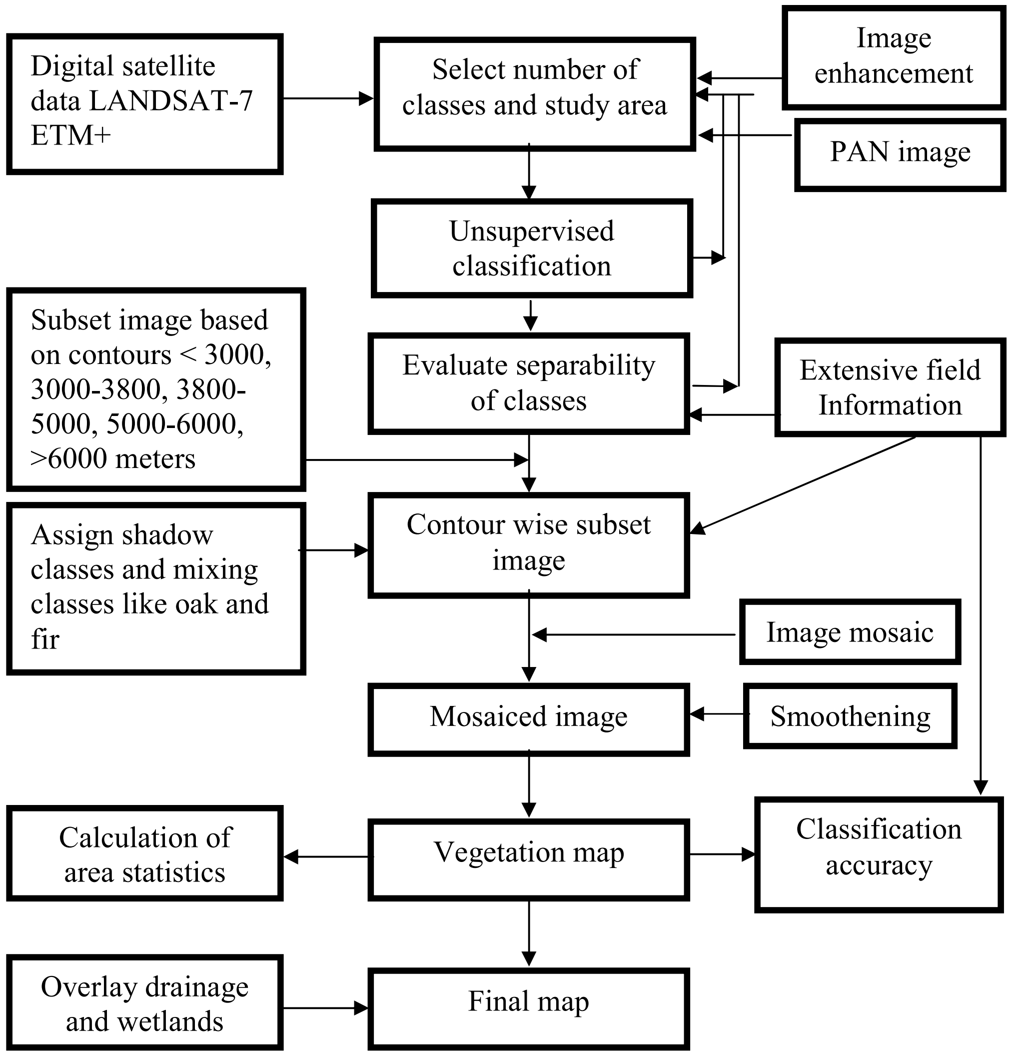
The IRS-IC LISS III Image as compared to the LANDSAT-7 ETM+ image has a higher spatial resolution but a lower spectral range. Georeferencing has to be done individually after procuring the image affecting the repeatability of the exercise across different users. While the georeferenced LANDSAT images can be freely downloaded from the web and even relatively older images are available facilitating change detection studies. The present study started with using IRS images while finally LANDSAT images were used because of the above mentioned advantages.

Persistent cloud cover during the monsoon months and snowfall in winter create a small window of a couple of months in early winter when the alpine zone can be adequately remotely sensed by satellites. The subscene corresponding to Sikkim was extracted from Landsat ETM+ scene (path/row, 139/041, 5th December, 2000). The input files after downloading were 'gunzipped' to convert them to the native GeoTIFF file format. The layer stack option in the image interpreter module of ERDAS was used and the bands 1 to 5 were selected to create the output multispectral image file. The georeference formats employed by the GLCF for Landsat imagery include a UTM projection and a WGS84 datum and ellipsoid. The image was reprojected to Polyconic projection and WGS84 spheroid and the study area subset.

Both the IRS-IC LISS-III and LANDSAT-7 ETM+ data classified in supervised and unsupervised (40 classes) mode separately, failed to show adequate separability between some of the vegetation classes like oak and conifer and subalpine thickets and dwarf bamboo thickets. Hence a hybrid classification strategy was adopted using LANDSAT data (Figure 3.1). A unsupervised maximum likelihood classification using Landsat ETM+ spectral bands 1,2,3,4,5 was carried out with 40 classes initially. Oak and fir classes did not separate out and hence unsupervised classification with 60 classes was tried out. Even then the oak and fir forests did not segregate. Also the shadow classes need to be classified into appropriate vegetation classes. These 60 classes were mapped to landcover classes based on information derived from ground truthing, image tone, context and pattern. Out of the 60 classes created in unsupervised classification 18 were of snow and ice, 14 were rock and glacier and 8 were shadow classes of vegetation and 17 non shadow vegetation classes. These 17 non shadow vegetation classes were mapped into vegetation types. The problem areas were the shadow areas (7 classes), temperate oak and subalpine fir forests not separating and temperate and subalpine bamboo thickets merging with krummholtz. The last problem was resolved by taking a buffer around KNP to include more temperate forests and this resulted in bamboo thickets separating out from *Rhododendron* thickets. The classified image was subset into 1000 meters contours of less than 3000 meters, 3000 - 3800 meters, 3800 – 5000 meters, 5000 – 6000 meters and greater than 6000 meters. For the shadow classes and oak and fir forests mixing, recoding was done to resolve this using elevation and ground truthing as a parameter. Manual recoding increases the classification accuracy but affects the repeatability of the classification process and hence was not attempted.

The separability of the classes and classification accuracy was then assessed. The standard accuracy assessment function generates a large number of random points which the user has to assign to a particular class value (vegetation type) based on ground truth data, previously tested maps, aerial photos or other data. This referenced data is then checked with the classified image and an accuracy assessment cell array is generated. When this process was carried out the main condition of referencing the 250 random pixels generated with vegetation type based on prior knowledge of the study area could not be met satisfactorily. Since at times these generated points landed in locations which were not surveyed or even if surveyed due to the high landscape heterogeneity, landcover type at pixel level could not be ascertained. However since unsupervised classification was used wherein classification classes were not derived from ground truth points alone, the issues related to biasing the test are not as severe here. Hence the 161 ground truth points were used for assessing the separability of the classes and classification accuracy.

Figure 3.1: Flow chart for hybrid vegetation classification



The various features like contours, watersheds, glaciers, lakes, peaks and reserve forest boundary were digitized from the Survey of India (1:25,000 scale) topographic maps in ERDAS IMAGINE version 8.5 software. The trekking trails and locations were digitized using Survey of India (1:25,000 scale) topographic maps as well as primary data collected during field survey. The population of the villages is as per the Census of India 2001 data (Anon 2001).

3.2.3 Landscape analysis

The landscape configuration study was carried out using FRAGSATS software version 3.3 (McGarigal *et al.* 2002). The grain of the study is the spatial resolution of the satellite image which is 30 meters, while the extent is 1784 km^2 which is the area of the KNP. Both natural and disturbed vegetation classes were used in the study. The final classified image of the study area which had 10 classes or patch types namely snow, rock, alpine meadow, alpine scrub, subalpine thicket, fir forest, oak forest, bamboo thicket, temperate scrub and forest blank was used as an input file. The input file with the above thematic layers was converted from unsigned 8 bit to signed 8 bit using the subset option in ERDAS. The class descriptor file was prepared with the above classes and standard run parameters were used. Indices relating to core area were not generated since they would be species dependent. The results were aggregated thematically at vegetation class level and spatially at watershed level and KNP level. The landscape characteristics were determined from the patch, class and landscape level metrices generated. Landscape indices, their methods of calculation, symbols and units used are as defined in the FRAGSTATS software version 3.3 (McGarigal *et al.* 2002).

3.2.4 Temporal change detection

Temporal change detection using image density slicing or thresholding on the two LANDSAT images acquired almost 24 years apart, on 23rd January, 1977 (NASA Landsat Program 1977) and 26th December, 2000 (NASA Landsat Program 2000). Density slice is a spatial histogram of image values which visually displays designated categories (Jensen 1996). Individual image values are grouped into separate categories where each category is significantly more distinct from each other than the individual values within a category. The density slice enhances the signal-to-noise ratio between categories, allowing visual discrimination of the spatial distribution of categories across space (Washington-Allen 1994). Normalized difference vegetation index (NDVI) has been found to be a sensitive indicator of the presence and condition of green vegetation. The NDVI helps compensate for changing illumination conditions, surface slope, aspect and other extraneous factors (Lillesand & Keifer 2000). NDVI for each of the images was calculated followed by change detection on this time series dataset of 1977 to 2000.

Secondary information from recent studies in the biodiversity and remote sensing sector of Sikkim like the "Biodiversity characterization at landscape level in north east India using satellite remote sensing and geographic information system", Forest cover mapping through digital image processing of Indian Remote Sensing Satellite data with special reference of Sikkim", "Rathong chu valley, Sikkim substate biodiversity strategy and action plan,", "Sikkim state biodiversity strategy and action plan", "Important bird areas of India, Sikkim state", "Carrying capacity study of the Tista river basin" were referred (Anon 2002; Anon 1994; Tambe *et al.* 2003; Lachungpa *et al.* 2003; Islam & Rahmani 2004; Anon 2005a ; 2005b ; 2005c).

3.3 Results and discussion

3.3.1 Landscape composition and extent

3.3.1.1 Classification and extent of broad landscape zones and vegetation types

At the landscape level the Greater Himalaya located in the southern and central parts of KNP comprise 86% of the park while the Trans Himalayan part located in the extreme north accounts for only 14%. Broad vegetation classes in KNP include temperate forest (11%), subalpine fir and krummholtz forest (14%), alpine scrub and meadows (22%). Snow and rock of non-vegetation classes occupy 53% area (Figure 3.2, Figure 3.3). The alpine zone as used in this study broadly includes the areas between 4,000 and 5,000 m elevation. Physiognomically it starts from where the krummholtz forests end and the alpine scrub vegetation starts and extends up to where the subnival vegetation begins. About 22% of the park with an extent of 390 km^2 falls within this zone. Alpine scrub and alpine herbaceous vegetation (including sedge meadows) are the major physiognomic units within this zone and have an extent of 33% and 67% respectively. Alpine herbaceous vegetation constitutes 15% of KNP and has an extent of 262 km^2. The broad vegetation types of KNP, their extent and spatial distribution is shown in Table 3.5 and Figure 3.4.

Figure 3.2: Proportion of broad landscapes zones in KNP

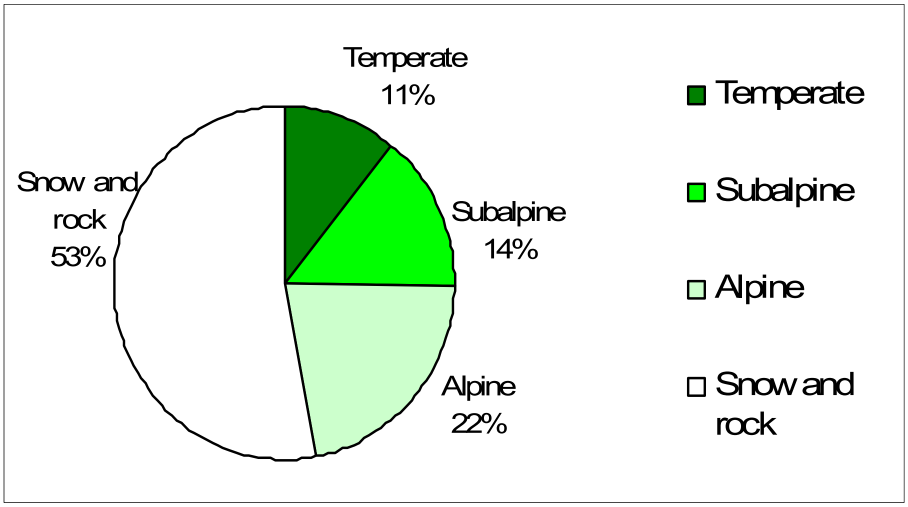


Figure 3.3: Spatial distribution of broad landscape zones in KNP

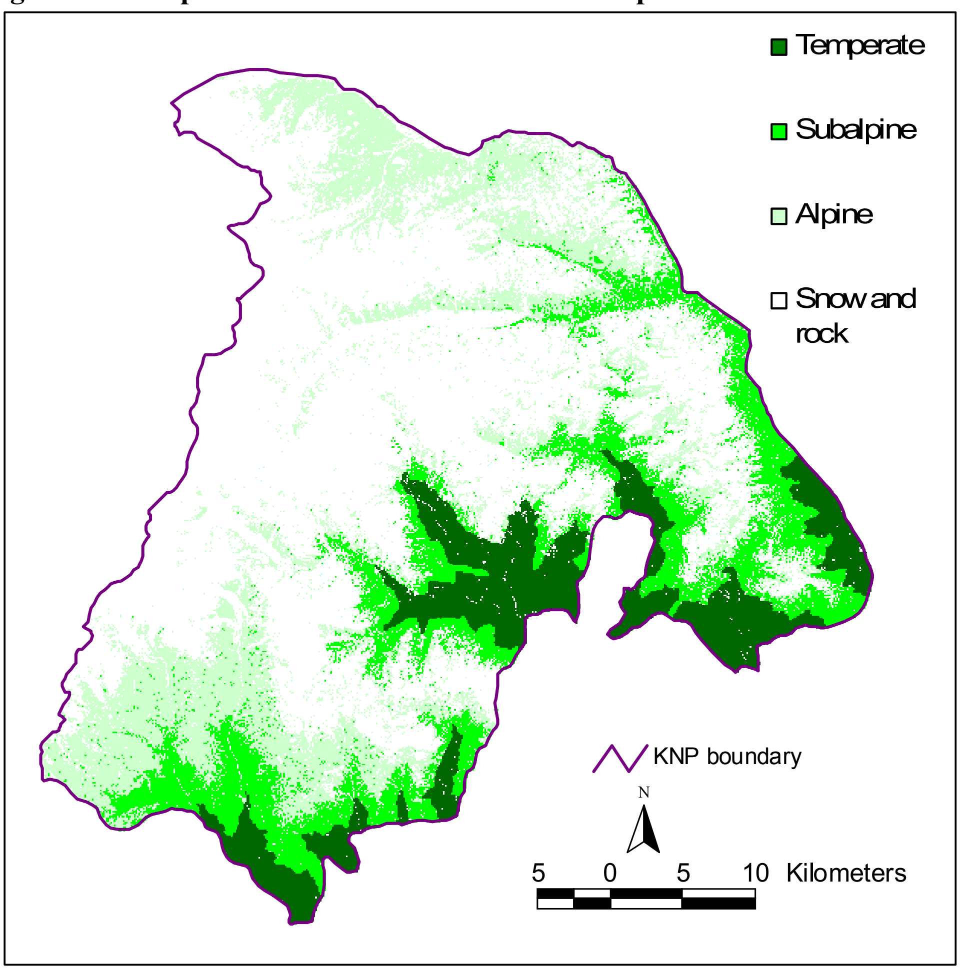
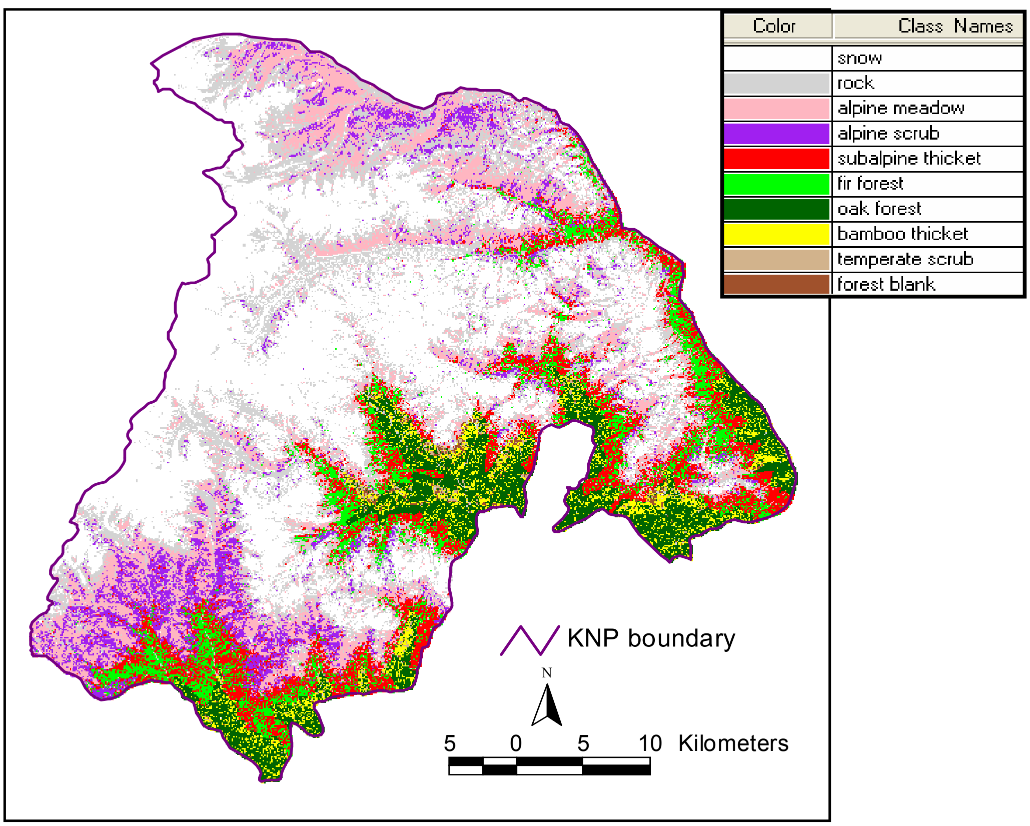


Table 3.5 : Broad vegetation types and their extent

Landcover type	Extent in KNP					
	Greater Himalaya		Trans Himalaya		Total	
	km^2	%	km^2	%	km^2	%
Snow	541.8	35.2	71.7	29.4	613.5	34.4
Rock	253.2	16.4	77.9	31.9	331.1	18.6
Alpine meadow	199.8	13.0	62.5	25.6	262.3	14.7
Alpine scrub	101.7	6.6	25.8	10.6	127.5	7.1
Subalpine thicket	150.5	9.8	3.6	1.5	154.1	8.6
Subalpine fir forest	100.3	6.5	2.7	1.1	103.0	5.8
Temperate forest	178.6	11.6	0.0	0.0	178.6	10.0
Temperate scrub	5.9	0.4	0.0	0.0	5.9	0.3
Forest blank	8.0	0.5	0.0	0.0	8.0	0.5
Total	**1,540**	**100**	**244**	**100**	**1,784**	**100**

Figure 3.4: Landcover map of KNP



3.3.1.2 Spectral separability and accuracy assessment

Spectral signature and separability of the landcover classes was obtained from the mean plots option of the signature editor in ERDAS. Figure 3.5 shows the spectral pattern plot of mean digital number (DN) in five bands for various landcover classes. Fir and oak could not be separated out and hence the combined spectral signature was used. The separability of the 7 broad landcover classes obtained from unsupervised classification was measured using Euclidean distance as the distance measure using the bands 1, 2, 3, 4, 5 using five at a time. It was found that the average separability was 158 and the minimum class pair separability was 25 between subalpine thicket and alpine scrub followed by 37 between subalpine thicket and bamboo thicket. 161 GPS points within the study area were used in 7 vegetation classes as a reference set and accuracy assessment was carried out. The confusion matrix generated indicates that amongst the vegetation classes alpine scrub has the lowest user accuracy of 64% while alpine meadow class has highest user accuracy of 88.89%, while the overall classification accuracy is 73.91% (Table 3.6, Table 3.7, Table 3.8). One drawback affecting the classification accuracy was that while the ground truthing information was collected in summer the remotely sensed image was of winter. On correcting the 12 ground truthing points affected by snow cover the overall classification accuracy improved to 81.37% with alpine scrub showing the lowest of 64% and alpine meadow the highest of 88.89% amongst the vegetation types (Table 3.9, Table 3.10). The mixing of alpine scrub spectral signature with alpine meadow and subalpine thicket vegetation in the transition zone results in its weak classification accuracy.

Table 3.6 : Spectral separability of the landcover classes across five bands

	Fir and oak	Bamboo thicket	Rock	Alpine scrub	Subalpine thicket	Alpine meadow	Snow
Fir and oak	X	75	88	38	44	92	387
Bamboo thicket		X	74	61	37	58	355
Rock			X	65	63	50	312
Alpine scrub				X	25	57	375
Subalpine thicket					X	53	367
Alpine meadow						X	346
Snow							X

Figure 3.5: Spectral signature and separability of the landcover classes over five bands

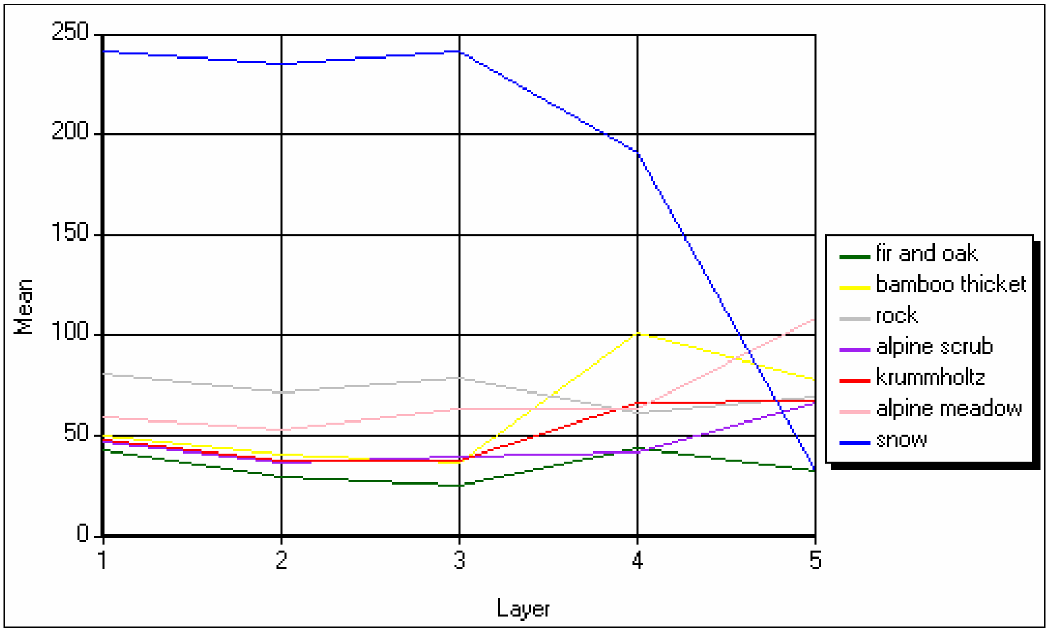


Table 3.7: Error matrix without winter snow correction

Classified data	Referenced data							
	Snow	Rock	Alpine meadow	Alpine scrub	Subalpine thicket	Fir forest	Oak forest	Classified totals
Snow	0	5	5	1	0	0	0	11
Rock	0	13	3	0	3	0	1	20
Alpine meadow	0	3	56	3	1	0	0	63
Alpine scrub	0	1	8	16	0	0	0	25
Subalpine thicket	0	0	1	3	20	2	0	26
Fir forest	0	0	0	0	1	7	0	8
Oak forest	0	0	0	0	0	1	7	8
Reference totals	0	22	73	23	25	10	8	161

Table 3.8: Accuracy totals without winter snow correction

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
snow	0	11	0	---	---
rock	22	20	13	59.09%	65.00%
alpine meadow	73	63	56	76.71%	88.89%
alpine scrub	23	25	16	69.57%	64.00%
Subalpine thicket	25	26	20	80.00%	76.92%
fir forest	10	8	7	70.00%	87.50%
oak forest	8	8	7	87.50%	87.50%
Total	161	161		119	73.91%

Table 3.9: Error matrix with winter snow correction

Classified data	Referenced data							
	Snow	Rock	Alpine meadow	Alpine scrub	Subalpine thicket	Fir forest	Oak forest	Classified totals
Snow	11	0	0	0	0	0	0	11
Rock	0	14	3	0	2	0	1	20
Alpine meadow	0	3	56	3	1	0	0	63
Alpine scrub	0	1	8	16	0	0	0	25
Subalpine thicket	0	0	1	3	20	2	0	26
Fir forest	0	0	0	0	1	7	0	8
Oak forest	0	0	0	0	0	1	7	8
Reference totals	11	18	68	22	24	10	8	161

Table 3.10: Accuracy totals with winter snow correction

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Snow	11	11	11	100.00%	100.00%
Rock	18	20	14	77.78%	70.00%
Alpine meadow	68	63	56	82.35%	88.89%
Alpine scrub	22	25	16	72.73%	64.00%
Subalpine thicket	24	26	20	83.33%	76.92%
Fir forest	10	8	7	70.00%	87.50%
Oak forest	8	8	7	87.50%	87.50%
Total	161	161		131	81.37%

3.3.1.3 Problems, causes and approaches in remote sensing analysis

The classification accuracy was affected by a number of challenges faced in digital classification of remotely sensed images in hilly terrain with high heterogeneity. The main problems along with the causes and approaches used to address them are mentioned in Table 3.11.

Table 3.11: Main problems, causes and approaches in the remote sensing analysis of KNP

Challenges	Causes	Approach used
Deep and variable intensity shadows which result in spectral signature mixing leading to difficulty in classification. Especially severe along east west oriented valleys were flanks with northern aspect are under shadow. Also results in inadequate ground truthing in inaccessible portions	Hilly terrain with steep topography	Band ratioing is an option but it reduces the intensity of the whole image. Contrast stretching reduces the problem to some extent. Supplementing with ground truthing and photographs was used
Getting cloud free satellite images	Long extended monsoon season	Images acquired in winter were used but here high alpine areas are under snow
Most of the alpine lakes are frozen and some alpine meadows are covered by snow	Snow cover in alpine zone in winter	Detailed search for early winter cloud and snow free images
The vegetation in the temperate and subalpine zone is luxuriant with multiple layers. Dwarf bamboo and Rhododendrons are especially abundant in the middle storey of the oak and conifer forests. While only the top layer can be remotely sensed.	Multiple canopies or layers of vegetation	Middle storey of vegetation can be detected in the large openings of the top canopy. However extent is difficult to estimate.
Oak and conifer forests and alpine scrub and subalpine thicket showed similar spectral characteristics	Spectral similarity of vegetation classes	For the mixing classes altitude was used as a parameter to recode the mixing classes

High variability in topography and climate result in a heterogeneous landscape where getting sufficiently large homogenous patches of vegetation for sampling is not easy. This patchiness in vegetation results in spatial mixing of the signature	Heterogeneous landscape	Ecotones to be avoided during sampling and ground truthing information should be recorded in the center of atleast 1 ha homogenous plots
Georectification errors due to use of other relatively low quality maps	Non availability of SOI topographical maps for border areas	Use of GPS for ground control points

3.3.2 Landscape configuration

Most of the class indices can be interpreted as fragmentation indices because they measure the configuration of a particular patch type, whereas most of the landscape indices can be interpreted more broadly as landscape heterogeneity indices because they measure the overall landscape pattern.

3.3.2.1 Class level fragmentation indices

The landscape composition aggregated at the vegetation class level for natural and disturbed vegetation classes is given in the first part of Table 3.12. Amongst the natural vegetation classes, alpine meadows which comprise 14.7% of KNP have the maximum number of patches (21,471) while temperate forest has the least number of patches (1,030). The mean patch size showed large variation across all vegetation types and was the largest for temperate forest (12.24 ha), low for fir forest (0.91 ha) and least for alpine scrub (0.81 ha). The patch density was highest in case of alpine meadows at 25.59 per km^2 and lowest for temperate forests at 1.23 per km^2. The effective mesh size was lowest for fir forest (4.25 ha), low for alpine scrub (7.99) and highest for temperate forest (88.29 ha). In general the disturbed vegetation classes that together comprise just 0.80% of KNP had less number of patches, had smaller patch size and low patch density. The second part of Table 3.12 indicates the shape of the landscape across different landscape classes. Amongst the natural vegetation classes alpine meadows, alpine scrub, subalpine thickets and fir forest showed similar values across all the shape indices, while temperate forests showed a slightly higher shape index.

3.3.2.2 Landscape level heterogeneity indices at watershed level

Amongst the seven major watersheds in KNP while Churong chu, Prek chu, Rangit chu, Lachen chu, Rangyong chu and Zemu chu show a characteristic Greater Himalayan character, Lhonak chu watershed in the extreme north is distinctively Trans Himalayan (Figure 3.7). Also Churong chu, Prek chu and Lhonak chu watersheds have been strongly influenced by valley glaciers which have receded while the Zemu chu watershed is dominated by the 25 km long Zemu valley glacier. Rangyong chu and Rangit chu valleys do not show strong influences by valley glaciers. Only a minor part of the Lachen chu watershed falls within KNP and hence it is not fully representative, while the true left bank of the Lhonak chu watershed is outside the KNP. The relief characteristics of these watersheds (Table 2.2) show that the relief ratio is lowest for the Trans Himalayan glaciated valley of Lhonak (RR=0.10), moderate for Greater Himalayan glaciated valleys of Zemu, Prek and Churong (RR=0.18) and highest for the Greater Himalayan non-glaciated valleys of Rangyong and Rangit (RR=0.29). The landscape characteristics aggregated at the watershed level including composition, shape, configuration and diversity are shown in Table 3.13.

Comparison of landscape composition across watersheds indicates that while Rangit chu shows the highest patch density (58.39), Lhonak chu (30.05) show the lowest patch density. The patch area (mean) is lowest in Zemu chu (0.77), low in Rangyong chu (1.01) and highest in Lhonak (1.28). The splitting index is extremely high in Zemu chu (4359) and lowest for Prek chu (147) while the effective mesh size is highest in Lhonak (134.98 ha) and very low in Zemu chu (16.39 ha).

The landscape shape as indicated by the various landscape shape indices shows a large intra-watershed and low inter-watershed variability. The landscape configuration as measured by contagion (clumpiness of cells) was lowest for Zemu chu (30.92%) and highest for Lhonak chu (49.81%). The aggregation index was also lowest for Zemu chu (60.63%) and highest for Prek chu (69.64%). Churong chu showed the lowest (44.54%) interspersion and juxtaposition index (dispersion of patches) showed while it was very high in case of Zemu chu (89.59%). Lhonak chu watershed is the least diverse and uneven, followed by Zemu chu and Churong chu while Rangit chu and Rangyong chu watersheds were the most diverse and even.

3.3.2.3 Landscape level heterogeneity indices for KNP

The landscape level metrices for KNP measuring landscape composition, shape, configuration and diversity were created in a similar manner (Table 3.14). The total vegetated area of KNP is 839 km^2 composed of 70,790 vegetated patches with a mean patch area of 1.17 ha showing large variation. The shape index of the patches is 1.26 while the perimeter area fractal dimension was 1.58. The landscape configuration had the Euclidean nearest neighbour distance of 85 meter, contagion of 39%, aggregation index of 65% and interspersion and juxtaposition index of 60%. The landscape diversity was 1.75 as per the Shannon's diversity index and the evenness as measured by the Shannon's evenness index was 0.84.

3.3.2.4 Main limitations and assumptions

Since the landscape analysis is carried out on the classified file obtained from digital image processing of the remotely sensed satellite image, the challenges and limitations of remote sensing analysis as detailed in Table 3.11 apply here as well. The indices relating to the landscape fragmentation and heterogeneity are applicable only for the top layer of vegetation visible to the satellite. So while for the alpine zone these indices present a realistic picture, the subalpine fir and temperate forests with a prominent middle storey and ground vegetation layer are analysed only with respect to the top canopy.

Table 3.12: Comparison of selected landscape indices measuring landscape composition and shape across different vegetation classes

Landscape indices at class level				Natural vegetation classes					Disturbed vegetation classes	
Category	**Name**	**Symbol**	**Units**	**alpine meadow**	**alpine scrub**	**subalpine thicket**	**fir forest**	**tempera te forest**	**temperate scrub**	**forest blank**
Landscape composition	Class area	CA	km^2	262	127	154	103	179	6	8
	Percentage of KNP	PLAND	%	14.7	7.1	8.6	5.8	10.00	0.30	0.50
	Number of patches	NP	none	21471	15568	10582	11226	1030	2103	1636
	Patch area (mean)	AREA_MN	Ha	1.21	0.81	1.44	0.91	12.24	0.28	0.49
	Patch area (SD)	AREA_SD	Ha	24.82	13.17	24.99	11.30	170.12	0.76	1.57
	Patch density of vegetated patches	PD	per km^2	25.59	18.56	12.61	13.38	1.23	2.51	1.95
	Effective mesh size	MESH	ha	39.06	7.99	19.53	4.25	88.29	0.00	0.01
Landscape shape	Perimeter area ratio (mean)	PARA_MN	none	1162	1185	1178	1186	1107	1224	1144
	Perimeter area ratio (SD)	PARA_SD	none	270	259	262	263	310	223	278
	Shape index (mean)	SHAPE_MN	none	1.27	1.23	1.27	1.25	1.47	1.16	1.23
	Shape index (SD)	SHAPE_SD	none	0.73	0.72	1.05	0.72	2.20	0.39	0.46
	Perimeter area fractal dimension	PAFRAC	none	1.57	1.57	1.60	1.57	1.58	1.59	1.53

Table 3.13 : Comparison of selected landscape indices measuring landscape composition, shape and configuration of watersheds in KNP

Landscape indices				Watershed name						
Category	**Name**	**Symbol**	**Unit**	**Lhonak**	**Zemu**	**Rangyong**	**Lachen**	**Rangit**	**Prek**	**Churong**
	Watershed characteristics			TH-G*	GH-G*	GH-NG*	GH*	GH-NG*	GH-G*	GH-G*
Landscape composition	Watershed area	CA	km^2	243	368	664	95	118	144	152
	Percentage of KNP	PLAND	%	14	21	37	5	7	8	9
	Number of vegetated patches	NP	none	7302	9927	29508	5218	6890	6622	5823
	Patch density of vegetated patches	PD	per km^2	30.05	26.98	44.44	54.93	58.39	45.99	38.31
	Landscape shape index	LSI	none	11.84	11.36	42.62	24.52	32.24	30.18	26.93
	Patch area (mean)	AREA_MN	ha	1.28	0.77	1.01	1.42	1.25	1.50	1.76
	Patch area (SD)	AREA_SD	ha	31.63	10.84	29.99	25.49	17.19	27.71	28.29
	Splitting index	SPLIT	none	402	4359	537	192	224	147	207
	Effective mesh size	MESH	ha	134.98	16.39	222.52	133.25	95.62	186.23	150.44
	Patch richness	PR	none	4	4	8	8	8	8	8
	Shannon’s diversity index	SHDI	none	0.85	1.17	1.81	1.62	1.76	1.68	1.42
	Simpson’s diversity index	SIDI	none	0.49	0.62	0.81	0.77	0.81	0.80	0.71
	Shannon’s evenness index	SHEI	none	0.62	0.84	0.87	0.78	0.84	0.81	0.68
	Simpson’s evenness index	SIEI	none	0.65	0.83	0.93	0.89	0.92	0.91	0.82
Landscape shape	Shape index (mean)	SHAPE_MN	ha	1.29	1.22	1.26	1.29	1.27	1.27	1.29
	Shape index (SD)	SHAPE_SD	ha	0.77	0.62	0.77	0.93	0.92	0.92	0.94
	Perimeter area fractal dimension	PAFRAC	none	1.58	1.57	1.58	1.60	1.59	1.58	1.56
Landscape configuration	Euclidean nearest neighbour distance (mean)	ENN_MN	meter	82.51	93.92	85.14	80.69	82.56	82.60	83.17
	Euclidean nearest neighbour distance (SD)	ENN_SD	meter	97.96	95.84	72.63	59.01	60.32	63.22	65.80
	Contagion	CONTAG	percent	49.81	30.92	36.24	41.64	37.07	40.86	47.94
	Aggregation index	AI	percent	67.60	60.63	62.29	66.01	63.38	67.66	69.64
	Interspersion and juxtaposition index	IJI	percent	51.01	89.59	61.37	49.64	58.12	51.49	44.54

** TH = Trans Himalaya, GH = Greater Himalaya, G = Dominant valley glacier, NG = No dominant valley glacier*

Table 3.14: Selected landscape indices measuring landscape composition, shape and configuration

Category	Name	Symbol	Units	Value
Landscape composition	Total vegetated area	TA	km^2	839
	Number of vegetated patches	NP	none	70,790
	Patch density of vegetated patches	PD	per km^2	84.37
	Patch area (mean)	AREA_MN	ha	1.17
	Patch area (SD)	AREA_SD	ha	27.63
	Effective mesh size	MESH	Ha	159
	Splitting index	SPLIT	none	2128
	Patch richness	PR	none	8
	Shannon's diversity index	SHDI	none	1.75
	Simpson's diversity index	SIDI	none	0.80
	Modified Simpson's diversity index	MSIDI	none	1.63
	Shannon's evenness index	SHEI	none	0.84
	Simpson's evenness index	SIEI	none	0.92
	Modified Simpson's evenness index	MSIEI	none	0.78
Landscape shape	Perimeter area ratio (mean)	PARA_MN	none	1173
	Perimeter area ratio (SD)	PARA_SD	none	264
	Shape index (mean)	SHAPE_MN	none	1.26
	Shape index (SD)	SHAPE_SD	none	0.82
	Perimeter area fractal dimension	PAFRAC	none	1.58
Landscape configuration	Euclidean nearest neighbour distance (mean)	ENN_MN	meter	85
	Euclidean nearest neighbour distance (SD)	ENN_SD	meter	74
	Contagion	CONTAG	percent	39
	Aggregation index	AI	percent	65
	Interspersion and juxtaposition index	IJI	percent	60

3.3.3 Landscape change

The changes detected as variation in NDVI in remotely sensed images could arise from differences in spatial and spectral resolution of the sensors, differences in shadow intensity, variability of snow cover, variability in atmospheric conditions, changes in the vegetation density and noise. The challenge is to significantly mask out the changes due to variations other than those emanating from changes in vegetation density. A number of challenges were posed during the change detection analysis carried out on LANDSAT 1977 (23rd January, 1977) and LANDSAT 2000 (26th December, 2000) images. Though the spectral bands 2 and 4 of MSS and 3 and 4 of ETM+ sensors used to assess NDVI are spectrally similar, minor variations do exist. Seasonally though the images are less than a month apart, the 1977 image shows more snow cover in the alpine zone specially in the Greater Himalayan part (south and central) of KNP. In the snowed areas it was observed that NDVI gets positively biased by decrease in snow cover during temporal analysis. This is because snow has scant reflectance in the mid IR region and hence has an NDVI value close to zero. There is variation in the shadow intensity as well, with the 1977 image showing darker shadows as compared to the 2000 image. Change detection in shadow areas is seriously hampered by variability in shadow intensity coupled with low spectral reflectance of vegetation. Hence all shadow areas are erroneously classified as a positive change during the change analysis. The spatial resolution of the 2000 image which is 30 meters was degraded to 60 meters to match with that of the old image. To overcome these challenges inferences from change detection analysis using NDVI are drawn only from the negative changes highlighted in the map, since the positive changes could be due to reduction in shadow intensity or decrease in snow cover between the two images. To reduce the impacts of errors due to other variations and noise the change detection threshold was set at more than 15% negative change in NDVI values between 1977 (when KNP was notified) and 2000 (Figure 3.6).

