STUDY OF ECOLOGICAL AND SOCIO-ECONOMIC AND LIVELIHOOD DIMENSIONS OF GRAZING EXCLUSION IN PROTECTED FORESTS OF WEST SIKKIM

In Collaboration with

DEPARTMENT OF FOREST ENVIRONMENT AND WILDLIFE MANAGEMENT, GOVERNMENT OF SIKKIM

June 2012

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ACCRONYMS

BRS	Barsey Rhododendron Sanctuary
DFEWM	Department of Forest Environment & Wildlife Management
EDC	Eco-development Committee
FGD	Focuss Group Discussion
GIS	Geographic Information System
GPS	Global Positioning System
JFMC	Joint Forest Management Committee
KBR	Kanchendzonga Biosphere Reserve
KNP	Kanchendzonga National Park
LISS	Live Internet Seismic Server
MAI	Mean Annual Increment
MNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
NDVI	Normalized Difference Vegetation Index
SKES	Sindrabung Kanchendzonga Eco-friendly Society

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EXECUTIVE SUMMARY

Centre for Development Finance (CDF) at the Institute for Financial Management and Research (IFMR) Chennai, in collaboration with the Department of Forest Environment and Wildlife Management, Sikkim (DFEWM) conducted this study to evaluate grazing exclusion policy in protected forests in West Sikkim. The goal of the study was to examine the effect of grazing exclusion on the health of forest ecosystems and also to understand the social and livelihood impacts on the forest dependent local communities living in fringe villages of the study area. Secondly through this study it was envisaged to develop a holistic framework that would be further used for a larger study on assessing grazing exclusion policy at State-wide level. The study was conducted across Barsey Rhododendron Sanctuary (BRS) and a part of buffer zone of Kanchenjunga Biosphere Reserve (KBR) in the West District of Sikkim. The Government of Sikkim adopting a conservation centric approach had banned open grazing in reserved forest areas in Sikkim from 1998. After over a decade of the ban being in force, it was significant for the policy makers to understand and gain a perspective on the effects of the total grazing ban on the health of the forest ecosystems. Besides the environment, the policy of grazing exclusion also had impacted the livelihoods of local herders and agro-pastoralists having dairy related livelihood dependencies. In this context the study assumed significance as it provided insights into the level of outcomes achieved by the implementation of the conservation centric policy.

The study adopted comprehensive evaluation framework comprising of two main components: ecology and socio-economic including livelihoods. The key aspects studied under ecology include vegetation parameters (forest structure and composition, regeneration, disturbance etc), soil parameters (soil chemical properties and soil erosion related information) of the area, hydrology (water sources flow & quality) and wildlife (trends in sighting). Under socio-economic aspects key aspects such as livelihood strategies, resource use, asset ownership and perception of the local communities towards the grazing ban were studied.

The data on vegetation and soil parameters was collected in the field using extensive field surveys while qualitative data was collected on hydrological and wildlife aspects. The area assessed varied between 2000 m to 4000m in altitude and comprised of 4 broad forest types: (i) Wet temperate forest (Oak and dwarf bamboo dominated) (ii) Moist temperate forest (Mixed coniferous) (iii) Sub-alpine forest (Birch/Fir & Rhododendron forests) & (iv) Sub-Alpine scrub (Rhododendron & scrub thickets). In each of the forest type zone, cow-shed spots were identified in high and low grazing intensity (disturbance) areas. The methodology prescribed by the Forest Survey of India was followed for collecting vegetation data from the plots. Also vegetation change detection was done using Multispectral IRS LISS III images with 23.5m spatial resolution for the West district of Sikkim. Details on socio-economic aspects were captured from local communities in the fringe villages at the study sites using combination of techniques such as household surveys focused group discussions (FGD) , key informant interviews, resource mapping exercises, timeline besides others.

The ecosystem impacts of the grazing ban can be said to be positive in terms of increase in vegetation cover and consequent improvement in the soil regime. The areas exposed to high grazing pressure having open canopy cover were found to be regenerating adequately. Among the species of conservation importance, Rhododendron spp. were observed to be adequately generating whereas the regeneration of Quercus spp was relatively inadequate. It was observed that regeneration levels of other species of fodder importance such as Litsea polyantha(poinle), Ilex dipyrena (lissey), Osmanthus suavis (sirlinge), was found to be inadequate near the plot areas. The gregarious Arundinaria maling (malingo) and Viburnum spp. (asare) regeneration could be cause of concern in the longer run and needs to be further studied. Efforts should be made to supplement the regeneration of the key species such as Quercus by forming ex-situ conservation zones by delineation of zones within existing natural regeneration areas or in-situ conservation techniques could be adopted. Habitat management plans for the grazing affected areas need to be developed taking variation of forest types into consideration. For this the disturbance hotspots in the region mapped through GIS and the rich repository of ecological information generated during the study can be combined to provide the necessary base. As for the soil profile, there seems to be a positive impact on soil characteristics overall. The reduction in pressure has resulted in reduction of soil erosion and there is a remarkable increase in the overall regenerative capacity (especially in BRS). This could be considered as a first step to the revival of soil fertility and key nutrients.

The details from the household survey provided insights into the magnitude of the livelihood impact associated with the policy implementation. It was observed that not only herders were impacted but also the non herder group was impacted though to a less extent. Amongst the herder group, caretakers and people with less land ownership were the most impacted. The livelihood model changed from agro-pastoral form with livestock being the mainstay to predominantly agricultural. Earlier mostly people used to practice subsistence agriculture and now they have adapted to doing agriculture as mainstay livelihood activity. The herd size owned has reduced from 20-30 per herder to 3-4 per herder household now. Post ban, livelihood options such as MNREGS and eco-tourism have been introduced in the region. The benefits from ecotourism though are limited and not equitably distributed. One of the major effects that the sample population associated with the ban on grazing in forests, was the rise in the incidences of wildlife causing damage to crops. This damage is felt most intensively by households having farms within 1.5 Km of the sanctuary boundary. The interactions with the local communities revealed that they appreciate the positive policy impacts on the ecosystem despite incurring economic losses through reduced income and crop damages. Also the dominant view was that they have now adapted to a life of fewer hardships and have better access to health and education facilities. The immediate need identified was to develop strategies to address the wildlife conflicts issue and the need of developing a livestock management system participatory in nature to improve the access to fodder and fuelwood resources. Overall the perception and information captured from the socio-economic survey can be used as an input for further policy refinement in the region.

A focused study needs to be carried out to understand effective solutions to minimize the impacts of wildlife conflicts and design appropriate strategies to tackle it. Also the need to develop a livestock management system using participatory approach was identified. Development of livestock management systems in the community forests areas or using innovative approaches using participatory model should be considered. The current eco-tourism model needs to be strengthened so that the benefits of eco-tourism are more equitably distributed. A comprehensive approach is vital for understanding the influence of the conservation policies. The policy impact matrix developed lists the critical ecological, social and governance aspects that are influenced by the policy. It captures the status of policy impacts and helps in identifying aspects that need to be further strengthened.

The purpose of carrying out evaluation of conservation policies was to provide the policy makers with meaningful and reliable information on the outcomes and impacts achieved by the policy on ecosystems as well as on the local communities. In low data environment, using alternative design options and frameworks using mix method approach as presented in the report offers useful insights on policy relevant parameters. The scope of current study was local in nature. To develop an understanding of the overall policy impacts across Sikkim a state-wide study is essential. It will help understand the policy effectiveness and influence across the region.

CHAPTER 1
INTRODUCTION

1.1. BACKGROUND

1.1.1. GRAZING AS AN ECOLOGICAL ISSUE

Indian Pastoralism, commonly considered as a nomadic activity, is classified according to the movement pattern; horizontal movement in dry land region and vertical movement in mountain areas. Another identifiable classification, as per degree of mobility ranges, from being pure nomadic to transhumant to agro pastoralists - all practiced in the Himalayas. Agro-pastoralism, an inter-dependent biological system of production, is one of the most dominant systems practiced in the Himalayas (Misri, 2002). The semi migratory system combines livestock rearing with arable agriculture and has played an important role in the physical, ecological and socio-economic development in the practicing region. However, sustainability of such systems has been questioned due to exponentially increasing livestock population, thereby increasing pressure on natural resources due to rapid degradation. Dwindling forests and pasture lands are unable to provide necessary fodder to large livestock populations; inviting conservation based policies for the natural resources. India itself has many indigenous pastoral tribes: Gujjars & Dhangars in North India, Gaddis in Himachal Pradesh, Bakarwals in Kashmir , Toda & Kuruba in southern India and Gurungs & Monpas in North East to state a few.

There are contrasting perspectives on the sustainability of current patterns of pastoral activity. Livestock numbers have been constantly increasing, but technology and management practices have not kept up with the increased pressure on resources. Overgrazing, a state where livestock population exceeds carrying capacity numbers, is resulting in soil erosion, soil compaction, decrease in water retention, increase in salinity, and nutrient loss. (Abril & Bucher, 1999) Similarly, the productivity of pastoral activity has lagged – increasingly strained resources are not being used more efficiently. In addition to pastoral activities, selective logging by herders, accompanying the livestock in forests, expedites the degradation process. As a consequence of all these factors, forest and grazing land around the world have come under enormous pressure leading to their rapid degradation.

This crunch is particularly evident in India: there is not enough feed and fodder available to support the growing livestock populations. This not only has national consequences, but also livelihood consequences as almost 60% of the cattle population is owned by small and marginal farmers.

With environmental degradation concerns rising, the outlook of central government has shifted to adoption of conservation-centric policies. Under the conservation-based approach, activities such as grazing and collection of forest products have been restricted in protected area networks. The basic objective behind these restrictions is to promote efforts for conserving biodiversity, protecting habitats for the dwindling wildlife population and providing a chance for the degraded forest ecosystems to recover from degradation. Considering the high dependency of the rural population on forest resources, policy implementation is a challenging task.

1.1.2. IMPACT ASSESSMENT OF CONSERVATION PROGRAMS

Conservation programs aim at protecting the environment and maintain an ecological balance in the region. But, there are contrasting perspectives on suitability and effectiveness of such conservation programs. Conservationists on one hand feel the need of such conservation centric policies while social scientists on the other hand are skeptic of them. The bigger question is "Is there a practical solution to this raging debate of social cause versus environmental cause?" The surge of such initiatives has also raised the need to investigate their role in attaining the desired set of objectives. Thus, evaluations of conservation interventions or policies assume significance in this context. However, there are few examples of such program evaluations of conservation policies or interventions especially in a developing country like India. There is a lot of literature available on the topic of program evaluation of developmental or environmental intervention. But most of it employs quantitative approaches requiring detailed data sets, securing which is a challenging task in most of the developing countries. Also program evaluations of conservation interventions are much more complex to execute in the field due to the composite and dynamic nature of ecosystems and the multitude of the factors acting upon them. Another significant issue pertains to the object of focus for such evaluations. Typically program evaluations focus on one aspect of the intervention or policy. For instance, some studies about forest degradation focus solely on the impact of disturbance on vegetation or soil aspects. On the other hand others focus solely on the implications of policy prescription on socio-economic pertaining to local communities. But there are very few studies that integrate the ecological and socio-economic aspects to present a holistic picture. Hence program evaluation of any conservation intervention has to take into account the complex interrelationships of various components in an ecosystem, including humans as a component of the ecosystem. Measuring direct impact can be difficult, given that changes are often the result of complex systemic interactions and can take a long time to evolve.

1.1.3. CURRENT SCENARIO IN INDIA VIS-À-VIS SIKKIM

India has a vast rural population, majority of which is engaged in primary income generation activities due to lack of new technology. Livestock rearing is an integral part of the various rural communities in the country. India had total livestock population of 529 million as in 2007 (National Statistics , 2007) Arable agriculture contributes as a major fodder resource of the country in the form of crop residues which is mainly fed to the livestock. Even though livestock population of Sikkim forms a mere 0.4 percent of national livestock population (Sikkim Government, 2007), animal rearing plays a bigger role in the mountainous states as it is a multiple dimensional activity. Livestock not only contribute to the livelihood of people, being their main income generating activity, but also assist in agriculture and help to meet the increasing demand for protein rich food items such as milk, egg and meat. The role of livestock in generating employment in rural economies has been established and livestock management programs have become an integral part of rural development programs.

Livestock in Sikkim mainly comprise of cattle (cow and buffalo) and sheep. Domestication of yak and its hybrids started in the early seventies in high altitudes. Population of domesticated yak and its hybrids escalated rapidly due to high production of milk while a negative trend was observed in sheep population. During the period of 1980-90, population of livestock was highest in Sikkim due to free availability of fodder. Total Livestock population in Sikkim has increased since last three decades with maximum increase in population of cattle, pig and yak hybrids. (Sikkim Government, 2007) With increasing population and livestock population, pressure on grazing lands and forest areas increased leading to perceived degradation. Sikkim adopted a green mandate with their flagship innovative programme “State Green Mission”, launched in 2006. Prior to this, Department of Forest, Environment and Wildlife (DFEWM) had implemented a ban on open grazing in reserved forest areas, plantations and near water sources in 1998. The ban was implemented phase-wise and now covers all the protected forest areas in the State. India has the largest number of livestock in the world and Sikkim shares about 1% of total livestock of the country. The livestock population of Sikkim across its four districts as in 2001 was approximately 0.5 million (M.N Jana). High levels of livestock population are, however, not a healthy sign for the economic development of the state. This increases the pressure on lands and forests on, which the livestock survives. Other problems created by livestock rearing are heavy loss of soil, frequent landslides, soil erosion, river bed cutting and a permanent geological erosion process, which are further accelerated and aggravated by the heavy precipitation, formation of unstable soil and rock and over grazing in the lands. The excessive usage of forest resources like fuelwood and fodder results in the degradation of the forest cover.

1.2. RATIONALE BEHIND THE STUDY

The purpose of this study was to examine the ecological impact of the grazing ban in the Barsey Rhododendron Sanctuary (BRS) and buffer zone of Kanchenjunga Biosphere Reserve (KBR). After almost a decade of the ban being in force, it was interesting to investigate the effect of a total grazing ban on the health of the forest ecosystems in the study sites. The various elements in an ecosystem are inter-linked with each other. Thus a change in status of one is bound to cause an alteration in some of the other elements. Accordingly, successful implementation of ban is supposed to improve the condition of the degraded forest landscape, but it is important to fully understand what aspects of the forest it helps more than others as well where its impact could be strengthened. Evaluations can also help understand other, potentially confounding, influences on forest health.

1.1.4. OBJECTIVES

Keeping in mind the inter linkages of various elements of ecosystem; the study was designed to undertake a holistic impact evaluation. Therefore, the study objectives are as below:

- To determine the change in habitat condition, hydrology and edaphic factors in the region after the implementation of the ban on grazing in reserved forest areas.
- To understand the perspectives of the local community on the grazing ban and to study the change in livelihood strategies adopted by them.
- To develop a feasible methodology for assessing impact in the absence of detailed longitudinal ecological or socio-economic data.
- To document relevant baseline data that can be used as a foundation for rigorous research on the future impacts of continuing or adjusting the grazing ban.
- To perform preliminary investigation on the issue of cross border grazing.

1.3. STUDY AREA

1.3.1. DESCRIPTION

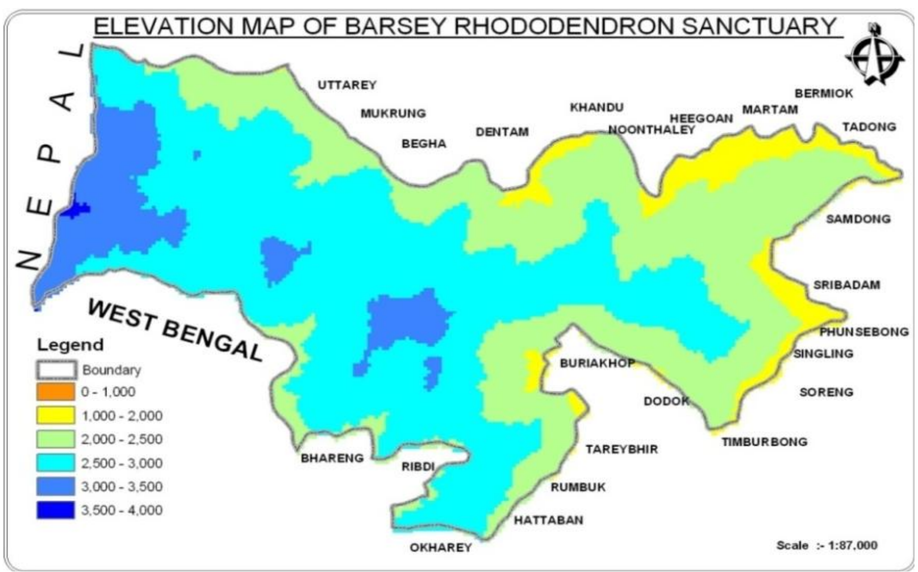

Figure 1.1 : Map of Barsey Rhododendron Sanctuary

Sikkim is a small peaceful State in the Himalayan Ranges. Its total geographical area is 7096 sq. km that is a mere 0.2% of India's size. Nevertheless, it is home to a variety of flora (4500 species) and fauna (150 species of mammals & 550 species of birds & 600 types of butterflies) that renders it one of the 26 biodiversity hotspots[1] of

[1] According to Conservation International, to qualify as a hotspot, a region must meet two strict criteria: it must contain at least 1,500 species of vascular plants (> 0.5 percent of the world's total) as endemics, and it has to have lost at least 70 percent of its original habitat. (http://www.biodiversityhotspots.org/Pages/default.aspx)

the world. The magnificent peak Mt. Khangchendzonga, the highest peak in India, also lies in Sikkim and its ranges extend from West to North. The immense variation in altitudinal range (from 300m to 8500m) in a relatively small landmass brings about the rich biodiversity found in the State. Grazing forms a significant livelihood activity in the mountainous state, as tribes such as Lepchas, Lachungpas, Gurungs, Bhutias were traditional herders and form a significant percentage of the population.

The study area was Barsey Rhododendron Sanctuary (BRS) situated between an altitude of 6500-12500 feet (latitude 27 11.39' N and longitude 88 07.06' E) in the western part of Sikkim. (Figure 1.1) It forms a vital corridor connecting the Khangchendzonga Biosphere Reserve (KBR) to its north with the Singalila National Park of West Bengal to its south. Spread over an area of 10,400 Hectares, the sanctuary shelters a wide range of floral and faunal elements and is considered a biodiversity hotspot. Rhododendron species like *Arboreum, Falconeri, Barbatum,* etc are found in abundance in Barsey. It houses a wide range of mammals like the Leopard, Leopard Cat, Yellow-throated Marten, Masked Palm Civet, Goral, Barking Deer, Asian Black Bear, Red Panda and the Crestless Porcupine. Bird species include the Common Hill-Partridge, Blood Pheasant, Satyr Tragopan, Himalayan Monal, Speckled Wood-Pigeon, etc. Spanning over different elevations, variation in vegetation can be noticed along with altitudes in the sanctuary. The climate here is mainly cold and wet, July being the wettest month with the average annual precipitation being in excess of 250cm. Areas above 2500m receive regular snowfall during the winter. It can be classified into Sub-Tropical (2200m – 2400m), Temperate (2400m – 3250m), and Sub-Alpine (3250 m – 4000 m) and Alpine forests (> 4000m) (Lachungpa & Tambe). The soil texture here is predominantly clayey.