Table 3.15 indicates that out of a total 1,358 km^2 of the park area below 5000 meters elevation, 80 km^2 (5.9%) has been impacted by a decrease of more 15% in NDVI values. This impact is not uniform so while as much as 20% of the areas below 3000 meters have been impacted, the vegetated areas above that in the subalpine and alpine zone show less than 4% change.

Ground truthing of the subalpine and alpine zone and GIS analysis of the temperate zone indicates that:

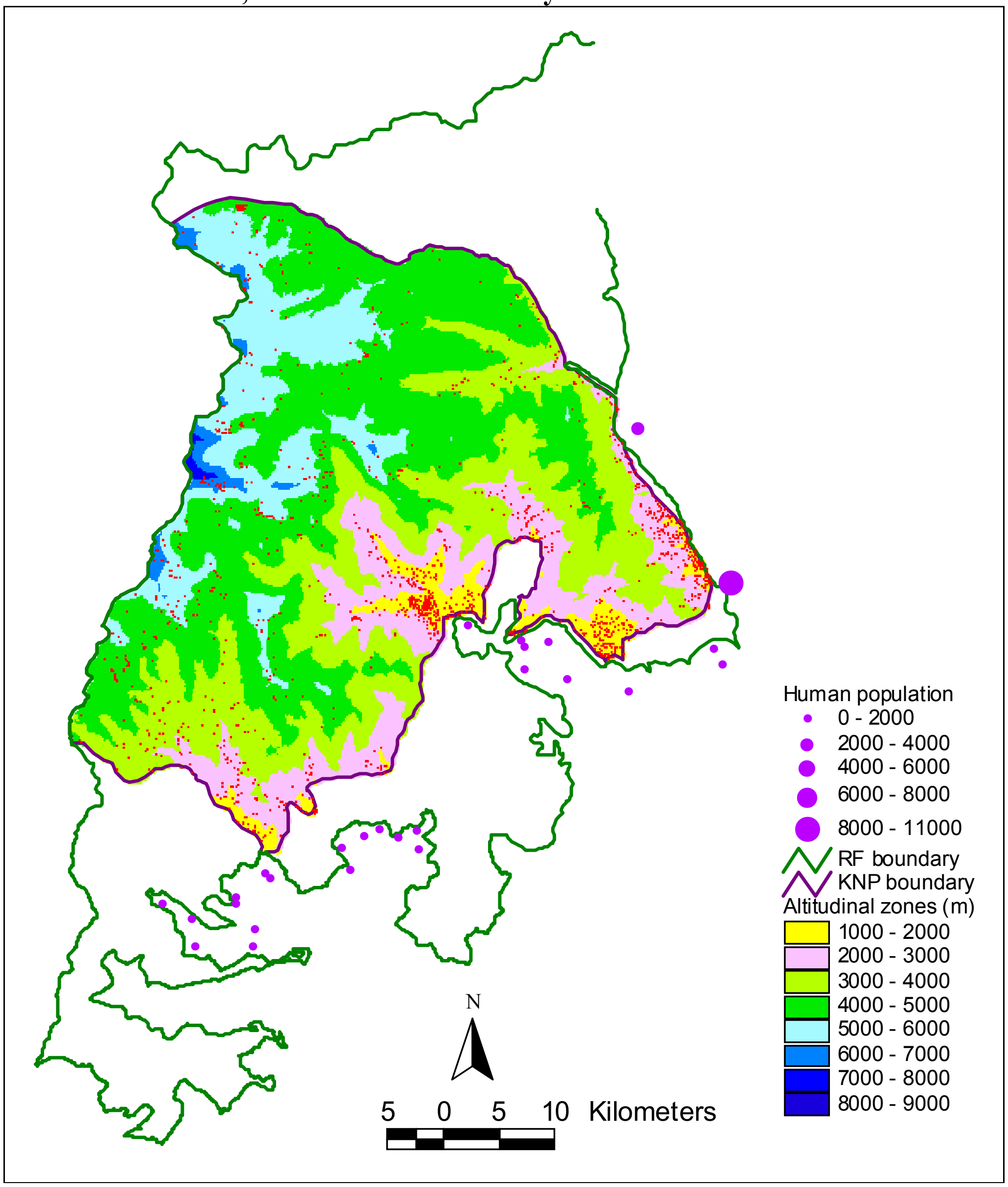
1. Subalpine and alpine zone (3000 – 5000 meters) show much less changes as compared to the zone below 3000 metes which show a significant area impacted by NDVI reduction.
2. Changes in the portions below 3000 meters of KNP are more extensive in those areas which are closer to human habitations. Parts of KNP between 1000 to 2000 meters elevation adjacent to the revenue blocks of Sakyong-Pentong, Shingik and Chungthang showed maximum negative change. A large forest fire is reported from Payongchu ridge above Sakyong-Pentong in the spring of 1998, which due to the difficult terrain could not be contained. Whereas portions of KNP away from human habitations and shielded by a reserve forest buffer showed less changes.

3. In the alpine zone, yak herders over the last 20 years have set fire and burnt Juniper scrub vegetation in pockets at Lampokhri and Neer-pokhri nikash converting this alpine scrub vegetation to grassy meadows thus reducing the NDVI. While in the subalpine zone the changes are mostly in the riverine zone which is impacted by glacial lakes outburst floods and changes in river course. In late 1980's two glacial lake (Pagala pokhri and Tinkune pokhri) outbursts are reported from southern KNP in West Sikkim.
4. Increase in area and reduced freezing level of the glacial lakes resulted in NDVI reduction and was detected as a negative change. A few alpine lakes like the South Lhonak tsho in the Trans Himalaya show a substantial increase in size.

Table 3.15: Extent of areas with more than 15% decrease in NDVI in KNP between 1977 and 2000 presented altitudinally

	Altitudinal zones			**Total**
	Less than 3000 m	**3000 – 3800 m**	**3800 – 5000 m**	
Area of KNP	253 km^2	458 km^2	647 km^2	1358 km^2
Area with greater than 15% decrease	51 km^2	16 km^2	13 km^2	80 km^2
% of area impacted by greater than 15% decrease	20.0%	3.6%	2.0%	5.9%

Figure 3.6 Map showing the spatial distribution of areas with more than 15% decrease in NDVI (shown as red dots) in KNP between 1977 and 2000 along with human settlements, reserve forest boundary and altitudinal zones



3.4 Conclusions

The challenges posed due to the hilly terrain, climate (cloud and snow cover), multi-layered vegetation structure and spectral characteristics of vegetation results in certain limitations in the accuracy of vegetation classification from remotely sensed satellite images in KNP. Extensive field knowledge of vegetation structure and altitudinal variation coupled with ground truthing is necessary to improve the accuracy of classification. The following recoding strategy was adopted which resulted in an overall improvement in the accuracy of classification but at the same time resulted in some limitations as well:

1. Areas under shadow were visually interpreted.
2. Spectrally oak and conifer forests were inseparable. Hence artificial segregation based on the 3000 meters contour was adopted. Due to this the hemlock forests between 2700-3100 meters got clubbed as oak forests in the lower reaches and fir forests in the upper reaches.
3. Spectrally the thickets of dwarf bamboo and Rhododendron are very close and separability is not complete. Complete separation was done artificially using the 3000 meters contour. This would have resulted in some misclassification in the transition zone.
4. Remotely sensed classification only senses the top canopy of vegetation. In the silver fir forests of KNP there is a dense middle storey of Rhododendron, maple and birch thickets while the upper reaches of the oak forests are characterized by impenetrable bamboo thickets. This middle storey vegetation is recorded only when there is a sizeable opening in the top canopy. Hence what the satellite senses as the extent of these extensive middle storey forests is akin to the proverbial tip of the iceberg.
5. Snowfall in winter covers the high alpine meadows, scree and subnival vegetation. Hence classification using winter satellite images invariably underestimates these vegetation classes while the snow cover is overestimated. Also by mid winter the glacial lakes start getting frozen and do not get completely segregated into a separate wetland or water class.

Hence a hybrid classification approach was used to refine the classification to acceptable limits for management purposes using extensive field information in the form of ground truthing, digital photographs and knowledge about the spatial pattern of vegetation. Since repeatability is the essence of science, manual recoding was not attempted but terrain features like altitude and aspect were used to selectively apply these changes.

A total of 10 landcover types were delineated using hybrid classification and their extent calculated namely snow (34.4%), rock (18.6%), alpine meadow (14.7%), alpine scrub (7.1%), subalpine thickets (8.6%), subalpine fir forest (5.8%), temperate forest (7.2%), bamboo thickets (2.9%), temperate scrub (0.3%) and forest blank

(0.5%). A vegetation characterization map of KNP was prepared showing the location and extent of the various vegetation types. Oak and conifer forests could not be separated spectrally. While the average separability of the paired classes was 158, subalpine thicket was found to be spectrally close to alpine scrub (25) and bamboo thicket (37). Comparison with 161 field gathered GPS points for vegetation classes showed 81% overall classification accuracy after correction for winter snow fall.

For landscape analysis the grain was fixed at the spatial resolution of the satellite image of 30 meters and the area of KNP was set as the extent. The classified thematic layer based on the LANDSAT-7 ETM+ satellite image of 26th December, 2000 was used as an input. Landscape level aggregation indicated that there were a total of 70,790 vegetated patches in KNP belonging to 8 vegetation classes (or patch types) with a patch density of 84.37 per km^2 and mean patch size of 1.17 ha. The Shannon's diversity index was 1.75 and the Shannon's evenness index 0.84. The perimeter area ratio (mean) was 1173 and the shape index (mean) 1.26. Clumpiness of the landscape as measured by Contagion was 39 and the scattering at patch level as measured by the Interspersion and Juxtaposition Index was 60.

The landscape composition and shape indices were calculated and aggregated at the class level to indicate the fragmentation. The alpine meadows had the largest number of patches and highest patch density (NP=21,471, PD=25.59) while the temperate forests were the most compact (NP=1030, PD=1.23). Landscape fragmentation as measured by the mean patch area and effective mesh size was highest for alpine scrub (AREA_MN=0.81, MESH=7.99) and fir forest (AREA_MN=0.91, MESH=4.25) and lowest for temperate forest (AREA_MN=12.24, MESH=88.29).

The landscape composition, shape, configuration and diversity indices were calculated and aggregated at the watershed and landscape level to indicate the heterogeneity. The patch density of vegetated patches was lowest for the Trans Himalayan glaciated valley of Lhonak (PD=30.05), moderate for Greater Himalayan glaciated valleys of Zemu, Prek and Churong (PD=37.09) and highest for the Greater Himalayan non-glaciated valleys of Rangyong and Rangit (PD=51.41). The Trans Himalayan, glaciated valley of Lhonak showed lower landscape diversity (SHDI=0.85) and evenness (SHEI=0.62) compared to Greater Himalayan valleys

(SHDI=1.58, SHEI=0.80). Also amongst the Greater Himalaya valleys, the glaciated valleys of Zemu chu, Prek chu and Churong chu showed lower landscape diversity (SHDI=1.42) and evenness (SHEI=0.78) as compared to the non-glaciated valleys of Rangit chu and Rangyong chu (SHDI=1.78, SHEI=0.86). The clumpiness is lowest and scattering highest in the Zemu (CONTAG=30.92, IJI=89.59) and Rangyong watersheds (CONTAG=36.24, IJI=61.37) with the Churong chu watershed (CONTAG=47.94, IJI=44.54) being at the other end of the spectrum showing high clumpiness. The east-west orientation of the watershed results in dominant north south aspects which harbour different vegetation types and result in increasing their scattering. While in north-south oriented valleys the role of aspect is subdued and does not result in different vegetation types and hence does not result in increasing scattering. This east-west orientation of watershed is high in Rangyong and dominant in Zemu where one can observe different vegetation types on either flank of the valley resulting in higher mixing or dispersal and consequently lower clumpiness in the landscape. Lhonak also being east-west oriented however shows high clumpiness since only the northern aspect of the watershed falls within the study area, negating the influence of aspect. The Euclidean nearest neighbour distance (mean) and Aggregation index also show similar trends. To conclude in the mountain watersheds of KNP while elevation gradient plays a major role in determining landscape composition, the landscape configuration is impacted largely by the orientation. Rangyong watershed with a high elevation gradient and a largely east-west orientation exhibits the highest overall landscape heterogeneity.

Change detection map using NDVI density slicing on the 1977-2000 LANDSAT time series images at 15% threshold level was prepared. The decrease in winter snow and increase in illumination of shadow areas resulted in a positive biasing of the change detection, hence only the negative changes were detected. Of the total 80 km^2 negative change detected upto 5000 meters elevation in KNP, the zone below 3000 meters showed the highest area impacted by reduction in NDVI (20%, 51km^2) followed by lesser changes in the subalpine zone (3000-3800 meters, 3.6%, 16km^2) and alpine zone (3800 – 5000 meters, 2.0%, 13km^2). Ground truthing of the impacted areas in the alpine zone indicated that the cause of NDVI reduction was the burning and clearing of alpine scrub habitats by the yak herders in a few pockets in the Prek chu watershed in southern KNP and increase in area and reduced freezing level of the glacial lakes. In the subalpine zone the changes were mostly in the riverine zone possibly due to change in river course or glacial lake outbursts in the past. For the zone below 3000 meters which showed largest areas impacted by negative change, GIS analysis was used by overlaying the reserve forest boundary, digital elevation model and the location of fringe villages. This analysis showed that subtropical portions (1000 to 2000 meters elevation) of KNP adjacent to the revenue blocks of Sakyong-Pentong, Singhik and Chungthang in North Sikkim showed highest negative change. Also the portions of KNP closer to human habitations showed greater negative change in vegetation compared to parts which were shielded by a buffer of reserve forest.

4.0 ALPINE VEGETATION: STRUCTURE AND COMPOSITION

4.1 Introduction

Plant exploration in India is more than two centuries old and was initiated by western plant scientists. The first plant collector to visit Sikkim was W. Griffith in 1843, followed shortly by Sir J.D. Hooker who made a monumental contribution to national floristics. Over the last 150 years many other plant explorers visited the national park region of Sikkim and contributed to the literature on the floral wealth of the Sikkim Himalaya (Table 4.1 and 4.2). The Botanical Survey of India (BSI) is the national institution with the mandate to survey and build taxonomic database through its network of national and regional Herbaria. In 1979 BSI established a regional center in Sikkim and since then has been regularly carrying out various studies on the floral wealth of the state. Along with BSI other recent floristic studies in KNP include those of Singh (2003), Anon (2005) and Maity (2007).

Table 4.1: Historical plant explorers in the KNP

Year	Visitor	Area visited in KNP
1843	W. Griffith	First plant collector to visit Sikkim
1848-50	J. D. Hooker	Singalila, Dzongri, Zemu valley, Thangu
1877	C. B. Clarke	Dzongri
1892-96	R. Pantling	Various parts of Sikkim, with emphasis on orchids
1892	G. A. Gammie	Singalila range, Dzongri, Yuksom, Lachen
1909-10	W. W. Smith and G.H. Cave	Zemu and Lhonak valley
1960	H. Kanai	Dzongri, Singalila range
1960-63	H. Hara	Various parts of Sikkim
1964	R. S. Rao	Various parts of Sikkim

(Adapted from Grierson & Long 1983)

Table 4.2: Important literature on the floral wealth of the Sikkim Himalaya

Year	Books	Authors
1849	The Rhododendrons of Sikkim Himalaya	J.D. Hooker
1854	Himalayan Journals. Notes of a naturalist. 2 vols.	J.D. Hooker
1894	The vegetation of temperate and alpine Sikkim. In Risley H.H. (ed.). The gazetteer of Sikhim	G.A. Gammie
1898	The orchids of the Sikkim Himalaya	G. King and R. Pantling
1911	The vegetation of the Zemu & Llonakh valleys of Sikkim	W.W. Smith and G.H. Cave
1926	A guide to the orchids of Sikkim	P. Bruhl
1929	The trees of northern Bengal	A.M. Cowan and J.M. Cowan
1983	Flora of Bhutan including a record of plants from Sikkim Vol. I, part I	A.J.C. Grierson and D.C. Long
1984	Flora of Bhutan including a record of plants from Sikkim Vol. I, part II	A.J.C. Grierson and D.C. Long
1987	Flora of Bhutan including a record of plants from Sikkim Vol. I, part III	A.J.C. Grierson and D.C. Long
1990	Sikkim Himalayan Rhododendrons	U.C. Pradhan and S.T. Lachungpa
1991	Flora of Bhutan including a record of plants from Sikkim and Darjeeling Vol. 2, Part 1	A.J.C. Grierson, D.G. Long
1994	Trees of the Sikkim Himalaya	T.D. Rai and L. Rai
1994	Flora of Bhutan including a record of plants from Sikkim and Darjeeling Vol. 3, Part 1	H.J. Noltie
1994	Medicinal plants of the Sikkim Himalaya: status, usage and potential	L. Rai and E. Sharma
1996	Flora of Sikkim Vol. 1, Monocotyledons	P.K. Hajra and D. M. Verma
2000	Flora of Bhutan including a record of plants from Sikkim and Darjeeling Vol. 3, Part 2	H.J. Noltie
2003	The medicinal plants of the Sikkim Himalaya	B. Gurung
2005	Carrying capacity study of Tista basin in Sikkim. Volume VI biological environment – terrestrial and aquatic Resources	Anonymous
2007	The wild flowers of Kanchenjunga Biosphere Reserve, Sikkim	D. Maity and G. G. Maiti

(Adapted from Grierson & Long 1983)

Sikkim with a geographical area of just 7,096 square kilometers is estimated to harbour 5,000 species of flowering plants (Hajra & Verma 1996). In terms of flowering plants per unit area it qualifies as one of the richest center of phyto-diversity in the Himalayan region (Table 4.3) (Anon 2005).

Table 4.3 : Comparative floral richness in the Himalayan region

State / Country	Geographical area (km^2)	Total flowering plants
Arunachal Pradesh	83,743	8,750
Bhutan	47,000	5,468
Sikkim	7,096	5,000
Nepal	140,800	5,900
Uttaranchal	53,483	4,220
Himachal Pradesh	55,673	3,500
Jammu and Kashmir	222,236	4,252

(Adapted from Anon 2005)

The vegetation of the KNP region as described by Sir J. D. Hooker the world renowned botanist in his inimitable style deserves mention here, "The Shingalila range, forming the political boundary between Sikkim and Nepal, springs from Kanchendzonga and extends southwards to the plains of Bengal. The super abundance of rhododendrons is the glory of the Shingalila Range. The banks of rivers between 8,000 and 14,000 feet are generally covered with Rhododendrons sometimes to the total exclusion of other wooded vegetation, especially near the snowy mountain, a cool temperature and great humidity being the most favourable conditions for the luxurious growth of this genus. Such conditions prevailing throughout the Shingalila range due to its proximity with the Kanchendzonga range. The silver fir extends to 13,000 feet and the junipers to 15,000 feet. Whereas the former is only a small, stunted, weather worn tree, the other, a prostrate, intricately branched shrub. For many miles the path runs through woods of *Rhododendron arboreum, R. cinnabarinum, R. falconeri, R. barbatum, R. campanulatum,* and *R. hodgsoni, Acer caudatum, Betula utilis, Pieris ovalifolia, Prunus rufa, Pyrus foliolosa, Pyrus macrophylla* etc. Here also are seen the last examples of the dwarf bamboo tribe, *Arundinaria spathiflora* and *Arundinaria racemosa*" (Hooker 1853).

Floristic study by Maity and Maiti (2007) indicate that the Khangchendzonga Biosphere Reserve contains 1,580 species of vascular plants comprising of with 106 pteridophytes, 11 gymnosperms and 1,463 species of angiosperms. The 1,463 species of angiosperms represented by 1,207 species of dicots, and 256 species of monocots are distributed under 598 genera and 138 families. The gymnosperms have 5 families in 9 genera and 11 species. The dominant families are Asteraceae, Rosaceae, Orchidaceae, Poaceae, Scrophulariaceae, Ericaceae and Primulaceae.

Like in other parts of the Himalaya while a number of historic and contemporary floristic studies have been conducted in Sikkim, vegetation classification has not yet received the desired attention. National classification at larger spatial scales covering forest types by Champion and Seth (1968), biogeography by Rodgers and Panwar (1988) and forest density by Forest Survey of India (1990s) is well established. 1980s saw the advent of remote sensing technology, which is primarily based on visual interpretation of the remotely sensed spectral response of vegetation. Over the last three decades, spatial vegetation mapping over broad scales has gained acceptance since it is rapid and cost effective. It is widely used by various national institutes like the Forest Survey of India (FSI), Indian Institute of Remote Sensing (IIRS), Wildlife Institute of India (WII) and others in various parts of the country. This technique is increasingly being used for forest inventory and mapping. Recent vegetation characterization studies in Sikkim using broad spatial scales include those carried out in collaboration with these agencies (Anon 1994, Anon 2002).

The objective of the current study was to assess the ecology of the alpine vegetation with respect to community composition, structure and fodder availability. Questions relate to what are the distinct vegetation types within the alpine zone, their structure and composition, fodder availability and recent impacts of anthropogenic factors.

4.2 Material and Methods

4.2.1 Field methods

Given that the study area in the alpine zone of KNP spanned across 390 km^2 in seven watersheds where all travel is on foot alone and with a short two months annual window to collect alpine vegetation data, a rapid and simple strategy to characterize the vegetation was adopted. The survey routes were decided in such a way that they covered the glaciated and non-glaciated valleys, altitudinal and aspect zones, traditional grazed and ungrazed pastures and locational features like livestock camps, tourist camps and wetlands. We stopped at regular intervals along the survey route to enumerate broad vegetation groups, followed by assessment of vegetation composition, past and present grazing patterns and threats if any. Assistance was taken from a group of local resource persons having experience of pastoralism, local NGOs, trekking support staff and forest staff.

A stratified approach based on remote sensing knowledge, topographical sheets and experience was used to divide the study area into recognizable entities or physiognomic units (viz. subalpine fir, alpine scrub, alpine meadow, etc). These vegetation groups were recognizable as a unit that is repeated in other areas of the landscape, i.e. a repeating assemblage of species. Sample sites were located within representative homogeneous areas of these preliminary vegetation groups (>1ha area). As far as possible sampling ecotones or breaks between distinct communities was avoided. Sample plots or replicates were then placed randomly within this sampling site for collecting vegetation data following standard phytosociological approach (Mueller-Dumbois & Ellenberg 1974, Kent & Coker 1992). For quantification of vegetation at each sampling site, ten replicates of square quadrates of 1m x 1m for herbaceous ground flora, five replicates each of 5m x 5m for alpine scrub and 10m x 10m for sub-alpine forest were laid following Kala *et al.* (1998) and Rawat and Adhikari (2002). Total cover of each plant species in a plot was assigned using percent cover. This rapid methodology is qualitative in the sense that species cover is estimated and quantitative in the sense that it gives a complete list of species for the plot. Measurement of parameters like altitude, aspect, slope, latitude, longitude, present biotic use and use by wildlife was recorded at each sampling site using standard techniques and equipments.

Angiosperms were enumerated systematically along the route and were further grouped under various categories viz., species of ethno-botanical value, important forage species, species of botanical interest and rare endemic plants. Most of the plants were identified closest to the genera and species in the field using the regional floras available namely Flowers of Himalaya (Polunin & Stainton 1987), (Flora of Bhutan 3 volumes which includes collections from Sikkim) and Trees of Northern Bengal (Cowan & Cowan 1929). Voucher specimens of unidentified plants were collected and later verified from other monographs and herbaria at Gangtok and Dehra Dun. Floristic websites at www.efloras.org were also consulted. Native uses of plants were noted from the local field guides.

The study area was surveyed in summer and winter seasons in 14 field visits spanning 125 days over a 3-year period from 2004 to 2006. A total of 600 specimens were collected from the alpine zone of KNP for herbarium. Vegetation data were collected from a total of 597 sample plots in 89 sampling sites. Consultations were conducted in 17 villages over 49 days to understand the traditional resource use pattern.

4.2.2 Vegetation analysis

The four most common approaches used in vegetation classification are gradient analysis, ordination, clustering, and tabular analysis. For classification of vegetation data an attempt has been made to combine traditional European methods of phytosociology, which mostly use the tabular approach, with the more modern numerical analysis tools, which rely more on multivariate analysis. Both these approaches are possible in vegetation data analysis softwares namely TURBOVEG and JUICE (Hennekens & Schaminée 2001, Lubomír 2002) (Figure 4.1). The computer software package TURBOVEG (for Microsoft Windows) was developed in The Netherlands for the processing of phytosociological data. This package comprises an easy-to-use data base management system. The program provides methods for input, import, selection, and export of relevés. In 1994, TURBOVEG was accepted as the standard computer package for the European Vegetation Survey. Currently it has been installed in more than 25 countries throughout Europe and overseas. TURBOVEG for windows 2.41 international single user version was used. The program JUICE developed from 1998 is designed as a Microsoft Windows application for editing, classification and analysis of large phytosociological tables or other ecological data. The software is freely distributed as an original package and can be downloaded from the website www.sci.muni.cz/botany/juice.htm. Various options include classification using cluster approach with TWINSPAN and PCORD methods, preparation of synoptic tables, automatic sorting of relevé tables, and export of table data into other applications (Hill 1979, McCune & Mefford 1999). JUICE is optimized for use in association with TURBOVEG, however, other import formats are also available. JUICE software version 6.4.50 was used in the analysis.

Figure 4.1: Software scheme used for numerical analysis of vegetation data

Input	Processing	Output
• Taxon inventory list from secondary sources • Field sampling data containing header and taxon abundance information	Data input and storage in datasheet Export in various formats	• Taxon inventory list (*.xls) • Taxon abundance matrix (*.xls) • Header matrix (*.xls)
• Taxon inventory list (*.DBF 4) • Taxon abundance matrix (*.CSV) • Header matrix (*.DBF 4)	 Data input and storage in database, taxon names validation Export in various formats	• Combined taxon abundance and header matrix (*.xml)
• Combined taxon abundance and header matrix (*.xml)	 Data editing, vegetation classification, Synoptic tables Twinspan, PCORD, Multivariate analysis	• Synoptic tables (*.doc) • Diagnostic species (*.doc) • Vegetation classification • α and β diversity

For preparing the synoptic table after hybrid classification the threshold fidelity value for diagnostic species is taken as (3), threshold frequency value for constant species as 60. In the absence of national standards on vegetation classification for India, the standards for associations and alliances of the U.S. National Vegetation Classification (NVC) system was followed wherever possible (Jennings *et al.* 2002).

Alpha diversity indices of richness (S), evenness (E), Shannon's diversity (H) and Simpson's diversity (D`) were calculated using the row and column summary option in PC-ORD version 4.41 (Table 4.6). Richness (S) was calculated as the number of non-zero elements in row, evenness (E) as H / ln (Richness), Shannon's diversity index (H) as - sum (Pi x ln(Pi)) and Simpson's diversity index (D`) for infinite population as 1 - sum (Pi x Pi) where Pi is importance probability in element i (element i relativized by row total).

4.3 Results and discussion

4.3.1 Community structure and composition

4.3.1.1 Vegetation types

Broad landscape level classification indicates that KNP comprises of temperate oak forests (11%), subalpine conifer and krummholtz forests (14%), alpine forests (22%) and snow and rock (53%) (Figure 3.1). The alpine zone as used in this study broadly includes the areas between 4,000 and 5,000 meters elevation. Physiognomically it starts from where the Krummholtz forests end and the scrub vegetation starts and extends up to where the subnival vegetation starts. About 22% of the park with an extent of 390 km^2 falls within this zone. Alpine scrub and herbaceous vegetation (including sedge meadows) are the major physiognomic units within this zone and comprise about 33 and 67% area respectively (Figure 3.2).

Based on remote sensing maps, SOI toposheets, earlier experience and reconnaissance visits the vegetation in the sub alpine and alpine zone of KNP were stratified into five physiognomic units namely: (a) sub-alpine fir forest (b) sub alpine thickets, (c) alpine scrub and (d) alpine meadow (e) riverine. Vegetation data from 280 quadrates in 56 sampling stations in the study area containing abundance data for 150 floral species was collected during the peak growing season of June and July in habitats in pristine condition.

Table 4.4: Vegetation plot data collected from the study area

Preliminary vegetation groups	No. of plots	No. of sampling stations	Sampling station id
Sub alpine silver fir	10	2	2,3
Subalpine thicket	15	3	12,38,43
Alpine scrub	70	14	6,7,8,9,10,11,14,15,16,17,36,42,44,49
Alpine meadow	135	27	21,22,23,24,25,26,27,28,29, 30,31,32,33,34,35,37,45,46,47,48,51,52,53,54,55,56,57
Riverine	50	10	4,5,13,41,50,1,18,19,20,39

Subsequently the numerical method of cluster analysis was carried out in PC-ORD, Version 4.41. The hierarchical cluster analysis with the linkage method as "Ward's" and the distance measure as Euclidean (Pythagorean) was chosen to classify the releve matrix into 15 clusters (Figure 4.2). Based on this numerical classification it was found that alpine meadow was segregating broadly into three clusters namely sedge meadow, marsh meadow and herbaceous meadow. Also sedge meadow was separated into three classes which were dominated by *Kobresia nepalensis*, *Kobresia duthiei* and *Kobresia pygmaea*. While the *Kobresia nepalensis* class had a subclass of subnival vegetation characterized by *Saussurea gossypiphora* and the herbaceous meadow was dividing into two classes with dominance of *Potentilla peduncularis* and *Anaphalis xylorhiza* respectively. The numerical classification based on floristics matched 93% with the initial phenological classification. The broad physiognomic characterization and altitudinal variation is shown in Table 4.6 and Figure 4.3. Hence the initial classification based on phenology was improved based on the new classes indicated by numerical classification and was combined to create the hybrid classification which is described in detail in Section 4.3.1.2. Plate 4.1a and 4.1b depict the broad vegetation types and communities.

Figure 4.2: Vegetation characterization of the alpine zone of KNP using cluster analysis

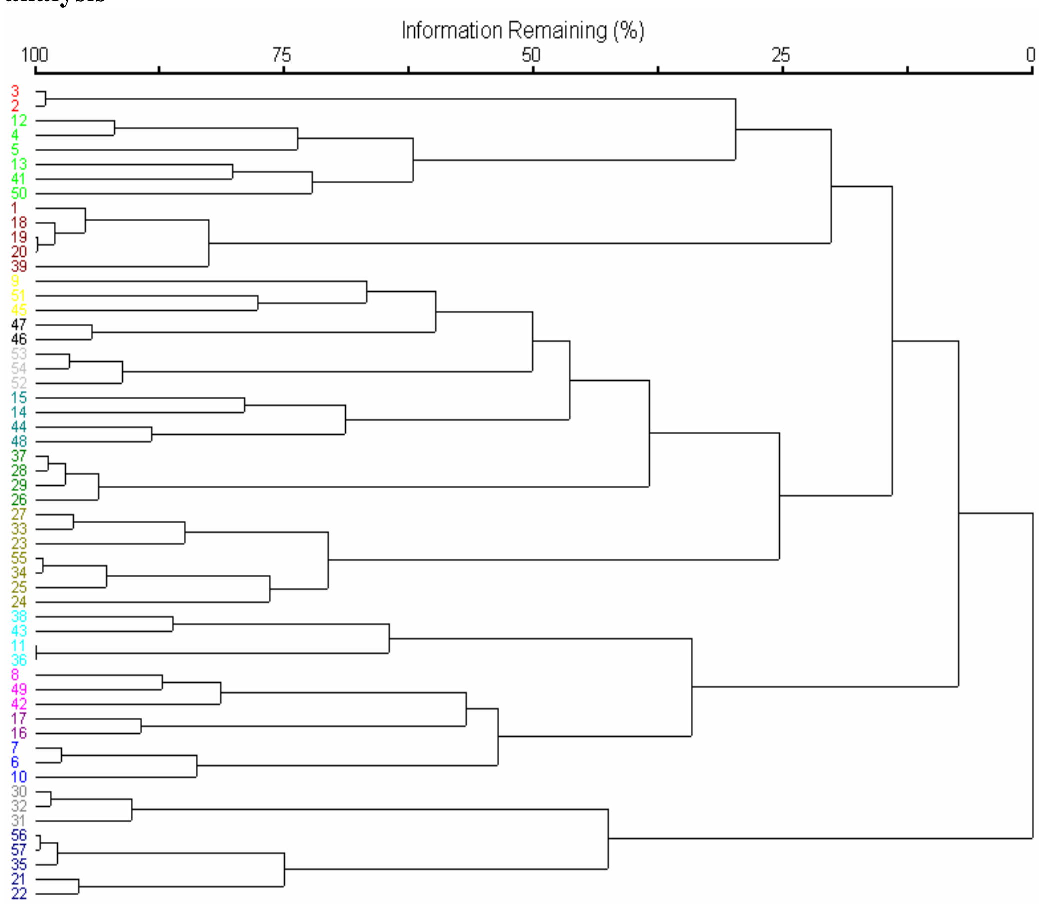


Table 4.5: Vegetation characterization of the alpine zone of KNP

Preliminary Vegetation Groups	Releve id
Sub alpine silver fir	2,3
Krummholtz	12,38,43
Juniper scrub	6,7,8,9,10
Rhododendron scrub	11,36,42,49
Marsh meadow	26,27,28,29,37
Sedge meadow	21,22,24,25,33,34,35,45,46,47,48,51,55,56,57
Herbaceous meadow	23,30,31,32,52,53,54
Morainic scrub	14,15,16,17,44
Riverine thicket	4,5,13,41,50
Riverine scrub	1,18,19,20,39

Table 4.6: Broad physiognomic characterization of vegetation

Vegetation Type (Champion and Seth 1968)	**Terrain features**	**Biotic pressure**	**Wildlife use**
Sub-alpine silver fir forest (14/C2, 12/C3(a,b))	(3100m – 3800m)	Silver fir for timber and firewood collection especially of Rhododendron by herders and trekking support staff	musk deer, Himalayan tahr, serow, satyr tragopan, Himalayan monal, yellow throated marten
Krummholtz thicket (15/C1)	(3600m – 4200m)	Firewood collection especially of Rhododendron by herders and trekking support staff	musk deer, Himalayan tahr, blood pheasant, satyr tragopan, Himalayan monal
Juniper scrub (16/E1)	(3700m – 4400m) north and northwest aspect	Firewood collection especially of Juniper by herders and trekking support staff, collection of twigs for incense, grazing and burning by herders	blue sheep, Himalayan tahr, red fox, musk deer, voles, Himalayan monal
Rhododendron scrub (15/C2/E1)	(3900m – 4600m) south and southeast aspect	Firewood collection by herders and trekking support staff	Nesting habitat for birds like finches, pipits, accentors etc
Morainic scrub	(3900m – 4500m) glaciated valleys along lateral and terminal moraines	Moderate grazing and trampling by yaks and sheep	blue sheep, snow leopard, pika, snow partridge, Himalayan monal, accentors, pipits, grandala, snow partridge, snow cock

Marsh meadow	(4000m – 4700m) lake basin, upper reaches of meandering river courses	Camping by trekkers and disposal of solid waste (garbage) also sacred sites for wetland pilgrimage	blue sheep, snow leopard, snow partridge, Himalayan monal, accentors, pipits, grandala, snow partridge and snow cock
Moist alpine meadow (15/C3)	(4000m – 5100m)	Heavy grazing and trampling by yaks and grazing by sheep	
Dry alpine meadow (16/C1)	(4500m – 5100m)		
Periglacial and subnival vegetation	(4,700m to 5,500m)	Occasional grazing by yaks and sheep	
Riverine thicket	(3600m – 4200m) edges of rivers and streams	Camping by tourists resulting in spread of solid waste along the popular trekking trails and camping sites	blood pheasant, thrushes, white capped redstart, white throated dipper
Riverine scrub	(3600m – 4600m) on river bed		

Figure 4.3: Altitudinal variation of vegetation types in the sub-alpine and alpine zone of KNP

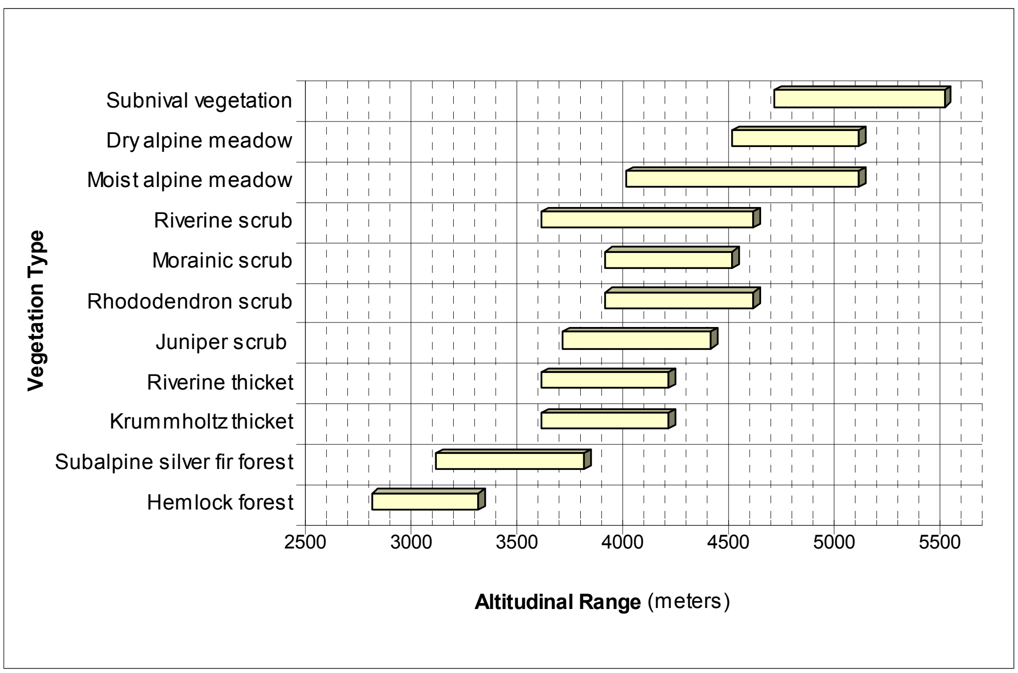


Plate 4.1a: Broad vegetation types and communities

Temperate oak forest

Sub-alpine silver fir forest

Krummholtz thicket

Krummholtz thicket

Salix sikkimensis riverine thicket

Myricaria rosea riverine scrub

Juniper scrub

Rhododendron scrub

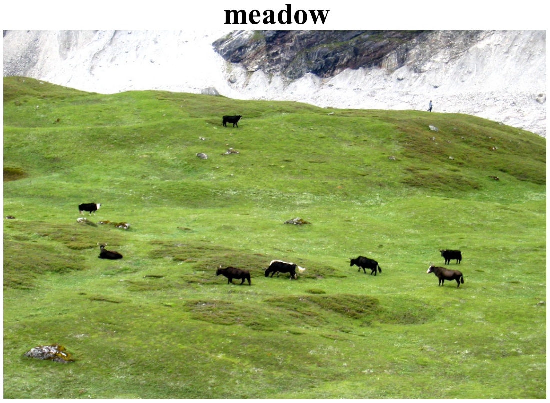
Plate 4.1b: Broad vegetation types and communities

Morainic scrub

***Deschampsia caespitosa* marsh meadow**

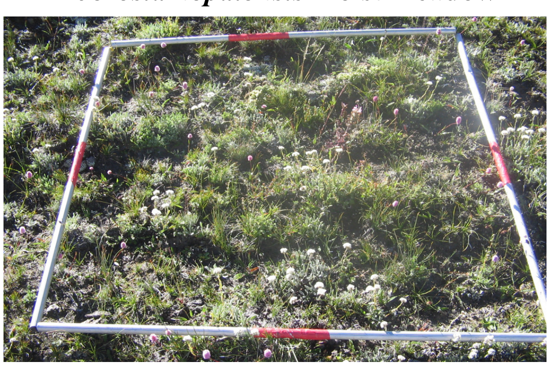
***Potentilla peduncularis* herbaceous meadow**

***Kobresia duthiei* moist meadow**



***Kobresia nepalensis* moist meadow**

***Kobresia pygmaea* moist meadow**



***Anaphalis xylorhiza* dry meadow**

Periglacial and subnival vegetation

4.3.1.2 Structure and composition

(a) Sub-alpine silver fir forest: Old growth *Abies densa* (silver fir) forest dominates the highest forested ridges of Sikkim and is extensive throughout the eastern Himalaya. Above Tshoka, between Phedang and Koktshurung (lower trek route), Kasturi urar (above Labdang), Tamrong and Jakchen are a few locations where they can be seen. These forests frequently occur between 3,100 and 3,800 meters and the soil is loam and high in organic content (OC = 5.12%). *Tsuga dumosa* and *Larix griffithii* in the temperate ecotone and *Juniperus indica* in the alpine ecotone share the top canopy which becomes increasingly stunted and sparse as the tree line is approached. Other than heavy rainfall, mist precipitation in this cloud-forest zone supports a luxuriant array of epiphytes, ferns, moss and lichens. The longest lichen in the world - *Usnea longissimia* hanging from the branches of trees and shrubs is a common sight here. These forests also receive snowfall in winter. The top canopy of *Abies densa* is sparse and supports in the middle storey a super abundance of impenetrable evergreen *Rhododendrons* and dwarf bamboo in the exposed valleys and *Betula utilis*, *Acer campbellii* and dwarf bamboo thickets in the inner valleys.

Gregarious thickets of *Rhododendron barbatum, Rhododendron cinnabarinum, Rhododendron hodgsonii* (kurlingo)*, Rhododendron thomsonii* and *Rhododendron campanulatum* (chimal) occur in the understorey. *Arundinaria maling* (maling) and *Thamnolcalamus aristata* (raat nigalo) are the important dwarf bamboos in the understorey. *Pieris ovalifolia* (angeri)*, Sorbus foliolosa* (pansi)*, Prunus cornuta* (lekh paiyun)*, Rosa sericea* (khorsane kanra)*, Viburnum nervosum* are the deciduous elements in the middle storey. Ground shrub flora consists of *Ilex intricata* (kurkure)*, Rubus paniculata* (kanre lahara), *Gaultheria trichophylla, Skimmia laureola*, *Rhododendron ciliatum,* and many herbaceous species of *Impatiens*, *Arisaema, Primula, Polygonum, Fragaria, Thalictrum, Maianthemum, Pedicularis, Heracleum* etc. A woody climber in Ranunculaceae - *Clematis montana*, an epiphytic Rhododendron - *Rhododendron camelliiflorum*, a leafless parasitic plant - *Boschniakia himalaica* are some of the interesting plants found here. Important ethno-medicinal plants include *Panax pseudo-ginseng*, *Aconitum ferox, Bergenia purpurascens, Gymnadenia orchidis* and *Smilax menispermoidea* (bet lauri).

In some parts of KNP and adjacent areas, fir forests have been cleared on stable warmer slopes for creating grazing pastures (kharkas). In the blanks heavily used by livestock, *Arthraxon microphyllus* (bonchu) along with moss is the dominant ground cover. Openings in the lower reaches are rapidly colonized by *Thamnocalamus spathiflorus* (raat nigalo) while the upper reaches show a dense pole sized regeneration of fir and *Rhododendron*. Silver fir is a source of durable timber used in construction of houses as well as cattle sheds. *Rhododendron* is preferred choice for firewood since it burns green and dwarf bamboos are used for weaving mats, as fodder and as bedding for calves. Juniper twigs are used as incense in Buddhist rituals.

Diagnostic species	Constant species	Dominant species
Rhododendron hodgsonii 7.4, Ilex intricata 7.4, Sorbus microphylla 6.7, Rhododendron wightii 6.7, Abies densa 6.2, Fragaria sp. 5.2, Viburnum nervosum 5.1, Betula utilis 5.1, Polystichum sp. 3.6, Rhododendron thomsonii 3.3, Rosa sericea 3.2	***Sorbus microphylla 100, Rhododendron wightii 100, Rhododendron hodgsonii 100, Ilex intricata 100, Fragaria sp. 100, Abies densa 100***	***Rhododendron hodgsonii 100***

(b) Krummholtz thicket: Extensive Krummholtz thickets usually found between 3,600 to 4,200 meters elevation are a unique feature of the Eastern Himalaya. Abundant in all the parts of KNP some of the locations where they can be found are below Thangsing, Gomathang, Laal jethi, Pairey jhareni, Pangding, Mon Lepcha and below Yabuk loghouse. They extend upwards from the tree line and gradually become stunted with elevation before giving way to the alpine scrub communities. Instead of growing vertically the trees are mostly dwarfed and prostate due to high winds and heavy snow pressure especially in the upper reaches. They favor shady and moist localities and are most luxuriant in the north and northwest aspects. These forests prefer rocky slopes on soils that are very acidic (pH = 4.32) with high organic carbon (OC = 6.67%). The vegetation formation is dense, thicket forming and impenetrable with the canopy height generally varying between one to four meters.

The following associations are easily identifiable viz., *Rhododendron campanulatum*, *Rhododendron lanatum*, *Rhododendron thomsonii* and *Rhododendron wightii* – *Rhododendron fulgens*. The floor is thickly carpeted with mosses and fallen leaves and is mostly devoid of other vegetation. *Bergenia purpurascens, Gymnadenia* *orchidis* and *Pircrorhiza scrophulariifolia* mats on sandy soil are the important medicinal plants in these forests. A ground orchid *Ponerorchis nana* and an Apiaceae with tall pink umbels - *Pleurospermum sp.* (seto cheeru) are some of the interesting plants here.

Near herder camps and tourist camping sites these forests have been cut for firewood. In these openings a few other plants such as gregarious *Berberis* clumps in the lower reaches and *Cassiope fastigiata*, *Spiraea arcuata*, *Primula sikkimensis, Potentilla peduncularis,* ferns and species of *Carex, Juncus, Polygonum*, *Fragaria* etc can be seen. *Bistorta vaccinifolia* colonizes the boulders and in marshy areas *Chrysosplenium sp.* can be seen.

Diagnostic species	Constant species	Dominant species
Bergenia purpurascens 6.0, Rhododendron campanulatum 5.1, Gaultheria pyroloides 4.2, Rhododendron anthopogon 4.1	***Rhododendron anthopogon 100,*** *Rhododendron campanulatum 67, Bergenia purpurascens 67*	*Rhododendron lanatum 33, Rhododendron campanulatum 33*

(c) Juniper scrub: Juniper scrub vegetation occurs generally in the 3,700 to 4,400 meters elevation zone and prefers warmer slopes having south and southwest aspect. This vegetation is not very abundant and can be found in Doring taar, Lampokhri, Ghumney, Khangarding and opposite Marco Polo camp in Zemu valley. *Juniperus recurva* and *Juniperus indica* are the two characteristic species forming associations. *Juniperus recurva* is prostate in habit and is found more commonly in the 3,700 to 4,100 meters elevation range. While *Juniperus indica* usually occurs in shrub form in the 4,000 to 4,400 meters elevation zone. In the dry inner valleys this Juniper ascends upto 4,800 meters.

In the *Juniperus recurva* association scattered *Juniperus recurva* clumps (under 0.6 meter tall) interspersed with meadows is the dominant structure. This vegetation is dominated by Juniper scrub which has atleast 40% cover while the grasses and sedges have upto 30% cover. *Carex alpina, Poa alpina, Calamogrostis filiformis* and *Kobresia nepalensis* are the important grasses and sedges. While the important constituents of the herb layer are *Rhodiola bupleuroides, Bistorta vivipara, Arisaema sp., Potentilla peduncularis, Potentilla coriandrifolia, Anaphalis royleana, Phlomis* *bracteosa, Aletris pauciflora* and species of *Primula* and *Pleurospermum.* These herbaceous plants generally take shelter in and around the Juniper and Rhododendron clumps. Juniper being slow growing, openings in the shrub layer is colonized by *Berberis angulosa* in the lower reaches and *Rhododendron setosum* in the upper reaches.

In the *Juniperus indica* association the height of the *Juniper indica* clumps varies between 0.40 to 1 meters with a cover of atleast 30%. *Juniperus recurva* is the other dominant shrub whose cover is less than 15%. In this layer *Rhododendron lepidotum* has a tendency to colonize the openings. Herbs and grasses cover atleast 10% with the herbaceous species being *Rhodiola bupleuroides, Rheum acuminatum* and species of *Pleurospermum* and *Potentilla.* This vegetation has been excessively burnt and cleared by the yak herders to increase fodder cover. The burnt patches show a substantial cover of *Calamogrostis filiformis, Anaphalis royleana, Agrostis pilosula, Festuca vallesiaca, Heracleum sp.* (ganer), *Pleurospermum sp.* (cheeru), *Rheum acuminatum* and *Hemiphragma hetrophylla*. Natural regeneration of Juniper is virtually absent in these burnt sites.
Both the species of Juniper were also harvested commercially in large quantities when collection and transit was permitted between 1970s and 1990s. *Aconitum ferox* and *Podophyllum hexandrum* are the important medicinal plants in this association and occur only in pockets.

Diagnostic species	Constant species	Dominant species
Juniperus indica 5.2, Juniperus recurva 4.6, Potentilla sp. 3.2, Poa alpina 3.2, Berberis angulosa 3.2	***Juniperus indica 80***	***Juniperus indica 40,*** *Juniperus recurva 20*

(d) Rhododendron scrub: Dwarf Rhododendron shrub vegetation is widespread in the higher ridges above the Krummholtz zone. This scrub is abundantly found in all the watersheds of KNP, some of the locations are Suke pokhri (Areylungchok), between Langbo and Theu la, Marco Polos camp and Ghumney deorali. This dwarf (less than 1 meter tall) alpine moist scrub favours the north and northeastern slopes and generally occurs between 3,900 to 4,600 meters. However in trans-Himalayan dry valleys it can ascend upto 4,900 meters. Heavy snow pack in winter insulates it from wind exposure and cold. This vegetation is very dense and the Ericaceous cover is more than 50% with very few gaps or openings. The shrub layer is co-dominated by *Rhododendron anthopogon* (sun-pate), *Rhododendron setosum* and *Rhododendron lepidotum.*

In openings a mix assemblage of *Cassiope fastigiata, Salix lindleyana, Juniperus recurva, Calamogrostis filiformis, Festuca valesiaca, Potentilla peduncularis, Potentilla coriandrifolia, Primula macrophylla, Megacodon stylophorus* and various species of *Pedicularis, Primula, Arisaema, Pleurospermum, Carex, Kobresia,* ferns and mosses occur.

Nardostachys grandiflora and *Anemone polyanthes* are some of the valuable ethno-medicinal plants in this vegetation. *Rhododendron anthopogon* is used as incense in Buddhist monasteries. Occasionally on undulating exposed terrain, herders clear this shrub layer to create artificial pastures (e.g. Charmane chaur) which on stabilizing are dominated by *Kobresia nepalensis* in the exposed parts and *Carex alpina, Potentilla coriandrifolia* and *Potentilla peduncularis* in the others.

Diagnostic species	Constant species	Dominant species
Rhododendron setosum 4.5, Morina nepalensis 4.1, Pedicularis trichoglossa 3.6, Lonicera hispida 3.6 Cassiope fastigiata 3.3, Calamogrostis filiformis 3.2	***Rhododendron setosum 100,*** *Rhododendron anthopogon 75*	***Rhododendron anthopogon 50,*** *Rhododendron setosum 25*

(e) Morainic scrub vegetation occurs in glaciated valleys along the lateral and terminal moraines between 3,900 and 4,500 meters elevation. Bikhbari, Chonrikhang, Deota ghar, Lamune, Sungmoteng tsho flank (Samiti lake) are some of the locations where this vegetation is found. This shrub-dominated vegetation is luxuriant and diverse in the lower reaches and becomes stunted and sparse in the upper reaches. *Potentilla fruticosa* (simte phool) is the diagnostic species of this vegetation and is most prominent in the middle elevations. In the upper reaches *Rhododendron lepidotum, Calamogrostis filiformis, Kobresia nepalensis, Saxifraga flagellaris* and *Dubyaea hispida* are the main associates. In the lower reaches shrubs like *Rhododendron lepidotum, Rhododendron setosum, Rhododendron anthopogon,* *Spiraea arcuata, Juniperus indica, Salix lindleyana, Lonicera sp.* along with *Geranium donianum, Calamogrostis filiformis, Epilobium wallichianum, Carex sp.* and *Bistorta vivipera* are found. Around livestock camps *Potentilla peduncularis* (namle jhaar) and *Ranunculus hirtellus* (khorsane) tend to colonize.

Diagnostic species	Constant species	Dominant species
Potentilla fruticosa 5.0, Spiraea arcuata 4.6, Dubyaea hispida 3.6, Arisaema sp. 3.6, Parnassia pusilla 3.2, Lonicera obovata 3.2, Lonicera sp. 3.2, Ligularia sp. 3.2, Aster flaccidus 3.2, Anaphalis nubigena 3.2	***Potentilla fruticosa 100,*** *Rhododendron anthopogon 60, Kobresia nepalensis 60*	*Rhododendron lepidotum 20, Potentilla fruticosa 20*

Alpine meadows: The alpine meadows cover the upper reaches of valleys and ridges beyond the scrub vegetation typically in the elevation zone of 4,000 to 5,100 meters. They are found in varied habitats ranging from stable valley bottoms to steep bouldery mountain slopes and from marshy flats to desert steppe. But for the marsh meadow association, it grows on highly acidic soils (pH = 4.82) with abundant organic carbon (OC = 6.09%). This vegetation comprises of dwarf sedges, grasses and herbaceous formations and seldom attains a height of more than 0.5 meters. Physiognomically and floristically they can be classified into five major associations namely *Kobresia nepalensis* moist meadow, *Kobresia duthiei* moist meadow, *Kobresia pygmaea* moist meadow, *Deschampsia caespitosa* marsh meadow and *Anaphalis xylorhiza* dry meadow. These meadows form an important summer grazing resource for the livestock production systems and wild ungulates like blue sheep (*Pseudois nayaur*), Himalayan tahr (*Hemitragus jemlahicus*) and musk deer (*Mochus chrysogaster*).

(f) *Kobresia nepalensis* moist meadow is the most widespread and dominant vegetation in altitudes ranging from 4,000 to 5,100 metes in the alpine zone. Panch-pokhri (beyond Goche-la), Dawathang shepherds camp (Kishong), south of Theu la (Thompyak chu) are some of the locations were these meadows can be seen at their luxuriant best. It occurs most luxuriantly on the smooth slopes and ridge tops in the upper reaches of moist, exposed, glaciated valleys. This dense soft mat like formation has an average height of 0.1 meters. The cover of *Kobresia nepalensis* varies a lot with micro-topography and codominates with *Bistorta milletii, Potentilla peduncularis, Rhododendron lepidotum, Primula capitata* and species of *Arenaria*, *Juncus* and *Carex.* Openings in rich soils are colonized by *Potentialla peduncularis,* around cattle camps by *Ranunculus hirtellus* (khorsane) and compacted soils by *Bistorta sp*.. *Picrorhiza scrophulariiflora* (kurki)*, Lomatogonium sp. (sharmaguru), Lomatogonium sp. (mahaguru)* are the valuable ethno-medicinal plans found in this vegetation. This is the most extensive and nutrient rich vegetation that sustains livestock and wild ungulate populations in the KNP.

Diagnostic species	Constant species	Dominant species
Cremanthodium sp. 4.6, Primula dickieana 3.2, Carex nivalis 3.2, Anemone trullifolia 3.2	***Kobresia nepalensis 100,*** *Rhododendron lepidotum 40, Potentilla peduncularis 40, Cremanthodium sp. 40, Bistorta milletii 40*	***Kobresia nepalensis 60***

(g) *Kobresia duthiei* moist meadow found in pockets prefers moist valleys on slopes that are bouldery and steep in the 4,000 to 4,600 meters elevation zone. This meadow occurs at Areylungchok, Rungdung himal, Narsing himal, Jaure himal and the ridge east of Shingo tsho to name a few. The vegetation is tussock forming dominated by *Kobresia duthiei* (cover greater than 40%) with an average height of 0.30 meters. In openings *Kobresia nepalensis, Kobresia capillifolia, Rheum acuminatum, Rhododendron anthopogon, Geranium donianum* and species of *Heracleum, Swertia sp.* and *Pleurospermum* and *Juncus* are usually found. Good population of valuable medicinal plants like *Aconitum ferox*, *Nardostachys grandiflora, Bergenia purpurascens* are found here. This vegetation as informed by the herders is preferred by the yaks and cow-yak crossbreeds and is sensitive to yak grazing and is usually located in pockets which are either free from grazing or only grazed by sheep.

Diagnostic species	Constant species	Dominant species
Kobresia duthiei 7.4, Kobresia capillifolia 4.6, Rheum acuminatum 4.2, Swertia sp. 3.2, Nardostachys grandiflora 3.2, Anemone sp. 3.2, Aconitum ferox 3.2	***Kobresia duthiei 100, Rheum acuminatum 80, Potentilla peduncularis 80,*** *Kobresia nepalensis 60, Juncus sp. 60*	***Kobresia duthiei 80***

(h) *Kobresia pygmaea* moist meadow is found in the upper reaches of the glaciated and relatively dry Zemu and Lhonak valleys in the elevation range of 4,400 meters to

5,100 meters. As the name suggests in the upper reaches this vegetation is dwarfed with the average height being 0.05 meters. Dolmasampa, Langbo and upper Zemu valley are some of the areas where this vegetation occurs. In the lower reaches along streams *Kobresia schoenoides* and *Bistorta vivipera* while in the upper reaches *Kobresia sp., Bistorta milletii, Potentilla fruiticosa* and *Aster falconeri* codominate. *Nardostachys grandiflora* and *Ephedra gerardiana* are the important medicinal plants found only in pockets.

Diagnostic species	Constant species	Dominant species
Bistorta milletii 5.2, Thalictrum alpinum 5.1, Primula capitata 5.1, Kobresia pygmaea 5.1, Kobresia sp. 5.1, Aster falconeri 5.1, Hedysarum sikkimense 5.0, Parnassia sp. 4.5, Gentiana sp. 4.4, Aletris pauciflora 4.4	*Parnassia sp. 75, Kobresia schoenoides 75, Hedysarum sikkimense 75, Bistorta milletii 75*	

(i) *Deschampsia caespitosa* marsh meadow occurs in the waterlogged flats adjacent to alpine lakes and in the upper courses of meandering streams, in elevations ranging from 4,000 to 4,600 meters. Lampokhri, Chamrey, Relli mathlo taar and Dokaney urar are some of the accessible alpine marsh meadows. This vegetation is tussock forming with the top height being less than one meter. Relative to other sub-alpine and alpine vegetation, it grows on less acidic soils (pH = 5.17) with limited organic carbon (OC= 1%). Floristically *Deschampsia caespitosa* (chamrey) clumps are dominant (cover greater than 40%) especially in edges of perennial watercourses. In the openings commonly occurring species include *Carex setigera, Lagotis kunawarensis, Potentilla coriandrifolia, Festuca valesiaca, Calamogrostis filiformis, Epilobium wallichianum* and species of *Pedicularis, Juncus*, moss and lichens. Fringe areas of the wetland away from the watercourses are gradually being reclaimed by *Rhododendron anthopogon, Cassiope fastigiata, Carex sp.* and *Potentilla peduncularis.*

Diagnostic species	Constant species	Dominant species
Deschampsia caespitosa 4.8, Ranunculus hirtellus 3.6	***Deschampsia caespitosa 100*** *Juncus sp. 75*	*Deschampsia caespitosa 50*

(j) *Anaphalis xylorhiza* dry meadow vegetation is unique to the trans-Himalayan glaciated valley flats in the 4,500 to 5,100 meters elevation zone. In the KNP it occurs in the Lhonak valley at Lungma, Rasung, Changsang and other adjacent locations.

This steppe vegetation grows in dry, arid conditions and is characterized by dwarf herbaceous formations (average height is 0.1 meters). The total vegetation cover decreases from 90% in the lower reaches to less than 40% in the upper reaches. *Anaphalis xylorhiza* is the dominant vegetation (cover greater than 20%) with the main associates being *Bistorta vivipera, Kobresia schoenoides, Kobresia nepalensis, Lancea tibetica* and various species of *Arenaria* and *Pedicularis.* Other species include *Aster diplostiphiodes*, *Delphinium caeruleum, Cyananthus incanuns*, *Cortiella sp., Scabiosa sp., Gentiana stipitata*, *Lonicera rupicola*, *Elymus nutans* and species of *Rhodiola* and *Oxytropis. Ephedra gerardiana* found in pockets is the valuable medicinal plant found here.

Diagnostic species	Constant species	Dominant species
Saxifraga sp. 6.6, Arenaria sp. 6.6, Saussurea nepalensis 6.0, Lancea tibetica 6.0, Euphorbia sp. 6.0, Ephedra gerardiana 6.0, Anaphalis xylorhiza 6.0, Arenaria sp. 5.3, Kobresia schoenoides 5.0, Festuca valesiaca 4.7, Delphinium glaciale 4.2, Delphinium caeruleum 4.2	***Saxifraga sp. 100, Kobresia schoenoides 100, Kobresia nepalensis 100, Festuca valesiaca 100, Arenaria sp. 100, Anaphalis xylorhiza 100,*** *Saussurea nepalensis 67, Lancea tibetica 67, Euphorbia sp. 67, Ephedra gerardiana 67, Arenaria sp. 67*	*Anaphalis xylorhiza 33*

(k) Periglacial and subnival vegetation are highly specialized plants occurring in high alpine areas between 4,700 to 5,500 meters elevation. It is easiest to spot them around alpine mountain passes at Tekepla, Theula, Lunala, Gochela, Kishongla, Khangla, Dawathang pass, Deorali pass and Relli top. This vegetation is prostate (average height less than 0.1 meters) and sparse (total vegetation cover is often less than 10%) and grows on skeletal soils dominated by scree slopes. Floristically the species commonly found here include *Saussurea gossipiphora, Saussurea tridactyla, Eriphyton wallichii, Meconopsis horridula, Meconopsis discigera, Corydalis meifolia, Tanacetum gossypinum, Kobresia nepalensis, Saxifraga caveana, Saxifraga engleriana, Saxifraga jacquemontiana, Anaphalis nubigena, Lagotis kunawarensis, Gentiana urnula, Delphinium glaciale, Veronica lanuginosa, Salix lindleyana, Rheum nobile, Primula tenuiloba, Primula sapphirina* and species of *Arenaria, Leontopodium, Lomatogonium* and *Gentiana.*

Diagnostic species	Constant species	Dominant species
Saussurea gossypiphora 7.4, Saxifraga caveana 5.1, Rheum nobile 4.2, Lomatogonium sp. 4.2, Lagotis kunawarensis 4.1	***Saussurea gossypiphora 100, Kobresia nepalensis 100,*** *Saxifraga caveana 50, Rheum nobile 50, Lomatogonium sp. 50, Lagotis kunawarensis 50*	***Kobresia nepalensis 50***

(l) *Salix sikkimensis* riverine thicket vegetation occurs along the river edges on sandy soils, in the riverine fringes of subalpine fir and krummholtz forest upto 4,200 meters elevation. Koktshurung, Talem, Jakchen, Tamrong and Churong chu bridge are some of the locations along the trekking trail where one can observe this vegetation. Pole-sized trees (average girth of 0.2 meters) that are densely packed (average 15 stems in 100m^2 area) dominate the top layer (canopy cover more than 70%). *Salix sikkimensis* is the diagnostic species of this vegetation with high cover (cover more than 30%). In moist valleys *Rhododendron lanatum, Sorbus microphylla, Rhododendron thomsonii, Rhododendron hodgsonii, Rosa sericea* and *Abies densa* are the main associates. In the inner valleys codominants in the top canopy include *Hippophae salicifolia*, *Betula utilis*, *Acer campbellii* and *Rhododendron hodgsonii.* Ground flora in this vegetation is sparse and is dominated by *Bistorta vaccinifolia*, *Rheum acuminatum*, *Epilobium wallichianum*, *Megacodon stylophorus*, regeneration of *Abies densa* and species of *Ribes, Impatiens, Polygonum, Heracleum, Thalictrum, Carex, Juncus,* moss and lichen.

Diagnostic species	Constant species	Dominant species
Salix sikkimensis 6.6, Carex orbicularis 4.6, Thalictrum sp. 3.2, Ribes sp. 3.2, Rheum sp. 3.2, Prunus cornuta 3.2, Potentilla cuneata 3.2, Pedicularis white 3.2, Fragaria daltoniana 3.2, Codonopsis sp. 3.2, Carex setosa 3.2, Anaphalis cunefolia 3.2	***Salix sikkimensis 100,*** *Epilobium wallichianum 60*	***Salix sikkimensis 40***

(m) *Myricaria rosea* riverine scrub vegetation is found in the riverbed on skeletal, sandy soils in the subalpine and alpine zone upto 4,600 meters elevation. The riverbed at Koktshurung (Prek chu), Deota ghar (Prek chu), Marco Polos camp (Zemu chu), above Tholpe shepherds hut and Churong chu bridge are some of the locations where one can spot this vegetation. The vegetation structure is mat forming prostate shrubs interspersed with herbs, grasses and sedges less than 0.3 meters in height.

Myricaria rosea is the characteristic species and the cover varies considerably (from 7% to 64%) with micro-topography and edaphic conditions. The other plants in this vegetation include *Epilobium wallichianum*, *Epilobium latifolium, Salix calyculata, Salix lindleyana, Bistorta vivipera, Geranium donianum, Oxyria digyna, Kobresia nepalensis, Festuca valesiaca, Hedysarum sikkimense* and species of *Juncus* and *Carex*.

Diagnostic species	Constant species	Dominant species
Myricaria rosea 6.0, Parrya platycarpa 4.6, Juncus sp. 3.4, Aconogonum molle 3.2	***Myricaria rosea 100,*** *Juncus sp. 80, Epilobium wallichianum 60*	***Myricaria rosea 60***

(n) Other vegetation: Aquatic submerged vegetation occurs in the shallow fringes of alpine lakes. *Najas sp.* at Sungmoteng tsho (Samiti lake) and *Hippuris vulgaris* and *Potamogeton filiformis* in the Muguthang marshes. Around cattle camps *Potentilla peduncularis* (namley jhaar), *Ranunculus hirtellus (khorsane), Primula macrophylla* (giddha pankhi), *Urtica hyperborea*, *Poa alpina* (dubo), *Rumex nepalensis* (halhale), *Ligularia mortonii* (barsey), *Senecio littus* (tori phuley) and *Berberis insignis* (chutro kanra) abound. Boktok, Cheurpangsu, Doring taar, Chonrigang (near HMI basecamp) Lamune, Chonrigang (below Lampokhri) and Lungma are some such herder camping sites. Landslides and fresh openings are colonized by *Polygonum sp.* while *Corydalis lathyroides, Impatiens sp.* and *Begonia sp.* occur on the moist rocky ledges.

4.3.2 Floristic structure, diversity and status

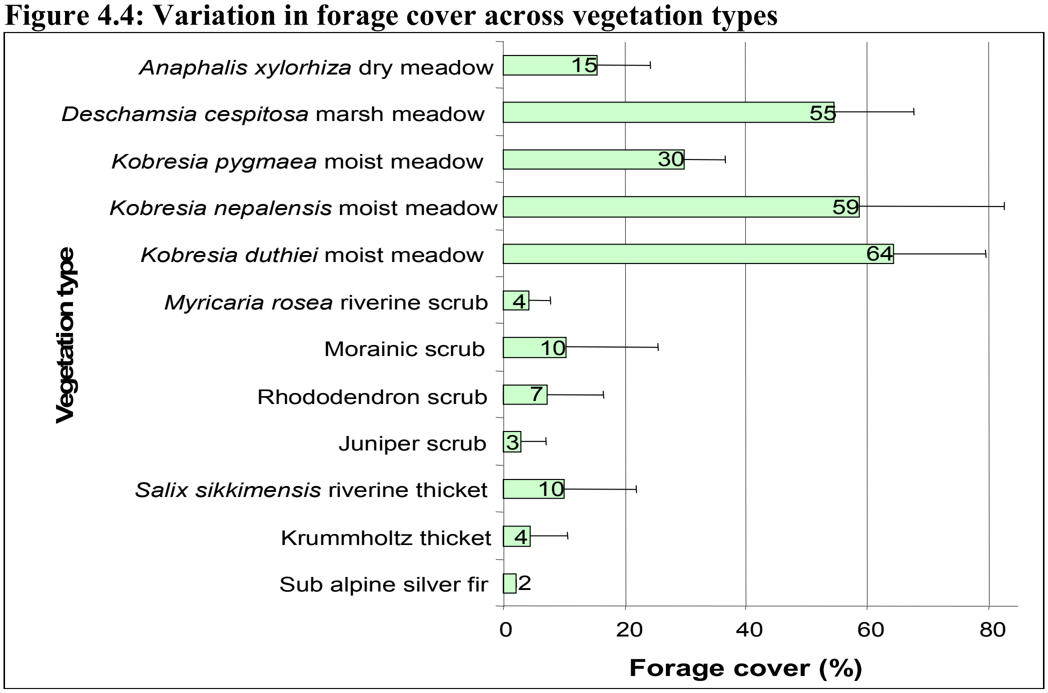
The key features of the alpine flora of KNP including structure, richness, diversity along with species of economic and conservation importance are described here.

4.3.2.1 Structure

In the alpine zone of KNP an inventory of 1106 vascular plants belonging to 310 genera and 70 families was prepared based on the Flora of Bhutan - 3 volumes which includes collections from Sikkim and other literature. Of these a total of 585 species within 243 genera and 67 families were recorded during the course of this study. The dominant families are Asteraceae (69 species), Ranunculaceae (35 species), Poaceae (32 species), Scrophulariaceae (30 species), Cyperaceae (28 species) and Rosaceae (28 species). The prominent genera are *Pedicularis* (21 species), *Carex* (18 species), *Saxifraga* (18 species) and *Rhododendron* (17 species). These species have been listed in Appendix 1. The gymnosperms in the temperate and subalpine zone include *Taxus baccata, Picea spinulosa, Larix griffithiana, Tsuga dumosa* and *Abies densa,* while *Juniperus indica, Juniperus recurva* and *Ephedra gerardiana* occur in the alpine zone. *Picea, Larix* and *Ephedra* prefer the dry inner valleys of Zemu and Lhonak while *Tsuga* favors the moist valleys. Two other conifers occur in the subtropical belt namely *Cupressus corneyana* (introduced as a sacred tree) and *Cryptomeria japonica* (cultivated).

In terms of forage cover the sedge meadow and the marsh meadow vegetation shows substantial fodder cover (greater than 30%). The herbaceous meadows and the subnival vegetation have a fair amount of forage cover (between 15% and 30%). While the subalpine and alpine scrub vegetation show only limited fodder availability (less than or equal to 10%) (Figure 4.4). To summarize all the fodder rich vegetation types are restricted to the alpine meadows, which form important summer grazing resources for the domestic livestock. However these meadows are not accessible during winter due to heavy snow-cover. While the subalpine forests and alpine scrub vegetation, which are available for a major part of winter have only limited fodder cover. This results in an acute scarcity of fodder for the livestock when they descend to the subalpine and temperate forests during winter.

Figure 4.4: Variation in forage cover across vegetation types



4.3.2.2 Richness and diversity

Table 4.7 gives the richness, evenness, α and β diversity indices for the various vegetation associations. In one meter square plots, richness (S) values varied from 4 to 13 with vegetation where succession is still active showing higher values. The richest vegetation occurs in the valleys where glaciers are still active or succession is in the seral stages. E.g. in the sedge meadows of Zemu valley (S=13), scrub vegetation in morainic environs (S=12.80) and herbaceous meadows of Lhonak valley (S=12.67). While the richness was lowest in habitats, which were unique and only specialized vegetation could survive like the subnival vegetation in the frigid zone (S=4), marsh meadows in the amphibious flats (S=5) and nutrient rich livestock camping sites (S=5).

Shanon's diversity index (H) varied from 1.44 to 2.48, it was lowest in specialized habitats, which needed advanced adaptation for survival like marsh meadows (H=1.44) and livestock camps (H=1.44). It showed higher values in glaciated habitats where succession is still active like sedge meadow in Zemu valley (H=2.48), herbaceous meadow in Lhonak valley (H=2.46) and morainic scrub (H=2.39). The trend of Shanon's diversity index (H) was similar to that shown by the Richness (R) values as it emphasizes the species richness component of diversity.

Evenness (E) varies from 0.76 to 0.97 with habitats where single species dominated showing lower values and vice versa. Alpine scrub habitats of Juniper and Rhododendron showed the lowest values due to dominance of Juniper (E=0.76) and Rhododendron (E=0.85) respectively. *Kobresia pygmaea* moist meadow in Zemu valley (E=0.97) and *Anaphalis xylorhiza* dry meadow in Lhonak valley (E=0.97) showed the highest values due to the absence of a single dominant species.
Simpson's diversity index (D`) combines both richness and evenness and it varied from 0.69 to 0.91. This index is preferred when the sample size varies. Juniper scrub (D`=0.69) and Rhododendron scrub (D`=0.71) showed the lowest values while the highest values (D`=0.91) were shown by *Kobresia pygmaea* moist meadow in Zemu valley and *Anaphalis xylorhiza* dry meadow in Lhonak valley.

Beta diversity measure of Harrison was calculated in JUICE software in five iterations and random selection method and varied from 0.21 to 0.53 (Table 4.7). The morainic scrub (β=0.45) and *Kobresia pygmaea* moist meadow (β=0.51) in Zemu valley where glaciers are still active and succession is in various seral stages showed maximum beta diversity. The lowest beta diversity was shown by Rhododendron scrub (β=0.21) and marsh meadow (β=0.22) where single species dominates.

Table 4.7: Richness, evenness, α and β indices of diversity

Vegetation Community	Richness	Evenness	Shannon`s diversity index	Simpson`s diversity index	Harrison beta diversity
	S	**E**	**H**	**D`**	**β**
Sub alpine silver fir	8.50	0.90	1.92	0.81	0.22
Krummholtz thicket	7.00	0.94	1.80	0.81	0.40
Riverine thicket	10.60	0.95	2.12	0.84	0.40
Juniper scrub	8.20	0.76	1.73	0.69	0.37
Rhododendron scrub	9.25	0.85	1.76	0.71	0.21
Morainic scrub	12.80	0.96	2.39	0.89	0.45
Riverine scrub	6.00	0.91	1.62	0.76	0.40
Kobresia duthiei moist meadow	6.80	0.91	1.74	0.78	0.42
Kobresia nepalensis moist meadow	7.60	0.88	1.70	0.73	0.36
Deschampsia caespitosa marsh meadow	5.00	0.91	1.44	0.72	0.22
Potentilla peduncularis moist meadow	5.00	0.91	1.44	0.72	0.23
Kobresia pygmaea moist meadow	13.00	0.97	2.48	0.91	0.53
Anaphalis xylorhiza dry meadow	12.67	0.97	2.46	0.91	0.26
Average	**8.71**	**0.91**	**1.89**	**0.79**	**0.34**

4.3.2.3 Economically valuable Plants

Plants that yield fodder, firewood, medicine and aroma are the main economic resources of the alpine landscape. The important fodder plants are *Kobresia nepalensis* (sun buki), *Festuca valesiaca* (rani buki), *Kobresia duthiei* (bhalu buki), *Kobresia capillifolia* (kesari buki), *Kobresia sp.* (ghode buki), *Juncus sp.* (suire buki), *Allium prattii* (dandu), *Heracleum sp.* (ganer), *Selinum tenuifolium* (cheeru), *Rheum acuminatum* (khokim), *Carex nivalis* (dharkhare), *Carex nigra* (harkat), *Phleum* *alpinum* (doodhe jhar), *Calamogrostis filiformis* (jou jhar), *Poa sp.* (dubo), *Deschampsia caespitosa* (chamrey), *Pleurospermum sp.* (shyamphul), *Kobresia schoenoides* (nana), *Kobresia pygmaea* and *Elymus nutans.* While in the sub alpine zone, *Heracleum sp.* (ganer), *Selinum tenuifolium* (cheeru), *Rubus paniculata* (kanre lahara, teen patey), *Ilex intricata* (kurkure) and *Polygonum polystachyum* (rani thotney) are the prime forage species. These plants provide the raw material to sustain a livestock biomass of 763 metric tonnes. The total annual turnover of the pastoral sector in KNP was Rs. 112 lakhs in 2004. Other than fodder, the pastoral sector also uses large quantities of firewood, which is used for heating, lighting and cooking purposes. *Rhododendron campanulatum, Rhododendron lanatum, Rhododendron hodgsonii* and *Juniperus indica* are the main plants used as firewood. About 0.36 metric tonnes of firewood is used annually by this sector with an economic value of Rs. 3.6 lakhs.

The important ethno-medicinal plants in the sub alpine and alpine zone are *Gymnadenia orchidis* (panch-amle), *Panax pseudo-ginseng* (ginseng), *Aconitum ferox* (bikh), *Aconitum spicatum* (bikhma), *Bistorta milletii* (pothi rambu), *Picrorhiza scrophulariiflora* (kurki), *Nardostachys grandiflora* (jatamanshi), wild garlic whose leaves are uses for seasoning curries - *Allium prattii* (dandu), *Lomatogonium sp.* (sharmaguru), *Lomatogonium sp.* (mahaguru), *Saussurea gossypiphora* (mykopila), *Rheum acuminatum* (khokim), *Bergenia purpurascens* (pakhanbhed), *Anemone polyanthes* (bhutkesh), *Rheum nobile* (kenjo), *Podophyllum hexandrum, Ephedra gerardiana* and *Cordyceps sinensis* (caterpillar mushroom). The distribution of these medicinal plants in the KNP is concentrated in select pockets (Table 4.8). Plate 4.2 illustrates some important medicinal plants of the alpine zone.