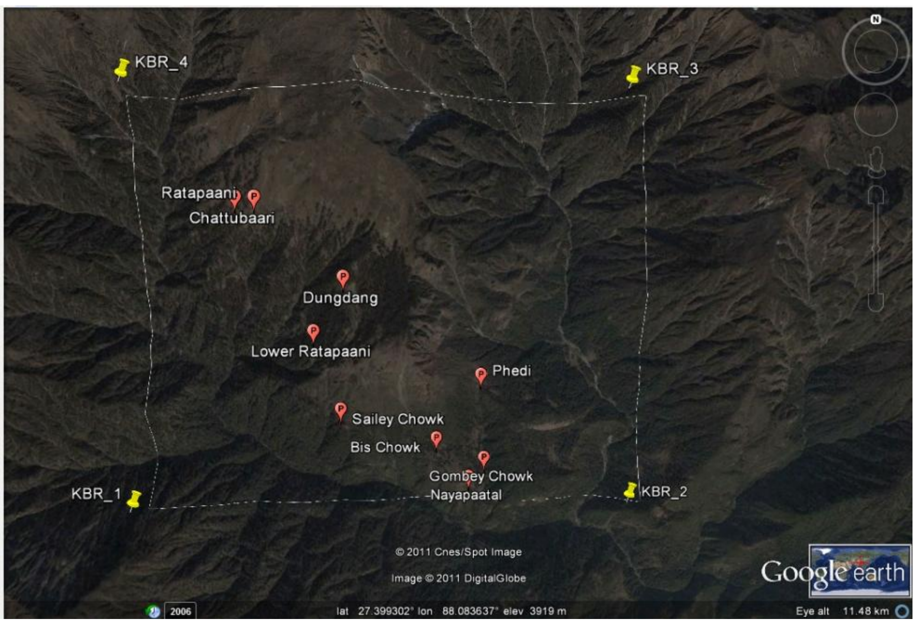

Figure 1.1.3 : Aerial image of buffer zone of KBR

The study was designed as an ex-post impact assessment of the exclusion policy due to lack of information about the pre ban time period for the same area. For this purpose a control site was chosen, which is similar in nature to the treatment site. The parameters considered for selection of a control site included topographical features (altitude, slope), long-run edaphic factors (soil type) and socio-economic conditions (viz. ethnicity of people, livelihood strategy, and grazing pattern) of people living in and around the area. (Refer to Appendix) The control site chosen was the Kanchendzonga Biosphere Reserve (KBR), the buffer zone of the Kanchendzonga National Park (1784km^2) which constituted 25% of the geographical area of Sikkim. This site was chosen to facilitate a comparison between the study site and the control site on the impact of the ban on grazing in the region. The Biosphere Reserve region is similar to Barsey Rhododendron Sanctuary in terms of forest type, altitudinal variation, vegetation, wildlife, etc and was fit to be a control site.

KBR, which is a buffer zone of about 836 sq. km is located between 27° 30'-27° 55' N and 88° 02'-88° 37' E.(Figure 1.2) It is connected to the adjacent Khangchendzonga Conservation Area in eastern Nepal, Barsey and Maenam Wildlife Sanctuaries in Sikkim and Singalila BR in Darjeeling district of West Bengal, through a number of corridors. The varying elevation of 1,220 to 8,586 m within an aerial distance of just 42 km with about 90% area above 3000 m and 70% above 4000 m makes this park a unique natural heritage hotspot in the world.

1.3.2. CULTURAL PROFILE

Even though Sikkim is the second smallest state in India, its population represents ethnic and cultural variety. The landlocked state, divided into four districts, has five major ethnic groups namely *Lepcha*, *Bhutia*, *Limbu*, *Nepalese* and plainsmen of Indian origin. Over twenty five communities reside in the state with *Nepali* being the commonly used language.

The villages surveyed are located in the West district of the state, spread across five Gram Panchayat Unit (GPU). Lower Mukrung Simbola panchayat ward has the highest population with 120 households while Upper Buriakhop ward in Burikhop GPU is least populated with only 45 households. (Table 1.1) Each of the wards is spread horizontally and vertically (across altitudes) into various villages (locally known as *basti*) where surveys were undertaken. Majority of the population in Singrangpong ward belongs to Scheduled Tribe caste while only 13 % of the population in Upper Buriakhop belongs to ST group. Highest population in the age group 0-6 years is in Lower Mukrung Simbola while maximum population in age group, above 60 years resides in Lower Begha ward. Majority of the population follows Buddhism and Hinduism while people practicing Christianity and Islam are in minority. (Table 1.2) On an average, literate population across five GPUs is 65% but people employed in the study site did not exceed 30 %. People employed as a percentage of total population was maximum in Upper Buriakhop (35%) where over 68% of the total population was literate. Workforce from other states and Nepal is recorded as Non local residents, which is highest in Singrangpong ward due to proximity to the international border.

Table1.1: Demographic profile of study site

Gram Panchayat Unit	Panchayat Ward	Total Households	Total Population	Employed Population (%)	Literate Population (%)	Non Local Residents (%)
Darap	Singrangpong	51	288	23.96	64.24	5.21
Maney Bung Sopakha	Lower Mukrung Simbola	120	699	22.75	65.09	1.14
Maney Bung Sopakha	Upper Mukhrung	118	663	29.11	67.72	0.60
Dentam	upper Begha	129	677	33.68	62.92	7.68
Dentam	Middle Begha	110	598	25.42	63.04	0.00
Dentam	Lower Begha	126	679	35.64	68.19	0.00
Burikhop	Upper Buriakhop	45	219	34.25	75.34	14.16
Burikhop	Buriakhop-Bichgaon	44	252	30.95	66.67	5.56
Burikhop	Lower Buriakhop	48	251	30.28	63.35	2.39
Okhrey	Bhareng	97	464	24.14	62.50	8.19

Table 1.2: Cultural Profile of the study site

Gram Panchayat Unit	Panchayat Ward	Age group		Religion			
		0-6 years	above 60 years	Buddhist	Hindu	Christian	Other
Darap	Singrangpong	26	11	209	70	9	0
Maney Bung Sopakha	Lower Mukrung Simbola	58	31	66	624	0	9
Maney Bung Sopakha	Upper Mukhrung	41	55	169	443	26	25
Dentam	upper Begha	55	53	508	120	27	0
Dentam	Middle Begha	44	40	564	16	18	0
Dentam	Lower Begha	51	64	386	282	11	0
Burikhop	Upper Buriakhop	9	17	158	44	17	0
Burikhop	Buriakhop-Bichgaon	14	26	235	17	0	0
Burikhop	Lower Buriakhop	13	18	97	141	5	8
Okhrey	Bhareng	45	57	360	102	2	0

1.3.3. EVOLUTION OF PASTORALISM

One of the first inhabitants of the Himalayan state were pastoralists from Nepal who had started establishing *goaths*[2] in the forests dividing the two nations. Lifestyle practiced in the region was semi nomadic in nature with horizontal and vertical movements; depending on the animal. Apart from construction and maintenance of cattle shed, fuel wood and fodder requirements were met by intense cutting and logging of nearby trees. Agro –pastoralism slowly evolved in the region wherein men-either alone or accompanied by a caretaker or eldest son stayed in goaths in forest areas while the female worked in agricultural land in village. In case of non availability of arable land, nearby forests were burnt to accommodate the need for practicing agriculture.

One of the first cattle shed was set up by the King in West district of Sikkim. Subsequently, after the state became a part of India, residents of nearby villages started establishing temporary cattle sheds in the nearby forests. Migratory route of these herders depended upon availability of fodder, water, animal type and hence was seasonal in nature. During summer, particularly from April to September, cows were left to graze freely in forest while movement of yaks, *urang* and *dzo* was restricted to sub alpine region. The animals continued to move in the same altitudinal zone even during breeding months (June to August for *dee* i.e. female yak and May- June for *urang*). During winter, typically after *diwali*[3], cow would be brought back to the homestead while other animals would proceed to lower altitudinal mixed coniferous forest. Products like *ghee*[4] and hard cheese were continuously made in *goaths* and sold to local traders fortnightly or monthly. *Patta system*[5], practiced by the *Chogal*[6] continued even after Sikkim joined India as a state in 1973 and was finally abolished in 1986.

1.3.4. LIVESTOCK POPULATION

Historical records indicate that domesticated livestock composition was limited to cows, buffalos, sheep and sometimes horses until first yak cow shed (*goath*) was established in early 1970s. (Figure 1.3) Herd size varied depending on the animal – a sheep herd owned minimum of 150 sheep while a cow or buffalo goath had a maximum of 20 of them.

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[2] In order to accompany livestock in search of fodder inside forests, pastoralists built temporary shelters, locally known as Goaths. These shelters were used to produce ghee and hard cheese from the milk milked from the livestock. Each pastoralist moved from one goath to another depending on season and fodder and water availability.
[3] Festival of lights celebrated in the month of October-November every year
[4] Home-made butter
[5] System developed by the king where in herders had to pay rent for grazing animals in the forest. The *patta*, as called by locals, varied from animal to animal and was paid yearly.
[6] King of Sikkim

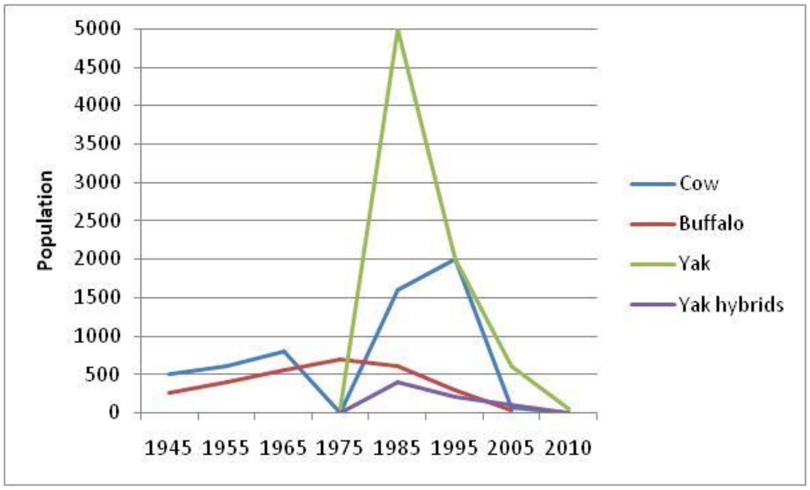


Figure 1.3: Trend depicting change in livestock population in Barsey Rhododendron Sanctuary

During the year 1972-73, a major forest fire destroyed forests on India-Nepal border. During this period, cow population was more than the buffalo while sheep population started to decline due to competition for fodder in sub alpine region. Domestication of yak continued to increase over the next five years until *Urang*[7] (female) and *Dzo*[8] (male), cross breeds of cow and yak were introduced in the region. These cross breeds, introduced in late 1970s and early 80s, were preferred over other animals due to better quality of milk and ability to carry huge amount of load. The preference was depicted in steep rise in population yak and its hybrids and decline in cow and sheep population. Until 1986, *patta system*, was practiced in the region under which herders who used to pay rents for grazing animals freely in the nearby forests. This local tax depended on type of livestock and was finally abolished in 1986. Hence rise in livestock population along with intensive deforestation for fuel-wood and fodder increased pressure on forest resources; thus inviting first notice for eviction of goaths and stop grazing in forests. The ban was finally implemented stringently in 2000, nearly over a decade after the first notice.

[7] Female of yak hybrid
[8] Male of yak hybrid

CHAPTER 2
APPROACH TO EFFECTIVE ASSESSMENT

2.1 INTRODUCTION

Environmental degradation is widely recognized as a result of unchecked growth of materialistic development combined with dismal formulation and enforcement of regulations. Since 1990's international organizations, national governments, grass root level institutions; have all started showing great concern for environment, with major initiatives being taken by each for conservation and protection. Long term policies balancing economic development and degradation are the central focus of policy formulations. The surge of such initiatives has also raised the need to investigate their role in attaining the desired set of objectives. Lack of monitoring of the implementation process adds to the problem of deficit information systems on environment, along with disseminating information. Despite the data issues, the environmental interventions need to be evaluated so as to provide an indication on the outcomes and outputs of such interventions. Program evaluations give the information regarding the effectiveness of the program and elucidate the details on the direction of the intended outcomes and impacts. In this context, they are useful tools for policy makers and aid in effective policy making. With the increasing involvement of national and state governments in tackling environmental problems, across ecosystems, such program evaluations assume significance especially in a country like India where policy implementation is a challenging task.

While conducting impact evaluations for the environmental programs, lack of data whether baseline or monitoring is one of the major challenges. In low data environment with huge data gaps, evaluators tend to use publically available generic national data sets as baseline. Total dependence on secondary data sources might present a skewed picture as the data collected may not be either for similar purpose or measurement units or time period. For example, Hills Leasehold Forestry and Forage Development Project, implemented by government of Nepal from 1993 used data collected by the technical agency in 1996, as baseline for an impact assessment study in 2003. Apart from data, conducting assessment after impact detectable time gap determines the efficacy of impact evaluation process. Results of impact evaluations for biodiversity services programs conducted immediately and after five years will vary, signifying that time period reveal success or failure of an intervention. Another instance of the same would be a 2005 impact evaluation study on ecosystem services government program implemented in Costa Rica in 1997, which provided insights into risks faced by farmers if the payments for conserved services stopped. In addition to these challenges, designing policy objective oriented evaluation study is vital.

What is to be done when impact assessment studies are limited by data constraints or political constraints or budget constraints? The question then is: Can rigorous general environment/development program evaluations serve as an effective input into informed policy making as an impact evaluations? Could effective program assessment be helpful in establishing program impacts in low data environments? This section deliberates on these questions and illustrates this by developing a framework for evaluate the effects of grazing exclusion policy. It also discusses in details the challenges faced while designing an impact assessment study for the grazing exclusion policy. It puts forward an in-depth account of the limitations of designing a conventional impact assessment study in low data environments.

2.2 EVALUATION IN LOW DATA ENVIRONMENTS

This section briefly describes the design alternatives for impact assessment type of exercise for conservation intervention and the challenges associated in applying them to low data environments. Subsequently, we discuss an effective framework that can be used to measure the impacts of conservation interventions. The area of conservation policy evaluation is still evolving and the rationale behind discussing the framework provided

2.2.1 AVAILABLE IMPACT ASSESSMENT FRAMEWORKS

Based upon when the program evaluation is conducted, the two broad types of evaluation approaches for impact assessment type of studies are:

- ***Before and after assessment***
  Comprises of comparing a scenario before the intervention to the one after the completion of the intervention. Such an assessment can be resource intensive, particularly when new data sets need to be collected. These are difficult to carry out in the absence of baseline data. The exercise is most applicable for programs that are regularly monitored and where baseline information is available.

- ***Ex-post impact assessment***
  Comprises of comparing an area or a group that has received the intervention to a similar area or group from whom the intervention was withheld. Such an assessment is characterized as summative evaluation and cross sectional data sets suffice the data need. The challenge in this case lies in establishing the "similarity" of the treatment and control groups – our ability to attribute current differences between the "treatment" and "control" group to the intervention being studied depends on how sure we can be that the two areas were similar before the intervention.

Adopting any of the above type of evaluation approach requires / necessitates a rich repository of available data sets which is usually difficult in real life projects. Establishing clear control sites or control groups is the crucial step in the ex-post assessments. For conservation intervention in the forestry sector that would mean identifying a site that has similar environmental, social, and economic characteristics as the proposed study site, but where the implementation of the conservation intervention differs from the study site. Quantitative strategies using either of experimental, quasi experimental or non experimental designs can then be applied to attribute the causal relationship. Experimental designs require complete random assignment of subjects to the control group and hence are tricky to apply in field situations for conservation interventions. Quasi experimental designs are relatively easier than experimental designs but they too require establishing a comparison group and their effectiveness depends a lot on the way the comparison group is established. In real life situations, the resource and time constraints are overriding factors that affect conducting such in-depth evaluations. Also, such evaluation shows the impact on a single entity i.e dependent variable which could be variable on deforestation rate or species specific. Such evaluations rarely capture or provide an explanation for the change in the ecosystems due to the intervention.

2.2.2 CHALLENGES OF EVALUATION IN LOW DATA SETTINGS

As described in the earlier section conducting impact assessments for conservation interventions in low data environments presents many challenges. The section below discusses some of the key challenges that are typically encountered in a rural or natural setting in data deficient regions.

LACK OF AVAILABLE DATA

Impact assessment designs are usually data intensive. For a successful impact study either, before and after data or cross sectional data for control and treatment groups or sites is essential. Evaluations for conservation interventions require data on environmental attributes such as forest cover, forest types, wildlife populations, water and soil quality, classified imagery etc. Usually secondary information on such relevant parameters is unavailable. Conducting a primary survey to capture data on relevant parameters is extremely expensive in terms of time and budget.

UNPLANNED NATURE OF PROGRAM EVALUATION

A program or policy evaluation for environmental policies is rarely done in developing countries like India. There are usually no budget allocations separately made for research components in such interventions. They are usually not planned and are mostly commenced after the intervention. In such cases, it becomes difficult to conduct an impact assessment as there is neither baseline data nor any regular monitoring information.

ENSURING SIMILARITY BETWEEN CONTROL AND TREATMENT SITES

The selection of a control site in an impact assessment study would be based on key attributes that would substantiate the similarity between the treatment and control sites. The attributes are selected in a way so that they should remain relatively constant over time and that they should be easily assessable. For conservation interventions in forestry, this means finding a control site that is similar in nature to the treatment site in terms of vegetation composition, topographical features (altitude, slope), long-run edaphic factors (soil type) and socio-economic conditions of people living in an around the area (ethnicity of people, livelihood strategy). Thus in real life conservation projects it is extremely challenging to establish a control site.

TERRAIN CHALLENGES

Collecting primary data is challenging and time consuming task especially in difficult natural settings. Also, seasonal element is an crucial criterion in vegetation characteristics. For example, there could be numerous considerations such as; a variety of annual herbs or grasses or medicinal plants have different growing seasons, shedding of leaves makes tree identification difficult etc. In order to capture the vegetation characteristics of the area sometimes seasonal surveys become important which requires more resources in terms of time and finance. Also, access to undisturbed locations could become an issue due to the dense growth or wildlife concerns or difficult terrain considerations.

PROLONGED INTERVAL BETWEEN INTERVENTION AND THE IMPACTS

Conservation interventions take substantial time for the ultimate impacts to show. Usually the policy interventions are designed for short to medium time frames. While the time taken by ecosystem to reflect the impacts of the intervention could be considerably more than that. In such cases, the evaluations conducted immediately after the intervention would not be able to capture the ultimate impacts. In such cases selecting appropriate associative parameters to measure the intermediate outcomes and to gauge the direction of the impact becomes a crucial step.

EXPERT KNOWLEDGE

Conservation interventions require a multidisciplinary approach. For a robust design inputs are needed from a variety of fields such as ecology, pedology, hydrology, imagery & social sciences. Besides these, local experts having in-depth knowledge and understanding of the area are also essential. Getting a multi-disciplinary team for small scale projects is an enormous challenge.

RESOURCE CONSTRAINTS

This is an overriding in most of the impact assessments constraint. Impact assessment studies are time and cost intensive. The scope of the study and design that can be employed depends to a great extent on the type of budget and time available for the study. Typically limited budgets and time are available for such studies as policy makers or governmental bodies who mostly commission such studies require rapid and informative assessments.

MISMATCH OF SCALES

The boundary of protected area network does not match with the administrative boundaries of districts and states. For example in Indian Forestry, the records might be available at a forest circle or forest division level which would not correspond with administrative boundary of a district. So it becomes to inter-link the socio-economic and ecological variables in such cases. Also sometimes the study is conducted at the micro level and secondary information is available only at district level. It becomes difficult in either case to utilize the data as micro level site could differ significantly from the larger landscape such as district in many ways.

BLANKET POLICY PRESCRIPTIONS

Forming control groups is an essential approach in most of impact evaluation designs. For conservation projects, to ascertain the causal relationship this translates to finding a control site and a control group similar to the study site (treatment) but which differs in implementation of the conservation policy. Usually policy prescriptions in conservation are brought in for a larger landscape (national or state level) and they usually cover all the protected forest areas and reserved forest areas. Thus, establishing control site or a control group becomes in these contexts.

2.3 EVALUATION DESIGN COMPONENTS FOR EFFECTIVE ASSESSMENT

The various elements in an ecosystem are inter-linked with each other. A change in the status of one is bound to cause an alteration in some of the other elements. Accordingly, successful implementation of the ban is supposed to improve the condition of the degraded forest landscape, but it is necessary to fully understand what aspects of the forest it helps more than others as well as where its impact could

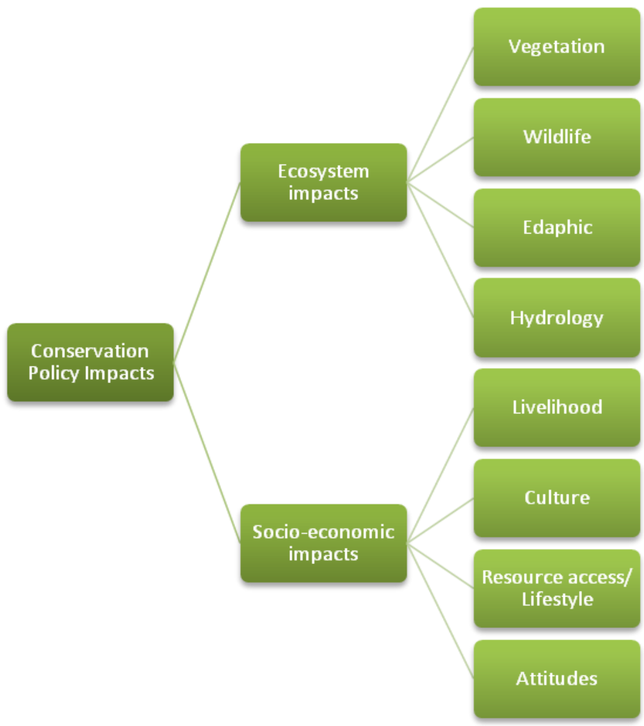


Figure 2.1 Schematic representation of identified components for evaluation of conservation intervention

be strengthened. Evaluations can also help understand other, potentially confounding, influences on forest health. Restricting the analysis to ecological characteristics in such a study can provide highly misleading policy inputs as it would overlook the opportunity costs of livelihood foregone by local communities. Thus, indicators referring to impact on welfare of people and ecology, both should be used as the basis of designing a holistic & effective program evaluation of the conservation intervention. Figure 2.1 provides a schematic representation of the distribution of impacts of a conservation policy across various thematic areas.

Accordingly, presented below is the framework designed for evaluating a grazing exclusion study. The framework can be adopted for other studies related to grazing in forest areas. The evaluation framework is divided into three main components: Vegetative, Physical and Social. A detailed criteria-indicator (C&I) framework can also be developed from this for a qualitative assessment. The section below describes in details the important parameters under each of these components and also provides an overview of the likely indicators to be considered by the study.

2.3.1. VEGETATIVE COMPONENT

One of the prominent and observable changes induced due to grazing is on vegetation in an area. When the density of domestic livestock increases, it leads to overgrazing of an area. Continued grazing pressure on forests could lead to change in species composition in the long run due to selective lopping and cutting of preferred fodder and firewood species. Also, this may cause increased abundance of unpalatable species and introduction of non native invasive species. Other than grazing by livestock the vegetation is also impacted by the activities of the herders. Also, increase in livestock densities leads to competition between wild herbivores and domestic livestock. Some of the issues could be site specific and it is important to understand and include those vegetative parameters in the evaluation. Table2.1.presents a list of important parameters that should be considered for a grazing related evaluation study.

Table 2.1: Identified Vegetative parameters for evaluation of grazing issue related studies

Parameter	Description	Recommended Indicators
Forest structure	Forests are characterized by vertical layers typically consisting of ground floor, understory, middle storey and over storey. Lopping and cutting of trees introduce alterations in the forest structure by making forests more open. And sometimes the pressures are felt more by a particular age-class distribution of trees.	Percentage of canopy density, Presence and status of forest layers, DBH distribution, tree height distribution
Species composition and distribution	Grazing and associated activities possibly could alter the vegetative composition of an area via activities like selective grazing, lopping etc. It is important to examine the extent of change brought about mainly in key species & medicinal plants from ecosystem and community needs point of view.	Three most common species as percentage of total growing stock, Ten most common species as percentage of total growing stock, Diversity indices, Species at risk, Fodder species as percentage of total growing stock, Fuelwood species as a percentage of total growing stock, Existence and distribution of medicinal plants, litter distribution, presence and distribution of medicinal plants
Wildlife sightings	Wild animals are extremely sensitive to changes and disturbances in their habitat. It is a measure to predict the impact on wildlife in the area	Area of plantations for habitat improvement works Number of sightings of wildlife / calls
Regeneration	Regeneration is one of the most important functions that are hampered by grazing. It is a measure to observe the status of recovery via regeneration	Species wise number of saplings, Coppice Regeneration,
Forest	It is important to examine the extent of	Presence of domestic livestock

Parameter	Description	Recommended Indicators
disturbances	change brought about by disturbance such as grazing, fire, cutting, lopping and introduction of non native and invasive species. This measure captures the vegetative health of the ecosystem	Percentage of vegetation affected by grazing, Area affected by forest fire, Percentage of area affected by lopping, cutting etc Species affected by the disturbance, Percentage of area under non native or invasive species

2.3.2. PHYSICAL COMPONENT

Overgrazing is a common phenomenon in pasturelands and forest areas and consequently it leads to deterioration in land quality and creation of wasteland. Typically an area subjected to overgrazing becomes more susceptible to threats like soil erosion, soil compaction and loss in moisture holding capacities besides other. While overgrazing could be a problem, available literature also shows instances where controlled grazing is beneficial to the site and has helped in improving the fertility of the area. Study of edaphic factors and hydrology constitutes a challenging task. Table 2.2 presents some main parameters to capture the soil stability and hydrologic functions for grazing affected forest lands.

Table 2.2: Identified physical parameters for evaluation of grazing issue related studies

Parameter	Description	Recommended Indicators
Soil composition, texture and structure	Soil constitutes a basic element of forest ecosystems. Health of the vegetation in an area is directly dependent on the health of the soil at a place. This measure attempts to capture the soil properties in the area	Percentage of Moisture Water holding capacity Bulk Density, Particle Density, Porosity, Soil texture
Soil chemical composition	Nutrient rich soil aids vegetative growth and in turn assists in improving habitat quality. Fertility of soils is a significant factor especially in hilly areas. Controlled grazing is considered beneficial for improving the soil quality at a place. This parameters gauges the effect of grazing on the nutrient levels	Level of acidity (or alkalinity) Soil Nutrients (N,P,K) Soil Organic Carbon content Cation exchange capacity
Soil stability	Vegetative cover or presence of organic matter in the top layer of the soil binds the soil particles together, in turn decreasing the erosion potential. The other factor is the structure of the top layer of soil itself. Loosely bind soils are more prone for erosion. In hilly terrains having steep slopes, water flow increases gullies and rills formation, which in turn accelerates soil degradation. Livestock tracks tend to result in	Soil stability test results Soil erosion status Soil compaction Gullies and Rills formation

Parameter	Description	Recommended Indicators
	gully formation especially in mountainous regions. This parameter classifies the erosive properties and degradation at site.	
Water quality	Quality of water in a catchment is a function of many factors. Undisturbed catchments will tend to have better water quality than the ones with disturbance. This parameter evaluates the water attributes.	Status of Water streams (seasonal/perennial), water quality tests
Recharge of aquifers	Overgrazing and other anthropogenic pressures hamper the hydrological regime by impacting infiltration rates and percolation rates and increasing surface run off. This parameter attempts to capture any change in hydrological properties after the ban on grazing	average ground water level in water bodies in the vicinity of forests during past 3-5 years

2.3.3. SOCIAL COMPONENT

In order to do a holistic impact evaluation, the study of the impact of conservation policy (in this case grazing exclusion) on the local economy and the lives of dependent local communities is essential. The significance of this aspect is for several reasons: first, the social component is important for assessing successful proliferation of the intended outcomes of the conservational policy i.e. grazing exclusion. Second, peoples' perceptions of the impact of a ban can be as important, if not more important, than its actual impact. The sustainability of any changes depends on the policy being either enforced or incentive compatible with the local community. Third, the social component may help to develop a more robust strategy if credible historical data based on peoples' recollections can be gathered. Such data must be handled with care, but it could help us do some limited before-and-after comparisons, which would in turn strengthen confidence in our results.

Table2.3: Identified elements of interest for evaluation of impact on socio-economic aspects

Study Elements	Description	Recommended Indicators
Livelihood strategies	Livestock rearing is a significant livelihood across communities in India. Livestock are the main source of milk and related products and many livelihood strategies are dependent or partially dependent upon it. Through this element, the impact of policy on livelihood strategies would be studied.	Livelihood strategies and income before and after the conservation policy implementation, asset ownership, debt , alternative means of livelihood

Study Elements	Description	Recommended Indicators
Cultural impacts	Due to conservational policy, access to earlier free forest resources is curtailed. This can bring about change in resource extraction pattern and also in lifestyle . Access to education and health could also be affected	Access to resource, Resource extraction pattern, making of local milk products,
Forest Fires	Relationship of forest fires and grazing is tricky considering that controlled grazing is regarded as beneficial for controlling forest fires, while heavy grazing along with fires is known to degrade forests. In addition the aspect of human induced forest fires is associated with grazing. This measure investigates the role of ban on the forest fire frequency	Frequency and distribution of forest fires
Wildlife conflicts	An increase in wild animal numbers is usually associated within conservational policies. This may lead to substantial increase in man-animal conflicts within the fringe areas An effort is made to document this and get people's perception on this issue	Damage caused by Wild animals, Frequency,
Perception towards the conservation policy	From a policy strengthening perspective it is important to understand how people perceive the conservational program.	Perception of local community on performance of conservational policy on environmental, health, education, livelihood aspects and participatory approach

2.4 CONCLUSION

The purpose of carrying out evaluation of conservation policies is to provide the policy makers with meaningful and reliable information on the outcomes and impacts achieved by the policy on ecosystems as well as on the local communities. The quantitative designs of impact assessments are statistically more robust and establish casualty but in real life conservation projects, it is difficult to implement such designs. Also in certain cases it is difficult to create treatment and control groups. In low data environment, using alternative design options and frameworks using mix method approach as presented in the paper offer useful insights on policy relevant parameters. The presented framework integrates qualitative and quantitative techniques, and it serves as an effectual approach to program evaluation for conservation interventions. The quantitative techniques provide the necessary logical base and ascertain the relationships statistically while the qualitative techniques help in substantiating the findings of the study. Thus it presents a feasible methodology for assessing impacts in the absence of detailed longitudinal ecological or socio-economic data.

CHAPTER 3
ECOLOGICAL HEALTH AND DISTURBANCE

3.1 BACKGROUND

Forest ecosystems have a key role in maintaining the ecological balance in a region and are part of social, cultural, historical heritage. In Sikkim, they are an integral part of life, for the forest dependent population living in and around the forests areas. Forests serve as the resource base for the sustenance of its population and the repository of biodiversity as well. The forests in the region are mainly used for fuelwood collection, fodder collection, timber for construction, grazing of livestock, medicinal and recreation purposes. The health of the forest ecosystems is a critical factor in maintaining the productivity levels and provisioning of the ecosystem services. Degradation and depletion of natural resources are the consequences of ever increasing anthropogenic pressures on the natural resources. Natural resource systems like forests though could be replenished naturally if harvest is within the carrying capacity of the ecosystem. Over-withdrawal from these resources leads to depletion of the critical stock essential for replenishment. The problem of over exploitation becomes even more crucial in fragile ecosystems such as the eastern Himalayas. The growth rate of vegetation is moreover lower in these regions, resulting in additional time for restoration and recovery of degraded landscapes. Thus the degradation of natural resources gains significance in this context.

From the mid-1970’s through the late 1990’s there was a rapid rise in the biotic pressures on the forests in terms of increasing livestock and increasing demand of forestry resources. The agro-pastoral lifestyle followed in the region was a foremost cause of concern as it was adversely affecting the health of forest ecosystems. According to the State forest report (2001), almost 25% of the forest cover was in the open forest category. The pastoral model followed in the region lead to increase in the land under degradation. Usually, adverse impacts on ecosystem health that can be associated with pastoral activities, such as manipulation of the vegetation, introduction of exotic species, selective grazing by livestock etc. Such change introduced in can lead to change in species composition over a long term period. Also differential impacts would be felt in different forest types.

With this background, the objective of this chapter is to understand the impacts of pastoral activities on the vegetation structure and composition of the forests in the region. The key aspects studied under ecology include vegetation parameters (forest structure and composition, regeneration, disturbance etc), soil parameters (soil chemical properties and soil erosion related information) of the place, hydrology (water sources flow & quality) and wildlife (trends in sighting).

This chapter is divided in two parts: Vegetation & Edaphic. In the first section we present observations and analysis on vegetation related parameters while in second we present the results of soil testing.

PART I: VEGETATION ANALYSIS

3.2 MATERIALS AND METHODS

3.2.1 FIELD SURVEY

The study area has a mountainous topography with difficult terrain. As the current study was commissioned for duration of one year, carrying out seasonal surveys was not in scope. Looking at the brief time availability for the project, a rapid and effective survey design was adopted. Extensive field surveys were conducted in November – December 2010 to collect detailed data on vegetation and soil parameters, while qualitative data was collected on hydrological and wildlife aspects. Prior to these, preliminary surveys were performed in September-October 2010 to understand the study area and to demarcate the sample locations. These locations were identified keeping in mind the main intention behind this component; i.e. to study the health of forest systems affected by pastoral impacts. The locations were established based upon discussions with the ex-herders in the region. The survey routes were marked to cover the low and high intensity grazed areas, so that the sample captures the entire range of the area affected by grazing and serve as a good representative.

In BRS has an altitudinal gradient of 1900m- 4100m. Before the implementation of the grazing ban, more than 200 cattle-sheds were spread across the sanctuary. Change in altitude, is accompanied by a change in vegetation type, and by a corresponding change in nature and form of livestock that graze. For example yaks are found only at the altitudes of 4000m and above while cattle and sheep graze at lower altitudes. Thus the impact of grazing on environmental variables would differ as the altitude varies. Hence we adopted a stratified approach and decided to take sample plots in and around these cattle-shed areas traversing across the altitudinal gradient, across different forest types. The benefit of using a stratified approach as per forest types was that it enabled us to capture any patterns (variation in impact of degradation caused by grazing across altitude) if they exist, and also provided, a good representative sample of the study site as the plots are spread across in the study locations.

The altitude of the study area varied between 2000 m to 4000m. Within this altitudinal range, the vegetation communities shift from temperate to subalpine forests. The forest types were stratified into 4 broad categories:

1. Upper Hill-Himalayan Wet Temperate Forest (Oak and dwarf bamboo dominated)
2. Moist temperate forest (Mixed coniferous)
3. Sub-alpine forest (Birch/Fir & Rhododendron forests)
4. Sub-Alpine scrub (Rhododendron & scrub thickets)

In each of the forest type zone, cow-shed spots were identified in high and low grazing intensity (disturbance) areas. The high and low disturbed areas were identified by consultations with local herders and forest officials. 10 plots were laid in each of the forest type zones within 1 ha radius of the cow-shed locations, except for the sub-alpine scrub forest where quadrants were laid. In all 60 plots of

0.1 ha each and 40 1 m2 quadrants were laid. Also, 70 soil samples were collected. The methodology prescribed by the Forest Survey of India was followed for collecting vegetation data from the plots. In each of the plot, four 3 m X 3m sub-plots were laid to capture regeneration and shrubs data and four 1m X 1m quadrants were laid to capture data on herbs. (FSI, 2002). A detailed inventory on important vegetation attributes such as canopy cover, regeneration, girth at breast height, tree height etc was prepared. Also details on forest disturbance such as lopping, cutting, fire, signs of domestic livestock grazing were also recorded. Any wild life signs during the survey were also recorded. Thus, we prepared a rich repository of ecological data on key attributes.

Figure 3.1: Field survey for vegetation and soil data collection

3.2.2 VEGETATION ANALYSIS

The analysis for the ecological characteristics was performed using two software packages *TURBOVEG for WINDOWS* and *JUICE 7.0 TURBOVEG* is a software package that helps in building a database management system for vegetation data. It's proprietary software developed by Mr. Stephen Hennekens. A licensed copy of the software was procured by coordinating with Mr. Hennekens. We have used TURBOVEG 2.91b for WINDOWS single user version. Excel spreadsheets were used for recording and storing the field data. Besides recording details of vegetation characteristics, the vegetation plot form captured species coverage characteristics using Old Braun- Blanquet scale. The Braun-Blanquet scale describes species abundance coverage individually for each species. The scale used and its interpretation is provided in the table 3.1. The vegetation data from the field was organized into required formats so as to enable its upload in the TURBOVEG software. The output from TURBOVEG serves as an input into the JUICE software. JUICE is a Microsoft® WINDOWS® application used for editing, classifying and analyzing large phyto-sociological tables. It is a freeware and can be downloaded from www.sci.muni.cz/botany/juice.htm We used JUICE 7.0 version for analysis. Figure 3.1 provides a schematic representation of the data analysis.

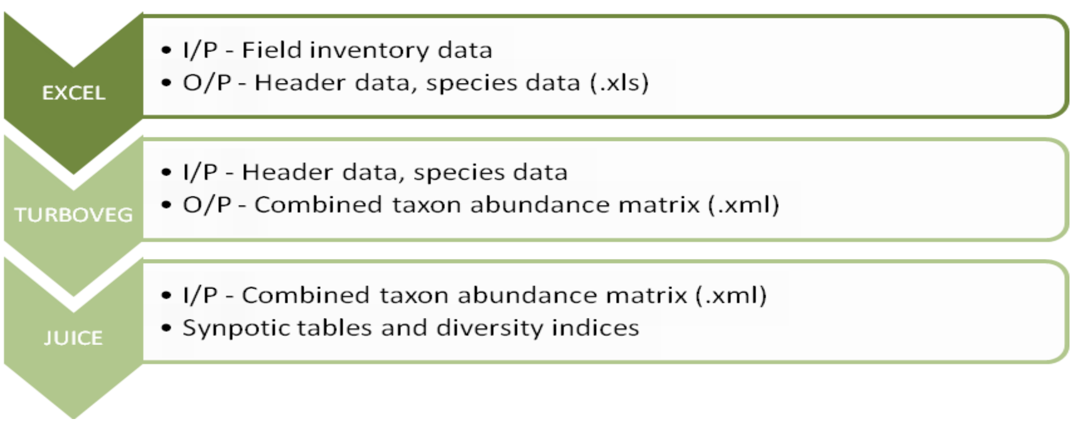


Figure 3.2: Schematic representation of vegetation data analysis ; Adapted from (Tambe, Ecology and Management of the alpine landscape in the KangchenDzonga National Park, Sikkim Himalaya, 2007)

Table 3.1: Description of adapted modified Braun-Blanquet scale (Mueller-Dombois & Ellenberg, 1974) of species abundance (Broadbent, 2010)

Codes	Description
+	Few with small cover
R	Solitary with small cover
1	Numerous but less than 1/20 cover or scattered with cover upto 1/20 < 5%
2	Any number, with 1/20 - 1/4 cover 5-25%
3	Any number, with 1/4 - 1/2 cover 25-50%
4	Any number, with 1/2 - 3/4 cover 50-75%
5	Any number, with cover more than 3/4 of the reference area

3.3 VEGETATION - RESULTS AND DISCUSSION

3.3.1 FOREST TYPES

In Sikkim Himalayas, the distribution of tree species changes rapidly with elevation. Moving up the altitudinal gradient, the forest type changes from subtropical forests to the subalpine forests through the temperate forests. In this study, we have adopted a broad classification of the forest types. The four categories are: Wet Temperate Forest, Moist temperate forest, Sub-alpine forest and Sub-Alpine scrub. Most of the cow-shed locations at the study sites were found to be in the above forest zones. In this section we briefly describe the vegetation communities associations found at the study sites.