Table 4.8: Availability of important ethno-medicinal plants in the KNP

Ethno-medicinal plant	Available locations
Lomatogonium sp. (sharmaguru)	Lampokhri, Jemathang
Lomatogonium sp. (mahaguru)	Relli Top, Yangzee Top, Kabur Lamcho
Aconitum ferox (bikh)	Khola Jhareni, Thulo Jhareni, Dhur, Sukey Pokhri, Opposite Marco Polo's camp, Bikhma taar
Aconitum spicatum (bikhma)	Upper Chonrigang (below Lampokhri), Pairey Jhareni, Kopchey
Picrorhiza scrophulariiflora (kurki)	Laduwa khola, Khola Jhareni, Tekepla, Pairey jhareni, Between Gochela and Panchpokhri, Yungkhari
Nardostachys grandiflora (jatamanshi)	Upper Chonrigang (below Lampokhri), Surgey danra, Pairey jhareni, Ghumney, Shyarbey, Areylungchok, Marco Polos camp to Green lake, Dolmasampa
Gymnadenia orchidis (panchamle)	Pairey Jhareni, Surgey danra, Between Koktshurung and Thangsing, Talem, Jakchen
Rheum acuminatum (khokim)	Areylungchok, Pairey jhareni, Shepsu top
Bergenia purpurascens (pakhanbhed)	Upper Chonrigang (below Lampokhri), Ghumney, Shyarbey
Anemone polyanthes (bhutkesh)	Upper Chonrigang (below Lampokhri), Surgey danra
Podophyllum hexandrum	Opposite slope of Marco Polos camp
Ephedra gerardiana	Resung, Changsang, Marco Polo camp to Green lake
Panax pseudo-ginseng (ginseng)	Talem, Jakchen
Cordyceps sinensis *(*caterpillar mushroom*)*	Below Marco Polo camp

Plate 4.2: Some important medicinal plants of the alpine zone

Podophyllum hexandrum

Ephedra gerardiana

Picrorhiza scrophulariiflora **(kurki)**

Nardostachys grandiflora **(jatamanshi)**

Aconitum ferox **(bikh)**

Gymnadenia orchidis **(panch-amle)**

4.3.2.4 Species of conservation importance

The KNP along with the adjacent reserve forests is home to as many as 22 endemic and 22 rare and threatened plants. New plant taxa have also been described recently namely *Myrmechis bakhimensis* (Orchidaceae), *Craniotome furcata* var. *sikkimensis* (Lamiaceae), *Craniotome furcata* var. *ureolata* (Lamiaceae) and *Cortiella gauri* (Apiaceae) (Maity & Maiti 2007). Species of high conservation value and botanical interest in sub-alpine and alpine areas of KBR include *Schizandra grandiflora* (a primitive climber with flowers like miniature *Magnolia*), *Helwingia himalaica* (bearing flowers at the center of the leaf and endemic to the Eastern Himalaya), *Circaeaster agrestis* (*Chloranthaceae* of uncertain affinity), *Pinguicula alpina* (an insectivorous plant), *Triosteum himalayanum* (endemic to Himalaya), *Brachycaulos simplicifolius* (an unusual herb of *Rosaceae*) among others. Few more alpine plants needing special mention for their high conservation significance are the wild poppies (*Meconopsis* sp.) which bear spectacular flowers and have several medicinal properties, species of *Corydalis, Rhodiola, Pleurospermum, Saussurea, Primula, Gentiana, Swertia, Pedicularis, Polygonatum* and several ground orchids. Among the rhubarb species *Rheum nobile* is particularly vulnerable owing to its striking inflorescence which is often plucked by the herders and local communities to make pickle.

Key floral species for conservation in the alpine zone are *Rheum nobile* (Kenjo), *Gymnadenia orchidis* (panch amle), *Nardostachys grandiflora* (jatamansi), *Ephedra gerardiana*, *Picrorhiza scrophulariiflora* (kurki), wild Alliums, Giant Lily (*Cardiocrinum giganteum*), Pseudo-ginseng (*Panax pseudo-ginseng*), *Pleurospermum* sp. and Caterpillar-mushroom (*Cordyceps sinensis*).

4.3.3 Effects of anthropogenic factors

Pastoralism, collection of medicinal and aromatic plants and subsistence hunting were the main livelihoods prevalent in the KNP traditionally, while since early 1990s trekking tourism sector has been expanding rapidly. In the year 1891, the human population of Sikkim was only 36,458 and this coupled with its geographical inaccessibility resulted in limited pressure on the natural resources historically. However after merger with India in 1975 developmental activities took place rapidly and better infrastructure and communication facilities were established. By 2001 the human population had increased to 5,40,851 while the livestock population (cattle, buffalo, yak, horse, sheep and goat) stood at 2,99,020 in 2003 (Risley 1894, Anon 2001, Anon 2003). Increasing populations and better accessibility resulted in rising anthropogenic pressure on the natural environment of KNP.

4.3.3.1 Impacts of pastoral practices

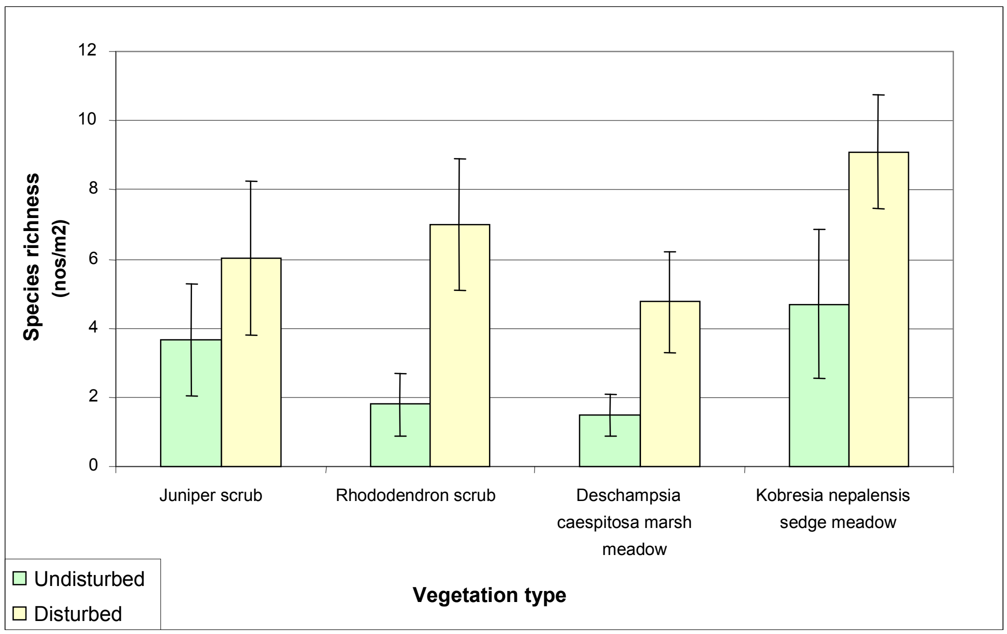
In the KNP the livestock biomass increased from 608 metric tonnes in 1950 to 763 metric tonnes in 2004 owing to a substantial rise in the populations of yak and cow-yak crossbreeds. The livestock impact units in the winter pastures increased from 2 to 17 (LUdays/ha) during this period. The main impacts of pastoralism on the natural environment are clearing and burning of forests, localized extraction of slow growing Juniper and Rhododendron firewood, spread of poisonous plants and a decline in the population of grazing sensitive plants. The herders managed over-stocking by artificially increasing the carrying capacity by cutting and burning vegetation with less fodder availability and converting it into artificial pastures or *kharkas*. Their rangeland maximizing strategy involved maximizing the growth of fodder grasses by reducing the cover of trees, woody thickets and shrubs. Also lopping of fodder trees in the temperate forests was done to meet their fodder demand during winter. The fact that these herders carried out habitat manipulation by converting vegetation types like Juniper scrub in the alpine zone and the oak, hemlock and fir forests in the temperate and sub alpine zones into man-made pastures is an indication that there was a scarcity of ground fodder.

In some parts of KNP and adjacent areas, fir forests have been cleared on stable sunny slopes for creating grazing pastures. Dungdang, Chattubari, Khola jhareni, Kalijhaar, Phalut, and Thulo dhaap are some of the locations where these pastures have been created. In 1973 a massive forest fire in West Sikkim laid waste large tracts of fir forests in KNP. In the blanks heavily used by livestock, *Arthraxon microphyllus* (bonchu) along with moss is the dominant ground cover. Openings in the lower reaches are rapidly colonized by *Thamnocalamus aristata* (raato nigalo), while the upper reaches show a dense pole sized regeneration of fir and Rhododendron. The herders also cultivated an exotic fodder grass *Pennisetum clandestinum* (ghode dubo) in the temperate openings as winter fodder. Juniper scrub grows on warmer slopes, which are also preferred by the herders for grazing. The shrub layer, which is unpalatable, provides a suboptimal habitat for grazing and is hence burnt and cleared to increase fodder cover. High resin content in Juniper makes it susceptible to fire. These forests have been burnt and cleared by the herders for grazing of livestock in pockets. Juniper scrub vegetation mostly in Prek chu watershed has been converted into grassy meadows. Neer pokhri nikash, Chonrigang, Pairey jhareni, Lampokhri, below Khola urar (opposite Surkey danra) and Dhurd are some such locations. The fodder availability increases significantly (P=0.02, CI=95%) as was observed in patches burnt 10 years back which showed an increased grassy cover of *Calamogrostis filiformis* (jau jhar), *Anaphalis royleana, Agrostis pilosula, Festuca vallesiaca, Heracleum sp.* (ganer), *Pleurospermum sp.* (cheeru), *Rheum acuminatum* and *Hemiphragma hetrophylla*.. Natural regeneration of Juniper was virtually absent in these burnt sites.

Many of the artificial meadows formed by clearing fir forests show a spread of poisonous plants like *Bupleurum sp.* (chattu), *Pieris formosa* (bolu) and *Lyonia ovalifolia* (angeri) in pockets. Plants sensitive to yak grazing found in pastures not grazed by them are *Heracleum sp.* (ganer), *Allium pratti* (dandu), *Kobresia duthiei* (bhalu buki), *Pleurospermum sp.* (seto cheeru), *Pleurospermum sp.* (shyamphul) and *Saussurea uniflora* (thulo dudhe jhaar). Most of these plants are annual or biannual, tall and nutrient rich and as informed by the herders also important food plants for the Himalayan musk deer. In places like Thangsing valley, Lampokhri area and Chamrey these plants were plentiful earlier before the advent of yaks in the 1980s. Some of the locations impacted by firewood collection by the herders and recently by trekking tourism in the Krummholtz zone are Gomathang, Boktok, Pangding, Dzongri and Thangsing.

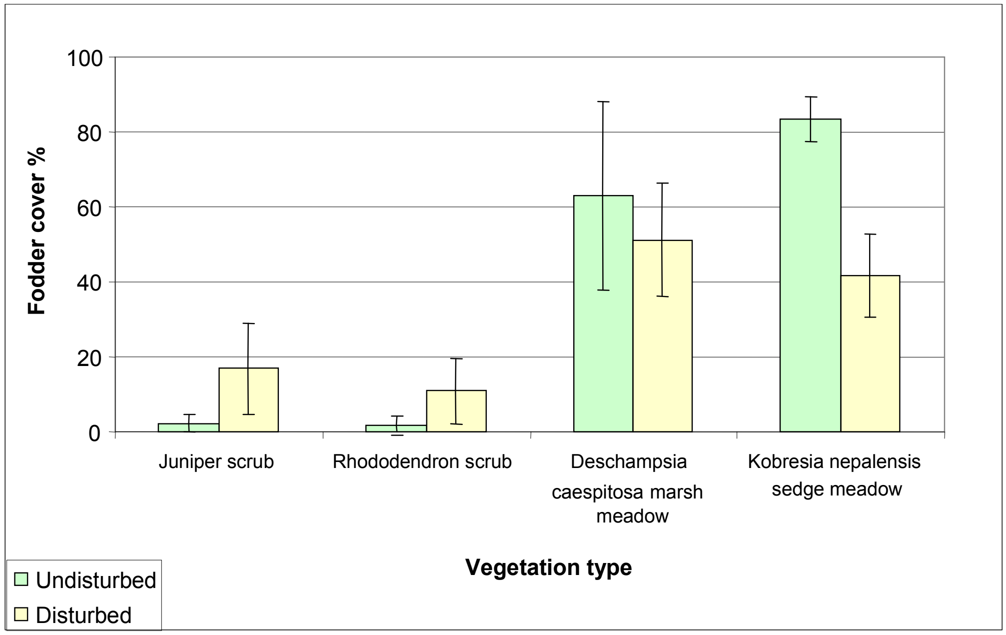
In terms of fodder availability the sedge and marsh meadows are the only habitats with adequate forage cover. However due to heavy snowfall these alpine vegetation are inaccessible for livestock during winter. In the Juniper and Rhododendron scrub habitats the species richness increases substantially with disturbance (Figure 4.7). Also this vegetation in an undisturbed state is largely unpalatable, but with disturbance mostly in the form of grazing and burning, the fodder cover increases significantly due to the presence of palatable vegetation like *Kobresia nepalensis,* *Calamogrostis filiformis, Festuca vallesiaca, Heracleum sp.* (ganer), *Pleurospermum sp.* (cheeru) and *Rheum acuminatum* (p=0.02, 95% CI). Hence the yak herders clear this shrub habitat to increase the fodder availability (Figure 4.8). In the marsh and sedge meadows also the disturbed plots show more species richness (Figure 4.7). In an undisturbed state these meadows have a very high fodder cover but with grazing due to the spread of unpalatable plants like *Potentilla peduncularis, Ranunculus hirtellus, Geranium donianum* the fodder availability reduces (Figure 4.8).

Figure 4.5: Impacts of disturbance (grazing and burning) on species richness in different vegetation types in the alpine landscape



n = 6 35 10 23 15 20 10 10

Figure 4.6: Impacts of disturbance (grazing and burning) on fodder cover (%) in different vegetation types in the alpine landscape



n = 6 35 10 23 15 20 10 10

4.3.3.2 Extraction of Medicinal and Aromatic plants

The forest department permitted commercial exploitation of medicinal plants resource (even from within the KNP) from early 1970s till late 1990s. From the alpine zone *Aconitum ferox* (bikh) and *Picrorhiza scrophulariiflora* (kurki) were in high demand while *Nardostachys grandiflora* (jatamanshi), *Rheum acuminatum* (khokim), *Lomatogonium sp.* (sharmaguru), *Lomatogonium sp.* (mahaguru) and *Rheum nobile* (kenjo) were traded in limited quantities. In the mid 1970s dried tubers of Bikh fetched Rs 600/*maund* while dried stems of Kurki used to fetch Rs 800-1000/*maund*. However Bikh trade was more lucrative since while drying its weight reduction was only 25% while Kurki reduced by nearly 75%. Winter collection was permitted for five months from October to February for two years consecutively followed by four years of rest period. Owing to the high profits the herders used to carry out even transborder collection from Lamidanra, Tawanagi, and Pemaden in Taplejung district of eastern Nepal. In terms of scale 3-4 truckloads of Bikh and 1-2 truckloads of Kurki (at the rate of 70 *maunds* per truckload) used to be harvested annually from the Churong chu watershed of KNP. In 2001 the Government viewed with concern the depletion of medicinal plants and non-timber forest produce excluding bamboos, grasses, plants used as food and cardamom from the forest areas of Sikkim. With a view to encourage regeneration of areas that were facing depletion of these resources, the Government banned the collection of all medicinal plants for commercial purposes, for a period of five years vide order No. 13/F/Env&WL, Dated the 6th September 2001. In 2006 this commercial ban was further extended by another five years.

Juniperus recurva (sikpa) and *Juniperus indica* (bhairung) whose resinous twigs yield sweet scents on burning are used as incense and also for manufacturing incense sticks. Lighting these is a customary practice in the religious ceremonies of Buddhists. With the setting up of these incense-making units in Darjeeling district in the 1970s a market was created for this aromatic forest produce. The forest department permitted the collection and transit of Juniper from forest areas (including KNP) after collecting nominal fees. Rigid controls were not applied on Juniper trade and it was permitted round the year without any rest years. The yak and *Urang* herders were the main collectors since they owned pack animals for transportation. Maximum collection took place from Boktok, Gomathang, Doring taar, Lampokhri and Thangu. The Juniper twigs were chopped into small pieces and left to dry on the forest floor. After drying the weight reduction was about 30% and this dried Juniper was packed into sacks and loaded onto *Dzos* for transportation to the local market. Gyalsing in West Sikkim and Mangan in North Sikkim were the main local markets. The local businessmen here bartered Juniper with salt and cattle feed in almost equal quantities by weight. Dried *Sikpa* used to fetch Rs 60/*maund* while dried *Bhairung* Rs 100/*maund* in the local market. On an average a herder used to sell 30 *maunds* of dried Juniper annually. To get a rough idea about the volume of this trade, from Churong chu watershed of KNP, 30 herder families used to sell 12 truckloads (900 *maunds*) of dried Juniper annually. Extensive collection took place from the alpine zone of Churong chu, Prek chu and Lachen chu watersheds within KNP and Rimbi chu watershed just adjacent to it. However owing to large-scale degradation of Juniper forests, this trade was discontinued by the forest department in the 1990s.

4.4 Conclusions

The vegetation of the subalpine and alpine zone was segregated into 12 vegetation associations namely sub-alpine silver fir forest, krummholtz thicket, Juniper scrub, *Rhododendron* scrub, Morainic scrub, *Kobresia nepalensis* moist meadow, *Kobresia duthiei* moist meadow, *Kobresia pygmaea* moist meadow, *Deschampsia caespitosa* marsh meadow, *Anaphalis xylorhiza* dry meadow, *Salix sikkimensis* riverine thicket and *Myricaria rosea* riverine scrub. In the Krummholtz the following associations were found viz., *Rhododendron campanulatum, Rhododendron lanatum, Rhododendron thomsonii* and *Rhododendron wightii – Rhododendron fulgens*.

The fodder cover was found to be high in the alpine meadows (15 - 64%) while the subalpine, krummholtz and alpine scrub vegetation showed very low fodder cover (2 - 10%). Amongst the alpine meadows, *Kobresia duthiei* moist meadow (64%), *Kobresia nepalensis* moist meadow (59%) and *Deschampsia caespitosa* marsh meadow (55%) showed high fodder cover.

In one meter square plots, Richness (S) and Shanon's diversity index (H) varied from 4 to 13 and 1.44 to 2.48 respectively. Vegetation where succession is in the seral stages like the *Kobresia pygmaea* moist meadows in Zemu valley (S=13, H=2.48) where the glacier is receding and morainic scrub (S=12.80, H=2.39) showing high richness. While in vegetation types which were specialized like the amphibious zone of marsh meadows (S=5, H=0.91) and nutrient rich livestock camping sites (S=5, H=0.91). The Evenness (E) and Simpson's diversity index (D`) varied from 0.76 to 0.97 and 0.69 to 0.91 respectively. Alpine scrub habitats showed low evenness and low values of Simpson's diversity index (D`) due to the dominance of Juniper (E=0.76, D`=0.69) and Rhododendron (E=0.85, D`=0.71). While high evenness and higher values of Simpson's diversity index (D`) was shown (E=0.97, D`=0.91) by *Kobresia pygmaea* moist meadow in Zemu valley and *Anaphalis xylorhiza* dry meadow in Lhonak valley. The beta diversity measures of Harrison showed higher values in vegetation types where succession is in various seral stages like the morainic scrub (β=0.45) and *Kobresia pygmaea* moist meadow (β=0.51) in Zemu valley. The lowest beta diversity was shown by Rhododendron scrub (β=0.21) and marsh meadow (β=0.22) where single species dominates.

Livestock production and commercial extraction of medicinal and aromatic plants are the main activities affecting the vegetation structure and composition. The alpine sedge vegetation with extensive cover of palatable species like *Kobresia nepalensis, Kobresia duthiei, Kobresia capillifolia* and *Kobresia pygmaea* supported a livestock biomass of 763 metric tonnes in 2004 during summer. The herders manipulated the structure and composition of the alpine scrub, subalpine silver fir and temperate oak forests by lopping the top canopy and removing the understorey and planted exotic grasses to increase the ground fodder biomass. *Pennisetum clandestinum*, *Arthraxon microphyllus* and lopping of fodder trees was the main source of winter fodder. This grazing and burning resulted in an increase in the species richness in the alpine vegetation while in terms of impact on fodder cover, alpine scrub showed higher fodder cover while the fodder cover in sedge and marsh meadows declined significantly. Plants sensitive to yak grazing found in pastures not grazed by them are *Heracleum sp.* (ganer)*, Allium pratti* (dandu), *Kobresia duthiei* (bhalu buki)*, Pleurospermum sp.* (seto cheeru), *Pleurospermum sp.* (shyamphul) and *Saussurea uniflora* (thulo dudhe jhaar). Most of these plants are annual or biannual, tall and nutrient rich. Many of the artificial meadows formed by clearing fir forests show a spread of poisonous plants like *Bupleurum sp.* (chattu), *Pieris formosa* (bolu) and *Lyonia ovalifolia* (angeri) in pockets.

Alpine medicinal plants mostly *Aconitum ferox* (bikh) and *Picrorhiza scrophulariiflora* (kurki) were in high demand and were collected from 1970s to 1990s in truckloads with dried tubers of *Bikh* fetching Rs 600/*maund* and dried stems of *Kurki* fetching Rs 800-1000/*maund*. The state government banned the commercial collection of medicinal plants for ten years from 2001 onwards. Aromatic plants *Juniperus recurva* (sikpa) and *Juniperus indica* (bhairung) were in high demand for incense making and large scale commercial collection was done by the yak and cow yak crossbreed herders between 1970s and 1990s. Dried *Sikpa* used to fetch Rs 60/*maund* while dried *Bhairung* Rs 100/*maund* in the local market and were collected in truck loads. This commercial collection was also banned in 1990s owing to the degradation of the Juniper forests.

There is a need to create medicinal plant conservation areas (MPCA) for *in situ* conservation of medicinal plants. The MPCA could be used as a source of planting material for *ex situ* cultivation of these valuable medicinal plants to sustain livelihoods in future. Planting material in the form of cutting and seeds may be allowed for propagation in medicinal plant development areas or nurseries (MPDAs). Grazing of livestock should not be permitted in these areas. There is a need for community endorsed MPCAs at Lampokhri, Narsing, Tekepla and Marco polo camp. Lampokhri is susceptible to winter fires and grazing by pack animals during the round trek from Yuksam to Labdang. Only one-way trek from Labdang to Yuksam should be permitted.

Species of conservation importance include 22 endemic, 22 rare and threatened plants and new tax recently described. Such botanical hotspots need to be listed and special conservation and monitoring measures need to be prescribed in the management plan that is under preparation. A detailed analysis of narrow endemics confined to alpine areas of Sikkim needs to be done. To begin with, the species named after the state (*sikkimensis* plants) need to be inventoried and documented in terms of their current status and distribution. Some of the examples are *Paraoxygraphis sikkimensis, Berberis sikkimensis, Podophyllum sikkimense, Corydalis sikkimensis, Draba sikkimensis, Astragalus sikkimensis, Hedysarum sikkimense, Sibbaldia sikkimensis* and *Saxifraga sikkimensis* to name a few.

In India while historically plant scientists focused on creating plant taxonomic inventories, over the last few decades landscape level vegetation mapping which is rapid and cost effective is gaining popularity. Between these bottom up and top down approaches, vegetation classification at the community level needs to be strengthened to bridge the knowledge gap between species and landscapes. There is a need for a national vegetation classification that will standardize the methods for vegetation sampling, analysis, nomenclature and peer review. Collaboration with the British and USA National Vegetation Classification (http://plants.usda.gov/, www.vegbank.org) will be useful in this regard. This will establish a long term monitoring protocol for vegetation in the country and facilitate mining of existing data from different sources.

5.0 PASTORAL PRACTICES: EVOLUTION AND SUSTAINABILITY

5.1 Introduction

Pastoralism in the Himalaya and its coexistence with wildlife has been a topic of intensive research, hot debate and limited "on ground" action. Several authors have studied the production potential and biomass uptake by the livestock in the alpine areas of Uttaranchal. Negi *et al*. (1993) and Sundriyal (1995) have observed that agro-pastoralists in the western and central Himalaya generally keep more number of cattle than really needed mainly because of easy access to free grazing areas and their inability to dispose or cull the population due to religious sentiments. While some authors believe that livestock grazing is essential to maintain species diversity in these areas (Naithani *et al*. 1992, Negi *et al*. 1993, Saberwal 1996), others advocate for more rational grazing practices and policies (Sundriyal & Joshi 1990, Rawat & Uniyal 1993, Mishra & Rawat 1998). Although the alpine pastures play an important role in relieving the grazing pressure on the forests and grazing lands of the lower altitudes, increased number of livestock and overuse of certain pastures can lead to degradation of high altitude grasslands including habitats of wild herbivores. Concerns have been expressed that unsustainable grazing would lead to altered plant communities, lowered range productivity, and cause soil erosion (Singh *et al*. 1999). Loss of biodiversity is an inevitable result of these changes. Detailed studies on the above parameters are limited from the Sikkim Himalaya.

Over the years different approaches have been used to evaluate the sustainability of pastoralism in the alpine rangelands. The commonly used tool is the carrying capacity study which tries to balance forage production with consumption requirement by livestock. The design of these carrying capacity studies assumes livestock production to be the main objective. This is rarely true especially in the Himalaya where the alpine landscape is a multiple use area, serving as a habitat for endangered flora and fauna, resource of valuable medicinal plants, source of major perennial rivers and also recently a destination for nature tourism (Miller, 1997). Hence inspite of a wealth of information generated from pastoral studies over the years, only some of them resulted in direct conservation action and pastoralism continues to be a topic of intense debate (Saberwal 1996, 1998, Fox 1997, Mishra & Rawat 1998).

Recent studies have used more innovative methods, which correlate the health of livestock production systems with the health of the alpine rangelands (Mishra *et al*. 2001). Competitive exclusion of the wild ungulates and conflict with carnivores has also been analyzed (Mishra 2001, Bagchi *et al*. 2004). These studies follow a livelihood-based approach wherein not only the grazing activity, but also the whole pastoral way of life is studied including direct and indirect impacts on wildlife.

The alpine areas of the Eastern Himalaya are relatively less studied compared to those of Western Himalaya. Pastoralism is less pervasive here as a way of life compared to the Western Himalaya, and alpine meadows with no significant grazing history still exist. The livestock assemblage in the Khangchendzonga National Park (KNP) includes yaks, cow-yak crossbreeds, cows, buffaloes, sheep and horses. Singh *et al*. (2002) studied the carrying capacity in one of the alpine meadows of KNP. He observed that enclosures increased the biomass by more than 50% in all the sites with the palatable species showing an improved recovery and while a few areas were overgrazed, the present grazing pressures were nearly within the carrying capacity limit of the alpine pastures.

The objective was to study the past and present livestock management practices and their impacts on the alpine landscape. Research questions relate to the temporal trend of livestock composition and population, ecological impacts and incomes and benefit sharing from this enterprise. The present study follows a livelihood-based approach and covers the spatial spread of the pastoral systems during all seasons. In this chapter an attempt has been made to provide answers to the sustainability of these pastoral systems by integrating the social, cultural, economic, ecological, political and legal dimensions. The social dimension of pastoralism covers the aspects of access, ownership pattern and equity in benefit sharing. In a democratic framework of governance this facet plays a critical role in shaping political will, which is vital for bringing about change.

5.2 Material and methods

An integrated approach using a combination of techniques like consultations with traditional resource users, field surveys and remote sensing and GIS was undertaken. Available records and archives were also consulted to understand historical pastoralism practices.

5.2.1 Village meetings

Information from herders, ex-herders and other traditional resource users was collected using appreciative participatory enquiry tools like historical time-line, participatory mapping and pair-wise ranking. Information on historical and current population trends, ownership pattern, migration routes, preferred fodder plants, impacts and incomes of pastoralism was recorded using these tools. The census of the sheep, yak, milch cow-yak crossbreed and pack animals owning families was carried out in the field as well as crosschecked in village meetings and with ex-herders. Consultations were conducted in 17 villages over 49 days and one focal group herder interaction workshop was also organized.

5.2.2 Field surveys

Ex-herders were used as field guides and assistants during the course of this study. Informal interviews of the herders were conducted in the field and information related to livestock holding, ownership pattern, migration and fodder preference was recorded. Crosschecking of this information with the ex-herders was very useful. Pastures with a significant grazing history and those relatively pristine were identified with the help of local resource persons. The study area was surveyed in summer and winter seasons in 14 field visits spanning 125 days over a 3-year period from 2004 to 2006. In the alpine meadows a total 129 square quadrats of $1m^2$ area each, 88 in disturbed and 41 in undisturbed in 21 sampling sites were laid in which the species, cover, biotic use and use by wildlife was recorded. Field verification of the changes in the temperate and subalpine reserve forests adjacent to KNP resulting from use by yak and cattle yak crossbreeds during winter were ascertained by ground truthing. Winter pastures in the reserve forests in Yambong valley and Barsey sanctuary in West Sikkim were covered. A total of 60 (10m x 10m) quadrates, 39 in disturbed and 21 in undisturbed in 16 sampling sites in the temperate and subalpine zone were collected. Vegetation data including species composition, density and girth at breast height (GBH) of the top and middle layers and species composition, cover and fodder availability in the ground cover was recorded.

5.2.3 Temporal change detection

Temporal change detection between the years 1977 and 2000 for the summer and winter pastures within and adjacent to KNP using LANDSAT satellite images was carried out following the procedure as detailed in section 3.2.4. The change detection threshold was set at greater than 15% and the NDVI changes due to the variation in area and freezing level of the alpine lakes were recoded as no change.

5.2.4 Data analysis

Herd owners when interviewed were inclined towards under reporting their livestock holding and under estimating their incomes. Comparatively the herd caretakers who were employed by the herd owners on wages were more forthcoming and reliable. The most reliable information on livestock was collected from them and from the ex-herders who had sold of their livestock recently since they did not have any direct stake in this enterprise. Deductive approaches were used to evaluate the economic traits of the pastoralism enterprise based on total livestock products sold and costs incurred. The stocking levels of different types of livestock was combined into a common measure of livestock unit (LU) based on the grazing study of Singh (1999). Accordingly 0.92 yak, 1.2 milch cow yak crossbreed, 1.2 horse, 1.2 *dzo* and 0.33 sheep were equated to 1 livestock unit (LU).

Forage analysis was carried out in the laboratory at Wildlife Institute of India. Key fodder plants of the summer and winter pastures were short listed for forage analysis based on field vegetation surveys, herder interviews and village meetings. Forage analysis including fiber and protein was carried out following standard procedures (Van Soest *et al.* 1991). The amount of Neutral Detergent Fiber (NDF), which is a measure of all the fiber in the forage, was measured using detergent and heat. The amount of Acid Detergent Fiber (ADF), which is the poorly digested and indigestible parts of the fodder (i.e. cellulose and lignin) and Acid Detergent Ash (ADA) was quantified using sulfuric acid and heat. Nutrient analysis was done using the standard modified Kjeldahl (AOAC 1990) method. The crude protein was calculated by multiplying the nitrogen (N%) in the diet with 6.25.

Relative Feed Value (RFV) was calculated from the estimates of Dry Matter Digestibility (DMD) and Dry Matter Intake (DMI) (% of BW) (Rohweder *et al.* 1978, Canbolat *et al.* 2006). % DMD = 88.9 - (0.779 x %ADF), DMI % of BW = 120 / %NDF, Relative Feed Value (RFV) = (%DMD x %DMI) /1.29, Quality Standard of the forage is determined by comparing with the range of RFV is Table 5.1.

Table 5.1: Legume, grass and legume-grass mixture quality standards

Quality standard [a]	CP, % of DM	ADF, % of DM	NDF, % of DM	RFV [b]
Prime	>19	<31	<40	>151
1	17-19	31-40	40-46	151-125
2	14-16	36-40	47-53	124-103
3	13-Nov	41-42	54-60	102-87
4	10-Aug	43-45	61-65	86-75
5	<8	>45	>65	<75

[a] *standard assigned by Hay Market Task Force of American Forage and Grassland Council*

[b] *Relative Feed Value(RFV)- Reference hay of 100 RFV contains 41 % ADF and 53 % NDF*

In the end the findings of the study were discussed thread bare with the ex-herders and their comments incorporated.

5.3 Results and discussion

5.3.1 Analysis of past and present pastoral practices

The cultural diversity of the local communities living adjacent to the KNP resulted in a variety of lifestyles. The *Gurungs* and *Mangers* were the shepherds, the *Bhutias* were the traders and yak herders, the *Lepchas* and the *Limbus* were the hunter-gatherers and shifting cultivators, the *Chettri* and *Bahuns* were the agro-pastoralists rearing cattle and the *Tibetan Dokpas* were the nomadic yak herders in the trans-Himalaya. The livestock includes sheep, cows, buffaloes, yak, cow-yak crossbreeds and horses. Historical records (Hooker 1855, Risley 1894, Smith & Cave 1911, Anon 1997) indicate that while sheep and trans-Himalayan yaks (Tibetan breed) were traditionally grazed, cows, buffaloes, yaks (Nepalese breed), milch cow-yak crossbreeds (*Urang*) and horses in the Greater Himalaya are relative newcomers to the alpine landscape of KNP.

The livestock composition within the Greater Himalayan habitats of the KNP has been changing rapidly over the last six decades (Table 5.2). Traditionally in the Greater Himalaya of the KNP, sheep were the dominant livestock that used to graze in the alpine meadows during summer and then descend down to the fallow farmer's fields during winter. From 1950 onwards this pattern changed and the Nepalese yaks too came into the picture in a big way and accessed the alpine meadows during summer and the sub-alpine silver fir and temperate oak forests during winter. Cattle too started using the sub-alpine fir and temperate oak forests during summer and used to descend down to the fallow agricultural fields during winter. The milch cow-yak crossbreeds started increasing from 1975 onwards and grazed in the sub-alpine silver fir forests during summer and temperate oak forests during winter. The sub-alpine silver fir and temperate oak forests between 2500 -3500 meters came under increasing pressure mostly after 1950 with the advent of these livestock. The expanding trekking tourism sector with its demand for pack animals encouraged *dzos* and horses from 1990 onwards.

While in the trans-Himalayan habitats of the KNP, Tibetan yak and sheep used to traditionally graze in the alpine meadows during summer. In winter they used to migrate to the wind-blown, snow-free Tibetan plateau north of the international border. Presently only the yaks remain which are confined within the national borders throughout the year.

The total livestock population in KNP reduced significantly from ca. 11,010 in 1950 to 3,710 in 2004, while the total livestock biomass increased from 608 to 763 metric tonnes during this period. Table 5.3 and 5.4 indicate the dynamics of livestock population and biomass in KNP over the last 54 years. The overall trend is of smaller sized livestock (e.g. sheep) giving way to larger sized livestock (yak and their crossbreeds). Buffalo in the Greater Himalaya and the Tibetan sheep or *Bherlung* in the trans-Himalaya have got extinct from within the KNP during this period. Plate 5.1 depicts these pastoral systems.

Table 5.2: Evolving pattern of livestock composition within Greater Himalaya of the KNP

Year	Season	Habitats			
		Alpine meadows (4000 – 5000 meters)	**Sub-alpine silver fir forests (3000 – 3500 meters)**	**Temperate oak forests (2500 – 3000 meters)**	**Agricultural fields**
Prior to 1950	Summer	sheep	no livestock	no livestock	no livestock
	Winter	heavy snow cover	no livestock	no livestock	sheep
1950 -1975	Summer	sheep, yak	cow and buffalo	cow and buffalo	no livestock
	Winter	heavy snow cover	yak	yak	cow, buffalo, sheep
1975 -2000	Summer	yak, male cow-yak crossbreed, sheep	cow and buffalo milch cow-yak crossbreed	cow and buffalo milch cow-yak crossbreed	no livestock
	Winter	heavy snow cover	yak	milch cow-yak crossbreed, yak	cow, buffalo, sheep, male cow-yak crossbreed
2000-2004	Summer	yak, male cow-yak crossbreed, horse, sheep	milch cow-yak crossbreed	no livestock	no livestock
	Winter	heavy snow cover	yak	milch cow-yak crossbreed, yak	sheep, horse, male cow-yak crossbreed

Table 5.3: Trend of livestock population in KNP from 1950 to 2004

Livestock Type	Population			
	1950	1975	2000	2004
Banpaala sheep (GH)	8800	5200	1500	1141
Tibetan sheep (TH)	1000	1000	0	0
Cow (GH)	100	600	200	150
Buffalo (GH)	0	200	50	5
Nepalese yak (GH)	50	200	800	779
Tibetan yak (TH)	1000	630[e]	750[e]	850
Milch cow-yak crossbreed (GH)	0	0	600	469
Pack animal (horses and *dzos*) (GH)	60	60	175	316
Total livestock population	**11010**	**7890**	**4075**	**3710**

GH = Greater Himalaya, TH = Trans-Himalaya, e = estimated

Table 5.4: Trend of livestock biomass in KNP (metric tonnes) from 1950 to 2004

Livestock Type	Biomass (metric tonnes)			
	1950	1975	2000	2004
Banpaala sheep (GH)	264	156	45	34
Tibetan sheep (TH)	30	30	0	0
Cow (GH)	30	180	60	45
Buffalo (GH)	0	60	15	2
Nepalese yak (GH)	13	50	200	195
Tibetan yak (TH)	250	158[e]	188[e]	213
Milch cow-yak crossbreed (GH)	0	0	210	164
Pack animal (horses and *dzos*) (GH)	21	21	61	111
Total livestock biomass	**608**	**655**	**779**	**763**

GH = Greater Himalaya, TH = Trans-Himalaya, e = estimated

Plate 5.1: Pastoral systems in KNP

Yak (Tibetan) herding in Lhonak TH

Yak (Nepalese) herding in GH

Sheep (*banpaala*) herding in GH

Sheep (Tibetan) herding in Lhonak

Cattle yak crossbreed (*urang*) herding in GH

Pack animal (*dzo*) herding in GH

Cow herding in GH

GH = Greater Himalaya, TH = Trans Himalaya

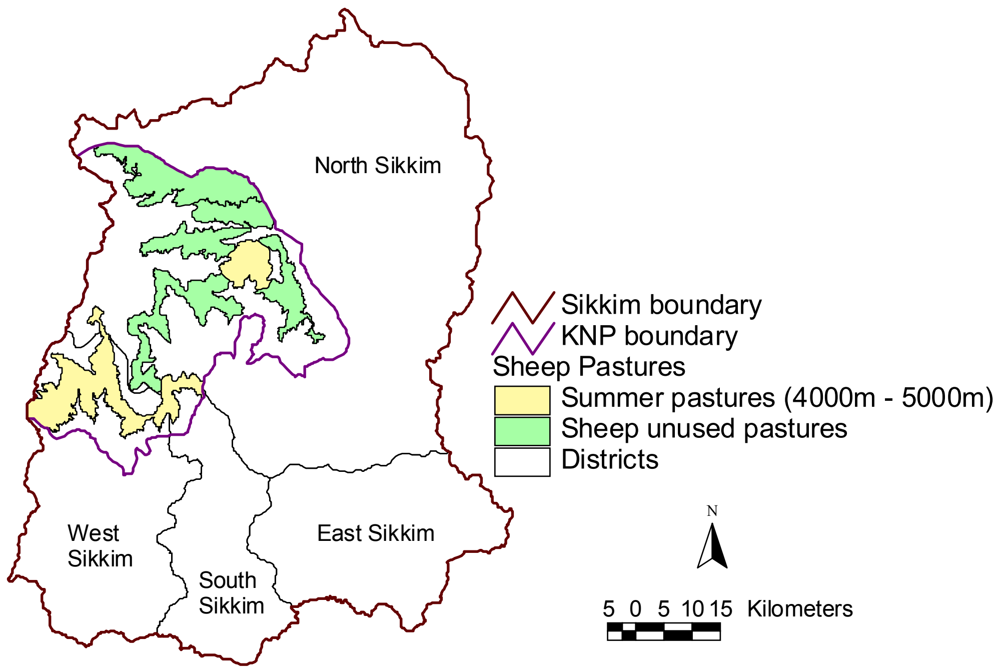
5.3.1.1 Sheep rearing in the Greater Himalaya

The earliest written records of sheep herding in the Greater Himalaya of KNP are found in the travelogue of Sir J.D. Hooker who writes about nomadic *Gurung* shepherds in the alpine meadows of West Sikkim (Hooker 1853). Sheep herding has been a traditional livelihood of the *Gurung* and *Manger* community. They are semi-nomadic, agro-pastoralists and their indigenous breed of sheep is known as b*anpaala.* These are reared mainly for sale of lambs and wool. In the KNP presently they access the Churong, Prek, Rangit and Rimpi (Rangyong) watersheds during summer while in winter they descend down to the fallow farmer's fields (Figure 5.1, Table 5.4).