3.3.1.1 WET TEMPERATE FORESTS

This is an intermediary zone between the sub tropical broadleaved forests to the temperate forests. The characteristic species of this zone are *Quercus* spp. in the upper canopy and dwarf bamboo species (Arundaria Maaling) forming the undergrowth. The *Quercus* spp. are accompanied by *Alnus* and *Symplocos* spp. usually abundant in the mid-hill forests. *Quercus* spp. was the dominant group in the upper canopy layer, with *Litsea polyantha* (poinle) and Acer cambelli (kapasi) co-dominating the top layer. In *Quercus* group, *Q. pachyphylla* (bante) was the most abundant with lesser distribution of *Quercus lamellose* (Bajrat) and *Quercus thomsonian*(Phalant). This was characteristic of the upper-hill forests as the other two species are more abundant in lower elevations. It was observed that the distribution of the species *Litsea polyantha* (poinle) and *Ilex dipyrena* (lisse) was more in KBR than BRS. The middle canopy was characterized by the presence of *Symplocos laurina* (kholme), *Symplocos theifolia* (kharane). The under storey was dominated by presence of *Arundinaria maling* (malingo), *Viburnum* cordifolium (asare) and *Daphne cannabina* (kagati).

3.3.1.2 MOIST TEMPERATE FORESTS

The zone is characterized by the presence of a mixture of the broad-leaved and coniferous species. In this zone, there is no prominent specie per se and the vegetation in this with zone is distinguished by the presence of a combination of species in mixed proportions. *Tsuga dumosa*. is the most dominant species in the upper canopy accompanied by *Quercus pachyphylla* (bante) and *Ilex dipyrena* (lisse). The middle canopy was characterized by the presence of Betula alnoides (saur), Osmanthus suavis (sirlinge) and Magnolia campbelli (Ghoge chanp). The under storey showed distribution of a unique bamboo species Thamnocalamus aristata (rato ningalo) and the Rhododendron spp .It was dominated by presence of *Viburnum* cordifolium (asare) and *Daphne cannabina* (kagati).

3.3.1.3 SUB ALPINE FORESTS

The zone is characterized by the presence of a Rhododendron spp. mixed with the coniferous *Abies webbiana*. The Abies spp. forms the top canopy layer while Rhododendron spp. forms the undergrowth. The presence of other species such as Himalayan cherry or bamboo species was less.

3.3.2 VEGETATION STRUCTURE AND COMPOSITION

3.3.2.1 TREE HEIGHT

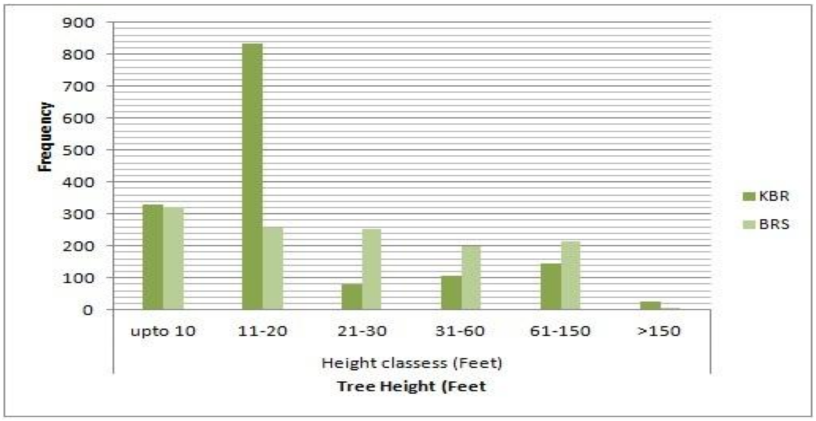


Figure 3.3: Comparison of tree height distribution in KBR and BRS

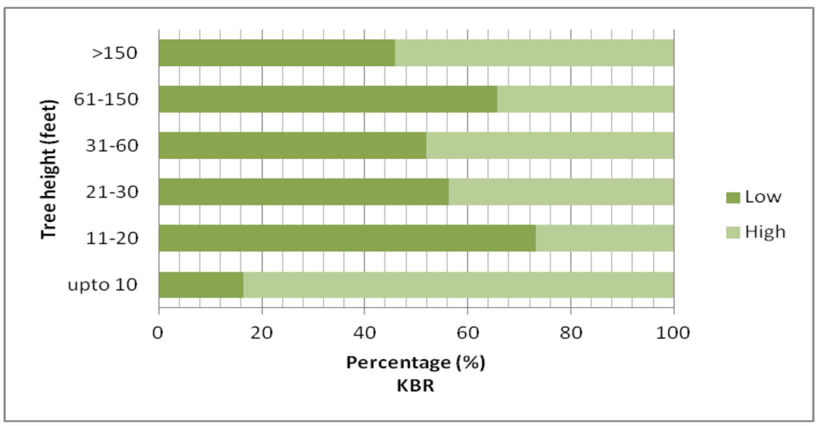


Figure 3.4: Tree height distribution in low and high grazing areas in KBR

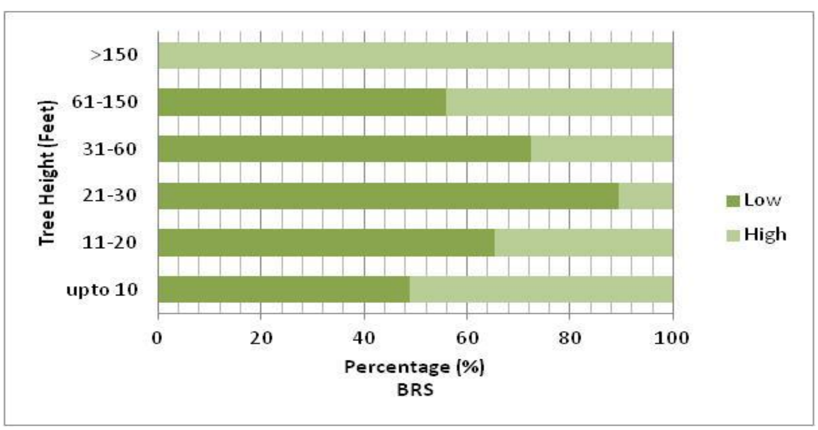


Figure 3.5: Tree height distribution in low and high grazing areas in BRS

The average height of the overstorey in KBR was 70 feet and in BRS it was 56 feet. The understorey in KBR was 12 feet and in BRS it was 20 feet. Looking at the tree height distribution gives a clearer picture. Overall KBR showed presence of more emergent trees --above 150 feet -- than BRS.(Figure 3.2) Most of these trees are concentrated in the wet temperate forests in the Nayapatal and bante chowk areas in KBR. KBR showed higher proportion of trees in the 11-20 feet category indicating regeneration in the area. BRS shows higher trees in the mature tree categories indicating fewer disturbances than KBR. The proportion of trees in the 21-30 feet and 31-60 feet is the lowest. This confirms to the trend of lopping and cutting medium age trees for use by the herders. Figure 3.3 and figure 3.4 show the percentage distribution of tree heights within the areas having high and low grazing pressure. In KBR most of the vegetation recorded below 10 feet was in high grazing pressure areas such as *Nayapatal* and *Thulodhap*. Here *Viburnum spp* regeneration is mostly contributing to this. As the percentage share of low category classes is high. IN BRS the proportion of trees in the 31-60 feet class is mere 11% in the high pressure areas. This shows absence of middle aged trees in the areas and depicts the need for forestry management intervention.

3.3.2.2 TREE GIRTH

The area showed variation in the tree girths across the forest types. The region is characterized by presence of old growth *Quercus*, *Tsuga and Abies species* mostly concentrated in the temperate forests. Figure 3.6 – Figure 3.8 presents the girth class distribution of the key species in the area.

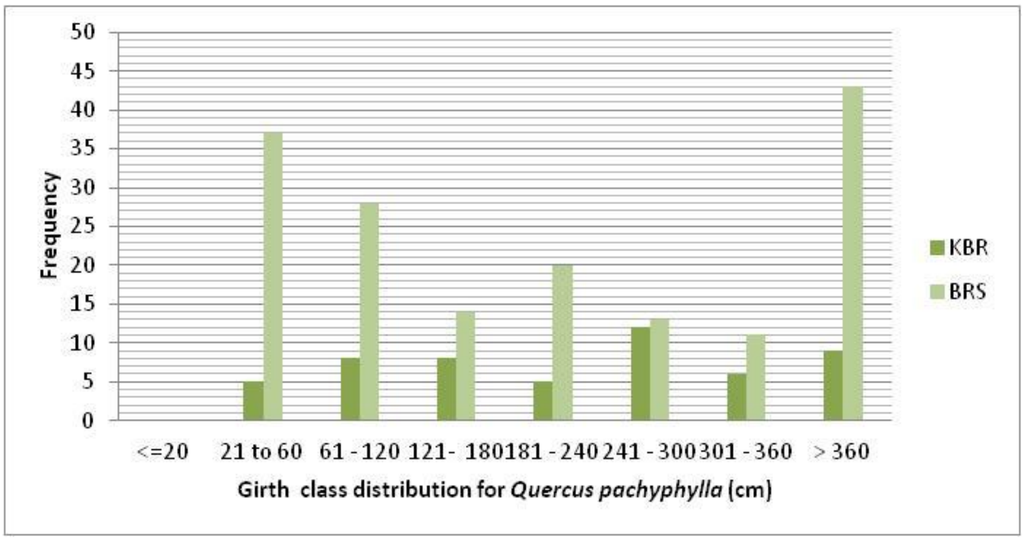


Figure 3.6: Girth class distribution for Quercus pachyphylla

Old growth Quercus spp were present in relatively higher numbers in BRS than KBR even in the grazing affected areas. This area corresponds to the cow-sheds close to Bhareng side of BRS. Some of these trees were heavily lopped. This area also shows profuse growth of *Arundinaria maling*. The distribution of Quercus in KBR on the other is relatively lower as the sample locations were exposed to severe grazing associated disturbances. The distribution of Tsuga dumosa was found to be relatively abundant in and around the sample locations in KBR than in BRS. Overall the distribution of hemlock in proximity to sample locations was found to be lower than other species. This is evident from the figures presented. From the insights gained through talking to local resource persons, it is understood that in BRS, the cow-shed density was lower near to Tsuga forests, as this area is close to *the sacred area.*

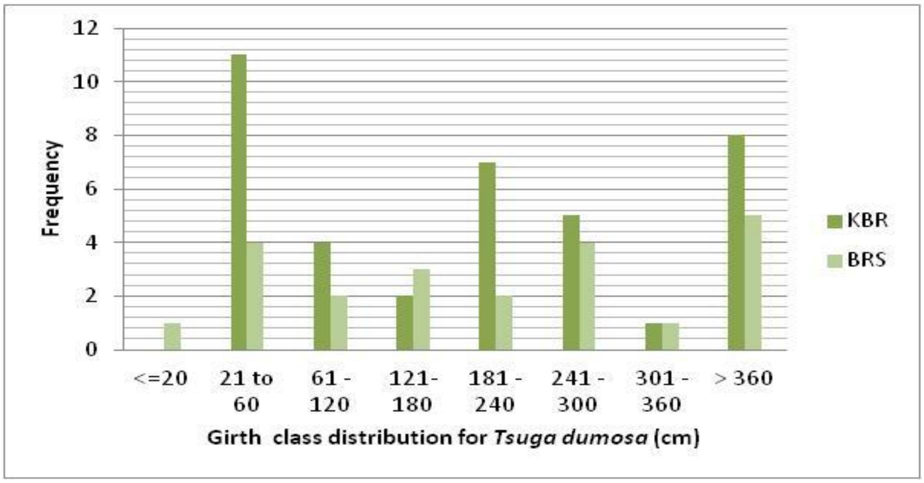


Figure 3.7: Girth class distribution for Tsuga dumosa

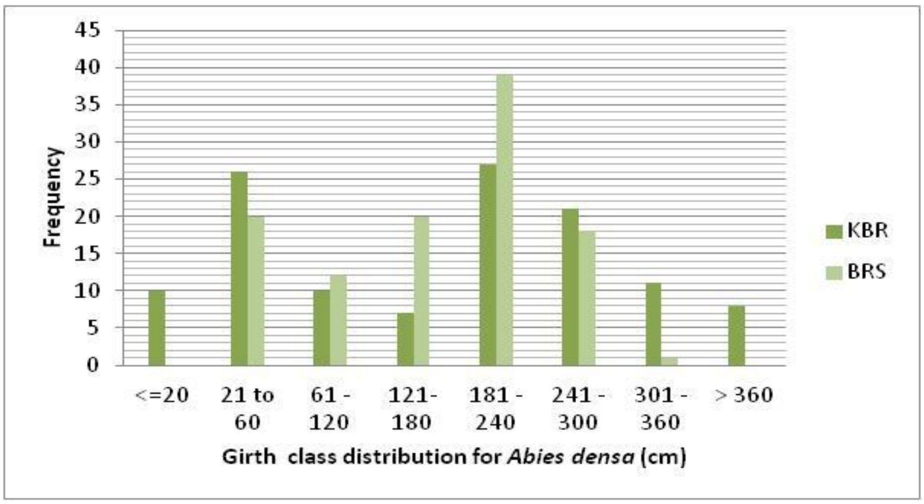


Figure 3.8: Girth class distribution for Abies densa

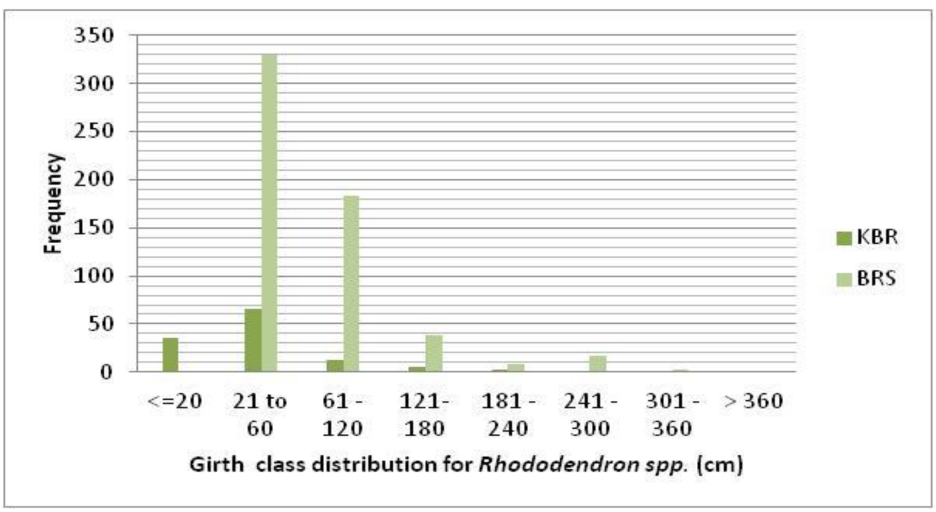


Figure 3.9: Girth class distribution for Rhododendron spp.

3.3.2.3 CANOPY COVER

High canopy cover is considered as a good sign of forest health while low canopy cover as a sign of degradation in tropical and temperate forests. We used the FSI standards of classifying the canopy classes into scrub (< 10% canopy cover, open (10-30% canopy cover), dense (31-70% canopy cover) and very dense (> 70% canopy cover). Figure 3.9 and 3.10 shows the percentage of plots under each of the above categories in BRS and KBR. The scrub class was not observed in this region. The reason for this, the plots laid for the study were laid in and around the cow-shed locations and not in the *kharka* areas Openings of almost 0.5 to 1 ha are usually formed in and around goath clusters. It is observed that BRS has more area in dense category than KBR.

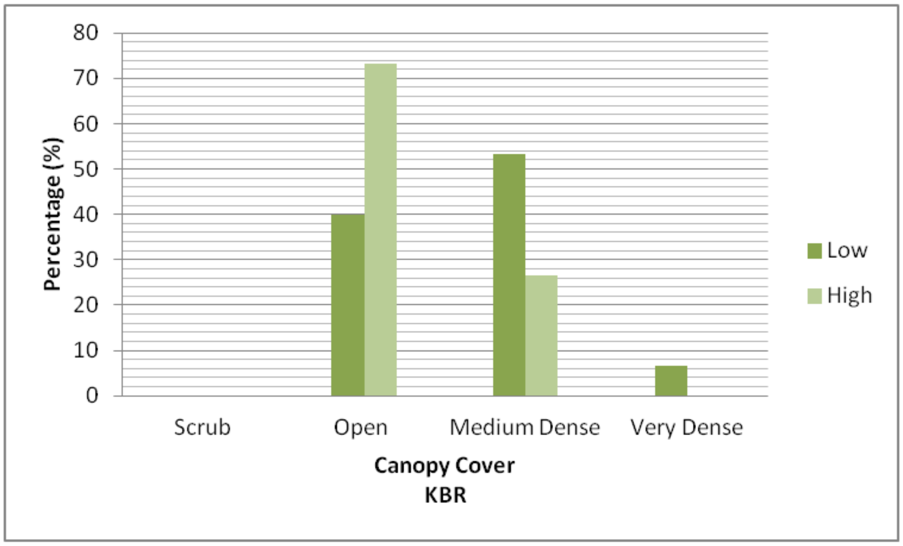


Figure 3.10: Canopy cover in low and high pressure grazing areas in KBR

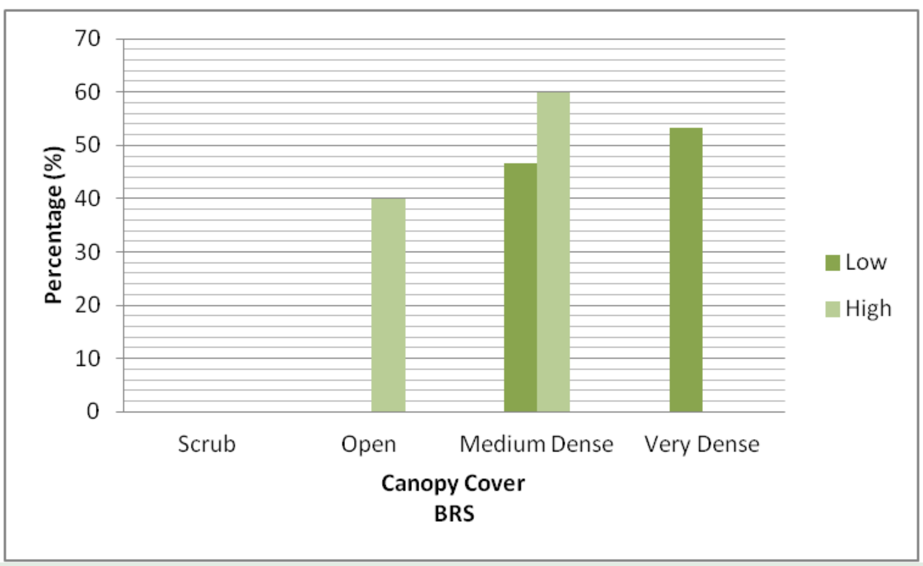


Figure 3.11: Canopy cover in low and high pressure grazing areas in BRS

3.3.3 SPECIES INVENTORY, FREQUENCY AND DENSITY

About 160 species were identified in the field during the inventory exercise (including grasses & ferns). This constituted 47 tree species, 15 shrub species and the rest 94 species forming the forest floor including medicinal plants, herbs, grasses, moss and ferns. Out of the 94 species, the botanical names for 42 species could be established and the rest are recorded in the local language (Nepali). A detailed list of the same is provided in the Annexure. About 9 species (excluding grasses, moss and ferns) occur in more than 30 plots. 3 out of these 10 species are the dominant herbs in the region: *Anaphalis adnata , Fragaria nubicola* and *Yame* (tibetian name of the herb). The other 7 species are the key species characterizing the forest types*: Viburnum cordifolium, Rhododendron arboreum, Quercus pachyphylla, Daphne cannabina, Arundinaria maling, Rhododendron barbatum* and *Abies webbiana* . This explains the similarity of the vegetation structure at the selected two study sites. Table 3.2 and table 3.3 exhibits the species at both sites occurring at more than 20% frequency at the sites. From this it is clear that the understorey at both the places is dominated by the Viburnum spp. It was extensively cut for firewood by the herders before the pre-ban period and now shows signs of profuse regeneration, mostly coppice in nature. Also it is observed that its regeneration is much stronger in KBR than BRS especially in the wet temperate forests of *Nayapatal* and *Gombey* chowk areas. Another significant difference in the two sites was in the distribution of the key species *Quercus pachyphylla* in the wet temperate oak forests. In KBR it constituted a mere 6% of the species composition in the oak forests zone, whereas in BRS it made up upto 40%. The most significant distinction between the two sites was the distribution of *Rhododendron spp.* As anticipated, the density of *Rhododendron spp was a lot higher* in BRS as compared to KBR as can be seen from the mean density values in the tables 3.2 and 3.3. There are dense *Rhododendron* forests in Barsey near *Taal*, *Asthal* areas. The grazing pressure in these areas was lower than in other part of the sanctuary hence the *Rhododendrons* are better preserved here. There was lopping and cutting in these areas earlier but as the natural concentration of the *Rhododendrons* is very high these areas hence despite the disturbance, it still maintains the stock.

Table 3.2: Species density and mean density in KBR

Species	Frequency (%)	Mean density
OVERSTOREY		
Quercus pachyphylla	57	3.06
Abies webbiana	53	7.44
Ilex dipyrena	47	2.93
Rhododendron arboreum	47	1.43
Rhododendron barbatum	43	3.31
Rhododendron hodgsonii	43	2.54
Tsuga dumosa	40	3.25
Litsea polyantha	30	3.11
Acer cambelli	27	1.50
Symplocos theifolia	27	1.13

Species	Frequency (%)	Mean density
Symplocos laurina	23	1.00
UNDERSTOREY		
Viburnum cordifolium	63	19.84
Daphne Cannabina	37	7.73
Eurya acuminata	33	12.00
Berberis spp.	20	3.13
Lyonia ovalifolia	27	1.13

Table 3.3: Species density and mean density in BRS

Species	Frequency (%)	Mean density
OVERSTOREY		
Abies webbiana	47	8.00
Magnolia campbelli	27	1.75
Quercus pachyphylla	60	10.39
Rhododendron arboreum	87	3.54
Rhododendron barbatum	60	15.78
Rhododendron hodgsonii	23	5.63
Tsuga dumosa	43	1.69
UNDERSTOREY		
Berberis aristata	23	6.25
Daphne Cannabina	77	2.22
Eurya acuminata	23	1.63
Lyonia ovalifolia	43	1.92
Pieris formosa	23	1
Viburnum cordifolium	93	7.54

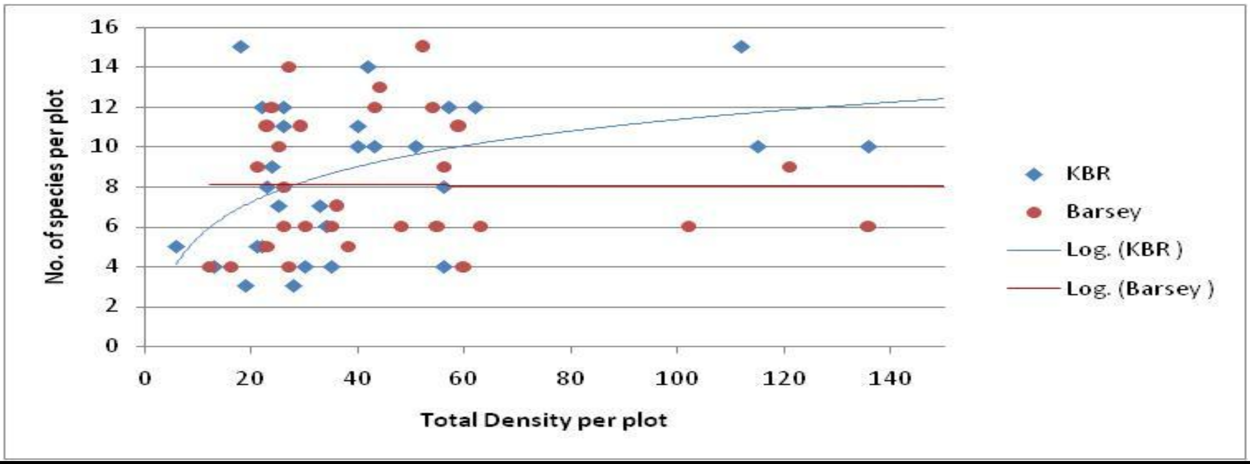
Total density of each plot was calculated as the total number of trees belonging to enumerated key species in each plot. The number of species per plot includes tree and shrub species. Average number of species per plot in each site was approximately 8. The average total density per plot in BRS was 53 whereas it was 46 in KBR.

Table 3.4: Average species richness

Forest Type	KBR		BRS	
Grazing pressure	***Low***	***High***	***Low***	***High***
Wet Temperate Forest	10.4	9.6	11.6	8
Moist Temperate Forest	11.2	12	12	6
Sub-alpine Forests	4.4	4.6	5.6	5.4

Table 3.5: Average total species density

Forest Type	KBR		BRS	
Grazing pressure	***Low***	***High***	***Low***	***High***
Wet Temperate Forest	81.4	40.4	28.8	25.4
Moist Temperate Forest	27	74	53	51



Forest Type	KBR		BRS	
Sub-alpine Forests	23.2	30.2	121	37.4

Figure 3.12: Species richness and Total Density per plot (line represents logarithmic trend line)

From the figure 3.11, it can be observed that there are three plots each in BRS and KBR having very dense vegetation. In KBR this can be attributed to the profuse growth of *Viburnum cordifolium* (Asare) while in BRS it corresponded to the presence of *Rhododendron spp.* resulting in quadrupling of total density per plot in the three exceptional plots in BRS. Table 3.4 and table 3.5 show that the species richness does not vary too much across the sites as well there is no significant difference between the low and the high degraded areas. As one moves high along the altitude, it is observed that the number of species starts reducing. The only exception is the high pressure area – *Thulodhap* – in BRS that had a relatively flat topography. This region shows almost 50% lower species richness than other areas in the moist temperate forests. Due to its conducive terrain for grazing, the area has been highly exploited and hence the species richness is lower. Earlier the cow-shed density was very high in this area and now there is enormous grassland that has been formed. This region shows good *rhododendron* regeneration towards *Dodwa* axis.

3.3.4 SPECIES REGENERATION

Regeneration in the plots was documented using the FSI methodology. The regeneration of the main woody species in the region was only noted. It was observed that due to absence of constant anthropogenic pressure, the region showed good regeneration. As per FSI, the regeneration in a plot was classified into adequate (if more than 18 seedlings) and inadequate (less than 18 seedlings). Figure 3.12 shows the adequacy of the regeneration across the different forest types. Plots in subalpine region showed more inadequacy due to closed canopy cover.

Table 3.6: Seedlings per ha in different forest types

Forest Type	KBR		BRS	
Grazing Pressure	*Low*	*High*	*Low*	*High*
Wet temperate forests	294	134	166	200
Moist temperate	800	220	306	386

forests				
Subalpine forests	966	372	292	344

In BRS, the presence of gregarious *malingo* regeneration was the reason for less regeneration of key species in wet temperate forests in BRS. The regeneration of *bamboo* was documented separately.

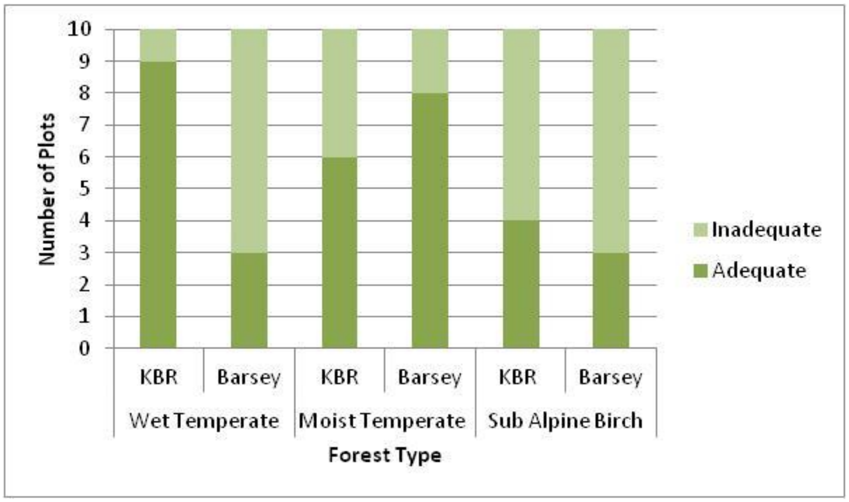


Figure 3.13: Adequate-Inadequate regeneration in forests

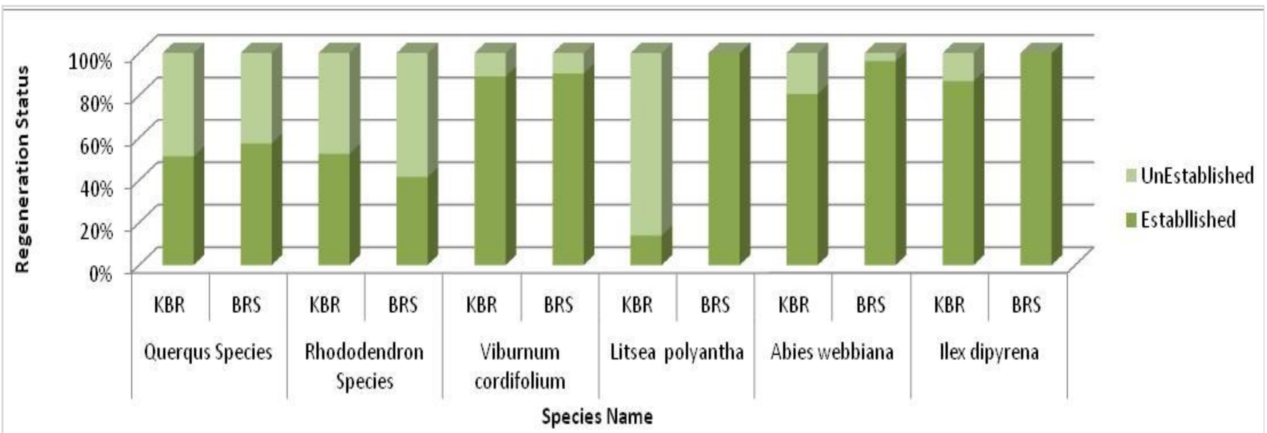


Figure 3.14: Key Species wise regeneration status in the study sites

Higher incidence of regeneration due to opening up of forest canopy was the main reason of gregarious regeneration in high grazing pressure areas in wet temperate forests (*Nayapatal*) and subalpine forests*(* *Dungdang Chattubari*) in KBR. Tables 3.6 provides the seedlings per ha values. Based on the size, the regeneration was further notified as established and unestablished following FSI standards. Refer Figure 3.13. Trees such as Acer cambelli (kapasi) and *Viburum Cordifolium* (asare) have shown moderate levels of regeneration in this area. Rhododendron (Barbetum) and Asare *(Viburum Cordifolium)* displayed high levels of regeneration throughout the sanctuary. The figure 3.13 shows that the regeneration in the sanctuary is more uniform when compared to the pattern shown in the KBR.

3.3.5 SPECIES DIVERSITY INDICES

Using indices in ecology for making observation on vegetation communities have been in use from a long time. This is especially an effective tool when used for comparing across similar forest types when one wants to study the difference in forest health in the selected locations. The identified and enumerated trees were used to calculate vegetation richness and diversity. The diversity indices were calculated by using TURBOVEG. It comes with built-in formulae to calculate four indices, namely: Richness, Shannon's diversity index, Evenness and Simpson's diversity index. This analysis is based on the input of the species abundance data collected in the field.

Table 3.7: Forest type and grazing pressure wise diversity indices for KBR and BRS

	KBR					
	LOW			*HIGH*		
	Wet temperate	Moist temperate	Subalpine forests	Wet temperate	Moist temperate	Subalpine forests
Richness	27	27	16	26	22	17
Shannon	2.62	2.62	2.30	2.66	2.73	2.30
Evenness	0.80	0.80	0.83	0.82	0.89	0.83
Simpson	0.89	0.88	0.87	0.90	0.92	0.86
	BRS					
Richness	26.8	29	12.2	18.8	18.82	15.2
Shannon	2.704	2.69	2.25	2.282	2.516	2.47
Evenness	0.824	0.802	0.904	0.78	0.864	0.918
Simpson	0.91	0.908	0.88	0.864	0.902	0.904

Species richness is defined as number of species per specified number of individuals or biomass in a plot. Richness has limited scope as it does not take corresponding species abundance values. Evenness refers to relative distribution of species in a site. High values of abundance indicate uniform distribution of species at a site. The Shannon and Simpson indices combine the richness and evenness of species in a single figure. They are based on the proportional abundance of species in each site. Table 3.7 represents a snap of the values for both the sites. Further the information is stratified based on the forest types and high and low disturbed areas. The values of the indices are almost same for both the sites indicating not much significant differences in the two sites. The evenness values are on the higher side for the sites and range between 0.74 – 0.94. As expected most of the subalpine areas fall in the high evenness (0.9 and above) category as this area is mostly comprised of *Rhododendron* spp. and *Abies* spp. evenly distributed in both the sites. The comparatively lower values of evenness (values less than 0.78) mostly belong to the oak and bamboo dominated forest areas of the wet temperate zone. This zone has higher species richness resulting in diverse stands mostly dominated by Quercus spp. The values of Shannon index are on the higher side indicating high species richness and diversity. The values become lower in subalpine forest as compared to the other forest type. The values are more or less equally distributed across low and high disturbed areas. The only exception was that subalpine zone in BRS. Here the high disturbed areas show higher value for Shannon- index as compared to the low disturbed areas. The reason for this is the profuse growth of Rhododendron species in the *Taal – Asthal* area in BRS. This shows that the two sites are mostly similar in composition and distribution of species across forest types.

3.3.6 FOREST DISTURBANCES

3.3.6.1 DISTURBANCE TYPE AND KEY SPECIES

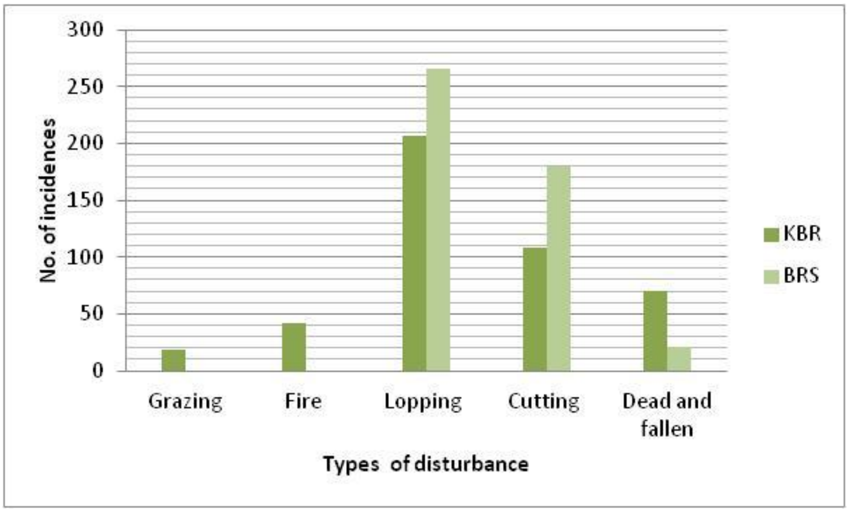


Figure 3.1 5: Types of disturbance and their incidence

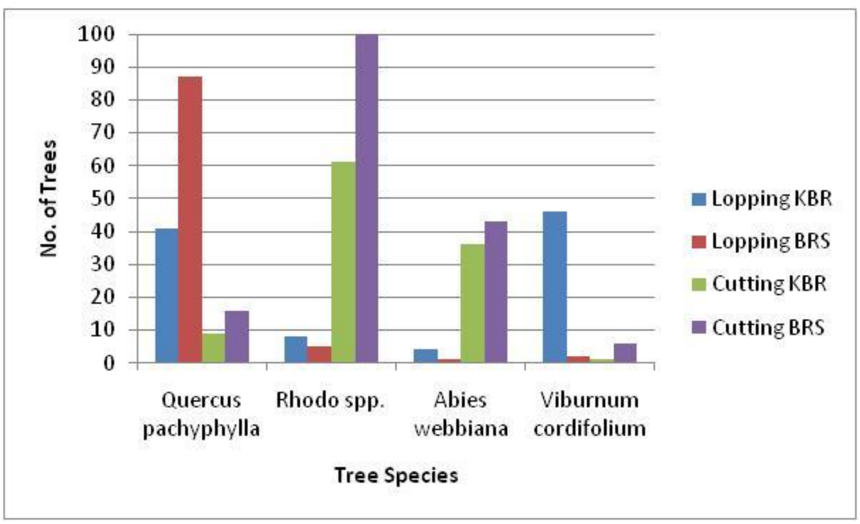


Figure 3.16: Types of disturbance

The forests in the region, had a high incidences of disturbance in the earlier period before ban as permanent cowsheds were established by the herders. Also the fringe communities used to depend on it for their household and livelihood needs. The pressure was mostly in terms of cutting and lopping of trees and grazing of domestic livestock throughout the year. The observed disturbances in the plots were categorized as fire, lopping, dead and fallen, cutting of trees and grazing as shown in Figure3.14 The disturbance type grazing indicates either presence or absence of the signs of domestic livestock grazing in terms of either sighting the livestock or in terms of presence of dung in the plot area. Rest all disturbances indicate, the actually observed incidences of the forest disturbance in the established plots.

Also it was observed that certain species were more preferred by the herders. Since the species in these temperate forests are also species of conservation importance, we have documented the intensity of the disturbance species-wise for key species. Figure 3.15 summarizes the findings for the key species in the area. Besides these, *Arundinaria malin(malingo) was the most preferred species that was cut in the oak and bamboo forests in the wet temperate zone.* Some of the other species that were cut and lopped in both the sites include Ilex dipyrena (lissey), Litsea species (Poinle) and Osmanthus suavis (sirlinge).