In late spring the sheep herders migrate up (*umbole*) to the high altitude pastures and return (*undole*) down to their villages by late autumn. During summer these herds reach the alpine pastures and the caretaker stays in makeshift sheds covered with plastic sheets to keep out the incessant rain. The herd composition is 95% female and is grazed in the adjoining meadows every morning and return to the caretakers shed before sunset. *Heracleum* (ganer), *Allium prattii* (dandu), *Selinum tenuifolium* (cheeru), *Kobresia nepalensis* (sun buki), *Deschampsia caespitosa* (chamrey), *Kobresia duthiei* (bhalu buki) and *Juncus sp.* (suire buki) is the prioritized ranking of preferred fodder plants by the shepherds. Mid June to mid September are the three summer months available for milk production, but the production is meager. The milk is processed into butter, which has a high demand owing to its soothing and cleansing properties.

Autumn (*undole*) is the lambing season for sheep and in spring (before *umbole*) the male lambs and the unproductive females are sold off in the village and fetch about Rs 2,000 each which is used to purchase rations for the summer months. As per the *Gurung* and *Manger* traditions male sheep are slaughtered in religious ceremonies like *Kul pooja*, *Naya deota puja* etc and social functions like marriages. The sheep are sheared twice, once in spring before *umbole* and then in autumn after *undole,* yielding totally about one kilogram of wool, which fetches Rs 50 in the local market. This wool is packed into bales of 2.5 kg each called *dharnis*. It is used to make mattresses (*bhurkhasan*), blankets (*raadi*) and jackets (*lukuni*) using the traditional handloom and natural red dye of the *Rubia cordifolia* (majito) plant.

Figure 5.1: Location of sheep pastures in KNP in 2004



In olden days occasionally wild dogs and rarely snow leopard used to depredate on the sheep in the alpine pastures. Guard dogs, fire and lanterns were used to keep the carnivores at bay. However over the last 30 years no such instance has come to light. There have been instances of sheep getting poisoned after feeding on the tender shoots of plants like *Aconitum ferox* (Bikh) and *Pieris formosa* (Bolu) during *umbole,* when other forage is in short supply. The shepherds have tremendous traditional knowledge of the alpine flora and fauna. They are adept at trapping alpine birds like Himalayan monal and snow partridge and hunting ungulates mostly musk deer and Himalayan tahr using traps and hunting dogs. During summer with no fodder collection duty the sheep herder indulges in hunting actively with his dogs. 20 kgs of *Rhododendron campanulatum* and *Juniperus indica* firewood is used daily for cooking and heating purposes.

The farmers of the temperate and sub-tropical belt who cultivated maize and paddy during the monsoons, used to invite these shepherds in winter, as the sheep herds penned on their fallow fields during night provided manure. Rations were provided by the farmer and the shepherds also got access to the village commons - thus a unique symbiosis existed between the semi-nomadic sheep herders and the sedentary farmers. Shepherds receiving shelter and rations and the farmer manure for his fields. This coexistence flourished till the advent of large cardamom and intensive farming systems. The maize fields were soon converted into large cardamom agro-forestry plantations and paddy fields brought under multi-cropping of pulses during winter. With this reduced access to winter pastures, the sheep herder was forced to reduce his herd size. Now large cardamom farming serves as an alternate source of income for the ex-sheep herders.

Prior to 1975 the owners used to herd their own flocks some of which had as many as 500 sheep. However, nowadays it is a common practice for households to pool their sheep together in a flock under a common caretaker. The caretaker is provided with rations, clothes, footwear, salt for the sheep and a nominal salary by the sheep owners. The sheep population declined rapidly from about 8,800 in 1950, and in 2004 there were a total of 1,141 *Banpaala* sheep in 10 flocks owned by 33 families accessing the KNP. The flock size varied from 60 to 150 with the mean being 114.10 (SD = 28.75), while the mean ownership was 34.58 sheep (SD = 25.48). These families belong to the villages of Dhoopi, Narkhola, Pokhri, Karjee, Rungdung, chung, Melli, Dechenthang and Sardung in West Sikkim and one household each from Sada-Phamtam in South Sikkim and Mangan in North Sikkim.

5.3.1.2 Yak rearing in the Greater Himalaya

The earliest written records of yaks in the Greater Himalaya of the KNP are found in the travelogue of Sir J.D. Hooker, who writes of yaks being used as pack animals by the Tibetans to smuggle salt from Tibet via the Khangla pass to the villages in West Sikkim (Hooker 1855). This breed of yak in West Sikkim is the Nepalese Yak (Anon 1997), which is smaller in size and has adapted to survive in the sub-alpine and temperate forests during winter. In the beginning of the 20th century there was only one royal herd of about 50 yaks of the king (*chogyal)* of Sikkim. Gradually with increased opportunities in the state of Sikkim, trans-border yak herders from eastern Nepal, started migrating here with their herds. They paid grazing fees to the forest department and lead a nomadic life of transhumance. It was only in the later half of the 20th century that they purchased land in the border villages of West Sikkim and shifted from pastoral nomadism to high altitude agro-pastoralism.

Yaks are reared mainly for sale of calves and dairy products. The female yak is crossed with the Tibetan stud bull (*fulang goru*) and the one-year-old calf called *Dimzo* is sold for Rs 5,000 to businessmen from Tibet. The yaks are milked only once, and a better part of the day is spent in churning the milk for butter and curdling it for cheese (*churpi*). The fresh cheese is pressed between stones and then hung above the fireplace to dry. After dehydration for a couple of months it becomes stone hard, and is then sold as hard cheese (*Supari)*. Butter and hard cheese are the two main dairy products.

With the onset of spring the midges (*bhusna)* and leeches make life miserable for the yaks in the sub-alpine forests. With snowmelt in April, the yaks start migrating to the summer pastures. The older yaks have a homing tendency and automatically reach the alpine meadows where they were born and reared. They access the Churong chu and Prek chu watersheds in the southern part of KNP during summer (Figure 5.2). In the alpine meadows the yak herders stay in permanent camps, which have stonewalls and roofing of silver fir planks. After spending four months in the high altitude pastures the yak herds start migrating down and cross the high altitude passes to reach the safety of the sub-alpine fir forests. Once these high passes get snowed, it is difficult for the herder to cross over and ascertain their well-being. The yak herds take over the sub-alpine pastures which were earlier vacated by the milch cow-yak crossbreeds during their down migration to the temperate forests. The winter pastures for the yaks exist outside the KNP at Kalijhaar, Gosha, Chewabhanjyang, Phalut, Singalila and Yambong in West Sikkim and Tholung in North Sikkim (Figure 5.2). The herder visits his animals once or twice a month to give them salt and to oversee their well-being. Depredation of yaks by wild dogs is frequently reported during winter in the absence of caretaker. Retaliatory killings by way of poisoning of livestock carcass take place during winters. During February 2006, 37 Himalayan griffon vultures were found dead in Yambong valley after feeding on three dead domestic dogs, which had consumed poisoned carcass.

Some of these yak herders also carried out lucrative trans-border trade with the herder families of Taplejung district in Eastern Nepal. Bartering rice, salt, liquor and gumboots in exchange for dairy products and making profits both ways. With the merger of Sikkim into India in 1975, developmental activities accelerated and opened new opportunities for contractors and builders in infrastructure development projects. The yak herders hired caretakers to tend to their livestock in the tough alpine terrain while they took advantage of this new opportunity being the only creditors in these remote border villages. With globalizations and better communication in the 1980s, there was a bigger market for dairy products extending beyond the borders of Sikkim into mainland India. Other than butter even "hard cheese" found a ready market now, making the dairy business very profitable. With increasing incomes some of the yak herders started playing an active role in village and state level politics and became quite influential. Soon some of them purchased land in the adjoining towns to gain access to better education, health and communication facilities, joining the mainstream and leaving the traditional farmers and sheep herders with their subsistence livelihoods far behind.

Impacts in the alpine meadows include daily use of 30 kgs of *Rhododendron campanulatum* and *Juniperus indica* firewood, burning Juniper scrub forests to increase fodder availability, laying traps for wildlife, trade in wildlife parts, extraction of medicinal and aromatic plants, retaliatory persecution of carnivores, trampling and wallowing by yaks causing soil erosion and presence of guard dog disturbing ground nesting birds and smaller mammals.

In 2004 the yak population in the Greater Himalaya of KNP was 779 in 11 herds. The herd size varied from 12 to 142 with the mean being 70.82 (SD = 34.63). These yaks were owned by 10 families with the mean ownership being 77.90 (SD = 50.56). The owners belong to the villages of Chongri, Uttarey, Darap, Begha, Tshoka, Melli and Pelling in West Sikkim and Mangan in North Sikkim.

5.3.1.3 Yak rearing in the trans-Himalaya

To the extreme north-west the trans-Himalayan Lhonak valley separates Sikkim from the Tibet Autonomous Region of China. The true right bank of this valley falls within the KNP. The accounts of White (1909) and Smith and Cave (1911) reveal that the Lhonak valley served as the summer pastures for the sheep and yaks of the herders from Khamba-jong province in Tibet and Sikkim. Traditionally the pastures of Thompyak chu valley due south of Lhonak, between Theu la and Thangchung la passes in Zemu watershed were not grazed due to its inaccessibility from the south and unsuitability of its wet climate to the livestock accustomed to the dryness of Tibet. After the Sino-Indian war in 1962, security forces of both sides manned this border restricting the traditional trans-border lifestyles. During the survey in Lhonak and Thomphyak chu in the summer of 2006 we came across ten *Dokpa* families of Muguthang hamlet who lead a semi-nomadic life of herding ca. 1000 yaks whose breed is known as the Tibetan yak. These yaks spend the summers at Dolmasampa, Lungma, Rasum and Thomphyak chu inside KNP while in winter they migrate to the ridges at Naku la, Kora la and Chorten Nyimala which are relatively snow free (Figure 5.2). Unlike yak management in the Greater Himalaya of KNP, which is individualistic, here it is collective under the overall supervision of the Lhonak headman (*pipon*).

5.3.1.4 Milch cow-yak crossbreed (*Urang*) rearing in the Greater Himalaya

The milch cow-yak crossbreeds locally known as *Urang* are a cross between a stud yak and a female cow. They can withstand alpine conditions better than the ordinary cow and produce more milk than the yak. They became financially lucrative when the market for hard cheese began to grow in the 1980's. These crossbreeds on mating with male yaks produce calves called *tole,* which lack the crossbreed vigour of their parents and are slaughtered for meat once they are one month old.

Figure 5.2: Location of yak pastures in KNP and adjacent forests in 2004

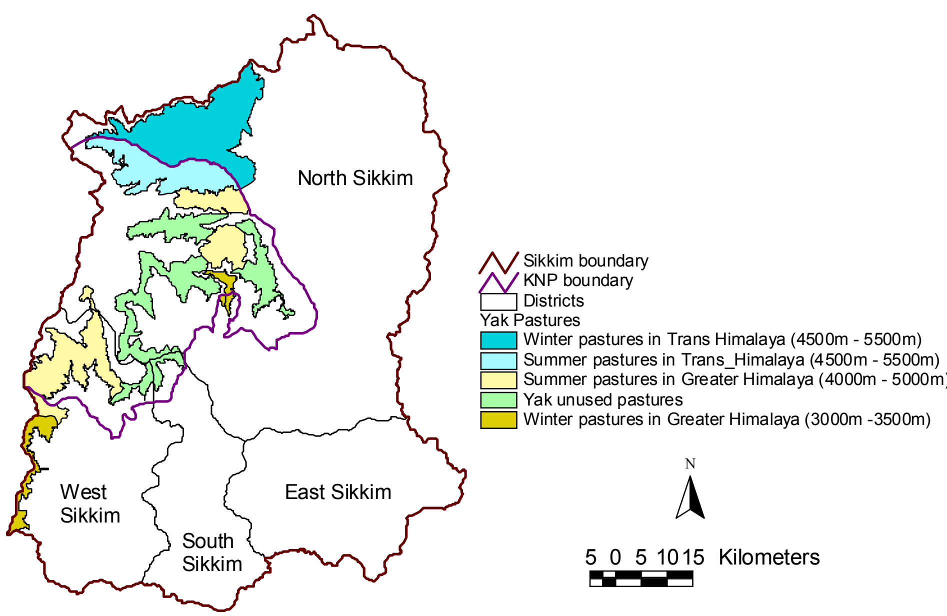
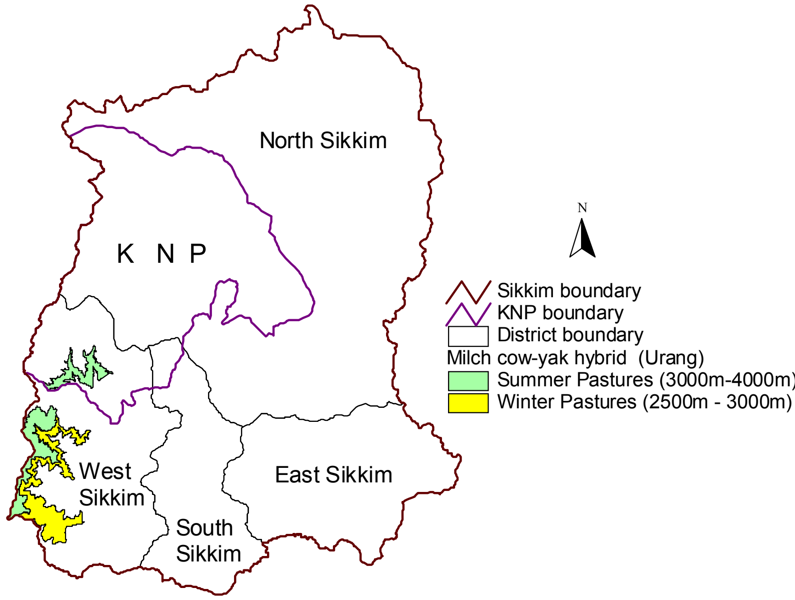


Figure 5.3: Location of milch cow-yak crossbreed pastures in KNP and adjacent forests



The *Urangs* are grazed in the sub-alpine fir and alpine scrub forests between 3,000 to 4,000 meters elevation during summer. In 2004 these crossbreeds accessed the alpine pastures of Boktok, Thangsing and Chonrigang within the KNP and Kalijhaar, Chewa-bhanjyang and Yambong adjacent to the KNP during summer. In winter they descend to the temperate pastures of Nayapatal, Thulo Dhaap, Deoningaley Dhaap, Barsey and Melli between 2500 - 3000 meters elevation adjacent to KNP (Figure 5.3). The cattle had recently vacated these pastures. Due to scarcity of ground forage during this time, lopping of fodder trees and feed supplementation with concentrates is done selectively for the milking animals.

In 2004 there were 19 herds with 469 milch cow yak crossbreeds and the herd size varied from 15 to 45 with the mean being 24.68 (SD = 9.01). 18 families owned these livestock with the mean ownership being 26.06 (SD = 14.14).

5.3.1.5 Pack animals (dzo and horse)

The sterile male from a stud yak and a female cow is called the *Dzo*. *Dzos* and horses are used as pack animals to carry the camping gear and rations of the trekking groups. The pack animals are free ranging without a caretaker and graze in the alpine pastures of Prek chu and Churong chu during summer and the sub-tropical and temperate forests adjacent to the villages during winter. They carry upto 60 kgs load during the trekking tourism season in spring and autumn. Owing to their high utility in this terrain, they are highly prized and valued by their owners. Horses are being recently used as pack animals and with growing tourism their numbers are also increasing. Villagers purchase the horses from Lachung and Lachen villages in North Sikkim at Rs 10,000 each. In 2004 there were 316 pack animals (228 *dzos,* 88 horses) from the villages of Yuksam, Chung, Tshoka, Chongri, Sindrabung and Uttarey in West Sikkim. These belonged to 63 families and the mean ownership was 5.02 (SD = 2.68).

5.3.1.6 Livestock management systems

While the livestock, cattle-shed (*goth*) and adjacent pastures (*kharka*) are individually owned the pastures are a common property resource. While selling the herd, the cattle shed as well as rights for the *kharka* are sold along with it. The management system is three fold namely self, caretaker and lease depending on the economic status of the livestock owner. In the self-managed the owner tends to the livestock himself and the incomes are at subsistence level. This is the most common system adopted specially by the sheep and *urang* herders. In the caretaker managed, the owner hires a caretaker who looks after the herd. The owner has to arrange for his rations, feed and salt for the livestock, monitor the dairy production in summer and markets the dairy products. The caretaker (*gothala*) is paid a nominal salary and his living expenses are paid for. The livestock owners who are economically well off adopts this management system. Most of the yak owners have caretakers managing their herds. When the owner is unable to get reliable *gothalas* he leases out his herd. The leaseholder has to deposit a fixed amount of dairy products per lactating livestock to the owner annually. The calves are shared equally amongst them. However the lessee has to arrange for his own living expenses as well as feed and salt for the livestock. However the lessee has to compensate the owner for any unnatural livestock mortality. Many caretakers, especially after they get married prefer to work under this system, since more hands are required. Also they need to have an above average economic status since the owner does not provide for living expenses, credit or salary. These caretakers, whose agility and speed over this rugged terrain is unmatched, possess tremendous traditional knowledge about this land and its biological resources.

5.3.1.7 Economics of pastoral enterprises

The incomes from these pastoral systems depend on the herd size, livestock management system and the breeding strategy. The fixed costs contain the expenses of hiring a caretaker, his living expenses, maintaining a cattle-shed and a stud bull, while the running costs (which vary with herd size) include the feed and salt requirements of the livestock. While sheep and yak give incomes from sale of calves, wool and milk products, the incomes from *urang* are only from the latter (Table 5.5). Pack animals (*dzos* and horses) are hired in the tourism sector. The total economic turnover of the 3,710 livestock accessing the national park was Rs 112 lakhs in 2004 with a bulk of the incomes going to yak and *urang* herders (Figure 5.4). The incomes from the animal husbandry of yaks, *urang*, sheep and pack animals with mean herd size and prices based on 2004 figures is shown in Tables 5.6 to 5.12. While the profits are the highest for the yak herder, the pack animals gives highest returns on investment, while sheep tops in terms of profits per unit livestock biomass. The major risks involved are early snowfall, falling off cliffs, feeding on poisonous plants, depredation by carnivores and diseases.

Table 5.5: Key economic traits of milch livestock

Economic Traits	Units	Yak	Urang	Sheep
Age of first calving	years	3 – 4	3 – 4	2 - 3
Gestation period*	months	9^{N} – 10^{C}	9^{N} – 10^{C}	6
Lactation length	months	8 – 10	6 – 8	6
Milking period	months	3 - 4	6	3
Daily milking yield	liters / day	1	2.5	0.35
Calving interval	months	17 – 18	15 – 16	1
Hair / Wool yield	kgs / year	0.5	0	1
Life span	years	18 – 22	18 – 20	10 -12
Total calving	no of calves	8 – 10	14 – 16	7 - 8
Adult weight	kg / livestock	250	350	30
Sale value of calf*	Rs / calf	5000^{C} / 1500^{N}	0	2000
Sale value when adult	Rs / livestock	6500	7500	2000
Sale value when old	Rs / livestock	4000 – 4500	2500 – 3500	2000

** C = Crossbreed calf, N = Normal calf*

5.3.2 Trans-boundary Issues

In Nepal livestock rearing is an important livelihood option and grazing permits are issued from the forest department after realizing nominal grazing fees. The incomes from pastoralism and herd size are at subsistence levels and the dairy products are bartered for household provisions from India. There are a large number of herders having an average herd size of about 20 livestock. However now with the initiation of the trans-boundary conservation project of The Mountain Institute (TMI) an NGO the following community based regulations are in force by the local community:

- Banning import of yak and yak crossbreeds from Sikkim into Ilam and Panchthar border districts of Nepal
- Opening up of new cattle shed (*goth*) and pastures (*kharka*) in the forests is not permitted now
- Ban on the collection of medicinal plants from the wild
- Cultivation of medicinal and aromatic plants in degraded forests as a livelihood option
- Carrying out large scale plantations in degraded sub alpine areas

Unlike in Nepal the Indian side of the Singalila range is under the protected area network, which includes Singalila National Park, Barsey Rhododendron Sanctuary and the KNP. As per the Indian wildlife laws, grazing is banned and strict enforcement of this ban is currently ongoing. Due to this law enforcement and availability of other livelihoods options most of the small herders have sold off their livestock. The number of livestock has reduced by more than 75% over the last 5 years and only a few influential herders owning about 520 yaks remain.

Though instances of trans-border grazing are less, however the migration route between the summer and winter pastures of the Indian herders lie through Nepal. The Sikkim herders spend a few days in the Nepal side while migrating from their winter pastures to the summer pastures during spring and also while returning during autumn. There is a big demand for dairy products mostly butter and hard cheese in Darjeeling. Also oxen from Nepal are herded on foot to Darjeeling and Sikkim where they are slaughtered for beef. Wild dogs are reported to be the biggest threat to the yaks especially in winter when the caretaker is usually not around to look after them. Retaliatory carcass poisoning is prevalent which has effects across the border. During the winter of 2005, domestic dogs got accidentally poisoned on the border and died in the Yambong valley of Sikkim. This started a chain of poisoning deaths claiming 37 Himalayan griffon vultures.

Figure 5.4: Distribution of Rs 112 lakhs annual pastoral turnover amongst the various pastoral enterprises in KNP in the year 2004

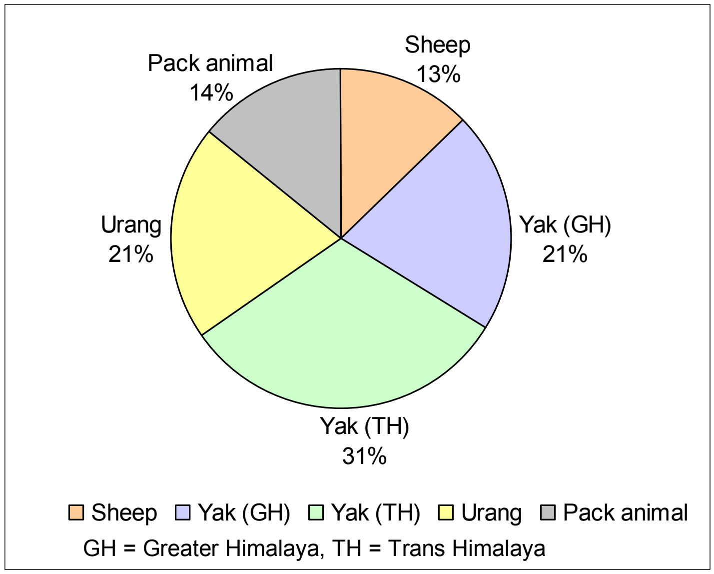


Table 5.6: Annual dairy incomes from the herd

Livestock type	Daily milk production	Monthly milk production	Monthly dairy products production				Production months	Annual dairy income
	liters / livestock	liters / livestock	Butter (kg)	Market price (Rs / kg)	Hard cheese (kg)	Market price (Rs / kg)	Months / year	Rs / livestock
A	B	C = B x 30	D	E	F	G	H	I = (D x E + F x G) x H
Yak	1	30	3.00	100.00	3.00	125.00	3.00	2025.00
Urang	2.5	75	5.00	100.00	5.00	125.00	6.00	6750.00
Sheep	0.35	10.5	0.75	200.00	0.00	0.00	3.00	450.00

… continued

Average herd size	% lactating	Livestock lactating	Livestock milked	Annual dairy income
Nos. / herd	%	Nos. / herd	Nos. / herd	Rs / herd / year
J	K	L = J x K	M	N = M x I
70	57	40	40	81,000.00
25	72	18	18	121,500.00
110	80	88	44	19,800.00

Table 5.7: Annual wool and meat incomes from the herd

Livestock type	Annual wool production	Market price	Annual wool Income	Annual wool Income	% of adults sold for meat	Rate	Annual meat income
	(kg / livestock)	Rs / kg	Rs / livestock	Rs / herd / year	%	Rs / livestock	Rs / herd / year
A	O	P	Q = O x P	R = Q x J	S	T	U
Yak	0.50	200.00	100.00	7000.00	10	4500	45000
Urang	0.00	0.00	0.00	0.00	0	0	0
Sheep	1.00	50.00	50.00	5500.00	16	2000	32000

Table 5.8: Annual incomes from calves

Livestock type	Average herd size	Total No of calves	No of calves* for sale	Calf market price	Annual calves Income
	Nos. / herd			Rs / calf	Rs / herd / year
A	J	V	W	X	Y = W x X
Yak	70	40	$20^{H} + 10^{N}$	5000^{H} and 1500^{N}	115,000.00
Urang	25	18	0.00	0.00	0.00
Sheep	110	88	44.00	2000.00	88,000.00

* Calves: H - Crossbreed, N - Normal

Table 5.9: Total annual incomes from the herd

Livestock type	Average herd size	Annual dairy incomes	Annual calves Income	Annual wool incomes	Annual meat incomes	Total Annual herd income
	Nos. / herd	Rs / herd / year	Rs / herd / year	Rs / herd / year	Rs / herd / year	Rs / herd / year
A	J	N	Y	R	U	Z = N+Y+R+U
Yak	70	81,000.00	115,000.00	7000.00	45,000.00	234,500.00
Urang	25	121,500.00	0.00	0.00	0.00	121,500.00
Sheep	110	18,000.00	80,000.00	5000.00	30,000.00	133,000.00

Table 5.10: Total annual costs of the herd

Livestock type	Average herd size	Average Daily requirement of cattle feed and salt for the herd						Monthly expenses on cattle feed and salt
	Nos. / herd	Cattle feed (kg) monsoon	Cattle feed (kg) winter	Market price (Rs)	Salt (kg) monsoon	Salt (kg) winter	Market price (Rs)	Rs / month / herd
A	J	a	b	c	d	e	f	g = (a+b) x c/2 + (d+e) x f/2
Yak	70	0	0	15.00	2.00	1.00	8.00	360
Urang	25	1	0	15.00	0.63	0.30	8.00	337
Sheep	110	0	0	15.00	0.57	0.57	8.00	137

… continued

Monthly Salary expenses of caretakers	Monthly living expenses of caretakers	No of caretakers	Total monthly caretaker expenses	Other costs	Total annual herd costs
Salary / month	Rs / month	Nos.	Rs / month	Rs / year	Rs / year
H	i	j	k	l	m
600.00	1500.00	3	6300	2500.00	82420
600.00	1500.00	2	4200	500.00	54939
600.00	1500.00	3	6300	500.00	77746

Table 5.11: Total annual profits from pack animals

Livestock type	Average herd size	Total hiring days in a year	Pack animal hiring rate	Caretaker rate including food	Feed, salt and grass costs of pack animal		Total annual pack animal profits
	Nos. / herd	Days / year / livestock	Rs / livestock / day	Rs / day	Rs / livestock / trekking day	Rs / livestock / 10 months of no trekking	Rs
A	J	n	o	p	q	r	s = (ox5 – p – qx5)xn – rx5
Pack animal (dzo or horse)	5	48.00	180.00	230.00	30.00	1200.00	18960.00

Table 5.12: Total annual profits from livestock

Livestock type	Average herd size	Livestock biomass	Livestock value	Asset value	Annual profit per herd	Annual returns	Annual profit per livestock	Annual profit per unit biomass
	Nos. / herd	kg	Rs / livestock	Rs / herd	Rs / herd	%	Rs / livestock	Rs / livestock biomass in kg
A	J	t	u	v	w = Z – m	x = w / v	y = w / J	z = y / t
Sheep	110	30	2000	220,000	65,554.29	29.80%	595.95	20
Yak	70	350	6500	455,000	152,080.00	33.42%	2,172.57	9
Urang	25	400	7500	187,500	66,560.80	35.50%	2,662.43	8
Pack Animal	5	375	10,000	50,000	30,000.00	60.00%	6,000.00	16

5.3.3 Sustainability of pastoral systems

A five dimensional model was used to study the sustainability of the various pastoral systems prevalent inside the Greater Himalaya of the Khangchendzonga National Park. The pastoral systems were ranked based on their economic, social, ecological, political and legal sustainability. The social sustainability was found out from the livestock ownership pattern and equity of benefit sharing. The livestock impact units and the negative impacts of the herder on wildlife and its habitat determined the ecological sustainability. The return on investment to the herd owner was used as an indicator of the economic sustainability. The state policy indicated the political sustainability and whether this livelihood was permitted under the law of the land was a measure of its legal sustainability.

5.3.3.1 Relative economic sustainability

Profit earned is highest for the yak and then by *urang* owner since the corresponding herd size owned by them is also much more (Figure 5.5). The return on investment which was used as an indicator of relative economic sustainability is the highest at 60% for the pack animals enterprise, while returns from other livestock production systems vary between 30-35% (Figure 5.6, 5.7). While in terms of profitability per unit livestock biomass, sheep herding is the highest followed closely by pack animals (Figure 5.8). The annual return from pastoralism (Figure 5.6) was used as a measure of the economic sustainability (Table 5.13).

Figure 5.5: Annual profit of each owner

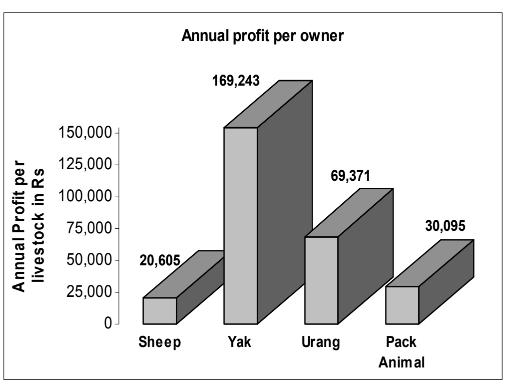


Figure 5.6: Annual returns from pastoralism

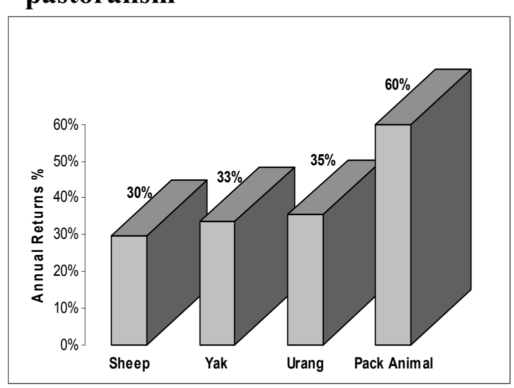


Figure 5.7: Annual profit per livestock

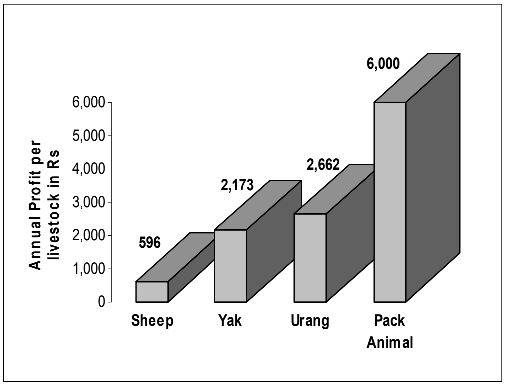


Figure 5.8: Annual profit per unit livestock biomass

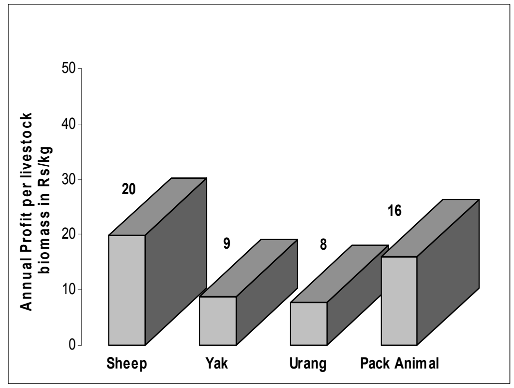


Table 5.13: Relative economic sustainability ranking of pastoral systems

	Sheep	Yak	*Urang*	Pack animal
Relative ecolomic sustainability ranking	0	1	2	3

5.3.3.2 Relative social sustainability

By social sustainability the issues related to ownership of livestock, incomes accrued and the sharing of these incomes are explored. We compare these with the per capita income of the state which was Rs 26,851 in 2005. In sheep rearing 33 families earn Rs 20,605 (SD = 13,991) each, from owning only one metric tonne of sheep biomass each. In yak husbandry nine families earn Rs. 169,243 (SD = 75,231) each, from owning as much as 19 metric tonnes of yak biomass each. 18 *urang* owners earn Rs 69,371 (SD = 24,002) each, from possessing nine metric tonnes of *urang* biomass. While 63 pack animal (horse and *dzo*) owners earn Rs 30,095 (SD = 16,089) each, from just two metric tonnes of pack animal biomass (Figures 5.9 and 5.10). To conclude in sheep and pack animal husbandry more people earn subsistence level incomes by owning limited numbers of livestock. While in yak herding only a few select households own large numbers of livestock and make hefty profits. This is a purely commercial venture and akin to ranching. *Urang* rearing falls in between subsistence level sheep and pack animal rearing and commercial yak ranching. The herder profits relative to the per capita income of the state was used as an indicator of livelihood inequity and an inverse measure of the relaive social sustainability (Table 5.14).

Figure 5.9: Distribution of livestock biomass amongst the herd owners

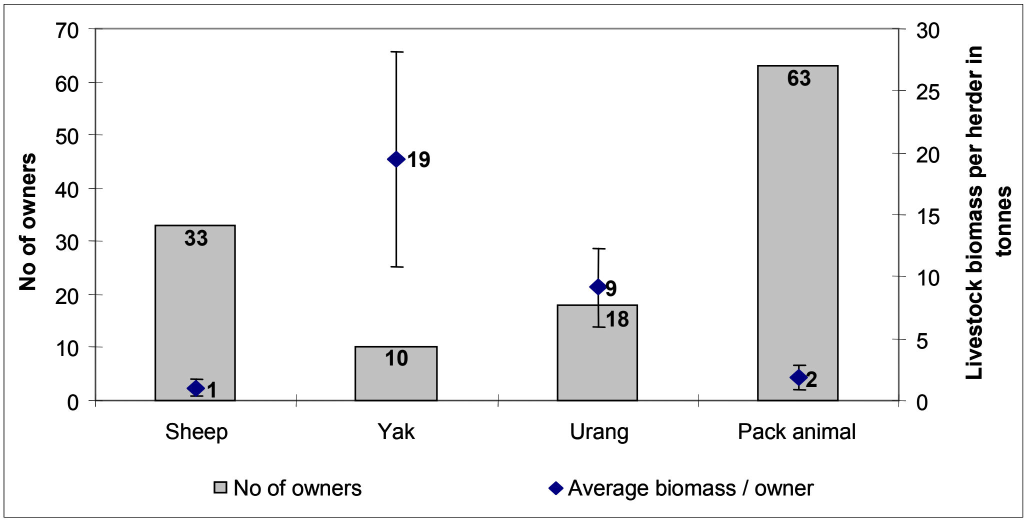
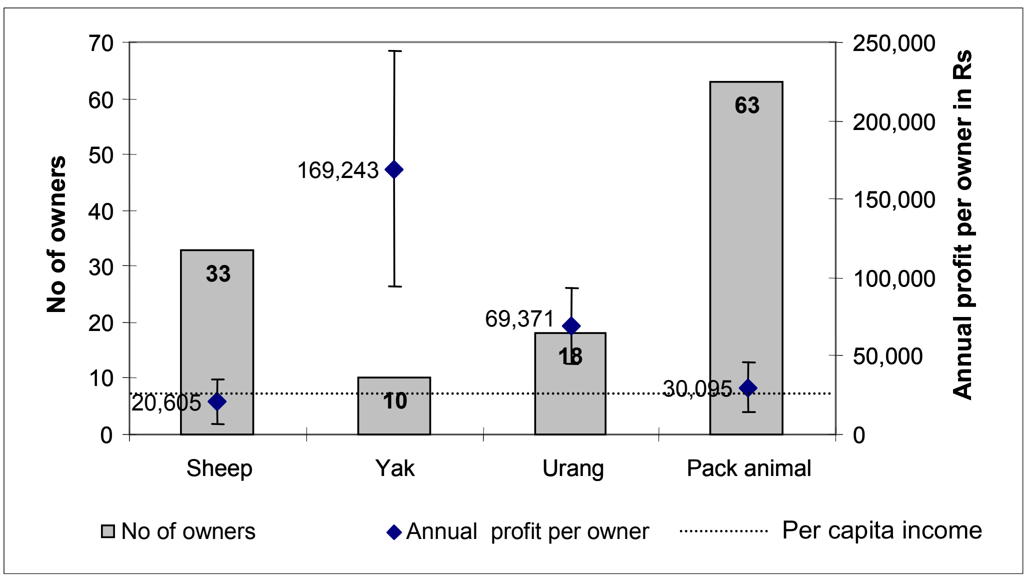


Figure 5.10: Pastoralism incomes, benefit sharing and comparison with the per capita income of the state



5.3.3.3 Relative ecological sustainability

A combination of approaches combining village meetings, field surveys, vegetation sampling, change detection from satellite images and recent scientific studies in the region were used to assess the relative ecological sustainability of the various pastoral systems.

Table 5.14 : Relative social sustainability ranking

		Units	Sheep	Yak (GH)	Urang	Dzo
Total profit generated	a	Rs lakhs	6.8	16.9	12.5	19
Number of households sharing this wealth	b	Number	33	10	18	63
Annual profit per herder household	c = a / b	Rs/herder	20,605	169,243	69,371	30,095
Herder profits relative to per capita income	d = c / PCI*	none	0.8	6.3	2.6	1.1
Relative livelihood inequity (RLI)	e	1 to 100 scale	12	100	41	18
Relative social sustainability ranking			2	0	1	3

**PCI = Rs. 26,851 for Sikkim state*

5.3.3.3.1 Livestock impact units

Table 5.15 and 5.16 give the trend of livestock impact units in the various watersheds of KNP over the last 50 years and a snapshot of the livestock composition in 2004. This indicates that though the livestock impact units (LIU) in the summer alpine pastures has been declining the LIU in the winter pastures of Rimbi chu, Kalij chu and Rammam chu has increased eight times over the last 50 years. This has been because of the change in composition of the livestock from predominantly sheep which used to descend to the farmer's fields in winter, to larger yak and their crossbreeds which stay in the temperate and subalpine forests during winter.

5.3.3.3.2 Herder impacts

The cultural traits of the herder are picked up traditionally while growing up in the pastoral livelihood. Impacts of the herder include impacts on wildlife and its habitat. The sheep herder has ample free time in the alpine meadows and indulges in regular hunting of musk deer, Himalayan tahr, alpine pheasants and partridges in his spare time using traps and hunting dogs. The yak herders resort to retaliatory carcass poisoning when wild dogs prey on their livestock when they are left unattended in winter. Dairy production of the *urang* herder is the highest and hence he has maximum impacts in terms of collection of slow growing *Rhododendron* *campanulatum* and *Juniperus indica* firewood, which burns green and lopping of fodder trees. Medicinal and aromatic plants are smuggled mostly by the yak and *urang* herders who own pack animals to transport them to the road head. The sheepherder stays in temporary, mobile sheds while the yak and *urang* herder own atleast two permanent cattle sheds each. The pack animal operator too has a fodder shed which is used to stack dry fodder for the trekking season. Ranking and summing the herder impacts indicates that yak and *urang* herders have maximum impacts followed by the sheepherder, while the pack animal herder has minimum impacts (Table 5.17, Plate 5.2).

Table 5.15: Trend of Livestock Impact Units (LIU) in the summer and winter pastures in the various watersheds of KNP and adjacent forests

Pasture Type	Watershed	Area (ha)	Livestock impact units (LIU) (LUdays/ha)			
			1950	1975	2000	2004
Summer Pastures						
4000m - 5000m Greater Himalaya	Churong and Prek chu	15898	39	10	16	14
	Rimpi chu	5782	5	12	10	8
	Thumpyak chu	5449	0	0	0	0
3500m - 4500m Greater Himalaya	Rimbi chu	2800	4	27	39	38
	Rangit chu	4723	13	25	2	2
	Zemu chu	6550	0	0	0	0
	Tista chu	6619	0	0	0	0
	Talung chu, Umram chu	12560	0	0	0	0
4500m - 5500m Trans Himalaya	Lhonak chu (right bank)	15954	Data not available			10
Average LIU		**76335**	**12.4**	**8.5**	**8.6**	**7.1**
Winter Pastures						
2500m - 3500m Greater Himalaya	Rimbi chu, Kalij chu, Rammam chu	16600	2	2	16	17
	Rimpi chu	1800	Data not available			6
4500m - 5500m Trans Himalaya	Lhonak chu	31500	Data not available			5
Average LIU		**49900**	**2**	**2**	**16**	**8.9**

Table 5.16: Livestock composition, stocking density (SD) and impact units (LIU) in the different watersheds in and adjacent to KNP in the year 2004

	Pasture Type	Watershed	Area (ha)	Yaks	Urang	Cow	Dzo	Horse	Sheep	LU	SD	Days	LIU
1	**Summer Pastures**												
	4000m - 5000m Greater Himalaya	Churong and Prek chu	15898	759	45	0	125	150	891	1226	0.08	180.00	**13.9**
		Rimpi chu	5782	70	0	150	0	0	70	268	0.05	180.00	**8.3**
		Thumpyak chu	5449	20	0	0	0	0	0	18	0.00	0.00	**0.0**
	3500m - 4500m Greater Himalaya	Rimbi chu	2800	0	499	0	75	0	0	599	0.21	180.00	**38.5**
		Rangit chu	4723	0	0	0	0	0	180	59	0.01	180.00	**2.3**
		Zemu chu	6550	0	0	0	0	0	0	0	0.00	0.00	**0.0**
		Tista chu	6619	0	0	0	0	0	0	0	0.00	0.00	**0.0**
		Talung chu, Umram chu	12560	0	0	0	0	0	0	0	0.00	0.00	**0.0**
	4500m - 5500m Trans Himalaya	Lhonak chu (right bank)	15954	924	0	0	0	0	0	850	0.05	180.00	**9.6**
		Total	**76335**	**1773**	**544**	**150**	**200**	**150**	**1141**	**3020**	**0.04**	**95.34**	**7.1**
2	**Winter Pastures**												
	2500m - 3500m Greater Himalaya	Rimbi chu, Kalij chu, Rammam chu	16600	759	544	0	200	150	0	1531	0.09	180.00	**16.6**
		Rimpi chu	1800	70	0	0	0	0	0	64	0.04	180.00	**6.4**
	4500m - 5500m Trans Himalaya	Lhonak chu (left bank)	31500	944	0	0	0	0	0	868	0.03	180.00	**5.0**
		Total	**49900**	**1773**	**544**	**0**	**200**	**150**	**0**	**2464**	**0.05**	**180.00**	**8.9**

Plate 5.2: Threats and impacts of pastoralism

Yak and *urang* descend to temperate and sub-alpine forests in winter

Winter pastures in the degraded temperate oak forests of Naya-patal

Secondary scrub of *Rosa sp.*, *Viburnum sp*. in winter pastures

Winter pastures in the degraded subalpine forests of Thulo dhaap

Winter pastures in the degraded subalpine forests of Kalijhaar

Trap laid for Himalayan musk deer

Trap laid for blue sheep

Poisoned Himalayan griffon vulture

Table 5.17: Negative impacts of herder on forests and wildlife

Negative impacts of herder	Units	Herder			
		Sheep	Yak (GH)	*Urang*	Pack Animal
Hunting, trapping of wildlife	rank	3	2	1	0
Retaliatory persecution of wild carnivores by carcass poisoning	rank	1	3	2	0
Firewood demand	tonnes / year [rank]	6 [1]	9 [2]	10.8 [3]	0 [0]
Lopping of trees for fodder	tonnes / year [rank]	0 [0]	1 [2]	3 [3]	0 [0]
MAPS* extraction	rank	1	2	3	0
Burning and cutting of *Juniper* scrub and *Rhododendron* and bamboo thickets	rank	1	2	3	0
Permanent cattle sheds	rank	0	3	3	1
Ferocious guard dog	rank	3	2	1	0
Total relative impacts		10	18	19	1
Relative rank		-1	-2	-3	0

** MAPS: Medicinal and aromatic plants*

5.3.3.3. Ecological sustainability

The conservation impact of the pastoral systems is a sum of the livestock and the herder impacts (Table 5.18) which was used as a measure of the ecological imapcts (Table 5.19).

Table 5.18 : Conservation impacts of pastoral systems

Parameter		Units	Sheep	Yak (GH)	Urang	Dzo
Relative impacts of herder	a		10	18	19	1
No of herders	b	number	10	10	19	63
Total impact of herders	c = a x b	1 to 100 scale	28	50	100	17
Total livestock population	d		1,141	779	469	316
Livestock units conversion factor	e	factor	0.33	0.80	1.20	1.20
Total livestock stay	f	days	180	365	365	240
Total livestock impact units	g = d x e x f	LU x days	67,775	227,468	205,422	91,008
Relative livestock impact units	h	1 to 100 scale	30	100	90	40
Relative conservation impacts	i = (c+h)/2	1 to 100 scale	**29**	**75**	**95**	**29**

Table 5.19: Relative ecological sustainability ranking of pastoral systems

	Sheep	Yak	*Urang*	Pack animal
Relative ecological sustainability ranking	3	1	0	3

5.3.3.4.2 Change detection

The spatial distribution of the changed areas mapped in Figure 5.11 indicate that spatially only 1.5% of the Trans Himalayan pastures and 2.5% of the summer pastures in Greater Himalaya in KNP showed reduction in the NDVI values. While a substantial portion (25%, 48 km^2) of the winter pastures comprising subalpine and temperate forests in reserve forests in and around KNP showed a decline in NDVI values (Table 5.20). The upper reaches of the Barsey Rhododendron Sanctuary were affected the most.

Table 5.20: Extent of areas with more than 15% decrease in NDVI values of vegetation in the summer and winter pastures within KNP and adjacent reserve forests between 1977 and 2000

Parameter	Summer pastures		Winter pastures	
Ecosystem	Greater Himalaya	Trans Himalaya	Greater Himalaya	Trans Himalaya
Altitudinal zone	Subalpine and alpine	Alpine	Subalpine and Temperate	Alpine
Location	KNP	KNP	KNP and adjacent RFs	Adjacent RFs
Use by livestock type	yak, cattle yak hybrid and sheep	yak and sheep	yak, cattle yak hybrid	yak and sheep
Total area (km^2)	318	108	191	178
Area with greater than 15% decrease	8	2	48	2
% of area impacted by greater than 15% decrease	2.5%	1.4%	25.0%	1.3%

Contemporary geospatial studies using remotely sensed data in the Barsey sanctuary also indicate that out of the total area of 120 km^2, 16.04 km^2 had a high and 47.10 km^2 had a medium disturbance index. Areas impacted by cattle sheds (*goth*) have been converted to degraded forests and scrub showing relatively high disturbance (Kushwaha *et al.* 2005).

5.3.3.4.3 Vegetation structure and composition of the summer pastures

Section 4.3.4.1 covers the impacts of pastoralism on the vegetation of the alpine zone. Heavily grazed subalpine pastures show an increased incidence of poisonous and unpalatable plants while certain grazing sensitive plants were not observed in the grazed alpine pastures (Plate 5.3). Figures 4.8 and 4.9 indicate the changes in the composition and fodder availability of vegetation due to the impacts of pastoralism (grazing and burning). While overall richness of species increases with disturbance, the fodder cover too increases in alpine shrub vegetation but decreases in sedge and marsh meadows.

Plate 5.3: Some alpine plants sensitive to yak grazing

Heracleum sp.

Pleurospermum sp.

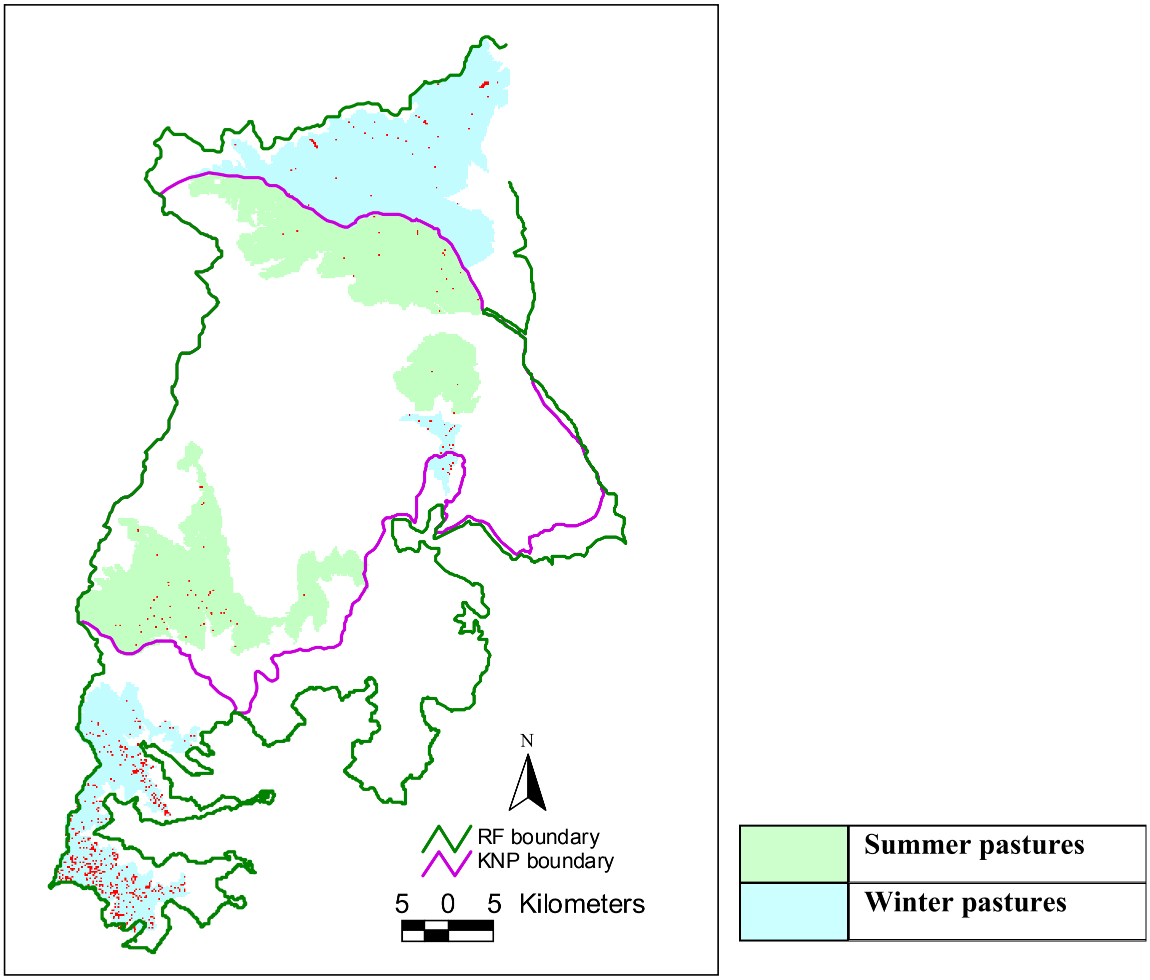
Saussurea uniflora

Pleurospermum sp.

Saussurea obvallata

Rheum nobile

Figure 5.11: Map showing the spatial distribution of areas with more than 15% decrease in NDVI (shown in red) in the summer pastures and winter pastures within KNP and adjacent reserve forests between 1977 and 2000



5.3.3.4.4 Vegetation structure and composition of the winter pastures

The temperate and subalpine forests between 2,500 to 3,500 meters form the winter pastures of the yaks and summer pastures of the cow-yak crossbreeds and cattle. The habitats are mostly evergreen oak forests and silver fir forests with dense under storey of dwarf bamboo and *Rhododendron* thickets and moss dominated ground cover. *Arundinaria maling* (malingo) and *Thamnocalamus aristata* (nigalo) are the main bamboo species that grow upto 15 to 20 feet tall with 7 to 10 cm GBH and are densely packed with an average of 325 stems per 10 X 10 m^2 plot. The herders open up *kharkas* or artificial pastures around their cattlesheds (*goths*) where the top canopy is opened, and the middle storey cleared to increase the ground fodder availability. South and east facing sunny aspects with moderate slope and perennial water availability are the preferred sites for *kharkas*. With the opening of the forest canopy and clearing of the bamboo understorey, thickets of secondary shrubs like *Viburnum erubescens, Berberis sp.* and *Rosa sericea* have increased substantially. In the blanks heavily used by livestock, *Arthraxon microphyllus* (bonchu) is the dominant ground cover along with some *Carex sp.* (harkat) and moss. The herders also plant an exotic fodder grass *Pennisetum clandestinum* (ghode dubo) in these openings (*kharkas*). Fodder trees of the *Moraceae, Lauraceae* and *Araliaceae* families are preferentially lopped in winter. *Ficus foveoleta* (dudhe lahara), *Ficus nerifolia* (dudhilo), *Schefflera impressa* (bhalu chinde), *Symplocos racemosa* (badam), *Ilex sp.* (lisse) and *Machilus sp.* (rani kaula) are the preferred fodder plants. The comparison of the vegetation structure and composition shows that attenuation in the top canopy and clearing of the bamboo understorey results in an increase in the secondary shrubs and a substantial increase in ground fodder cover (Table 5.21).

Table 5.21: Comparative analysis of impacts of pastoralism on the vegetation characteristics of temperate and subalpine forests

Vegetation characteristics	Units	Undisturbed		Disturbed	
100m^2 square plot		Mean	SD	Mean	SD
Number of trees	nos	3.67	2.22	0.62	1.58
Total basal area of trees	m^2/ha	103.01	82.61	20.57	50.61
Number of bamboo stems	nos	324.38	138.73	0.66	2.19
Number of secondary shrubs	nos	0.81	1.97	9.54	16.27
Ground fodder cover	%	1.81	1.42	75.66	20.75

Studies on the red panda (*Ailurus fulgens)* ecology in the Singhalila National Park, West Bengal which is contiguous with the Barsey sanctuary of Sikkim indicate that they are relatively more abundant within an altitudinal range of 2800±3600 m (Pradhan *et al.* 2001). Higher bamboo cover, bamboo height and canopy cover emerged as important habitat components in sites used by it. Red panda diet consisted chiefly of bamboo leaves and both species of bamboo, *Arundinaria maling* and *Thamnocalamus aristata* predominantly present as understorey in Singhalila National Park were eaten. The diet of bamboo was supplemented by seasonal fruits and bamboo shoots. Winter happens to be the mating season of the red panda. Before 1993 a minimum of 80±90 g*oths* (cattle stations) were present inside Singhalila National Park and wildlife poaching was widespread prior to the establishment of the Park. Each *goth* had a minimum average of 30±50 cattle. Establishment of a cattle station required clearing of vegetation, thus causing gaps in the canopy cover. The area was also bereft of bamboo, an important component of red panda habitat.

Further west in central Nepal in the Langtang National Park too studies on pastoralism and red panda were carried out (Yonzon & Hunter 1991). These studies indicate that loans and one-year advance payments encouraged the farmers to maintain large herds of *urang* (yak-cattle hybrid), and in many areas overgrazing has resulted. Damage resulted not only from excessive grazing but also from trampling, which both crushed vegetation and compaction of the soil. Another indication of overgrazing was the abundance of plant species associated with dry disturbed sites, such as *Berberis sp.* and *Rosa sp.* even on north-facing, predominantly moist slopes (Shrestha 1988). The presence in the area of large herds of *urang*, their herders, and dogs has led to the death of many red pandas a species that is probably on the verge of extinction in Langtang.

5.3.3.4.5 Forage quality

Quantifying the protein and fiber content is important for determining the quality of forage. Plate 5.4 illustrates the key fodder plants in the alpine and subalpine zones. Laboratory analysis of these plants was carried out and the results are placed in Table 5.22. Low fiber content (NDF less than 40%), high potential digestability (ADF less than 31%) and high protein content (CP more than 19%) are the desirable traits of top quality prime forage (Rohweder *et al.* 1978). While poor quality forage has high fiber content (NDF more than 65%), high potential indigestability (ADF more than 45%) and low protein content (CP less than 8%).

Amongst the alpine grasses and sedges it was noted that they had uniformly very high fiber content (NDF greater than 64). High fiber content generally reduces the potential intake of forage because of the low energy bulk. The forage digestability varied a lot with *Kobresia schoenoides* being highly indigestable (DMD=54) while *Carex sp.* (DMD=66) showed very high digestable characteristics. All the other grasses and sedges showed average digestability. Their protein content too varied a lot (CP between 9% to 18%). *Sun buki* was found to have a very high protein value of 18% amongst the key grasses and sedges. The Apiaceae member *Heracleum sp.* (ganer) was strongly recommended by the herders as high nutrient forage preferred not only by their domestic livestock but also by the Himalayan musk deer. The forage analysis revealed that *ganer* had a very high intake value (NDF=43%), good digestability (ADF=37%) and very high protein content (CP=23%) confirming that it was indeed a high quality (RFV=129) forage species of the alpine meadows.

Table 5.22: Protein and fiber levels in key alpine forage (collected in June 2005)

Fodder Species	NDF	ADF	CP	DMD	DMI	RFV[b]	QS[a]
	%	%	%	%	%		
Heracleum sp. (ganer)	43	37	23	60	3	129	1
Carex sp. (harkat)	64	29	9	66	2	97	3
Kobresia capillifolia (kesari buki)	72	36	15	61	2	79	4
Kobresia duthiei (bhalu buki)	77	36	15	61	2	74	5
Kobresia nepalensis (sun buki)	78	36	18	61	2	72	5
Kobresia schoenoides nama)	78	44	16	54	2	65	5
Festuca valesiaca (rani buki)	81	41	11	57	1	65	5

[a] *Standard assigned by Hay Market Task Force of American Forage and Grassland Council*
[b] *Relative Feed Value(RFV)- Reference hay of 100 RFV contains 41 % ADF and 53 % NDF*

Amongst the temperate and subalpine forage incuding loppings from fodder trees, *Ficus nerifolia, Acer campbellii, Symplocos impressa, Ilex sp.* and *Schefflera impressa* showed high RFV (Table 5.23).

Table 5.23: Protein and fiber levels in key temperate and subalpine forage (collected in December 2006)

Fodder Species	NDF	ADF	CP	DMD	DMI	RFV[b]	QS[a]
	%	%	%	%	%		
Ficus nerifolia (dudhilo)	37.52	17.59	9.78	75	3	186	P
Acer campbellii (kapashe)	38.40	20.96	13.20	73	3	176	P
Symplocos impressa (badam)	38.11	30.40	12.47	65	3	159	P
Ilex sp. (lisse)	42.26	28.96	6.15	66	3	146	1
Schefflera impressa (bhaalu chinde)	43.36	30.49	8.27	65	3	140	1
Quercus lamellosa (buk)	47.55	35.21	9.81	61	3	120	2
Ficus foveolata (dudhe lahara)	51.21	35.54	10.22	61	2	111	2
Lindera assamica (painle)	53.95	34.64	12.02	62	2	107	2
Ilex intricata (kurkure)	54	50	14	66	2	97	3
Quercus pachyphylla (baante)	60.03	34.37	12.36	62	2	96	3
Thamnolcalamus aristata (raat nigalo)	66.55	33.38	11.32	63	2	88	3
Carex sp. (harkat)	66.15	33.87	8.12	63	2	88	3
Pennisetum clandestinum (ghode dubo)	74.35	32.90	5.45	63	2	79	4
Arthraxon lancifolius (bonchu)	71.20	40.25	9.51	58	2	75	4
Arundinaria maling (malingo)	76.95	37.35	12.74	60	2	72	5
Rubus paniculata (kanre lahara)	47	40	22	54	2	65	5
Machilus sp. (raani kaula)	90.69	33.69	10.74	63	1	64	5

[a] *Standard assigned by Hay Market Task Force of American Forage and Grassland Council*
[b] *Relative Feed Value(RFV)- Reference hay of 100 RFV contains 41 % ADF and 53 % NDF*

Plate 5.4: Some important subalpine and alpine fodder plants

Kobresia nepalensis **(sun buki)**

Kobresia duthiei **(bhalu buki)**

Ilex intricata **(kurkure)**

Festuca valesica **(rani buki)**

Heracleum sp. **(ganer)**

Polygonum sp. **(rani thotne)**

Rubus paniculata **(kanre lahara)**

Pennisetum clandestinum **(ghode dubo) - exotic**

Schefflera impressa **(bhalu chinde)**

5.3.3.5 Relative political sustainability

The current ruling political party of Sikkim – Sikkim Democratic Front (SDF) in a policy decision in 1995 banned the practice of open grazing in the reserve forests of South and West Sikkim districts. This policy decision was challenged by the herder associations in the Sikkim High Court's but the high court reaffirmed the notification passed by the forest department banning grazing in reserve forests vide its judgment dated 14th May, 1999.

Addressing the National Development Council Meeting at New Delhi on 1st September, 2001 the chief minister Dr. Pawan Chamling remarked that, "Sikkim has an exemplary record of taking tough decisions to save forests. Tree felling has been severely restricted. Grazing has been banned in the reserve forests. The government has also initiated steps to make Sikkim a plastic and polythene-free state. We have been able to both traditionally and scientifically conserve our rich biological diversity. On the environmental conservation front the Sikkim's Chief Minister was voted as the greenest chief minister of India in the opinion poll conducted by New Delhi's Centre for Science and Environment." Pack animals which are used in tourism sector, which is a thrust area of the current government were considered outside the purview of this grazing ban.

As a consequence of the implementation of this ban open grazing of cattle reduced considerably and more than 10,000 cattle and 500 agro-pastoralists were phased out from the sub-tropical and temperate forests of the state between 2000 and 2003. In terms of the number of beneficiaries in the pastoralism enterprise in the Greater Himalaya of KNP in 2004 there were 10 yak herders, 18 *urang* herders, 33 sheep herders and 63 pack animal owners. While the 500 ex-cattle herders who removed their livestock were against the yak and *urang* herders continuing in the forests. Though the yak herders were demographically outnumbered they were influential in village and constituency level politics and this provided them immunity from the grazing ban (Table 5.24).

Table 5.24: Relative political sustainability ranking of pastoral systems

	Sheep	Yak	*Urang*	Pack animal
Relative political sustainability ranking	0	2	1	3

5.3.3.6 Relative legal sustainability

The pastoralism livelihood involves not only grazing but also use of firewood, lopping for fodder, constructing permanent cattle sheds and herders staying inside forests. This livelihood spanned across three legal categories of forests namely reserve forests, sanctuary and national park. As per the legislations associated with these forest categories the following offences were deemed to have been committed:

- Encroachment due to the construction of the permanent cattle sheds.
- Illegal felling of trees and poles while construction or repairing of the permanent cattle sheds or *goths*
- Illegal felling of trees and poles, lopping of trees while collecting firewood and fodder
- Hunting or abetting the same by laying traps and letting lose guard dogs at night
- Damage to habitat due to proliferation of unpalatable species, setting fire and clearing up of forests
- Damage to plantations, when the livestock descend to the temperate forests in winter
- Grazing of livestock without permit
- Entering into sanctuary, national park and reserve forest without permit

Most of the summer pastures of the herders were within the Khangchendzonga National Park where grazing and destruction of habitat is banned vide Section 35 of the Wildlife Protection Act 1972. Some of the summer pastures and the winter pastures were within Barsey Rhododendron Sanctuary and reserve forests. Destruction of habitat in a sanctuary is banned vide Section 29 of the Wildlife Protection Act 1972, while in reserve forests grazing and destruction is banned vide section 20 of the Sikkim Forests, Water

Courses, Road Reserve (Protection and Preservation) Act 1988. Further the supreme court in its WP No 202/95 dated 14th February, 2000 has "restrained states from ordering even the removal of dead, diseased, dying or wind fallen trees and grassed from national parks and sanctuaries."

Stringent national wildlife laws especially those pertaining to national park make livestock grazing illegal. Without grazing permits any livestock can enter into a reserve forest, sanctuary or national park, only by being a part of the tourism sector (Table 5.25).

Table 5.25: Relative legal sustainability ranking of pastoral systems

	Sheep	Yak	*Urang*	Pack animal
Relative legal sustainability ranking	0	0	0	3

5.3.3.7 Relative sustainability ranking

The ranking in the six dimensions of relative sustainability were condensed together in Table 5.26. The model indicates that the pack animal is most sustainable followed by sheep and that yak and cow-yak crossbreeds herding is relatively unsustainable in the Greater Himalaya. It was also found that more than the ecological carrying capacity the socio-economic issues like equity in ownership and benefit sharing were given much more importance at the village level while assessing the sustainability of the pastoral systems.

Table 5.26: Six dimensional relative sustainability model of pastoral systems

Dimension	Sheep	Yak	Urang	Pack animal
Social	2	0	1	3
Economic	0	1	2	3
Ecological	3	1	0	3
Political	0	2	1	3
Legal	0	0	0	3
Relative sustainability Index	**5**	**4**	**4**	**15**

5.4 Conclusions

Historically the pastoral systems in the KNP evolved in close consonance with the patterns in the climate and fodder availability. Traditionally the *gurung* and *manger* shepherds (agro-pastoralists) performed long distance transhumance to access the rich fodder resources of the alpine meadows during summer and during winter returned back to the villages with their flocks. While in the Trans Himalaya the nomadic *dokpa* pastoralists migrated between their summer and winter alpine pastures with their Tibetan yaks and sheep. This harmony between the subsistence needs of man and nature's bounty existed till the middle of the twentieth century.

From the mid twentieth century, transborder *Bhutia* yak herders from eastern Nepal started migrating and settled in the border villages of West Sikkim adjacent to KNP. With the merger of Sikkim into India in 1975, rapid development created new opportunities and markets. In order to meet the growing demand for dairy products, the herd size of the recently introduced pastoral systems like the yak and the cow yak crossbreeds started increasing. In summer they accessed the moist alpine meadows till the winter snowfall forced them down to Yambong and Barsey sanctuary. Here the structure and composition of the subalpine and temperate forests had to be changed substantially for them to be able to support large livestock populations. The pastoralists altered the top and middle layers of vegetation and the undergrowth by lopping, clearing and burning to increase the ground fodder biomass. The problem is exacerbated due to the overlap between summer and winter grazing grounds when often the same pastures are grazed by cattle-yak crossbreeds and cattle in summer and yaks in winter.

The livestock impact units of the yaks and cattle-yak crossbreeds in the temperate and subalpine forests (oak and fir with bamboo under storey between 2500-3500 m) during winter increased more than 8 times (from 2 to 17 LUdays/ha) between 1975 to 2004. Change detection study in the 1977 to 2000 time series indicate that 25% of these forests, having an extent of 48 km^2 show more than 15% reduction in NDVI values. Contemporary geospatial studies using remotely sensed data in the Barsey sanctuary also indicate that out of the total area of 120 km^2, 16.04 km^2 had a high and 47.10 km^2 had a medium disturbance index. Areas impacted by cattle sheds (*goth*) have been converted to degraded forests and scrub showing relatively high disturbance (Kushwaha *et al.* 2005).

Vegetation sampling in 10 meter square plots in Dungdang, Naya-patal, Barsey, Jorebotey, Thulo Dhaap and Kalijhaar revealed that the herders had opened up *kharkas* or winter pastures adjacent to their cattle sheds (*goth)* especially in the sunnier aspects with moderate slopes. The number of trees reduced from 3.7 (SD=2.22) to 0.6 (SD=1.58) while the basal area reduced from 103 m^2/ha (SD=83) to 21 m^2/ha (SD=51), maximum change was noticeable in the understorey of bamboo (*Arundinaria maling* and *Thamnocalamus aristata*) whose stem density reduced from 324.38 (SD=138.73) to 0.66 (SD=2.19). The ground fodder availability in these *kharkas* with *Arthraxon microphyllus* (bonchu) and supplemented with *Pennisetum clandestinum* (ghode dubo) increased substantially from 1.81% (SD=1.42) to 75.66% (SD=20.75).

Scarcity of natural fodder during the long winter season from November to March is one of the biggest hurdles in sustainable livestock production in KNP. The herders are very ingenious and in vegetation types that have limited natural fodder cover they increase the fodder availability by opening up *kharkas* by burning, cutting, lopping and introducing exotic fodder grasses. The artificial carrying capacity (ACC) of these man made meadows is substantially more than the natural carrying capacity (NCC) of the vegetation. Recent studies in the Singhalila and Langtang national parks indicate that top canopy trees of oak and fir coupled with bamboo thickets in the undergrowth serve as the habitat for the rare and endemic red panda which has been driven to extinction due to disturbance from livestock, herders and their dogs.

After studying the ecological impacts of these pastoral systems, the other aspect that was explored was that of livelihood benefits and equity. The per capita income of the state which was Rs 26,851 in 2005 was used as the baseline. The yak herder earns 6.3 times, the *urang* herder 2.6 times, the pack animal owner 1.1 times and the sheep herder 0.8 times from pastoralism relative to this. In terms of livestock biomass ownership 9 yak herders owns 19.5 MT (SD=8.7) each, 18 *urang* herders own 9.1 MT (SD=3.2), 63 pack animal herders own 1.9 MT (SD=1.0) and 33 sheep herders own 1.0 MT (SD=0.7). To summarise few yak herders earn high incomes by maintaining large herds followed by the *urang* herder. While a substantial number of sheep and pack animal herders earn subsistence level of incomes from owing small herds.

To conclude in the Greater Himalaya of KNP, sheep were traditionally grazed while the yak, cattle yak hybrids (*urang)* and the pack animals (dzo and horse) are recently introduced. The yak and *urang* pastoral systems have substantially impacted the oak and fir forests with bamboo understorey, which is also the habitat of the endangered red panda. Comparatively the sheep which descend down to the agricultural fields during winter and pack animals that are free ranging without an attendant herder have lesser impacts. Yak herding livelihood showed the highest inequity with benefits concentrated amongst a few followed by *urang* herding. Relatively the sheep and pack animal herding provided benefits to a larger section of society and were more equitable. Lower impacts and greater equity in benefit sharing made the sheep and pack animal herding relatively more sustainable than the high impact and inequitable yak and cow yak crossbreeds pastoral systems.

6.0 Conservation Management: Strategy, Experiments and Emerging Trends

6.1 Introduction

The Himalaya is the youngest of the world's mountain chains and has amongst the highest peaks in the world. The Himalaya and the Trans-Himalaya altogether cover ca. 16.2% of India's geographical area (3.3 million km^2) spanning across the five states of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Sikkim and Arunachal Pradesh from west to east. At present there are 15 national parks and 60 wildlife sanctuaries in the Himalayan region that cover ca. 9.6% of its geographical area which is much higher compared to the national average of 4.7% (Rawal & Dhar 2001, National Wildlife Database 2005).

National forest and wildlife laws (Anon 1980, Anon 2003b) envisage sustainable grazing management by banning it in strict nature reserves (national parks) and regulating it in other protected areas (sanctuaries and reserve forests). Lack of people's support and political will have resulted in only a weak or sporadic enforcement of these stringent laws (Chhatre & Saberwal 2005). Consequently grazing is pervasive in most of the protected areas in the country (Kothari *et al*. 1989) and the same holds true for KNP which was notified in 1977.

One of the objectives of this study was to identify ecologically sensitive areas in the alpine zone based on the conservation status of endangered species. This would provide the basis for preparing a zonation plan and evolving management strategies for the long-term conservation of the alpine zone of KNP. The questions relate to what are the ecologically sensitive areas, planning zonation of the existing landuse practices, what co-management experiments are possible and finally how to garner political support for implementing this plan.

6.2 Material and methods

This chapter is based on the findings of the pervious chapters 2, 3, 4 and 5 relating to the study area, landscape characteristics, vegetation dynamics and pastoral and other landuse. The conseration zones are based on the criteria of endemic, endangered and indicator speices and special habitats. For identifying these zones a combination of techniques including vegetation sampling, wildlife sighting and use data and consultations with traditional resource users was done. Conservation zonation for blue sheep, Himalayan musk deer, red panda, Himalayan tahr, alpine pheasants and medicinal plants was carried out followed by endorsement by the local community and notification by the state government.

The funding pattern of the park directorate relating to grant in aids received from government of India was obtained from the official records of the Sikkim forest department for the three financial years 2002-2003, 2003-2004 and 2004-2005. Information related to tourist arrivals to KNP between the years 2002 to 2006 covering numbers, date, duration and nationality was collected from the police and forest checkposts and Yambong ecotourism committee in Nambu. Also 33 advocacy presentations to community leaders, NGOs, policy makers and six press releases in the local newspapers were given for wider dissemination. The findings of this study were framed as a government notification and the processing of the same for government approval was also facilitated.

6.3 Traditional management of KNP

The funding support for the conservation programmes of the park directorate is received from the Ministry of Environment and Forests, Government of India though three centrally sponsored schemes. These schemes are "Assistance to states for development of national parks and sanctuaries", "Assistance for management action plan of Khangchendzonga Biosphere Reserve" and the "National afforestation programme under the forest development agency". The average annual grant of these three schemes from 2002-2003 to 2004-2005 amounts to Rs. 129 lakhs. Table 6.1 indicates the major activities and average annual spending on each of these components. The national afforestation programme has habitat improvement and afforestation as the major component with budget breakup amongst the various other components predetermined by the funding agency. But the other two schemes are flexible and allow the protected area manager to plan the breakup of funds amongst the various components. The figures show that the priority of the KNP management is afforestation and habitat improvement (63%) and infrastructure development (24%) with low priority given to ecodevelopment (6%), protection (4%), awareness (2%) and research (1%).

Table 6.1: Funding priorities of the park directorate (2002-2005)

Component	**Activities**	**Average Annual Funds**	**% of Funds**
		Rs in Lakhs	
Afforestation and habitat improvement	Plantation of trees, fodder and firewood plants, bamboo, medicinal plants, soil and moisture conservation, assisting natural regeneration, water holes, habitat improvement for red panda and shapi etc.	**82**	**63%**
Infrastructure development	Construction of forest offices, trekking trails, bridges, log huts, trekker huts, watch-towers, procurement of jeeps, barracks, LCD projector etc	**31**	**24%**
Ecodevelopment	Distribution of sewing and knitting machines, piglets, horticulture and large cardamom seedlings, LPG connection, pressure cooker, organizing health camps, trainings etc	**8**	**6%**
Protection	Trap demolition, expeditions, equipment and bikes for staff, awards, wireless sets, arms, ammunition etc	**5**	**4%**
Awareness	Village meetings, nature trips for school students etc	**2**	**2%**
Research	Preparing inventory of flora and fauna, census and preparing management plan	**1**	**1%**
	Total	**129**	**100%**

The activities related to construction of forest offices, log huts, barracks, watch towers etc should ideally help in improving the protection status of the park but they are classified under the infrastructure development component since they are mostly unmanned and not in use. In the absence of a long term management plan, planning over annual budget cycles was done. The KNP managers focused on habitat improvement, afforestation and infrastructure development with little funding support for protection, livelihoods or financial assistance to the pastoralists, as a result the ecological impacts of pastoralism only grew. A large chunk of funds were used for reducing the impacts of the threats and not the root cause of the threat itself. Conflict resolution and livelihood support for the herders should have received more attention and commercial grazing and medical and aromatic plants extraction should have been curtailed. This lack of vision resulted in deterioration in the conservation status of KNP during the first 25 years of its existence. It took a farsighted chief minister to provide conservation vision and galvanize the forest department to initiate conservation action.

6.4 Conservation zonation

The conservation zonation for medicinal plants and sensitive species was attempted (Figure 6.1, 6.2). Four Medicinal Plants Conservation Zones (MPCAs) namely Lampokhri, Narsing, Tekepla and Marco Polo camp have proposed. Areylungchok and Panch pokhri for Himalayan musk deer, Narsing, Phim phu and Dawathang for Himalayan tahr, Yongjethak and Green lake for blue sheep, Tekepla for alpine birds, Bakhim for red panda, Gomathang for *Juniperus indica* stands and the sacred lakes of Ome tsho (dudh pokhri) and Kishong tsho have been proposed for conservation zonation. It is envisaged that these sites would be kept inviolate and free from the impacts of future expansion of trekking tourism and other landuse practices. Community endorsement and government notification has also been completed for three MPCAs, two for musk deer, two for Himalayan tahr, one for blue sheep and one for alpine birds.