3.3.6.2 DISTURBANCE INCIDENCES ACROSS SITES

The observed incidence of cut and lopped trees within the plot boundaries was approximately the same in both the sites. i.e. In KBR it was above 70% and in BRS it was about 65%. Though, the frequency of lopping and cutting incidence was lower in the plots in BRS, as compared those in KBR. The major difference observed was in the number of cut trees. In BRS it was about 180 and in contrast KBR had 108. The reason for this was the high incidence of *Rhododendron* cutting from *Taal / Asthal* region in BRS. According to the discussion with the local resource persons even though this region has less cow-shed density, but the herders preferred this area for cutting trees for fuel wood especially in winters, due to high density of Rhododendron spp. in this area. Approximately 36% of the plots in KBR recorded damage due to forest fire while no such incidences were recorded in BRS. The fire affected trees in plots located in sub alpine forests in KBR region stand testimony to the massive forest fire on India-Nepal border in 1973. Another noticeable difference between the two sites was in the presence of domestic livestock still grazing in forest areas. No animals were observed in BRS while 63 % of the total plots in KBR had animal dung; indicating continuation of animal grazing practices in the region. Sighting of animals such as *cow, horse, dzo, & yak* during transect walks in the KBR region supplemented the perception of persistence of grazing in reserve forests. Table 3.8 provides a snapshot view of the incidence of the disturbances.

Table 3.8: Forest type wise and grazing pressure wise incidence of disturbances (Nos.)

Forest Type	**KBR**		**BRS**	
Grazing pressure	***Low***	***High***	***Low***	***High***
Wet temperate forests	51	85	63	65
Moist temperate forests	62	62	67	99
Subalpine forests	163	71	151	34

Lopped trees were observed in all the plots in oak forests in both the sites while 60 and 40 percent of plots in KBR and BRS had the signs of cutting of trees. Similar trends were noticed in mixed coniferous forests in both sites In case of lopping the trend was found to be contrasting in the sub-alpine forests; as over 90 % of the plots documented incidences of cutting while only 40% and 10 % of the plots in KBR and BRS had lopping incidences. In this region ground fodder is mostly utilized by livestock and hence the lopping incidences are few.

PART II: EDAPHIC ANALYSIS

Overgrazing is a common phenomenon in pasturelands and forest areas consequently leading to deterioration in land quality and creation of wastelands. Typically an area subjected to overgrazing becomes more susceptible to threats like soil erosion, soil compaction and loss in moisture holding capacities, formation of rills and gullies and in extreme cases, ravines. Soil is protected from surface disturbance by a crust that prevents erosion caused by wind and water. Various anthropogenic activities, including overgrazing destabilize the surface crust and in some cases it can get completely damaged. In pasture lands or forest areas subjected to grazing such effects could be minimized if efficient livestock management practices are being followed or if controlled grazing is practiced. Although, the recovery of soil properties is a slow process and hence sufficient time has to be given for the soils to be restored. While overgrazing can become a problem, available literature also exemplifies site level benefits of controlled grazing including improving soil fertility.

Soil stability primarily controls the fertility, productivity and sustainability of an ecosystem. Thus, the study of edaphic factors of the region becomes imperative to understand the regenerative capacities and status of the soils in the region post ban implementation

3.4. SOIL SAMPLING

Soil samples were collected from both sites: BRS, where a complete ban on grazing had been implemented and KBR, where day grazing is still being practiced to a limited extent. This was performed with the intention to capture the changes induced in the physical and chemical composition of soils. The sampling strategy for collecting information on soils across the two sites is as given below.

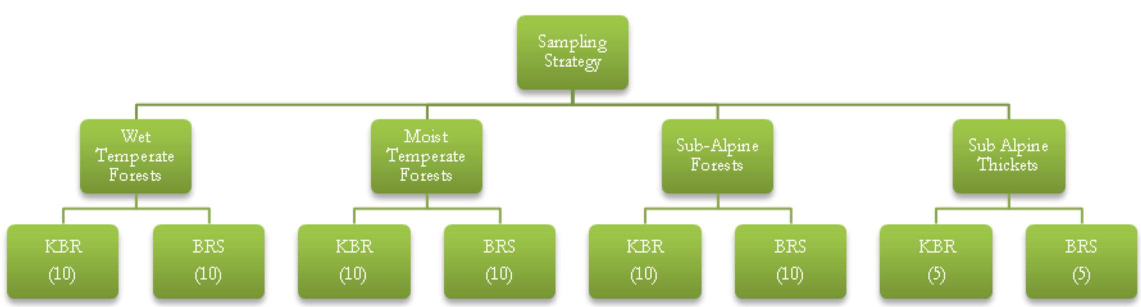


Figure 3.17: Sampling Strategy for soil samples

On both the sites viz. KBR & BRS, soil samples were stratified based on forest types and grazing intensity. Soil samples were collected by laying 1m x 1m sub plots in and around the 0.1 ha plot across the four types of forests. In all, 70 soil samples were collected across both the sites. This includes 10 samples at the sub-alpine thickets region. The soil samples were collected as per the methodology prescribed by the *Manual of Instructions for Field Inventory* published by the Forest Survey of India (FSI). The soil samples collected during the field study were tested at the *Dr. Panjabrao Deshmukh Krishi Vidyapeeth, College of Agriculture, Nagpur* using scientific methods of soil testing.

3.5. SOIL - RESULTS AND DISCUSSION

The quality of a soil can be studied by looking at its core properties namely its physical and chemical composition. These properties vary across different topographies, forests types and agro-climatic zones. In this section we present observations and analysis on the soil properties in the study area. Due to technical and resource constraints only chemical properties of the soil were tested and observations were made on the general physical soil form at the study sites and associated anthropogenic characteristics. Besides, detailed observations were made on terrain characteristics at the sampling sites.

3.5.1. SOIL GENERAL CHARACTERISTICS

Soil texture, structure and rockiness influence its fertility and aid its regenerative capacity. Considering that the study area was subjected to livestock grazing, the extent of disturbance to soil characteristics caused by it becomes necessary to be documented. These characteristics determine the type of vegetation that can thrive in the region. As the ecological survey was designed along the routes taken by the herders, the soils studied can be broadly classified into main groups viz. Soils of summits & ridges and soils of side slopes of hills. Detailed information on soil and terrain characteristics viz. soil texture, soil colour, soil consistency, coarse fragments, rockiness, humus, visual soil disturbance, soil erosion etc. was documented by studying soils around the cattle-shed & grazing areas and the details are presented in the annexure. The observations on the characteristics were categorized as per FSI standards. The general topography of the region was undulating. The sample plots were taken mostly on the side slopes of mountains or near summit regions. Based on the average slope of the plot area, we classified the plots into 4 categories namely flat, gentling rolling, hilly and very hilly as per FSI standards on plot slopes. As shown in Figure 3.17, 80% & 60% of the plots in KBR and BRS respectively belonged to hilly category. The soil colour was observed to be predominantly black and brown at both the sites indicating presence of organic content. In addition rockiness of the terrain was also observed. Rockiness was divided into 4 categories as per FSI : No rock, low (less than 30% area covered by rocks), medium (30-80% of area covered by rock) and high (above 80% area covered by rock). Though both the sites viz: KBR (75%) and BRS (65%) were observed to be low on rockiness, there were some plots that had medium to high rockiness. These regions coincided mostly with areas subjected to high grazing pressure earlier. Insights from ex-herders indicated that in these areas high soil erosion rates were observed especially during rainy season and exposure of rocks resulted from this. In KBR this region coincided with plots taken around *Nayapatal* and *Phedi* regions while in BRS high rockiness was observed along *Thulodhap*. Moreover the current soil erosion status indicates that most of these areas show signs of moderate erosion like mild gullies and rills formation on top soil. This reveals that forest areas subjected to high grazing pressures earlier became degraded through erosion of top soil and the 6-8 years of rest period through removal of anthropogenic activity has resulted in improving the soil degradation status of the region. Figure 3.17 – Figure 3.20 present comparison of some important characteristics from grazing impacts perspective across KBR and BRS. 80% of sample plots in KBR and 60% in BRS were observed to have undergone mild levels of erosion (slight surface erosion). All the sample plots of KBR showed signs of the presence of current grazing whereas only 35% of the corresponding plots of BRS indicated grazing.

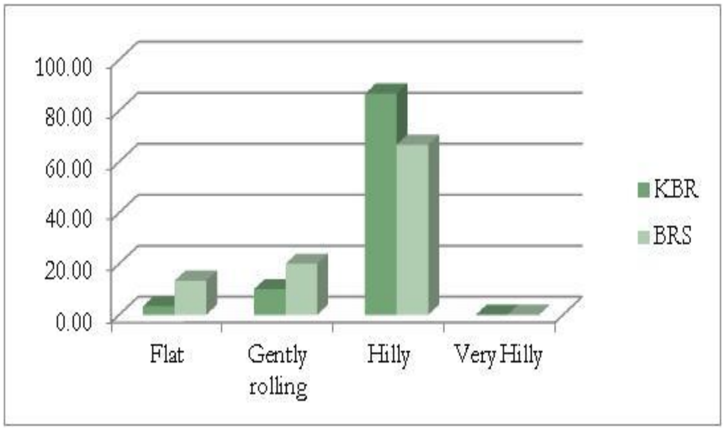


Figure3.18: Average slope of sample locations

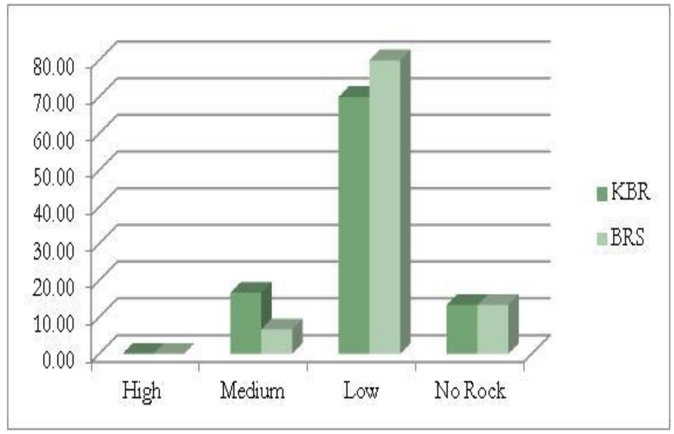


Figure 3.19: Rockiness of sample locations

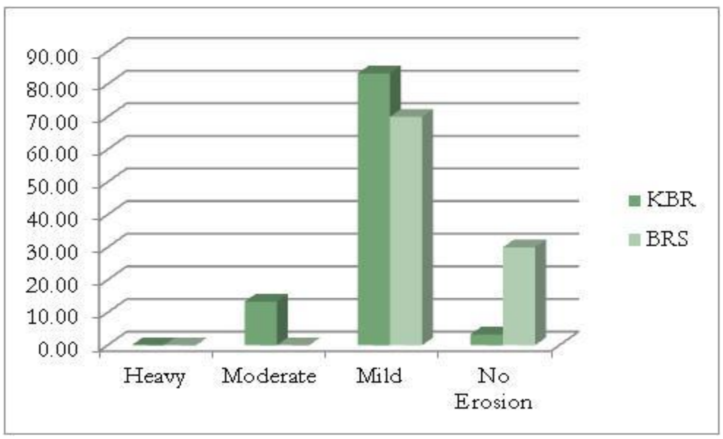


Figure 3.20: Soil Erosion at sample locations

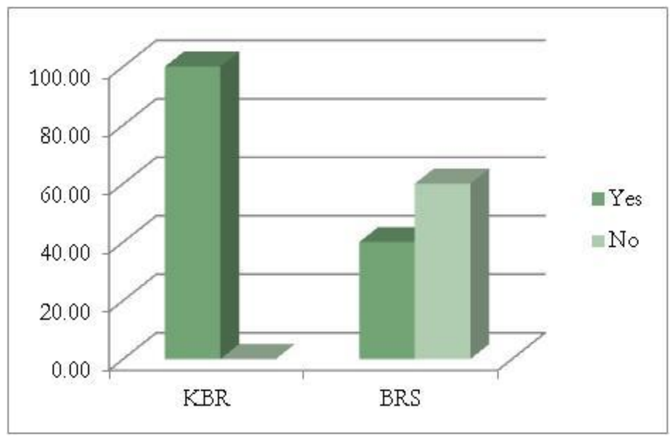


Figure 3.21: Presence of grazing at sample locations

3.5.2. SOIL CHEMICAL PROPERTIES

Chemical composition of an area differs significantly due to varying grazing pressure in the area This section captures the variation in key chemical characteristics between areas of high grazing intensity and low grazing intensity. Also, forest types could have a significant bearing over the surface soil elemental composition. Hence structured comparisons of chemical characteristics of soil across different forest types are undertaken to highlight the differential impact of grazing on the two sites viz. BRS and KBR. The following chemical properties have been studied for the collected samples:

Cation Exchange capacity (CEC) is the maximum number of total cations of any class that a soil is capable of holding at a given *pH* value[9]. It is a measure of nutrient retention capacity, soil fertility and the capacity to protect groundwater from cation contamination (Montana State University, 2004)

Soil Electrical Conductivity (SEC) is indicative of the ability of an aqueous solution to carry an electric current. Plants are detrimentally affected, both physically and chemically, by excess salts in some soils and by high levels of exchangeable sodium in others. Soils with an accumulation of exchangeable sodium are often characterized by poor fineness and low permeability making them unfavorable for plant growth[10] (Texas A & M University).

Nitrogen, Potassium, Phosphorous and Soil Organic Content (SOC): The organic fraction of a soil, although usually representing much less than 10-15% of the soil mass by weight, has a great impact on soil's chemical characteristics. Soil organic matter comprises chiefly of carbon, hydrogen, oxygen, nitrogen and smaller quantities of sulphur and other elements. The organic fraction serves as a reservoir for the plant essential nutrients, nitrogen, phosphorus, and sulphur, increases soil water holding and cation exchange capacities, and enhances soil aggregation and structure (Montana State University, 2004).

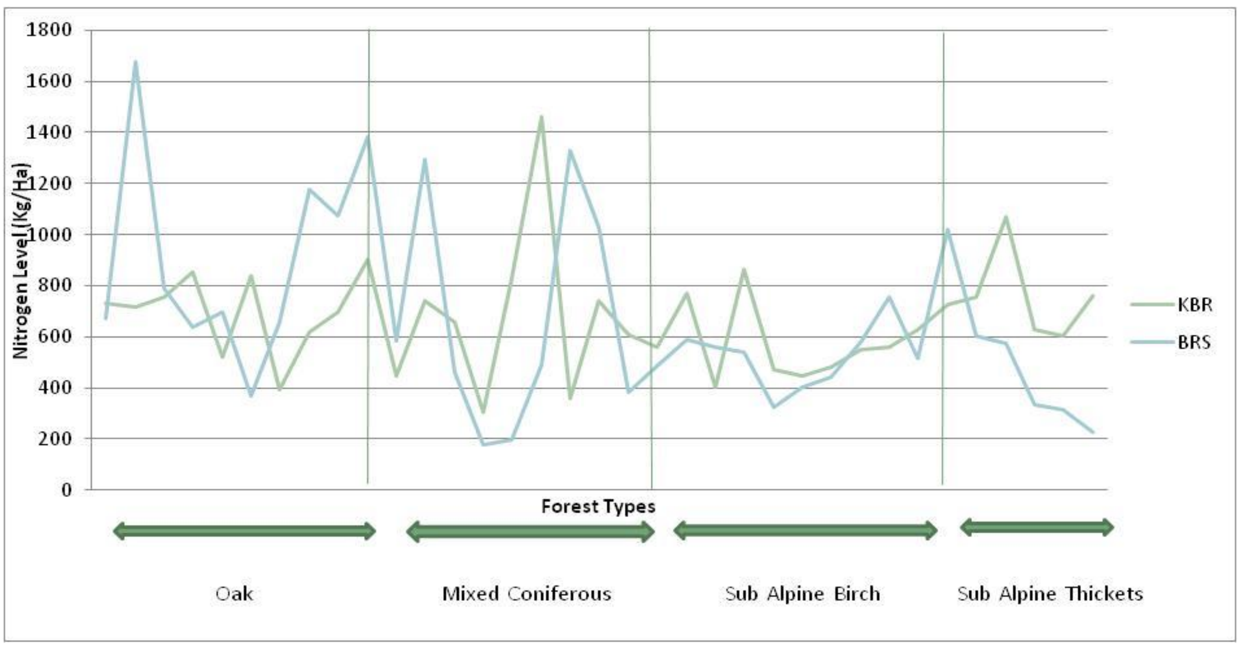


Figure 3.21: Nitrogen Content of soil samples

[9] p^H value indicates the basicity or acidity level in soils. It ranges from 0 to 14, with 7 being neutral. A pH below 7 is acidic and above 7 is basic. It plays a vital soil characteristic as it specifically affects plant nutrient availability by controlling the chemical forms of the nutrient.

[10] In reality, salt sensitive plant species may be affected by conductivity less than adequate levels and salt tolerant species may not be affected by concentrations of up to twice this maximum tolerance limit. Thus interpreting of salinity results need to be performed with a sufficient scientific knowledge and utmost care.