6.5 Classification of pastoral scenarios and conservation strategy

The Pastoralism Classification Tool (PCT) has been prepared to assist in classifying the pastoral systems into four scenarios based on their conservation impacts and equitable sharing of livelihood benefits. The PCT can be applied at the pastoral system level or at

Figure 6.1: Medicinal plants conservation zones (MPCAs)

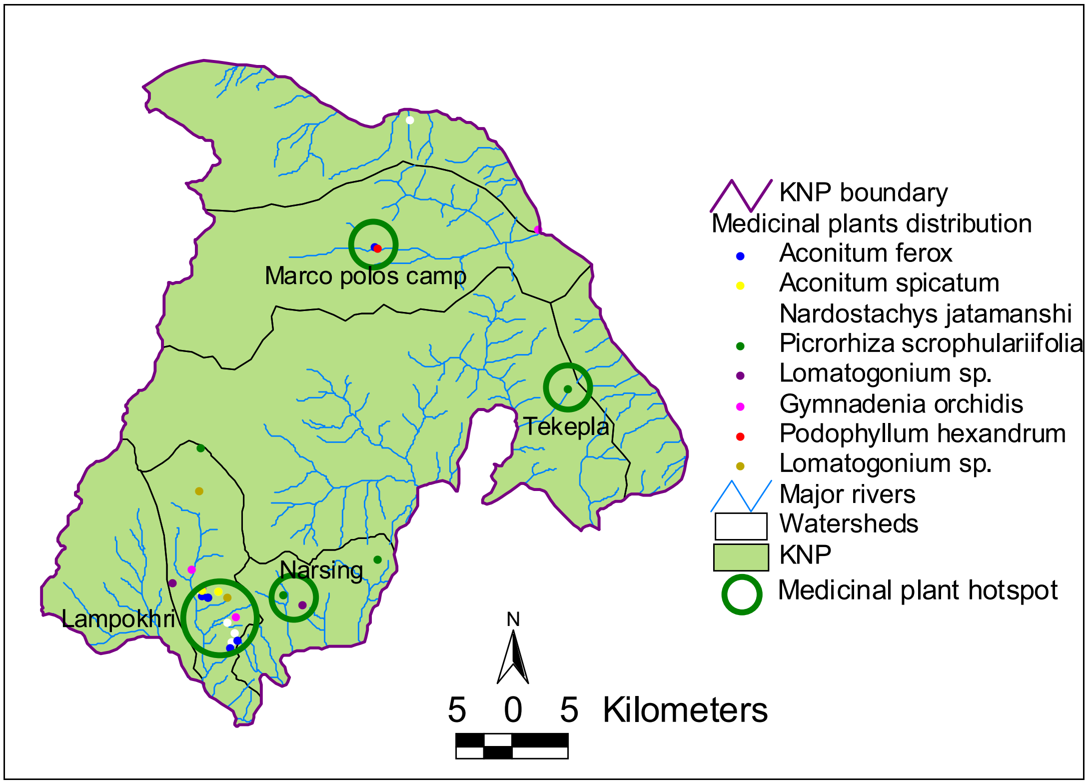
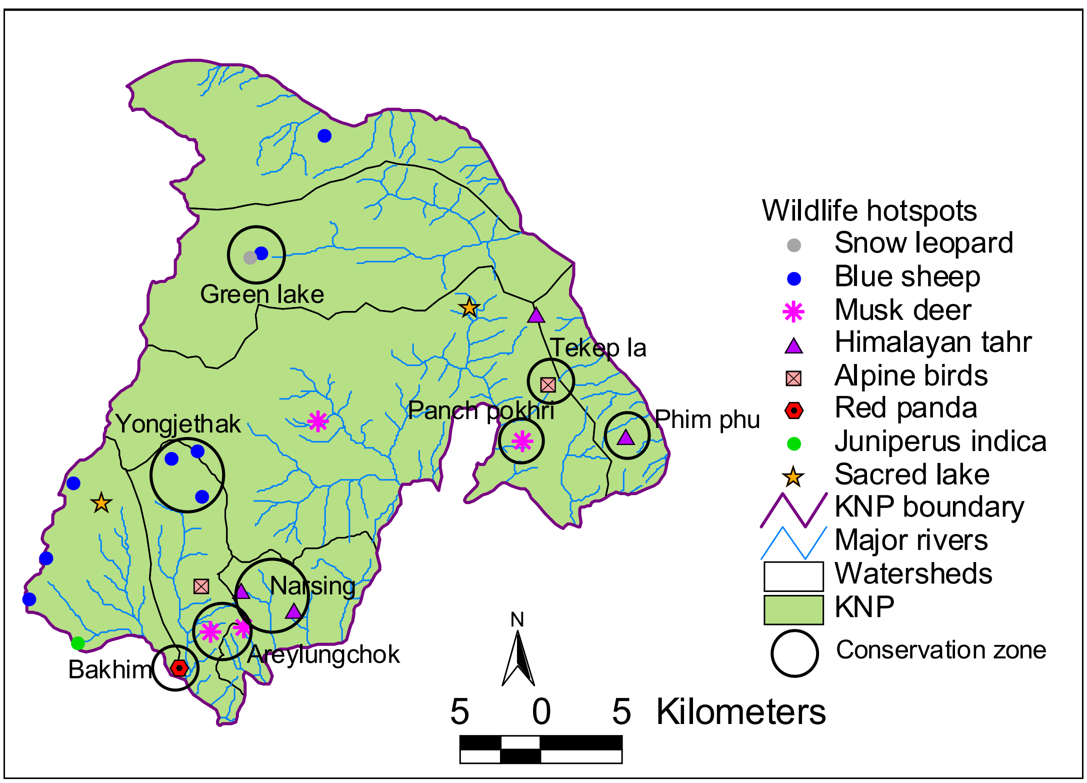


Figure 6.2: Conservaton zonation of sensitive species



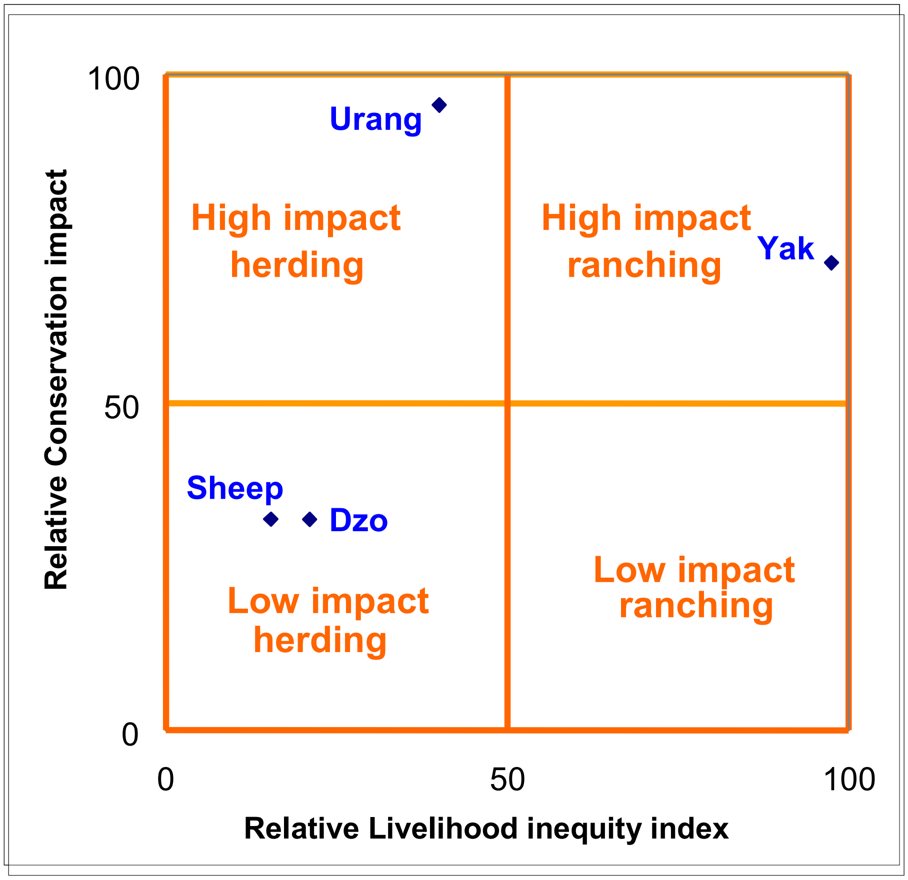
the herder household level depending on the resources available and the heterogeneity of the pastoral practices. The horizontal axis (X) depicts the livelihood inequity and is derived from the per capita incomes of the herder families in various pastoral systems relative to the per capita income of the state. Higher values of livelihood inequity indicate that fewer families are deriving commercial level incomes while lower values indicate the presence of more number of families earning subsistence level incomes (Table 5.14). The vertical (Y) axis depicts the impacts of the pastoral livelihood on the environment, and is derived from the livestock biomass days and the environmental impacts of the herders (Table 5.18).

There are broadly four scenarios possible namely high impact ranching, high impact herding, low impact ranching and low impact herding (Table 6.2, Figure 6.3). Inside a protected area landscape, the low impact herding is the best scenario and the high impact ranching the worst one. Management interventions should try to facilitate the shift of the pastoral system towards the best scenario. Often diverse strategies are needed for addressing different pastoral scenarios and generally ranchers who have commercial level of livelihoods are more resistive to change since they have greater stakes. Comparatively the herders when provided with adequate livelihood support are generally more amenable to change. Based on the outputs of this matrix, the state policy and the legal status of this livelihood, the park manager can decide on the nature of intervention needed.

Table 6.2 : Classification of pastoral scenarios

Case	Range of Relative Livelihood Inequity Index (RLII) and Relative Conservation Impact (RCI)	Pastoral Scenario
Case 1	RLII<50, RCI<50	Low impact herding
Case 2	RLII<50, RCI>=50	High impact herding
Case 3	RLII>=50, RCI<50	Low impact ranching
Case 4	RLII>=50, RCI>=50	High impact ranching

Figure 6.3: Pastoral scenarios present in KNP in 2004



6.6 Experiments in participatory management

6.6.1 Livelihoods strategy and outcomes

In 2004 The Mountain Institute (TMI), jointly with the Sikkim Forest Department and Khangchendzonga Conservation Committee (KCC) took up an appreciative planning exercise in these villages to learn about the lifestyles of the people and how they could be made more eco-friendly. The dream of the herders was to generate substantial incomes from trekking tourism, have toilets in every house and have a community run dairy in their village.

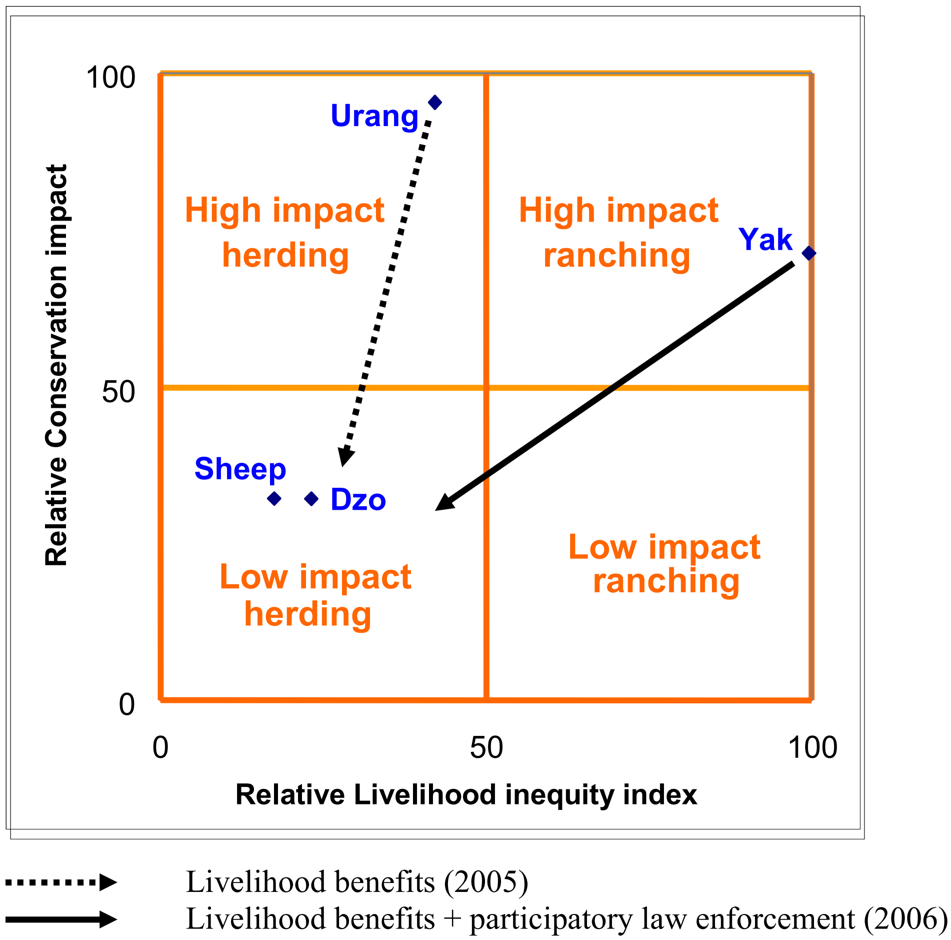
The activities carried out included strengthening of village institutions, livelihood support to ex-herders and a household sanitation programme. The villagers were organized into women's saving and credit groups, a local NGO – Khangchendzonga Eco-friendly Society and the Sindrabung JFMC. These village based organizations created environmental awareness at the grassroots. New livelihood opportunities like off-season vegetable production, organic farming and cooperative dairy were initiated for the ex-pastoralists. In order to reduce the transition shock from agro-pastoralism to a sedentary lifestyle, support for household toilets was given. For providing alternative livelihood through ecotourism the new 14-day alpine trekking ecotourism package "*Yambong Singalila*" was developed. The Yambong Ecotourism Committee (YEC) was formed in 2005 to manage Yambong tourism. Wide publicity was done through the local media, trekking companies in Gangtok and Darjeeling and the website www.yambong.com. A total of 314 overseas tourist and 13 domestic tourists visited this new destination between October 2005 and December 2006. The local ecotourism service providers who served as porters, assistant guides and *dzo* operators earned Rs 16 lakhs. About half of this income was earned by the herders and ranchers who functioned as assistant guides and *dzo* operators.

6.6.2 Conservation strategy and outcomes

With increasing incomes from ecotourism it was observed that the number of *urangs* reduced considerably from 469 to 240 between 2004 and mid 2006 with the herders selling them off to Nepal. The number of yaks however showed a relatively lesser decline from 779 to 624 during this period, with the yak ranchers taking benefits from both pastoralism as well as ecotourism. It was observed that providing alternative livelihood support was only sufficient to substantially wean away the herders and not the ranchers whose greed was involved and not need. Hence it was realized that only providing livelihood support was not sufficient. Consequently advocacy with the policy makers of the state was carried out and they were sensitized regarding the impacts of yak ranching. At the same time the local community of the village was mobilized to garner public support against yak ranching. The nine yak ranchers formed an association and lobbied with the policy makers to purchase their livestock at Rs 16,000/yak. The 500 ex-herders opposed this move and demanded that if this was the case, then even they should be compensated since they had removed their livestock from the forests voluntarily.

This lobbying and counter lobbying succeeded in bringing about a new yak herding policy which banned the grazing of yaks in the reserve forests of West Sikkim. The conservation equation had now changed, the local community was mobilized, the policy makers were sensitized and the forest department was activated (Figure 6.4).

Figure 6.4: Pastoral management strategies applied in KNP in 2005 and 2006



6.6.3 Participatory law enforcement

"The state government has recently reviewed the impact of "Ban on grazing in Reserve Forests" and removal of cattle-sheds. The Department has been appreciated for its efforts for removing of large numbers of cattle-sheds in different districts which has resulted in improving the status of forests, water sources and wildlife. However no progress has been made in the eviction of yaks (and their hybrids) from West and East Sikkim. This has resulted in not only in deterioration of the temperate and alpine forests

and degradation of the wildlife habitats but has also generated heartburn amongst the cow-herders whose cattle-sheds have been removed from the forests.

Yak ranching is a recently introduced landuse, and yaks are exotic to West and East Sikkim. About 1200 yaks (and hybrids) are currently in West Sikkim itself and migrate between Khangchendzonga National Park, Barsey Sanctuary and the adjoining reserve forests. Impacts include use of Rhododendron and Juniper firewood in large quantities, poaching of wildlife, retaliatory persecution of wildlife, smuggling of endangered medicinal plants like kurki, jatamanshi, bikh etc for trade, trampling by yaks causing landslides, presence of ferocious dog disturbing ground nesting birds and smaller mammals. Large areas have been degraded specially in Yambong, Chewabhanjyang, Kalijhaar, Phalut and Thulo Dhaap.

Accordingly you are directed to take urgent action for the eviction of all the yaks and yak sheds from within West and East Sikkim by 31st March, 2006. The action should include dismantling of all the yaks sheds, sending the yaks back to their places of origin outside Sikkim, along with legal action against the yak owners and their caretakers" (excerpts from the forest secretary's directive to the law enforcement agencies).

In July 2006 a combined team of forest officers, armed police, magistrate and local NGOs carried out eviction of the yak ranchers from the forests and dismantled the cattle sheds. This exercise was facilitated by the forest department and surprisingly the local community took the lead.

6.6.4 Regulating trekking tourism

Tourism is an important means of achieving socio-economic development. However if not controlled properly, can have devastating and irreversible impacts on the environment, culture and identity of the people. Realizing these problems and the fact that the resources on which tourism is based are limited and fragile, there is an urgent need to develop the trekking industry based on the principle of sustainability.

There has been a growing concern regarding the impacts of trekking tourism on the fragile ecosystem and forests of the state. Main impacts relate to:

- Accumulation of non degradable waste
- Growing use of Rhododendron and Juniper firewood
- Pollution of water bodies like sacred lakes and streams due to camping

Though the trekking companies have adopted an ecotourism code of conduct, possibly due to increased competition and with an objective to maximize profits, often nature has been abused due to the above impacts. A regulation is needed to put the responsibility of the visitors and their support staff including porters, cooks and guides following the code of conduct, on the travel company organizing the trek. This will foster a more responsible tourism, making it binding on the travel agents and the trekkers to follow eco-friendly practices.

The camping right on the Samiti lake bank (Sungmteng Tsho) is rapidly degrading this sacred lake. Since the camping is on the lake, the visitors and support staff defecate on the lake bank and the pack animals are also all kept here. This is also the habitat for water birds and blue sheep. This site needs to be given higher conservation importance. The camping site should be shifted to Lamune, which is just a 20 minutes walk below the lake with water availability, and also being less windy, will ensure a more comfortable camping. This will also increase the value of the lake and preserve its sacredness.

6.6.5 **Participatory monitoring of the high altitudes** (locally known as *himal*)

Though most of lower and middle hill forests have been brought under the Joint Forest Management (JFMC/EDC) network, the upper hill forests of the Himalaya, inspite of determined efforts, still continue to be under inadequate management, beset with threats and need urgent interventions. The main threats being unregulated grazing, unplanned trekking tourism, hunting and trapping of wild animals, smuggling of medicinal and aromatic plants, lack of regular monitoring and less awareness amongst the security forces. Effective conservation of the *himal* by forest staff alone is very difficult due to its high altitude, remoteness, tough terrain, harsh climate and limited resources available.

Further lack of adequate infrastructure and facilities make every patrolling visit more like an expedition, with a large contingent of support staff and resultant high attendant costs.

The support of the villagers practicing traditional subsistence livelihoods here needs to be enlisted in conservation management. Such villagers, who are willing, need to be recognized as *Himal Rakshaks* (Honorary Mountain Guardians) and their capacity building done. Institutionalizing people's participation through *Himal Rakshaks* (honorary mountain guardians) for high altitude biodiversity monitoring is needed. There is an urgent need to involve pack animals operators, sheep herders, trekking support staff, ex-herders, ex-hunters, NGOs etc in conservation with duties, benefits, powers and capacity building. This joint initiative with the JFMC, EDC, shepherds and *Himal Rakshaks* will result in a more effective, participatory "on ground" conservation of the KNP jointly with the forest department.

6.7 Emerging trends

With the livelihood support from Yambong tourism and participatory law enforcement the number of *urangs* decreased from 469 to 15 between 2004 and 2006. The nepali yaks on the other hand reduced from 779 to 505 during this period (Table 6.3, Table 6.5). The pastoralists earned about Rs 8.00 lakhs by providing service as assistant guides and *dzo* pack animal operators between October 2005 and December 2006. With the substantial reduction in the number of cattle yak crossbreeds and yaks the livestock impact units in the temperate oak and subalpine conifer forests reduced from 16.6 to 7.7 LUdays/ha (Table 6.4).

The *Himal Rakshak* policy was notified by the government in February, 2006 and 21 *Himal Rakshaks* (mostly ex-pastoralists) were appointed and trained in biodiversity monitoring by the forest department and the local NGOs in 2006. The Yambong Singalila trekking trail along with the designated camping sites was approved as a part of the Singalila ecotourism promotion zone. The camping site at Samiti lake was shifted to Lamune which provided a more comfortable camping and at the same time reduced the impacts to the lake and the wildlife. The regulation of trekking was framed providing a legal basis to the code of conduct with penalties for the defaulters. Based on the recommendations of this study the State Government made the following policy changes which can be accessed from the forest department website at www.sikenvis.nic.in:

- Sikkim Wildlife (Regulation of Trekking) Rules 2005
- Singalila and Dzongu ecotourism promotion zones
- Lampokhri, Tekepla and Narsing MPCAs
- Inviolate conservation zones for Himalayan musk deer, Himalayan tahr, blue sheep and alpine pheasants
- Guidelines for the appointment of *Himal Rakshaks*
- Yak and yak crossbreeds eviction policy
- Shifting of tourist camping site from Samiti lake to Lamune

Table 6.3: Trend of livestock population in KNP from 1950 to 2006

Livestock type	**Population**			
	1950	**2000**	**2004**	**2006**
Banpaala sheep (GH)	8800	1500	1141	912
Tibetan sheep (TH)	1000	0	0	0
Cow (GH)	100	200	150	145
Buffalo (GH)	0	50	5	0
Nepalese yak (GH)	50	800	779	505
Tibetan yak (TH)	1000	750^{e}	850^{e}	944
Urang (GH)	0	600	469	15
Pack animal (*dzos* and horses) (GH)	60	175	316	434
Total livestock population	**11010**	**4075**	**3710**	**2955**
GH = Greater Himalaya, TH = Trans Himalaya, e = estimated				

Table 6.4: Livestock composition, stocking density (SD) and impact units (LIU) in the different watersheds in and adjacent to KNP in the year 2006

	Pasture Type	Watershed	Area (ha)	Yaks	Urang	Cow	Dzo	Horse	Sheep	LU	SD	Days	LIU
1	**Summer Pastures**												
	4000m - 5000m Greater Himalaya	Churong and Prek chu	15898	520	0	0	125	170	891	976	0.06	180.00	**11.1**
		Rimpi chu	5782	45	0	145	0	0	46	231	0.04	180.00	**7.2**
		Thumpyak chu	5449	20	0	0	0	0	0	18	0.00	0.00	**0.0**
	3500m - 4500m Greater Himalaya	Rimbi chu	2800	0	25	0	110	0	0	30	0.01	180.00	**1.9**
		Rangit chu	4723	0	0	0	0	0	180	59	0.01	180.00	**2.3**
		Zemu chu	6550	0	0	0	0	0	0	0	0.00	0.00	**0.0**
		Tista chu	6619	0	0	0	0	0	0	0	0.00	0.00	**0.0**
		Talung chu, Umram chu	12560	0	0	0	0	0	0	0	0.00	0.00	**0.0**
	4500m - 5500m Trans Himalaya	Lhonak chu (right bank)	15954	924	0	0	0	0	0	850	0.05	180.00	**9.6**
		Total	**76335**	**1509**	**25**	**145**	**235**	**170**	**1117**	**2165**	**0.03**	**95.34**	4.9
2	**Winter Pastures**												
	2500m - 3500m Greater Himalaya	Rimbi chu, Kalij chu, Rammam chu	16600	520	25	0	235	170	0	712	0.04	180.00	**7.7**
		Rimpi chu	1800	45	0	0	0	0	0	41	0.02	180.00	**4.1**
	4500m - 5500m Trans Himalaya	Lhonak chu (left bank)	31500	944	0	0	0	0	0	868	0.03	180.00	**5.0**
		Total	**49900**	**1509**	**25**	**0**	**235**	**170**	**0**	**1622**	**0.03**	**180.00**	**5.9**

Table 6.5: Trend of livestock biomass in KNP from 1950 to 2006

Livestock type	Biomass (metric tonnes)			
	1950	2000	2004	2006
Banpaala sheep (GH)	264	45	34	27
Tibetan sheep (TH)	30	0	0	0
Cow (GH)	30	60	45	44
Buffalo (GH)	0	15	2	0
Nepalese yak (GH)	13	200	195	126
Tibetan yak (TH)	250	188[e]	213[e]	236
Urang (GH)	0	210	164	5
Pack animal (*dzos* and horses) (GH)	21	61	111	152
Total livestock biomass	**608**	**779**	**763**	**590**

GH = Greater Himalaya, TH = Trans Himalaya, e = estimated

6.8 Discussion

Though the park has ample financial resources at its disposal, a major chunk of the total budget of the park is spent in afforestation, habitat improvement and infrastructure creation. Important sectors like livelihoods support to the herders and poachers, protection and research are not given adequate emphasis. For the first two and a half decades of its existence, inadequate staffing, absence of strong local partnerships and weak management capacity prevented the park management from implementing significant conservation initiatives within the park. The pastoralists used the park resources as per their wish and substantial manipulaton of the structure and composition of the pristine temperate and subalpine forests took place. To meet their fodder requirements of their growing herds during winter the pastoralists opened up *kharkas* or winter pastures by resorting to heavy lopping and removing the bamboo undergrowth in the temperate and sub-alpine forests which is the habitat for the endangered state animal - red panda.

Yak and cow-yak crossbreed herding and trade in medicinal and aromatic plants were the main source of livelihood for the agro-pastoral communities. Broadly there were two social classes in the village, the herders or those who lead subsistence pastoral livelihoods and the ranchers who owned large yak herds. These herders used to barter their dairy products for rations, and this trade was monopolized by the yak ranchers. With better communication and expanding markets the dairy business soon became lucrative. Also the yak ranchers started playing an active role in village and state level politics. Concerns were raised about the environmental impacts of pastoralism including use of firewood in large quantities, retaliatory persecution of wildlife, smuggling of valuable medicinal plants and opening up of the canopy to create artificial winter pastures.

In 2004 with the support of The Mountain Institute, a non-profit conservation and education organization, skill development, income generation and institution building activities were taken up in partnership with the forest department and the villagers. Yambong tourism started flourishing and the herders with these new options for income generation were amenable to voluntarily shift away from high impact pastoralism. The ranchers however continued to enjoy benefits from pastoralism as well as from the new livelihoods. The ex-herders, villagers and local NGOs united and cooperated in advocating for the removal of ranchers from within the national park. This democratic force brought about a change in the grazing policy of the government and yak and milch cow-yak crossbreed grazing was banned within the national park. The implementation of this ban is currently underway and the yak population declined by 35% and milch cow-yak crossbreed by 97% between 2004 and 2006. The vision for 2008 is to further reduce the population of Nepalese yaks to less than 300 and at the same time generate annual incomes of more than Rs 20 lakhs for the local community from Yambong tourism from about 400 tourists.

6.9 Conclusions

The conservation implications based on the findings of the present study are:

- Landscape indices aggregated at the watershed level gave interesting insights on how the inherent properties like relief, glaciations, rain-shadow and orientation affect landscape characteristics.
- This is amongst the first initiatives to classify the alpine vegetation of Eastern Himalaya. In India while traditionally plant scientists focused on creating plant

taxonomic inventories, over the last few decades landscape level vegetation mapping which is rapid and cost effective is gaining popularity. Between these bottom up and top down approaches, vegetation classification at the community level needs to be strengthened to bridge the knowledge gap between species and landscapes. There is a need for a national vegetation classification that will standardize the methods for vegetation sampling, analysis and peer review. Collaboration with the British and USA National Vegetation Classification (http://plants.usda.gov/, www.vegbank.org) will be useful in this regard. This will establish a long term monitoring protocol for vegetation in the country and facilitate mining of existing data from different sources.

- An integrated model to map the ecological and social aspects of pastoralism was prepared. This model indicated that the yak and cattle yak crossbreeds (*urang*) had relatively more conservation impacts specially in the sub-alpine and temperate forests and the benefit sharing was socially inequitable relative to the sheep and pack animal pastoral systems. This integrated approach has a lot of potential for influencing policy makers.
- Long term studies are needed to assess the impact of reducing livestock populations on the vegetation and wildlife. Intensive studies on the ecology of the sensitive species in the conservation zones also need to be taken up.

Some of the lessons learnt from the management experiments are as follows:

1. The general practice when it comes to managing pastoralism is to regulate the livestock numbers based on the carrying capacity. However at the village level issues of incomes and benefit sharing (social carrying capacity) were equally important. The people were concerned about issues like who owns the livestock and what are the incomes ? i.e. equity in benefit sharing was an important issue of concern other than ecological impacts.
2. Alternative livelihoods provided worked very well for satisfying needs but not greed. It was initially envisaged that with increasing alternate incomes from Yambong tourism the herders and ranchers would voluntarily give up pastoralism. However only the herders who had subsistence level incomes were amenable to this livelihood

change. While the yak ranchers garnered benefits from both ecotourism as well as pastoralism.

3. Earlier pastoralism was the major landuse in the alpine landscape. Only the herders accessed the high altitudes, but when trekking tourism was initiated a large section of the villagers also started getting benefits from this common property resource. Community based tourism emerged as a competing landuse for yak ranching and being more equitable and broad based created a strong people's force for the conservation of the resource (alpine landscape) on which it was based.
4. A strong political will is necessary for taking up long term conservation initiatives. The state of Sikkim is blessed with a political leadership which is very keen to conserve its natural resources. This support from the highest level is a must to implement conservation measures which bear long term benefits.

Creating national parks bound by strict national laws and providing adequate funding support is not sufficient to secure their future. The challenge of using these funds to forge partnerships with the local community, providing livelihood support for subsistence level of dependencies and forcing out commercial level of dependencies has to be met. Multi-disciplinary ecological and socio-economic research is needed to distinguish between the need and greed based livelihoods and their impacts. Such studies will provide a basis for shaping political will which is vital for bringing about change.

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Annexure 1: List of vascular plants recorded form the alpine zone of KNP

Family / Scientific Name*	Collection Number / Photo	Use / Remarks
GYMONSPERMS		
Abies densa Griff.	photo-198	Timber
Ephedra gerardiana Stapf. *var. sikkimensis* Stapf.	32758	Medicinal
Juniperus indica Bert.	photo-406	Incense
Juniperus recurva D. Don	28974/32419	Incense
Juniperus squamata D. Don	site record	Fuelwood
Larix grifithiana Carr.	site record	Timber
Tsuga dumosa (D.Don) Eich.	photo-199	Timber
ANGIOSPERMS		
Ranunculaceae		
Aconitum bisma (Ham.) Rapaics		Medicinal / Poisonous
Aconitum ferox Seringe	photo-373	Extremely poisonous
Aconitum gammiei Stapf		
Aconitum gymnandrum Maxim.		
Aconitum heterophylloides (Bruhl.) Lauen.		
Aconitum hookeri Stapf.	32544/32724	Medicinal
Aconitum laciniatum (Bruehl.) Lauen.		
Aconitum nakaoi Tamura		
Aconitum naviculare (Bruehl.) Stapf.		
Aconitum novoluridum Munz.		
Aconitum spicatum (Bruhl.) Stapf.	32459	Poisonous
Actaea acuminata Royle	site record	
Anemone demissa Hk.f. & T.	site record	
Anemone griffithii Hk.f. & T.		
Anemone obtusiloba D. Don	site record	
Anemone polyanthes D. Don	28925	
Anemone rivularis DC.	site record	
Anemone rupestris Hk.f. & T.		
Anemone rupicola Camb.		
Anemone smithiana Laune. & Panigr.		
Anemone trullifolia Hk.f. & T.	photo-517	
Anemone vitifolia	28993	
Callianthemum pimpenelloides (D. Don) Hk.f. & T.		
Caltha palustris L.	28918	Medicinal
Caltha scaposa Hk.f. & T.	photo-6203	
Cimicifuga foetida L.		
Clematis buchananiana DC	site record	
Clematis montana DC.	28935	
Clematis tongluensis (Bruehl.) Tamura		
Clematis zemuensis WW Sm.	photo-6843	
Delphinium candelabrum Ostenf.		
Delphinium caeruleum Camb.	32710	
Delphinium drepanocentrum (Bruhl.) Munz.		

Delphinium glaciale Hk.f. & T.	32786	Medicinal
Delphinium ludlowii Munz.		
Delphinium viscosum Hk.f. & T.	32558	
Oxygraphis endlicheri (Walp.) Bennet & Chandra	site record	
Paraoxygraphis sikkimensis WW Sm.		
Ranunculus adoxifolius Hand. - Mazz.	site record	
Ranunculus brotherusii Freyn.	site record	
Ranunculus hirtellus D. Don	32455	
Ranunculus pegaeus Hand.-Mazz.		
Ranunculus pulchellus Mey.	site record	Ripened fruit used as chilly
Ranunculus sarmentosus Adams.	site record	
Ranunculus sikkimensis Hand.- Mazz.		
Ranunculus trichophyllus Chaix	site record	
Ranunculus tricuspis Maxim.	site record	
Souliea vaginata Franch.		Syn - *Coptis ospriocarpa*
Thalictrum alpinum L.	site record	
Thalictrum chelidonii DC.	site record	
Thalictrum cultratum	29073	
Thalictrum platycarpum Hk.f. & T.	site record	
Thalictrum elegans Wall. ex Royle	site record	
Thalictrum foetidum L.		
Thalictrum minus L. var. majus	site record	
Thalictrum reniforme Wall.	site record	
Thalitcturm rutifolium Hk.f. & T.		
Thalictrum secundum Edgew.		
Thalictrum setulosinerve Hara		
Thalictrum virgatum Hk.f. &T.		
Thalictrum sp.1	32490	
Trollius pumilus D. Don	site record	
Berberidaceae		
Berberis angulosa Hk.f. & T.	site record	
Berberis concinna Hk.f. & T.	site record	
Berberis hookeri Lemaire		
Berberis insignis Hk.f. & T.	28975	
Berberis macrosepala Hk.f. & T.	site record	
Berberis thomsoniana Schneid.		
Berberis tsarica Ahrendt.		
Berberis umbellata var. branii	site record	
Berberis virescens Hk.f.		
Podophyllaceae		
Podophyllum hexandrum Royle	site record	Medicinal
Circaeasteraceae		
Ciraeaster agrestis Maxim		Rare; Botanical Interest
Papavaraceae		
Cathcartia villosa Hk.	32438	Syn - Meconopsis villosa

Meconopsis bella Prain	site record	ll. M. aculeata slender, less prickly
Meconopsis discigera Prain	29029	
Meconopsis grandis Prain		
Meconopsis horridula Hk.f. & T.	29067/32738	Medicinal
Meconopsis lyrata (Cummins & Prain.) Prain		
Meconopsis paniculata Prain	28939	
Meconopsis simplicifolia (D. Don) Walp.	28924	
Meconopsis sinuata Prain		
Meconopsis superba Prain		
Fumariaceae		
Corydalis cashmeriana Royle	28964	
Corydalis cavei Long		
Corydalis chaerophylla DC.	photo-6451	
Corydalis changuensis Long		
Corydalis crispa Prain		
Corydalis dubia Prain		
Corydalis ecristata (Prain) Long	site record	
Corydalis filicina Prain		
Corydalis flaccida Hk.f. & T.	20944	
Corydalis graminea Prain		
Corydalis hendersonii Hems.	site record	
Corydalis juncea Wall.	photo-6730	
Corydalis laelia Prain		
Corydalis lathyroides Prain	site record	
Corydalis latiflora Hk.f. & T.		
Corydalis longipes DC.	site record	
Corydalis meifolia Wall.	site record	
Corydalis ophiocarpa Hk.f. & T.		
Corydalis polygalina Hk.f. & T.		
Corydalis sikkimensis (Prain) Fedde		
Corydalis stracheyi Prain		
Corydalis trifoliata Franch	photo-6434	
Fumaria capreolata L.		
Hypecoum leptocarpum Hk.f. & T.	site record	
Brassicaceae		
Aphragmus oxycarpus (Hk. f. & T.) Jafri		
Arabidopsis himalaica (Edgew.) Schulz.	site record	
Arabidopsis lasiocarpa Schulz.		
Arabidopsis mollissima (Mey) Schulz	site record	
Arabis glandulosa Kar. & Kir.		
Arabis pterosperma Edgew.		
Arcyosperma primulifolium (Toms.) Schulz	site record	Syn *Eutrema primulifolium*
Barbaraea elata Hk.f. & T.	photo-6163	
Barbaraea intermedia Boreau	photo-6154	Syn B. vulgaris var. sicula
Braya tibetica Hk. f. & T.		
Capsella bursa-pastoris (L.) Medik.		
Cardamine grifithii Hk.f. & T.		
Cardamine impatiens L.		

Cardamine loxostemonoides O. Schulz.	site record	Syn C. pratensis L.
Cardamine macrophylla Willd.	photo-6301	Used as vegetable
Cardamine trifoliata		
Cardamine violacea		
Christolea himalayensis Camb.		
Cochlearia himalaica Hk. f. & T.		
Descuraina sophia (L.) Webb. ex Prantl.	site record	Sisymbrium sophia L.
Dilophila salsa Thoms.		
Dontostemon glandulosus (Kar. & Kir.) Schulz.	site record	
Draba altaica (C. A. Meyer) Bunge	site record	
Draba cholaensis WW Sm		
Draba elata Hk.f. & T.		
Draba ellipsoidea Hk.f. & T.		
Draba eriopoda Turcz.		
Draba gracillima Hk. f. & T.	site record	
Draba humillima O. Schulz		
Draba lanceolata Royle		
Draba lasiophylla Royle - 2 vars.	site record	
Draba oariocarpa O. Schulz		
Draba oreades Schrenk	site record	
Draba polyphylla O. Schulz		
Draba sikkimensis		Syn D. tibetica var. sikkimensis
Draba stenobotrys	site record	
Draba tibetica Hk. f. & T.		
Erysimum deflexum Hk.f. & T.		
Erysimum funiculosum		
Erysimum hieracifolium L.	site record	
Erysimum longisiliquum		
Erysisum pachycarpum Hk. f. & T.		
Eutrema deltoideum (Hk.f.&T.) Schulz		
Eutrema himalaicum Hk.f. &T.	site record	
Hedinia tibetica (Thoms.) Ostenf.	site record	
Lepidium apetalum Willd. [L. ruderale]	site record	
Lepidium capitatum Hk. f. & T.	site record	Used as vegetable
Lepidostemon pedunculosus Hk.f. & T.		
Lignariella hobsonii (Pearson) Baehl.	28968	Syn Cochlearia hobsonii
Loxostemon pulchellus Hk.f & T.		
Microsisymbrium axillare (Hk. f. & T.) Schulz.		Syn Guillenia axillare (Hk.f. & T.) Bennett
Parrya nudicaulis (L.) Boiss.	site record	
Parrya platycarpa Hk.f. & T.		
Pegaeophyton minutum Hara		
Pegaeophyton scapiflorum (Hk. f. & T.) Marq. et Shaw	photo-6162	
Pycnoplinthopsis bhutanica Jafri		Syn Pegaeophyton bhutanicum Ham.
Sisymbrium himalaicum Hk.f. & T.	29038	
Thlaspi alpestre L.	site record	
Thlaspi andersonii (Hk. f. & T.) O. Schulz		
Thlaspi arvense L.	site record	
Thlaspi cochlearioides Hk. f. & T.		

Thlaspi montanum L.		T. cochleariforme = T. alpestre
Torularia humilis (C. A. Mey) Schulz		
Violaceae		
Viola biflora L.	28914	
Viola bulbosa Maxim		
Viola kunawarensis Royle	site record	Medicine
Viloa pilosa Bl.		
Caryophyllaceae		
Arenaria bryophylla Fernald	site record	
Arenaria ciliolata Edgew.	site record	
Arenaria debilis Hk.f. & T.		
Arenaria densissima Wall.ex Edgew.	site record	
Arenaria depauperata (Edgew.) Hara		
Arenaria edgeworthiana Majumdar	site record	
Arenaria ferruginea Duthie ex Williams		
Arenaria festucoides Benth.		
Arenaria glanduligera Edgew.		
Arenaria littledalei Hemsley		Syn A. thangoensis
Arenaria melandryiformis Williams		
Arenaria melandryoides Edgew. & Hk.f.		
Arenaria orbiculata Royle ex Edgew.		
Arenaria oreophila Hk.f. &T.		
Arenaria polytrichoides Edgew. & Hk.f.		
Arenaria pulvinata Edgew. & Hk.f. & T.	site record	
Arenaria stracheyi Edgew.		
Cerastium fontanum Baumg		Syn C. vulgatum
Cerastium glomeratum Thuill.		
Gypsophila cerastioides D. Don	site record	
Holosteum umbellatum L.		
Lepyrodiclis holosteoides (Meyer) Frenzl		
Pseudostellaria heterantha (Maxim.) Pax		Syn. Stellaria bulbosa
Sagina japonica (Sw.) Ohwi		
Sagina saginoides (L.) Karsten		S. procumbens
Silene amoena L. [S. tenuis Willd.]		
Silene bhutanica (W Sm) Majumdar		S. indica var. bhutanica
Silene caespitella Williams		
Silene gonosperma (Rupr.) Bocquet	20941/32800	
Silene griffithii Boiss		
Silene indica Otth		
Silene nigrescens (Edgew.) Majumdar	32714	
Silene songarica (Fisch., Mey & Ave-Lall) Bocq.		
Silene stracheyi Edgew.		
Stellaria congestiflora Hara		
Stellaria decumbens Edgew.	photo-668	
Stellaria lanata Edgew. & Hk.f.		
Stellaria monosperma Buch.- Ham. ex D. Don		
Stellaria palustris Retz. [S. glauca With.]		
Stellaria patens D. Don		

Stellaria subumbellata Edgew. ex Hk.f.		
Thylacospermum caespitosum (Camb.) Schischk.	site record	
Tamaricaceae		
Myricaria rosea W.W. Sm.	28956	
Hypericaceae		
Hypericum choisianum Robson	photo-6080	Syn H. hookerianum
Hypericum himalaicum Robson	site record	
Hypericum monanthemum Dyer		
Hypericum reptans Dyer		
Coriariaceae		
Coriaria terminalis	photo-6468	
Geraniaceae		
Geranium collinum M. Bieb	site record	
Geranium donianum	28948	
Geranium lambertii Sw.		
Geranium nakaoanum Hara	32708	
Geranium polyanthes Edgew.		
Geranium sp.1	site record	
Oxalidaceae		
Oxalis leucolepis Diels		
Balsaminaceae		
Imaptiens kingii Hk.f.	photo-1159	Syn I. gamblei
Impatiens falcifer Hk.f.	photo-6878	
Impatiens gammiei Hk.f. & T.		
Impatiens laxiflora Edgew.		
Impatiens occultans Hk.f.		
Impatiens sulcata	32489	
Impatiens tuberculata		Syn I. agantantha
Aquifoliaceae		
Ilex intricata	32416	
Celastraceae		
Euonymus frigidus Wall.		
Aceraceae		
Acer caudatum	photo-6410	Fuel wood
Fabaceae		
Astragalus acaulis Baker		
Astragalus concretus		
Astragalus kongrensis	site record	
Astragalus lessertoides		
Astragalus ridigulus		
Astragalus sikkimensis		

Astragalus strictus	site record	
Astragalus tongolensis		
Astragalus zemuensis		
Chesneya nubigena	photo-6683	Syn *Spongiocarpella purpurea*
Gueldenstaedtia himalaica	29015	
Hedysarum sikkimense	29017/32771	
Oxytropis arenae-ripariae	29037	
Oxytropis lapponica		
Oxytropis sericopetala	photo-6168	
Parochetus communis		
Piptanthus nepalensis	site record	
Stracheya tibetica	site record	
Thermopsis barbata	site record	
Rosaceae		
Brachycaulos simplicifolius **D**ixit & Panig.		Rare/ Endemic
Cotoneaster acuminatus	site record	
Cotoneaster microphyllus	site record	
Cotoneaster simonsii Baker	site record	
Fragaria daltoniana	site record	
Fragaria nubicola	site record	Fruits edible
Geum elatum G. Don		
Geum macrosepalum Ludlow		
Geum sikkimense Prain		
Potentilla anserina L.	site record	
Potentilla arbuscula	29016	Syn P. fruticosa
Potentilla argyrophylla		
Potentilla biflora Willd. Ex Schlech.	site record	
Potentilla bifurca L.	site record	
Potentilla calliginosa Sojak		
Potentilla coriandrifolia	28967	
Potentilla cuneata Leh.		
Potentilla eriocarpa	site record	
Potentilla eriocarpoides Karuse		
Potentilla forrestii W.W. Sm.		
Potentilla fruticosa	32506	
Potentilla latipetiolata		
Potentilla leuconota	28908	
Potentilla microphylla	29018	
Potentilla monanthes Lehm.		
Potentilla nivea	29084	
Potentilla peduncularis - 3 vars.	29034/32709	
Potentilla polyphylla Lehm		
Potentilla pterocarpa		
Potentilla saundersiana Royle	site record	
Potentilla spodiochlora Sojak		
Prunus cornuta	32508	Fuel wood; Fruits edible
Prunus rufa	site record	
Rosa sericea	29035	
Rubus fragaroides Bert.		

Rubus hypargyrus	32417	
Rubus sikkimensis Hk.f.		
Sanguisorba diandra (Hk.f.) Nordborg	photo-6472	Syn Poterium diandrum
Sanguisorba filiformis (Hk.f.) Hand.-Mazz.	site record	
Sibbaldia compacta		Endemic to Sikkim
Sibbaldia macropetala Murav.		
Sibbaldia micropetala		
Sibbaldia parviflora Willd.	site record	Syn S. cuneata
Sibbaldia perpusilla		
Sibbaldia perpusilloides		
Sibbaldia purpurea	site record	
Sibbaldia sikkimensis		
Sibbaldia trullifolia		
Sorbus arachnoides Koehn.		Syn - S. foliolosa auct.
Sorbus microphylla Wenz.	32448	
Sorbus prattii Koehn		
Spiraea alpina		Syn - S. ulicina
Spiraea arcuata	28934	
Spiraea bella	site record	
Saxifragaceae		
Bergenia purpurascens (Hk.f. & T.) Engler	28973	
Chrysosplenium carnosum Hk.f. & T.	site record	
Chrysosplenium forrestii Diels		
Chrysosplenium grifithii Hk.f. &T.		
Chrysosplenium nudicaule	29048	
Chrysosplenium sigalilense Hara		
Saxifraga andersonii	29068	
Saxifraga aristulata Hk.f. & T.		
Saxifraga asarifolia Sternb.	site record	
Saxifraga brachypoda D. Don	site record	
Saxifraga brunonis		
Saxifraga caveana W.Sm.	32794	
Saxifraga chumbiensis Engl. & Irm.		
Saxifraga clivorum H. Sm.		
Saxifraga coarctata W. Sm.		
Saxifraga cordigera	_	Syn S. palpebrata
Saxifraga diversifolia	photo-6727	
Saxifraga dungbooii Engl. & Irmsch.		
Saxifraga elliptica Engl.& Irm.		
Saxifraga engleriana	29025/32796	
Saxifraga fastigiata	28902	
Saxifraga filicaulis Seringe		
Saxifraga flagellaris	site record	
Saxifraga gageana W.W. Sm.		
Saxifraga georgei Anth.		
Saxifraga glabricaulis H. Sm.		
Saxifraga granulifera H. Sm.		
Saxifraga hemisphaerica		
Saxifraga hispidula	site record	
Saxifraga hookeri Engl. & Irm.		

Saxifraga inconspicua W. Sm.		
Saxifraga jacquemontiana Decne	32711	
Saxifraga kinchingingae Engle.		
Saxifraga kingiana Engl. & Irm.		
Saxifraga latiflora Hk.f. & T.		
Saxifraga llonakhensis W.W. Sm.		
Saxifraga lychintis Hk.f. &T.	photo-6786	
Saxifraga melanocentra	32799	
Saxifraga microphylla Hk.f. & T.		
Saxifraga montana H. Sm.		
Saxifraga moorcroftiana		
Saxifraga mucronulata	29040	
Saxifraga nigroglandulifera Balak.	site record	Synb S. nutans
Saxifraga pallida	site record	
Saxifraga parnassifolia		
Saxifraga perpusilla Hk.f.& T.		
Saxifraga pilifera		
Saxifraga pluviarum W.W. Sm.		
Saxifraga pseudopallida		
Saxifraga pulvinaria	photo-6418	
Saxifraga punctulata Engler	32766	
Saxifraga saginoides	29026/32711	
Saxifraga sikkimensis		
Saxifraga sphaeradena H. Sm.		
Saxifraga stella-aurea Hk.f. & T.		
Saxifraga subsessiliflora Engl. & Irm.		
Saxifraga subspathulata		
Saxifraga tentaculata Fisch.		
Saxifraga umbellulata		
Saxifraga viscidula Hk.f. &T.		
Parnassiaceae		
Parnassia cabulica	29076	
Parnassia chinensis		
Parnassia nubicola	site record	Medicinal
Parnassia pusilla Arnott.	photo-6499	
Parnassia tenella		
Parnassia wightiana Wt & Arn.	photo-6534	
Grossulariaceae		
Ribes acuminatum G. Don	site record	Wild Edible Fruit
Ribes alpestre Decne	site record	Syn R. grossularia
Ribes glaciale	site record	Wild Edible Fruit
Ribes laciniatum Hk.f. &T.	site record	
Ribes luridum Hk.f. & T.		
Ribes orientale	32761	Wild Edible Fruit
Crassulaceae		
Cotyledon ewersii	site record	
Rhodiola atsaensis (Frod.) Ohba		
Rhodiola bupleuroides Wall ex Hk. f. & T.	32439	

Rhodiola chrysanthemifolia	photo-805	Syn *Sedum linearifolium Royle*
Rhodiola coccinea		
Rhodiola crenulata (Hk.f.&T.) Ohba		
Rhodiola fastigiata	photo-6780	
Rhodiola himalensis	29027	S. quadrifidum var. himalense
Rhodiola hobsonii		
Rhodiola humilis		
Rhodiola sherriffii		
Rhodiola smithii		
Rhodiola stapfii		
Rhodiola wallichiana (Hk.) Fu	site record	
Rhodioloa cretinii	site record	
Sedum gagei Hamet		
Sedum oreades (Decne) Hamet	site record	
Sedum triactina Berger		
Sedum trullipetalum Hk.f. & T.		
Hippuridaceae		
Hippuris vulgaris	32728	
Onagraceae		
Circaea alpina	site record	
Epilobium alpinum L.		
Epilobium latifolium	32443	
Epilobium origanifolium Lamk.	site record	
Epilobium reticulatum Cl.	site record	
Epilobium speciosum	photo-6277	
Epilobium wallichianum	32433	
Apiaceae		
Angelica officinalis	site record	Medicinal
Bupleurum 1	site record	Poisonous for yaks
Bupleurum 2	site record	
Bupleurum longicaule	28927	
Cortiella hookeri Cl.	29008	
Heracleum 1	site record	
Heracleum nubigenum Cl.	photo-6288	
Heracleum sublineare Cl.	site record	
Pimpinella hookeri	site record	
Pituranthos acronemaefolia Cl.		Valuable forb
Pituranthos bella Cl.		Valuable forb
Pituranthos hookeri Cl.	site record	Valuable forb
Pleurospermopsis sikkimensis	28982	Valuable forb
Pleurospermum apiolens Cl		
Pleurospermum hookeri	photo-716	
Selenium tenuifolium	site record	Medicinal
Selinium wallichii	20942	
Trachydium 1	site record	Valuable forb
Trachydium dissectum Cl.	site record	Valuable forb
Trachydium hirsutum Cl.		

Trachydium novum-jugum Cl.		
Trachydium obtusiusculum Cl.		
Vicatia cuneifolia	site record	
Araliaceae		
Panax pseudo-ginseng Wall.	photo-6320	Potential for future medicine
Caprifoliaceae		
Lonicera acuminata Wall.	site record	
Lonicera angustifolia Wall.	photo-6326	Fuel wood
Lonicera decipiens Hk.f. &T.	site record	
Lonicera hispida Pall.	32759	
Lonicera litagensis Batal.		
Lonicera myrtillus	32456	
Lonicera obovata	32768	
Lonicera rupicola Hk.f. &T.		Fuel wood
Lonicera spinosa Jacq.	site record	Fuel wood
Lonicera tomentella Hk.f.& T.	site record	
Triosteum himalayanum	photo-6838	Endemic to Himalaya
Viburnum erubescens DC.	site record	
Viburnum nervosum	32411	Fuel wood
Hydrangeaceae		
Hydrangea aspera	site record	
Rubiaceae		
Galium aparine L.		
Galium exile Hk.f.		
Galium acutum Edgew.		
Valerianaceae		
Nardostachys grandiflora	32469	Used in treating internal body pain
Valeriana hardwickii	site record	
Valeriana wallichii	site record	Incense; Medicinal
Dipsacaceae		
Dipsacus atratus Hk.f. & T.		
Dipsacus inermis	site record	
Morina delavayi Franch.		
Morina polyphylla DC.	site record	
Morina longifolia DC.		
Morina nepalensis	32458/32783	
Scabiosa hookeri Cl.	32723	
Asteraceae		
Anaphalis cuneifolia (DC.) Hk	site record	
Anaphalis deserti Drumon		
Anaphalis desertii Drumm		
Anaphalis hookeri Cl.		
Anaphalis margaritacea (L.) Benth.		

Anaphalis nepalensis (Spreng.) Hand.-Mazz.	32712	
Anaphalis royleana DC. - 3 vars		
Anaphalis subumbellata Cl.		
Anaphalis triplinervis	32515	
Anaphalis xylorhiza Sch.-Bip	32712/32750	
Artemisia biennis Willd.	site record	
Artemisia campbellii Cl		
Artemisia desertorum Spreng.		
Artemisia minor Jacq.	site record	
Artemisia parviflora D.Don	site record	
Artemisia stricta Edgew. non Heyne ex DC.		
Aster albescens (DC.) Hand.-Mazz.		Syn *Microglossa albescens* Cl.
Aster asteroides (DC.) O. Ktze. ssp. *asteroides*	site record	
Aster diplostephoides (DC.) Cl.	32756	
Aster flaccidus Bunge ssp. *flaccidus*	photo-6205	Syn A. tibeticus Hk. f. p.p
Aster heliopsis Griers.		
Aster himalaicus Cl.	site record	
Aster polycepsis Chen.		
Aster stracheyi Hk. f.	site record	
Aster tricephalus Cl.		
Brachyaactis anomala (DC) Kitam.	site record	
Carpesium cernuum L.		
Carpesium scapiforma Chen & Hu		
Cavea tanguensis (Drumm) W.W. Sm.		
Chrysanthemum atkinsonii Cl	site record	
Cicerbita lessertiana DC.	site record	
Cicerbita macrantha	site record	
Cirsium eriophoroides (Hk. F) Petak	photo-6409	
Cirsium falconeri (Hk. f.) Petrak	site record	
Cirsium verutum (D.Don) Spreng.	site record	Cnicus involucratus DC
Cremanthodium 1	site record	
Cremanthodium cremanthodioides	32713A	
Cremanthodium decaisnei Cl. - 2 vars.	site record	
Cremanthodium disoideum Maxim.		
Cremanthodium ellisii (Hk.f) Kitam.	site record	
Cremanthodium oblongatum Cl.		
Cremanthodium palmatum - 3 ssp.		
Cremanthodium pinnatifidum Benth.		Senecio himalayensis
Cremanthodium reniforme	28984	
Cremanthodium thomsonii	site record	
Cremantodium retusum (DC) R. Good		
Crepis tibetica Babc.		
Doronicum roylei DC	site record	
Dubyaea hispida	site record	
Erigeron acer L. [E. alpinus L]	site record	
Erigeron alpinus var. *multicaulis* Hk. f.	site record	
Erigeron andryaloides (DC.) Cl.		
Erigeron bellidioides Cl.		
Erigeron ellisii Hk f.		
Erigeron kumaonensis (Vierh.) Wendel		

Erigeron monticolus DC.		
Erigeron multiradiatus (DC.) Benth. & Hk.f.	site record	
Erigeron patentisquana Cl.ex. Jeff.		Syn E. alpinus var. patentisquama
Gerbera nivea (DC.) Sch.– Bip.	site record	
Heterpappus gouldii (Fisch) Griers.		
Hypochoeris radiata L.		
Inula macrosperma Hk.f.		
Jurinea cooperi Anthony		
Lactuca bracteata Hk.f. & T.	site record	
Lactuca cooperi Anth.		
Leibnitzia nepalensis (Kuntze) Kitam.	site record	
Leibnitzia ruficoma (Franch) Kitam.		
Leontopodium 1	site record	
Leontopodium 2	site record	
Leontopodium alpinum Cass.		
Leontopodium haastioides Hand.-Mazz.	photo-6221	
Leontopodium himalayanum DC	photo-6612	
Leontopodium jacotianum P. Beauv.	site record	
Leontopodium monocephalum Edgew.	photo-6592	
Leontopodium nanum (Hk. f & T.) Hand.-Mazz.	photo-6722	
Ligularia 1	site record	
Ligularia amplexicaulis DC. [Senecio amplexicaulis]	site record	
Ligularia hookeri		Syn *Doronicum hookeri*
Ligularia kingiana (WW Sm) R. Mathur		
Ligularia mortoni	32418	Fodder for wild herbivores
Nannoglotis hookeri (Hk.f.) Kitam.		
Prenanthus scandens Hk.f. & T.	site record	
Prenanthus sikkimensis Hk. f.		
Pseudognaphalium affine (D Don) Anders.		
Saussuera cf. sericea Chen & Liang		
Saussuera donkiah Sprig		
Saussurea andersonii Cl.		
Saussurea auriculata Sch - Bip.	site record	Syn *S. hypoleuca* Spreng
Saussurea caespitosa var. depressa		
Saussurea candolleana Cl.		
Saussurea gossypiphora D. Don - 3 Vars.	32477/32795	Wool used as cotton substitute
Saussurea graminifolia Wall. ex. Hk. f.	site record	
Saussurea hookeri Cl.		
Saussurea katochaete Maxim		
Saussurea laneana WW Sm		
Saussurea leontodontoides	32535a	
Saussurea nepalensis Spreng	site record	
Saussurea nishiokae Kitam	site record	
Saussurea obscura Lipsc.	site record	
Saussurea obvallata (DC.) Sch.-Bip.	photo-6412	
Saussurea pachyneura Franch.		
Saussurea pantlingiana WW Sm		
Saussurea piptatera Edgew.		
Saussurea polystechoides Hk f.		

Saussurea simpsoniana Lipsch.	site record	
Saussurea spicata Kitam.		
Saussurea stella Maxim	32717	
Saussurea sughoo Cl.	site record	
Saussurea taraxacifolia Wall. ex DC.	32792	
Saussurea tridactyla	20966	
Saussurea uniflora (DC.) Wall	32553/32725	
Saussurea wernerioides Sch.- Bip. ex Hk. f		
Saussurea yakla Cl.		
Senecio acuminatus Wall. Ex DC.		
Senecio alatus DC.		
Senecio albopurpureus Kitam.		
Senecio bilugulatus WW Sm		
Senecio candolleanus Wall. ex DC.	site record	
Senecio chenopodifolius DC.		
Senecio chola WWSm		
Senecio graciliflorus DC.	site record	
Senecio kumaonensis Duthie ex Jef.		
Senecio laetus Edgew.	photo-6250	
Senecio raphanifolius Wall ex DC.		
Senecio royleanus DC		
Senecio tetrantha DC.		
Solidago virga-aurea L.		
Soroseris glomerata	site record	
Soroseris hookeriana (Cl.) Stebb.		
Soroseris pumila	32785	
Tanacetum dolichophyllum (Kitam) Kitam.		
Tanacetum gossypinum Hk.f. & T.	32787	
Tanacetum nubigenum Wall.	site record	
Tanacetum tibeticum Hk. f. & T. ex Cl.		
Taraxacum officinale Weber	site record	
Taraxacum sikkimense	site record	
Waldhemia glabra (Decne.) Regel	32716	
Youngia depressa (Hk.f.&T.) Babc.		
Youngia gracilipes (Hk. f.) Babc. & Steb	site record	
Youngia racemifera (Hk.f.) Babc.		
Youngia simulatrix Babc.		
Youngia stebbiana		Y. gracilis
Campanulaceae		
Campanula aristata Wall.	site record	
Campanula modesta	photo-6808	
Codonopsis benthami		
Codonopsis 1	29014	
Codonopsis affinis	site record	
Codonopsis foetans	site record	
Codonopsis subsimplex		
Codonopsis thalictrifolia	site record	
Cyananthus incanus	32555	
Cyananthus inflatus	site record	
Cyananthus microphyllus		

Cyananthus pedunculosus		
Cyananthus lobatus	site record	
Lobelia erecta Hk.f. & T		
Pyrolaceae		
Pyrola sikkimensis Krisa.	site record	
Ericaceae		
Cassiope fastigiata D. Don	28936	
Cassiope selaginoides Hk.f. &T.	photo-6546	
Diplarche pauciflora	photo-6543	
Gaultheria pyroloides Miq.	site record	Syn *G. pyrolifolia Cl*
Gaultheria trichophylla Royle	32406	
Pieris formosa (Wall.) D.Don	site record	Fuel wood
Rhododendron aeruginosum Hk.f.	site record	
Rhododendron anthopogon D. Don	28921	Incense
Rhododendron argipeplum Balf.		
Rhododendron baileyi Balf.		
Rhododendron barbatum G. Don	site record	Fuel wood
Rhododendron campanulatum	28940	
Rhododendron camelliflorum	site record	
Rhododendron campylocarpum	32410	
Rhododendron ciliatum	32414	
Rhododendron cinnabarinum	28931	
Rhododendron fulgens	32412	
Rhododendron glaucophyllum Rehder		Syn *R. glaucum* Hk.f.
Rhododendron hodgsonii	site record	
Rhododendron lanatum	site record	
Rhododendron lepidotum	28913	
Rhododendron nivale Hk.f.	site record	
Rhododendron pendulum Hk.f.		
Rhododendron pumilum Hk.f.		
Rhododendron setosum	28912	
Rhododendron thomsonii	28932	
Rhododendron triflorum Hk.f.	site record	
Rhododendron wallichii Hk.f.		
Rhododendron wightii	32409	
Vaccinium sikkimense	32413	
Diapensiaceae		
Diapensia himalaica Hk.f. & T.	photo-6714	
Primulaceae		
Androsace densissima	28988	
Androsace grandifolia		
Androsace hookeriana Klatt		
Androsace lehmanni Wall.		
Androsace sarmentosa	32496	
Androsace selago Hk.f. & T	photo-6441	
Androsace tapete	photo-6164	
Primula bellidifolia King		

Primula calderiana	site record	
Primula capitata	29002	
Primula caveana	28923	
Primula concinna Watt.		
Primula denticulata Sm.	site record	
Primula dickieana Watt.	32702A	
Primula elongata Wall.		
Primula elwesiana King		
Primula gambeliana Watt		
Primula glabra Klatt.		
Primula glomerata	site record	
Primula hookeri Watt.		
Primula involucrata Wall.	photo-6445	
Primula kingii Watt.		
Primula macrophylla	29086	
Primula muscoides Hk.f.		
Primula obtusifolia Royle - 2 vars.		
Primula petiolaris	28944	
Primula primulina	28942/32704	
Primula pulchra Watt		
Primula pusilla Wall.		
Primula reticulata Watt		
Primula sapphirina Hk.f. & T	site record	
Primula sikkimensis	28901	
Primula soldanelloides	29053	
Primula stirtoniana Watt.		
Primula stuartii Wall.	site record	
Primula tenella King		
Primula tenuiloba	32493	
Primula tibetica Watt.	photo-6200	
Primula uniflora Klatt.		
Primula vaginata Watt.		
Gentianaceae		
Crawfurdia puberula		
Crawfurdia speciosa Wall.	site record	
Gentiana amoena Cl.		
Gentiana carinata	site record	
Gentiana elwisii Cl.		
Gentiana infelix Cl.	site record	
Gentiana micans Cl.		
Gentiana nubigena Edge.	site record	Medicinal
Gentiana ornata Wall.	site record	Medicinal
Gentiana phyllocalyx Cl.	32702C/32706	
Gentiana recurvata Cl.		
Gentiana robusta	32731	
Gentiana sikkimensis Cl.		
Gentiana stipitata	32770	
Gentiana tubiflora Wall.	32798	
Gentiana venusta	32770	
Gentiana urnula	32702D	

Gentianella sp.	photo6575	
Helinia elliptica D. Don	site record	
Jaeschkea microsperma Clk.	site record	
Megacodon stylophorus	28922	
Lomatogonium sp.	site record	
Swertia ciliata Cl.	site record	Medicinal
Swertia cuneata Wall.	site record	
Swertia hookeri	32526	
Swertia multicaulis Don	site record	
Swertia rex Cl.		
Swertia speciosa	32702B	
Boraginaceae		
Anchusa sikkimensis Cl.	site record	
Cyanoglottus denticulatum DC.	photo-6299	
Eritrichum munroi Cl.		
Eritrichum pustulatum Cl.	site record	
Eritrichum pygmaeum Cl.	site record	
Myosotis hookeri Cl.		
Onosma bicolor Wall.	32769	
Onosma emodi Wall.		Medicinal
Paracaryum glochidiatum	site record	
Trigonotis multicaulis Benth		
Trigonotis rotundifolius	site record	
Solanaceae		
Mandragora caulescens Cl. ssp. caulescens	site record	
Anisodus luridus spreng	site record	
Scrophulariaceae		
Euphrasia chumbica R.R. mill		
Euphrasia melanosticta R.R.mill	photo-6395	
Hemiphragma heterophyllum	32428	
Lancea tibetica	32779	
Oreosolen wattii	28996	
Oreosolen williamsii	site record	
Pedicularis albiflora (Hk.f.) Prain	photo-6588	
Pedicularis bella Hks		
Pedicularis bicornuta	32472	
Pedicularis chumbica Prain		
Pedicularis clarkei Hk.f.		
Pedicularis collata Prain		
Pedicularis confertiflora Prain	site record	
Pedicularis cooperi Tsoong		
Pedicularis daltonni PrainYakLa; Chhola:		
Pedicularis denudata Hk.f.	site record	
Pedicularis diffusa Prain		
Pedicularis elwesii Hk.f.	site record	
Pedicularis excelsa Hk.f.		
Pedicularis flexuosa Hk. f.	site record	
Pedicularis furfuracea Wall. ex Benth	site record	

Pedicularis garckeana Maxim,Dzongri		
Pedicularis gibbera Prain		
Pedicularis globifera Hk.f.		
Pedicularis gracilis Benth. Lachung	site record	
Pedicularis heydei Prain	site record	
Pedicularis instar Prain & Maixm		
Pedicularis integrifolia Hk.f.		
Pedicularis lachnoglossa Hk.f.	site record	
Pedicularis longiflora ssp tubiformis	site record	
Pedicularis lyratamaxim		
Pedicularis megalentha D. Don	photo-6278	
Pedicularis microcalyx Hk.f.		
Pedicularis molllis Benth	site record	
Pedicularis nana Fischer		
Pedicularis nepalensis Prain	site record	
Pedicularis odonophora Prain- Na Tong;		
Pedicularis oederi Vahl. Ssp branchiophylla	photo-6223	
Pedicularis pantlngii Prain Li		
Pedicularis paradoxa (Prain) Yamaz		
Pedicularis pauciflora (Prain) Pennell		
Pedicularis pennelliana Tsoong		
Pedicularis polygaloides Hk.f.-		
Pedicularis purpurea	32517	
Pedicularis pyramidata	32432	
Pedicularis regeliana Prain		
Pedicularis rhinanthoides Schrenk 2ssp labellata	site record	
Pedicularis robusta Hk.f. Lachung		
Pedicularis roylei Maxim		
Pedicularis schizorrhyncha Prain		
Pedicularis scullyana Prain ex Maxim	site record	
Pedicularis sikkimensis Bonati ex WW Sm		
Pedicularis siphonantha D. Don	site record	
Pedicularis tantalorhyncha Bonati-Pr		
Pedicularis tenuicaulis Prain		
Pedicularis trichoglossa Hk.f.	32721	
Picrorhiza scrophulariiflora	28943	Medicinal
Scrophularia pauciflora Benth.	site record	
Veronica caria Benth.		
Veronica cephaloides	site record	
Veronica deltigera Benth. V. capitat var capitat		
Veronica himalensis D.Don		
Veronica lanuginosa	29093	
Veronica persica poir.		
Veronica umbelliformis Pennell		
Acanthaceae		
Strobilanthus lachenensis		
Selaginaceae		
Lagotis cashmeriana		
Lagotis clarkei Hk.f.		

Lagotis crasifolia Prain		
Lagotis kunawarensis	29087	
Lagotis spectabilis Kurz.		
Orobanchaceae		
Boschniakia himalaica	28972	
Lentibulariaceae		
Utricularia brachiata	photo-6858	
Prezwalskia subbarai (CEC Fischer) Grubov.		Syn. *P. tangutica* sensu Sanjappa
Pinguicula alpina L.	site record	Insectivorous; Botanical Interest
Lamiaceae		
Dracocephalum hookeri Cl.		
Dracocephalum speciosum	site record	
Dracocephalum heterophyllum	photo-6215	
Elsholtzia eriostachya Benth.	32734	
Elsholtzia strobilifera Benth.	site record	
Eriophyton wallichii	32546/32797	
Galeopsis tetrahit L.		
Nepeta lamiopsis Benth		
Nepeta thomsonii Benth		
Phlomis bracteosa	photo-6332	
Phlomis breviflora	28941	
Phlomis rotata Benth.	photo-6197	
Phlomis tibetica		
Salvia campanulata Wall.	photo-6334	
Plantaginaceae		
Plantago depressa Willd = p. libetica	site record	
Chenopodiaceae		
Axyris prostrata L.		
Microgynoecium tibeticum Hk.f.	site record	
Polygonaceae		
Aconogonon campanulatum (Hk.f.) Hara		
Aconogonon molle	site record	
Aconogonon tortuosum	site record	Medicinal
Aconogonum polystachyum	32415	
Bistorta affinis	28949	
Bistorta amplexicaulis	site record	
Bistorta emodi	site record	
Bistorta griffithii		
Bistorta macrophylla	site record	
Bistorta milleti Leveille	site record	
Bistorta perpusilla		
Bistorta vaccinifolia	32424	
Bistorta vivipera	32452/32700	Medicinal, alba variety
Koenigia delicatula	site record	

Koenigia forrestii		
Koenigia islandica	site record	
Koenigia nepalensis	site record	Syn P. filicaule
Koenigia nummularifolia	site record	
Oxyria digyna	28960	
Persicaria glacialis	site record	
Persicaria runcinata	site record	
Persicaria sibirica	site record	
Rheum acuminatum	28963	
Rheum australe		Rare; Medicinal
Rheum globulosum Gage		
Rheum nobile	site record	Eaten as pickle
Rheum spiciforme Royle	site record	
Bignoniaceae		
Incarvillea himalayensis Juss.		
Santalaceae		
Thesium pachyrhizum A. DC.	site record	Botanical Interest
Euphorbiaceae		
Euphorbia luteo-viridis		
Euphorbia sikkimensis	32701C	
Euphorbia stracheyi Boiss.	32733	Useful fodder plant
Urticaceae		
Parietaria micrantha Ledeb.	site record	
Pilea racemosa	site record	
Urtica hyperborea	32746	Found around cattlesheds
Betulaceae		
Betula utilis	site record	Religious
Salicaceae		
Salix calyculata Anders.	photo-6419	
Salix daltoniana Anders	site record	
Salix lindleyana. var. microphylla	32499	
Salix lindleyana	site record	
Salix myrtillacea Anders.		Fuel wood
Salix oreophila Andrs.		
Salix pseudocalyculata Kiura		
Salix serpyllum Anders.		
Salix sikkimensis	32450/32762	Fuel wood
Orchidaceae		
Aphyllorchis parviflora		
Calanthe himalaicum		
Calanthe tricarinata	site record	
Calanthe alpina	site record	
Cypripedium elegans		
Epipogium aphyllum		

Gymnadenia orchidis	site record	Medicinal
Habenaria arietina		
Habenaria clavigera		
Habenaria ensifolia		
Habenaria latilabris	site record	
Herminium josephii	32607	
Herminium laceum		
Herminium monorchis	site record	
Herminium pugioniforme	site record	
Listera longicaulis		
Listera pinctorum		
Listera teunis		
Microstylis muscifera	photo-6371	
Neottia listeroides		
Neottianthae secundiflora		
Peristylus fallax	site record	
Platanthera stenantha		
Poneorchis chusua	photo-6341	
Ponerorchis nana		
Ponerorchis spathulata	28929	
Satyrium nepalense	site record	
Satyrium ciliatum		
Zingiberaceae		
Roscoea alpina	site record	
Roscoea auriculata	photo-6087	
Iridaceae		
Iris goniocarpa Baker		
Iris kemaonensis D. Don	site record	
Iris clarkei Hk.f.		
Smilacaceae		
Smilax rigida	32403	Syn S. myrtillus var. rigida
Convallariaceae		
Maianthemum fuscum	site record	Syn. *Smilacina fusca*
Maianthemum oleraceum	site record	Syn *Smilacina oleracea*
Maianthemum purpureum	29030	Syn. *Smilacina purpurea*
Ophiopogon wallichianus		Syn *O. intermedius var. parviflorus*
Paris polyphylla	site record	
Polygonatum cathcartii		
Polygonatum cirrifolium	site record	Medicinal
Polygonatum hookeri	site record	
Polygonatum kansuense	photo-6513	
Polygonatum leptophyllum		
Polygonatum sibiricum		
Polygonatum singalilense Hare		Endemic
Polygonatum verticillatum	photo-6500	
Theropogon pallidus	site record	

Trillidium govanianum	site record	
Liliaceae		
Alertis pauciflora	28916	
Aletris glabra Bureau & Frach.	site record	
Aletris gracilis Rendle	photo-6281	
Allium fasciculatum Rendle		
Allium macranthum Baker		
Allium prattii CH Wright	20957	
Allium sikkimense Baker		
Allium wallichii Kunth	site record	
Clintonia udensis	site record	
Fritillaria roylei	photo-6637	
Fritillaria cirrhosa D. Don	28958	Medicinal
Gagea lutea (L.) Ker Gaw.		
Lilium nanum Klotz	photo-6637	
Lloydia delicatula		
Lloydia flavonutans Hara	site record	
Lloydia longiscapa	photo-6194	
Lloydia serotina		
Lloydia yunnanensis		
Notholirion macrophyllum (D. Don) Boiss.	site record	
Streptopus simplex	28911	
Tofieldia himalaica Baker	site record	
Juncaceae		
Juncus allioides Franch.	site record	
Juncus amplifolius A. Camus	site record	
Juncus benghalensis Kunth.		
Juncus brachystigma Samuel.		
Juncus bryophilus Noltie		
Juncus bufonius L.	site record	
Juncus cephalostigma Samue.		
Juncus chrysocarpus Buchen.	site record	
Juncus clarkei Buchen	site record	
Juncus concinnus D. Don	site record	
Juncus duthiei (Cl.) Noltiie		
Juncus glaucoturgidus Noltie		
Juncus gracilicaulis A. Camus		
Juncus grisepachii Buchen.	site record	
Juncus himalensis Klotz.	site record	
Juncus kingii Rendle		
Juncus leucanthus Royle ex D.Don		
Juncus leucomelas Royle ex D. Don		
Juncus minimus Buchen.		
Juncus nepalicus Miyamoto & Hara		
Juncus ochraceus Buchen.		
Juncus perpusillus Samuels		
Juncus sikkimensis		
Juncus sphacelatus Decne	photo-477	
Juncus thomsonii Buchen.		

Juncus trichophyllus WW Sm		
Juncus triglumis L.		
Juncus uniflorus WW Sm	site record	
Luzula multiflora	site record	
Araceae		
Arisaema jacquemontii Bl.	29032	Subsidiary food
Arisaema nepenthoides (Wall.) Marit. & Schott.	photo-6152	
Arisaema propinquum Schott	site record	
Arisaema utile Hk.f.		
Juncaginaceae		
Triglochin maritima L.	site record	
Triglochin palustris L.	site record	
Potamogetonaceae		
Potamogeton filiformis Pers.	32749	
Eriocaulaceae		
Eriocaulon alpestre Hk.f. & T.	site record	
Cyperaceae		
Blysmus compressus	site record	
Bulbostylis densa (Wall.) Hand.-Mazz.	site record	
Carex duthiei Cl. (Carex duthiei)	site record	Syn *Carex atrata* L. subsp. *pullata*
Carex fucata Boott ex Cl.	site record	
Carex haematostoma Nees	site record	
Carex inanis Kunth	site record	
Carex infuscata Nees	site record	
Carex lehmannii Drejer		
Carex microglochin Wahlenb.	site record	
Carex moorcroftii Falc. ex Boott.	site record	Syn *C. melanantha* ssp. Moorcroftii
Carex munda Boott	site record	
Carex nigerrima Nelmes	site record	Syn *C. atrata*
Carex nivalis	32481	
Carex notha Kunth.	site record	
Carex nubigena D. Don	site record	
Carex obscura Nees	site record	
Carex orbicularis Boott	site record	
Carex parva Nees	site record	
Carex praeclara Nelmes		
Carex pseudofoetida Kukenth.		
Carex psychrophylla Nees		
Carex setosa Boott		
Carex stenophylla Wahlb.	site record	
Carex stracheyi Boott ex Cl.		
Carex supina Willd. ex Wahlb.		
Carex teres Boott	site record	
Carex tristis M. Bieb.	site record	
Carex vulpinaris Nees		

Carex atrofusca Schkuhr.		
Kobresia capillifolia	site record	
Kobresia clarkeana Kukenth.		
Kobresia curticeps (Cl.) Kukenth.		
Kobresia duthiei	32466	Important winter fodder
Kobresia esenbeckii (Kunth) Noltie		
Kobresia fragilis Cl.		
Kobresia gammiei Cl.		
Kobresia humilis (Mey) Serg.		
Kobresia laxa Nees	site record	
Kobresia nepalensis	28992/32480	
Kobresia prainii Kukenth.		
Kobresia pygmaea Cl	site record	
Kobresia schoenoides (Mey) Steud.	photo-6792	
Kobresia sikkimensis Kukenth.		
Kobresia sp.	site record	
Kobresia stiebriztiana Hand.-Mazz.		
Kobresia unicoides (Boott) Cl.		
Kobresia vaginosa Cl.		
Kobresia vidua (Boott ex Cl.) Kukenth.	site record	
Poaceae		
Agrostis hookeriana		
Agrostis inaqueglumis	site record	
Agrostis nervosa		
Agrostis pilosula	site record	
Agrostis triaristata		
Anthoxanthum flexuosum		
Anthoxanthum hookeri		
Briza media		
Bromus himalaicus	site record	
Bromus staintonii		
Bromus sylvaticus		
Calamogrostis emodensis	site record	
Calamogrostis filiformis	32422	
Calamogrostis nivicola		
Calamogrostis scabrescens	site record	
Calamogrostis tibetica	site record	
Catabrosa sikkimensis Stapf		
Colpodium wallichii	site record	
Danthionia cachemyriana	site record	
Danthionia cumminsii		
Deschampsia c. ssp. sikkimensis	site record	
Deschampsia caespitosa	site record	
Elymus schrenkianus	site record	
Elymus himalayanus	site record	
Elymus nutans	32735	
Elymus thoroldianus		
Festuca bhutanica		
Festuca boriana		
Festuca cumminsii	site record	

Festuca leptopogon		
Festuca polycolea	site record	
Festuca stapfii		
Festuca tibetica	site record	
Festuca undulata Stapf		
Festuca valesiaca	32420/32705	
Festuca wallichiana		
Glyceria tonglensis Cl		
Helictotrichon parviflorum		
Helictotrichon virescens	site record	
Himalayacalamus falconerii	site record	
Himalayacalamus hookerianus		
Oryzopsis munroii	site record	
Phleum alpinum	site record	
Poa annua L.	site record	
Poa cf attenuata		
Poa dzongicola Noltie		
Poa eleanorae Bor		
Poa gammieana		
Poa hirtiglumis Stapf.		
Poa lachenensis Noltie		
Poa longii Noltie		
Poa ludens		
Poa mustangensis Rajbh		
Poa nepalensis		
Poa nitide-spiculata		
Poa pagophila	site record	
Poa polyneuron		
Poa poophagorum Bor	site record	
Poa pratensis L	site record	
Poa pseudotibetica Noltie		
Poa rahmooniana Noltie		
Poa rajbhandarii Noltie		
Poa sikkimensis		
Poa sp.1	site record	
Poa stapfiana	site record	
Stipa duthiei Hk.f.		
Stipa koelzii R.R. Stew.		
Stipa milleri Noltic		
Stipa mongholica	site record	
Stipa purpurca Griseb	site record	
Stipa rahmooiana Noltie		
Stipa roborowskyi Rosh.		
Stipa roylei	site record	
Trikeraia oreophila		
Trisetum scitulum Bor		
Trisetum spicatum	site record	

* Plant inventory was prepared based on secondary sources mainly “Flora of Bhutan – 3 volumes” which includes collections from Sikkim, and only those taxa were collected that could not be identified in the field.