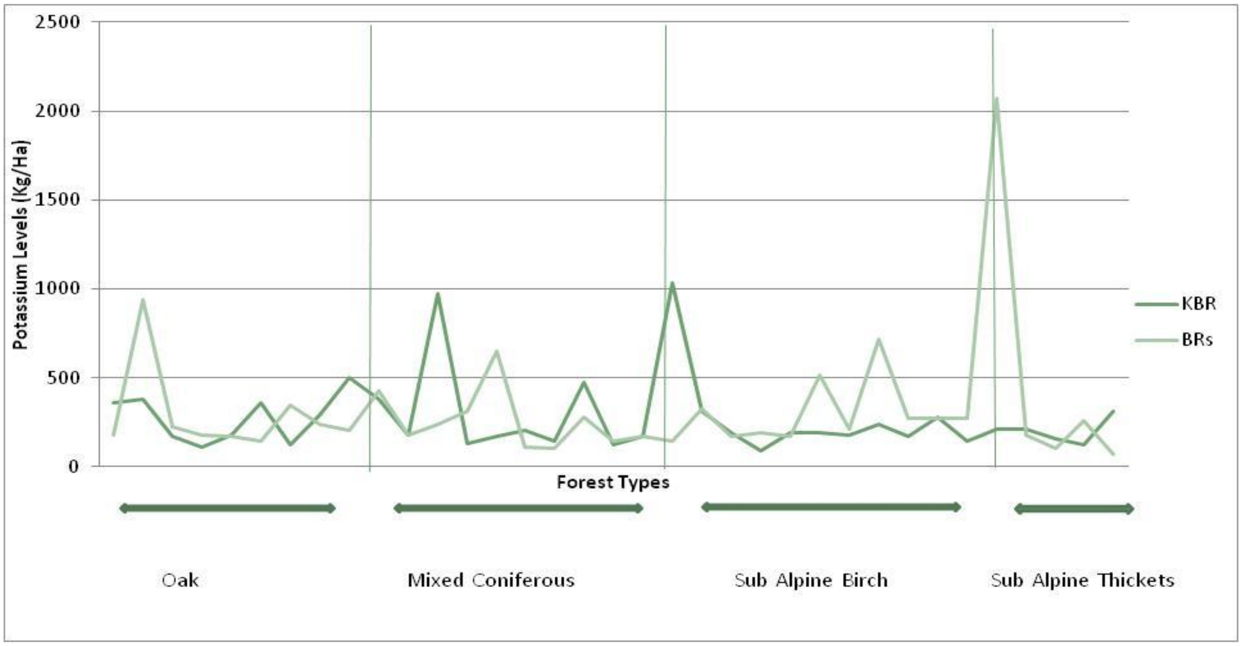


Figure 3.22: Potassium Content of soil samples

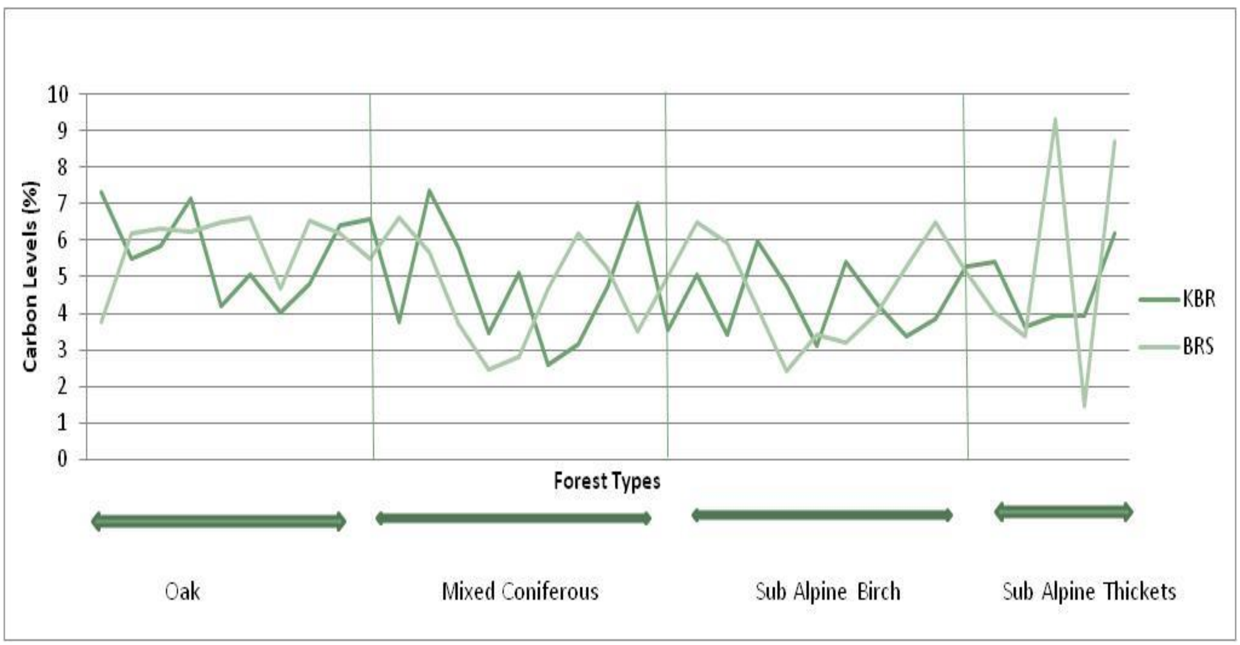


Figure 3.23: Carbon Content of soil samples

The nitrogen, potassium and carbon content of the sample areas across both the sites are displayed above in the figures 3.21, 3.22 and 3.23. The horizontal axis shows the spread of sample plots across forest types at both the sites while the vertical axis shows the corresponding nutrient levels at each of the plot locations.

3.5.2.1 HIGH GRAZING INTENSITY

It is observed that the CEC levels are marginally higher in BRS across both the Upper Hill Himalayan Temperate Forests (21%) and Moist Temperate Forests (12%). This indicates a higher capacity of the soils in BRS forests to retain soil nutrients and fertility levels when compared to KBR. With regard to SEC levels in the Upper Hill Himalayan Temperate Forests, the soils of BRS are observed to be significantly higher (127%) than KBR. [11]

Table 3.9: Comparison of chemical properties across forest types in high grazing intensity areas

High Grazing Intensity	Average of CEC (Meq/100 g)			Average of SEC mS/cm			Average of Ph		
Forest Type	KBR	BRS	% Diff.	KBR	BRS	% Diff.	KBR	BRS	% Diff.
Upper Hill Himalayan Temperate	20.90	25.36	21%	73	172	137%	4.59	3.81	-17%
Moist Temperate	22.51	25.11	12%	105	76	-27%	4.61	4.58	-1%
Sub Alpine	21.70	20.35	-6%	54	55	3%	4.27	4.35	2%

It is observed that only in the Upper Hill Himalayan Temperate Forests, BRS displays a higher Nitrogen (30%), Potassium (13%), and Phosphorous (6%) content whereas the SOC of BRS is almost on par with KBR.

Table 3.10: Comparison of NPK and SOC values in high grazing intensity areas

Forest Type	Average of Nitrogen(Kg/Ha)			Average of Potassium(Kg/Ha)			Average of Phosphorus(Kg/Ha)			Average of SOC %		
	KBR	**BRS**	**% Diff**	**KBR**	**BRS**	**% Diff**	**KBR**	**BRS**	**% Diff**	**KBR**	**BRS**	**% Diff**
Upper Hill Himalayan Temperate	716	933	30%	240	271	13%	27.52	29.16	6%	6.01	5.90	-2%
Moist Temperate	620	543	-12%	495	298	-40%	59.39	23.63	-60%	5.28	3.79	-28%
Sub Alpine	590	484	-18%	202	273	36%	30.02	14.84	-51%	4.44	4.48	1%

[11] The adversity or benefits of high levels of SEC aren't to be studied at the site level but at the species level to understand the specific impact caused by the characteristic to the vegetation.

3.5.2.2 LOW GRAZING INTENSITY

In areas where low grazing pressures was experienced, in both KBR & BRS, the CEC and SEC levels in BRS are remarkably higher than their KBR counterparts as shown in Table 3.11. This could be due to the higher rates of soil regenerative capacity in BRS, post ban implementation, as compared to KBR where partial grazing pressure is still experienced.

Table 3.11: Comparison of chemical properties across forest types in low grazing intensity areas

Forest Type	Avg. of CEC (Meq/100 g)			Avg. of SEC mS/cm			Avg. of pH		
	KBR	BRS	% Diff	KBR	BRS	% Diff	KBR	BRS	% Diff
Upper Hill Himalayan Temperate	23.82	24.68	4%	73	122	66%	4.97	4.33	-13%
Moist Temperate	23.85	42.26	77%	70	99	40%	4.37	4.01	-8%
Sub Alpine	22.74	31.36	38%	47	89	88%	4.36	4.16	-5%

It can be noticed, as shown in Table 3.12, that as compared to the areas earlier subjected to high grazing intensities, the regeneration of key nutrients in low grazing intensities areas of BRS is considerably higher than in KBR. This could be reasoned to the fact that due to lower pressure experienced even prior to the grazing exclusion policy and the complete ban on grazing in BRS in the last 13years, significant revival of key nutrients in the soils of has taken place

Table 3.12: Comparison of NPK and SOC values in low grazing intensity areas

Forest Type	Avg. of Nitrogen(Kg/Ha)			Avg. of Potassium(Kg/Ha)			Avg. of Phosphorus(Kg/Ha)			Avg. of SOC %		
	KBR	BRS	% Diff	KBR	BRS	% Diff	KBR	BRS	% Diff	KBR	BRS	% Diff
Upper Hill Himalayan Temperate	691	895	30%	332	338	2%	35.90	37.02	3%	5.38	5.88	9%
Moist Temperate	723	745	3%	225	168	-25%	29.3	30.98	6%	4.02	4.92	22%
Sub Alpine	591	663	12%	195	347	78%	84.79	25.64	-70%	4.47	4.81	8%

3.5.2.3 REGENERATIVE CAPACITY

The CEC and SEC levels in BRS as compared to KBR, as shown in Table 3.13, exhibit a conspicuous increase implying a better regenerative capacity in BRS. This also points to a better nutrient retention capacity in BRS region, as compared to KBR, and significant improvement since the implementation of the grazing exclusion policy.

3.5.2.4 NUTRIENT RETENTION

The retention of key nutrients in this case is found to be similar between the two sites. In the case of Nitrogen alone, there is a positive change in nutrient content levels of BRS (8%)

Table 3.13: Comparison of Regenerative Capacity and Nutrient Content across the sites

Site (KBR-1, BRS-0)	Average of CEC	Average of SEC mS/cm	Average of Nitrogen	Average of Potassium	Average of Phosphorus	Average of SOC	Average of pH
KBR	22.59	70.33	655	281	44.49	4.93	4.53
BRS	28.19	102.23	710	283	26.88	4.97	4.21
Percentage Gap	**25%**	**45%**	**8%**	**0%**	**-40%**	**1%**	**-7%**

3.6. CONCLUSION

This chapter provides a detailed discussion on the composition, structure, regeneration and disturbances introduced in the study area. The ecosystem impacts of the grazing ban can be said to be positive in terms of increase in vegetation cover and consequent improvement in the soil regime. The areas exposed to high grazing pressure having open canopy cover were found to be regenerating adequately. Among the species of conservation importance, *Rhododendron* spp. were observed to be adequately generating whereas the regeneration of *Quercus spp* was relatively inadequate. It was observed that other the regeneration levels of the other species of fodder importance such as *Litsea polyantha*(poinle), *Ilex dipyrena* (lissey), *Osmanthus suavis* (sirlinge), was found to be inadequate near the plot areas. Efforts should be taken to promote ex-situ conservation of such species. The gregarious *Arundinaria maling* (malingo) and *Viburnum spp*. (asare) regeneration could be cause of concern in the longer run. Habitat improvement plans need to be developed for such areas. As for the soil profile, there seems to be a positive impact on soil characteristics overall. The reduction in pressure has resulted in reduction of soil erosion and there is a remarkable increase in the overall regenerative capacity (especially in BRS). This could be considered as a first step to the revival of soil fertility and key nutrients. The use of software's for vegetation ecology such as JUICE and TURBOVEG has proved highly useful. The data from the working plan exercise should be stored in such systems so that a rich ecological data repository can be made. For a conservation promoting State like Sikkim, this will go a long way in their efforts to promote the conservation in the State at the international forums.

CHAPTER 4
CHANGE DETECTION: A REMOTE SENSING APPROACH

4.1 BACKGROUND

Geographic Information System (GIS) has been widely recognized as a useful management tool in environmental planning as it provides an ability to manipulate, analyze and display spatial data, thus enhancing the decision making process. (Miller, 1997) In addition, the technologies such as GPS, remote sensing offer value additions to sustainable forest management practices resulting by providing higher levels of precision and efficacy. (Hamzah, 2011) Synoptic view, map like format and repetitive coverage makes satellite remote sensing imagery a viable source of gathering quality land cover information at local, regional and global scales. (Foody, 2002) Multi spectral and multi temporal data collection systems have also made it possible to prepare maps of the remote and inaccessible mountainous regions. (Saha, Arora, Csaplovics, & Gupta, June 2005) Such tools are widely used by researchers and practitioners to monitor land cover and land-use change. Data extracted from such techniques can be assessed to develop a better understanding of the anthropogenic pressures on the forest ecosystems. (Rindfuss & Stern, 1998)

Change detection using remotely sensed data serves as a cost effective and efficient solution for monitoring of larger landscapes. Also it finds major application in remote inaccessible areas and in situations where it is not feasible to have ground based inventory. Several techniques have been developed to discern changed area of interest between two or more images dating to different time periods. The change detected can be ascertained by difference in radiance values which are caused due to various factors like atmospheric conditions, sun angles, slope, aspect, rainfall etc. (Mas, 1999) Image differencing is widely used for change detection. The pixel digital values of image captured from the earlier image is subtracted from the image that this taken at a later date/time. Even though this method allows only one band of information to be processed, it is preferred due to its simplicity in computation, accuracy and interpretation easiness. (Hayes & Sader, 2001) Time series change detection between two independent land cover images can also be detected using computation of the normalized vegetation diversity index (NDVI). NDVI has a high correlation with green biomass, crown closure and leaf area index and is least affected by the topographic factors. Consequently it provides/captures the vegetation change results in a better way than other similar indices. (Sader, Hayes, Hepinstall, Coan, & Soza, 2001) Another set of analysis techniques used to delimit significant areas of change, is comparison between two independent land cover classifications. This post classification approach is a comparative analysis of classified images obtained at different time. Hence its accuracy depends on accuracy of previous individual classifications. (Stow, Tinney, & Estes, 1980)

In this section, we assess the change in forest vegetation post implementation of grazing exclusion policy in Barsey Rhododendron Sanctuary. The main objective is to determine the spatial extent of changes introduced in the land-use pattern of the study area over the years. The temporal change dynamics is examined after a four year interval i.e. between 1998 and 2004-08. Change detection findings are done to provide a new dimension to understand the impact of grazing exclusion policy and are complementary to the findings of ground based vegetation surveys and social surveys. The remote sensing approach of change detection is limited to Barsey Rhododendron Sanctuary.

4.2 APPROACH

The study area was surveyed in the months of November-December 2010 over a 45 day time period. Prior to this, preliminary surveys were undertaken in the months of September- October 2010 for identification of the affected sites, characterized by incidences of disturbances such as grazing, lopping and cutting and existence of cattle shed. Site identification was done with the help of the ex-herders. Ground reference points and altitude were recorded using a GPS device in addition to the vegetation type. A hand-held Garmin, eTrex (Vista HCx) model, was used for this purpose. Apart from these 60 GPS points, grazing routes used by the herders were also marked with the device. Digital photographs of the landscape were also taken to assist in visual interpretation of various sites where plots were laid.

4.3 MATERIALS AND METHODS

In order to detect the changes in vegetation post implementation of grazing ban, remote sensing images depicting landscape prior to 1998 and post 1998 were mandatory. Multispectral IRS LISS III images, with 23.5m spatial resolution, of West Sikkim district for the year 1998 were obtained from Indian Institute of Remote Sensing (IIRS), Dehradun. Forest type classified image, 1:50,000 scales, developed by IIRS for “Biodiversity Characterization at Landscape level in North East India using Remote Sensing and GIS project” was also obtained. Combined IRS LISS III image of Sikkim, for the year 2004 and 2008, captured during the months of February and March was obtained from the Working Plan Division of Forest Environment & Wildlife Management Department (DFEWM), Government of Sikkim. (Table 1) A detailed classified image as per forest type, elevation, aspect, drainage, land use for BRS was also provided by the department. The provided images were reprojected and geo-refferenced in Arc GIS 9.3 software. Change detection analysis was done through ERDAS IMAGINE 8.5 software. Besides, all the GPS points were mapped on Google Earth in order to visually detect change in vegetation using historical images provided by the software.

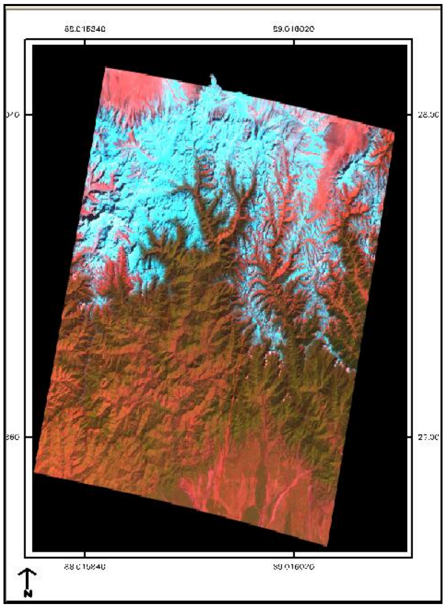


Figure 4.1 : LISS III image of Sikkim captured in 2000

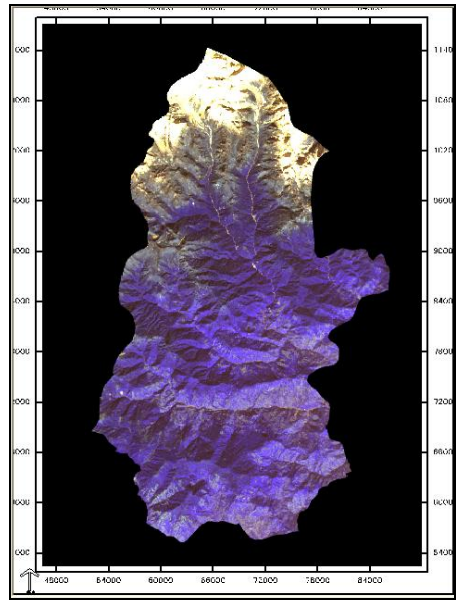


Figure 4.2 : LISS III image of West Sikkim captured in 1998

Table4.1 : Image Characteristics

Year	Image type	Source
1998	LISS III	Indian Institute of Remote Sensing (IIRS), Dehradun
2008	LISS III	Forest Environment & Wildlife Management Department, Government of Sikkim

4.3.1 IMAGE PRE-PROCESSING

The images provided by IIRS and DFEWM belonged to WGS 84 Spheroid but had different projection types. The 1998 image i.e. the pre ban image, had Lambert Conformal Conic projection type while 2004-08 image, i.e. post ban image had Polyconic type of projection. Hence reprojection of 1998 image to polyconic type was a pre-requisite for any further analysis. Further on georefferencing, i.e. aligning aerial images to points on earth was done based on GPS points marked during forest surveys as well the post ban image. These transformations, done in Arc GIS software, resulted in making the images comparable and hence change detection analysis was further ca carried.

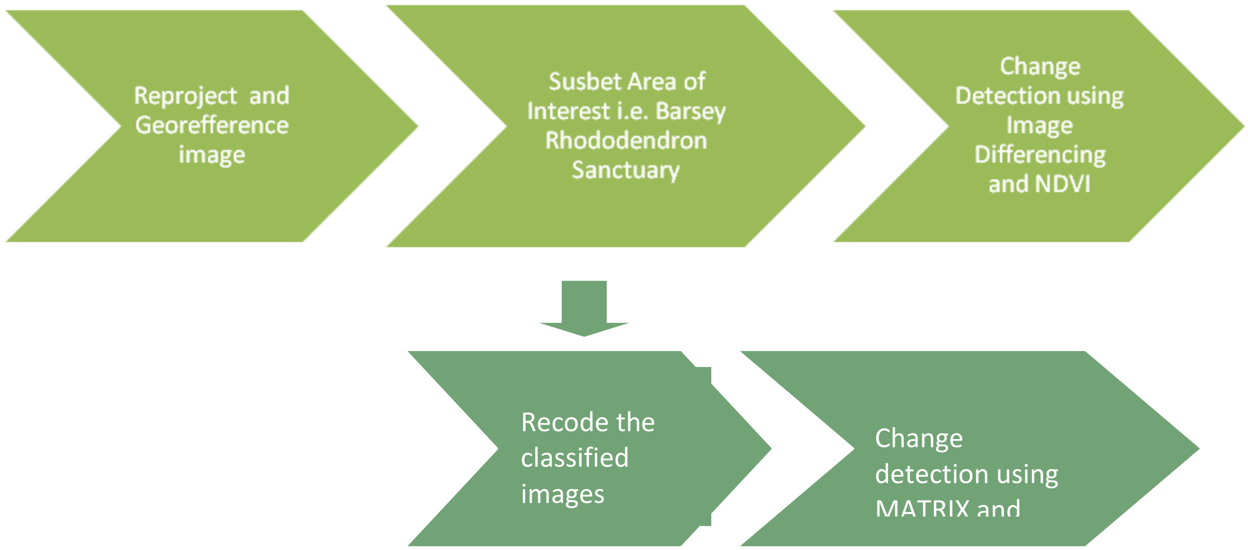


Figure4.3 : Flow chart of Change Detection Analysis

Three change detection approaches were employed in ERDAS IMAGINE 8.3 software: Image differencing (highlighting the changed areas based on the number of pixels), NDVI (based on reflectance values of vegetation type) and post classification comparison (using matrix and summary operations). Matrix and Summary operations in ERDAS compare two unsigned 8 bit thematic images and produce a resultant matrix depicting change with respect to a reference image, in this case pre ban image. Output of matrix is an image depicting changes while Summary provides a detailed transformation matrix stating change in area in different classes of classified image.

Google Earth was used to map the trek routes and GPS points of vegetation plots laid during the field survey. These plot points were classified as per three forest types: Upper Hill-Himalayan Wet Temperate forest, Moist Temperate forest and Sub Alpine forests. (Figure 4.4 and 4.5) The locations of the quadrants laid in the sub-alpine scrub zone were also marked.

4.3.2 CHANGE DETECTION

4.3.2.1 IMAGE DIFFERENCING

False Color Composite (FCC) images of the study site, obtained on different time intervals, were provided as input to generate an image difference and highlight the change file. The input was given to Change Detection option in the Utilities section of the Image Interpreter in ERDAS. Areas exceeding user defined threshold values were highlighted in the change file, while the difference file represented the change in brightness values using a grey scale image.

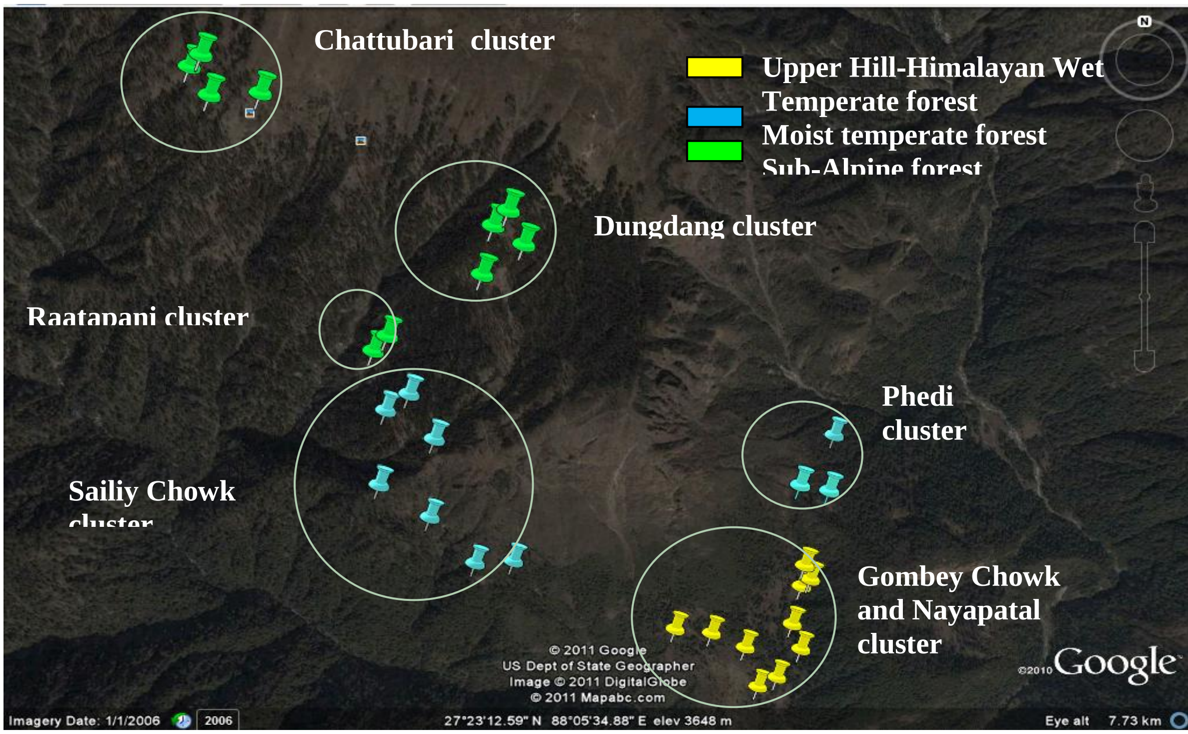


Figure 4.4 : GPS points and Clusters in buffer zone of KBR

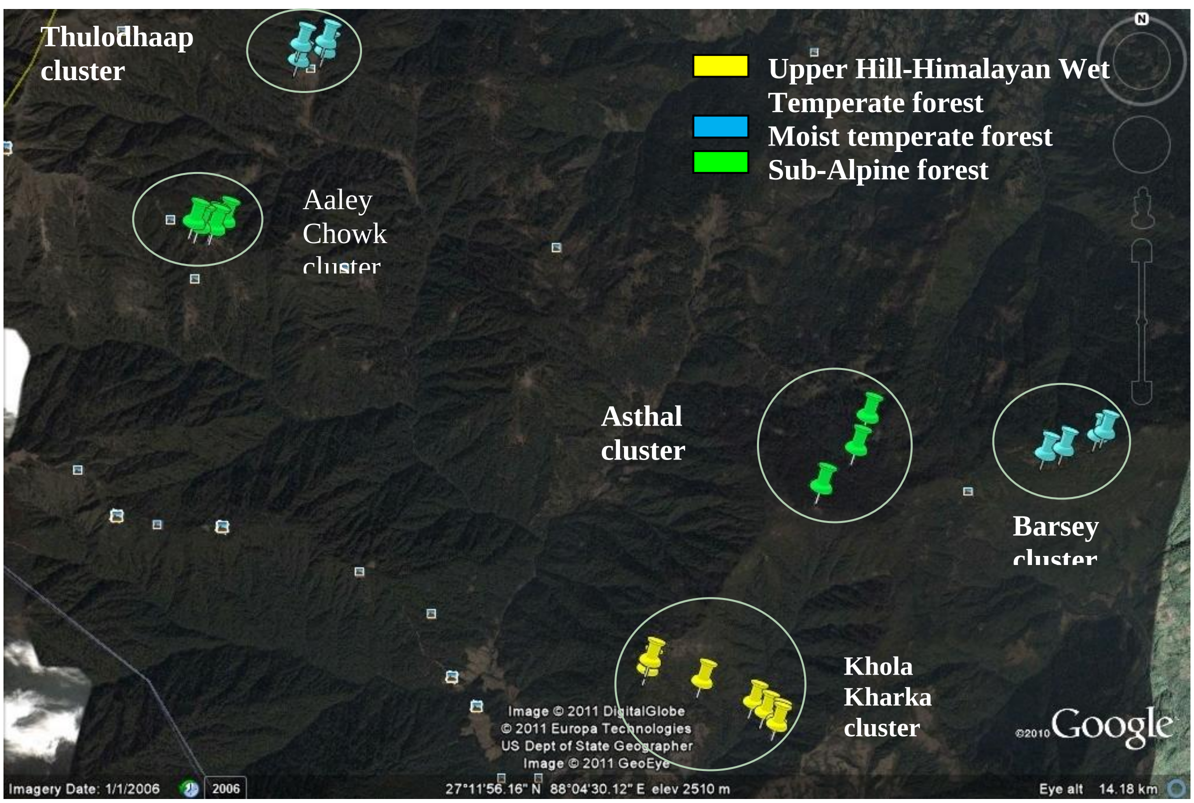


Figure 4.5 : GPS points and Clusters in Barsey Rhododendron

4.3.2.2 NDVI

FCC images of Barsey Rhododendron sanctuary captured in 1998 and 2008 were used to calculate the NDVI values. This technique related to existence of green biomass, calculates the vegetation index using the following formula:

NDVI = (NIR-RED)/ (NIR+RED)

Where NIR is the near-infrared band response for a given pixel, MSS band 4 and
RED is the red response, MSS band 2.

NDVI values range from -1 to 1 where all values <0 are representing areas with no-vegetation. For positive values, following interpretation was adopted:

Table 4.2: NDVI values and interpretation (Julien, Sobrino, & Verhoef, 2006)

NDVI value range	Interpretation
< 0.2	Bare Soil
0.2 <NDVI<0.4	Mix of Bare Soil and Vegetation
> 0.4	Vegetation only

For NDVI values between 0.2 and 0.4, proportion of vegetation (P_v) of vegetation is calculated from the NDVI values using the equation provided by (Julien, Sobrino, & Verhoef, 2006):

$$P_v = (NDVI - 0.2)^2 / 0.09$$

4.3.2.3 POST CLASSIFICATION COMPARISON

Similar class names, for both the classified images, are required as a prerequisite to undertake this approach. Thus the available images were recorded and reclassified so as to get an accurate transformation matrix depicting changes in each class. The recoded images were provided as an input to Matrix and Summary option in GIS Analysis section of Interpreter tab in ERDAS. The resultant image and matrix is examined to study the conversion from each classification in 1998 to all the classes in post ban image.

Table 4.3 : Details of Forest Types in different classified images

Forest type classes in 1998 image	Forest Type classes in 2004-08 image
Montane Wet Temperate	Upper Hill Himalayan Wet Temperate
Himalayan Moist Temperate	Moist Temperate
Sub Alpine Forest	Sub Alpine Forest
Scrub	Sub Alpine Scrub and Meadow
Agriculture	Agriculture
	S. Agriculture
Barren Land	Forest Blank
Snow	Snow and Glacier
	S Snow and Glacier
	SS Snow and Glacier

4.4 RESULTS

4.4.1 IMAGE DIFFERENCING

Threshold values of 20, 40, 60 and 80 percent were used for highlighting change in the study site region. The figures depict where the change has taken place at the study site while table computes the change in area as per threshold values. The series of figures highlight the increase (in green) and decrease (in red) of area with respect to varying threshold values (taken as % of brightness) i.e. 20, 40, 60 and 80. The increase as well as decrease in area indicated by Table4.4 indicates towards a slow pace of landscape restoration in study site. Keeping in mind that a four year time period is less for any major visible change in landscape, small shifts can be seen in lower ranges of threshold values. The highlighted area is maximum for threshold value as 20 percent while it is least for any increase /decrease over 80 percent.(figure 4.6)

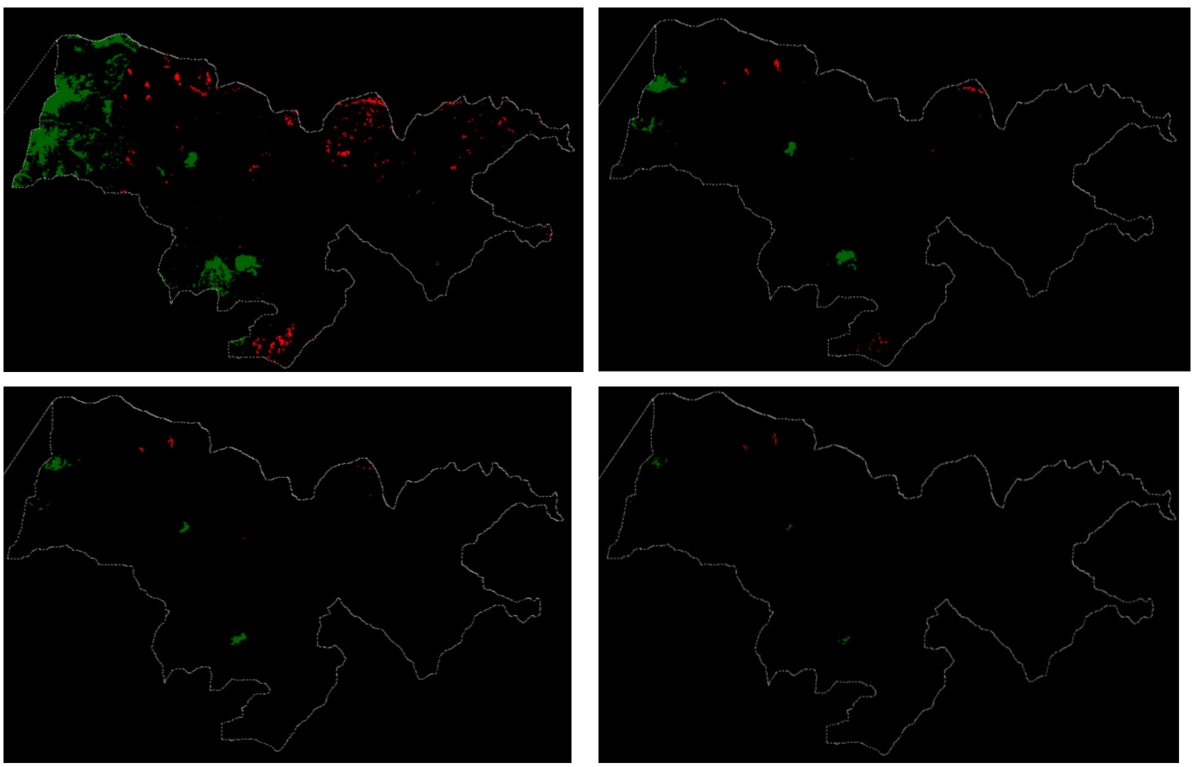


Figure 4.6: Regions Highlighting change w.r.t to threshold values of 20% (Top left), 40% (Top right), 60% (Bottom left) and 80% (Bottom right)

Table 4.4: Change in area in accordance to brightness values

Brightness Threshold values (in %)	Area (sq. km)	
	Increase	Decrease
20-40	5.73	1.18
40-60	0.61	0.11
60-80	0.37	0.03
>80	0.12	0.03

4.4.2 NDVI

This index points to the changes from “no forest” to “forest” without making a distinction between natural forest and secondary forest. (Lung & Schaab) The NDVI value computed were grouped into classes (refer to Table4.2) and area under each class was estimated.It was seen that area under bare soil (NDVI less than 0.2) remained apporximately the same with a minor decrease of 2.36 % in the post ban image (2004-08). Number of pixels in the NDVI value class of 0.2 to 0.4 was the highest in both the images, indicating maximum area covered by soil and vegetaion. Maximum change in area , 35 %, is observed in class with NDVI value ranging between 0.2 and 0.4.(Table 5) Difference in seasons has affected the area under vegetation only class as NDVI values of forest area covered with snow in the post ban image have been computed as less than zero. This is a significant area which when added to area under vegetation only class of post ban image will make it approximately equivalent to the area in the corresponding class of the pre ban image. Further estimating the proportion of the vegetation in this class, in both the images, it was seen that proportion of vegetation has increased in this class. Moreover, the NDVI values were categorized into percentiles, and an increasing trend in area under each percentile range was seen. Approximately 70 % increase is seen under the second quartile followed by a 60 %increase in the third quiartile.(Table 4.6) Eventhough area under the vegetation only class is decreased, the increasing trend in quartiles depcit movement from lowest to highest NDVI class. This indicates conversion of barren land into vegetated areas which eventually, after considerable time period, will become dense vegetation.

Table4.5 : Comparison of area under each NDVI range

NDVI values	Interpretation	Area (Sq. km.)	
		Post Ban	Pre Ban
<.2	Bare soil	26.39	27.03
.2 to .4	Soil and vegetation	90.52	58.42
>.4	Vegetation only	20.19	46.92

Table4.6 : Change in proportion of vegetation for area between 0.2 < NDVI< 0.4

Percentile range	Area (sq. km)	
	Post ban	Pre Ban
20	14.17	10.27
40	17.24	10.20
60	19.16	12.00
80	39.94	28.37

4.4.3 POST CLASSIFICATION COMPARISON

Classified images of the study site were used to quantify the percentage change in area under each classification. The image is a result of Matrix operation while Table 4.6 is a result of Summary analysis in ERDAS software. The lighter regions in the image represent less change, in terms of area, between classification types while as the shade becomes darker the level of change increases. (Figure 4.7)

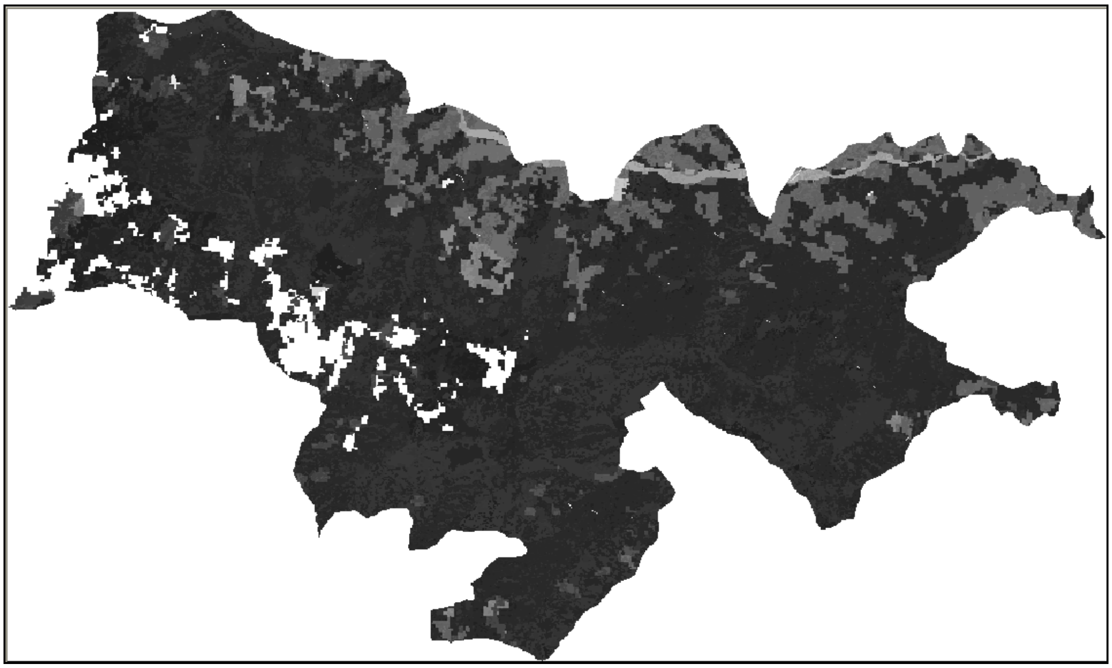


Figure 4.7: Image representing post classification changes

Evaluating each classification type, it was seen that settlement area during pre-ban period has been converted mostly into Alder forests (72.31%), Upper Hill Himalayan Moist Temperate forest (9.74%) and agriculture (14.36%). Temporary cattle sheds inside forests, classified in pre-ban period as settlement, were mostly now converted into Upper Hill Himalayan Moist Temperate forest (open and degraded) while agriculture and alder forests have come up in temporary cattle sheds in fringe areas. Alder forests mainly constitute of cardamom and *Alnus Nepalensis*, commonly known as *Utis*, which are grown by villagers in fringe areas. Similarly over 25 % of the barren land, in pre ban period, was classified as Upper Hill Himalayan Moist Temperate forest in post ban image while the remaining constituted as under Alpine scrub, Sub alpine thickets, Moist temperate forests, thickets categories, depending on the elevation. However, approximately 20 % of the barren land still remained barren, even after four year time period, indicating slow pace of restoration of the forest landscape. Land under agriculture, at higher altitudes, during pre ban period is now classified as sub alpine thicket while at lower elevations, the area now falls under either moist temperate forests, middle hill forests, or upper hill Himalayan moist temperate forest. 3% of the agricultural land in the pre ban period, mostly near fringe areas, continues to be agricultural land. Similar trend was observed for scrub land, as only 1% of it continues to be classified under the same category, while most of it was now classified as various forest types depending on elevation. (Table 7) No major visible shifts were documented in forest types due to difference in classification levels in the available images. Effects of the different season images were seen during this analysis as 63.5 percent of area under snow was classified as moist temperate forests while 10.5 percent area was classified as thickets in post ban image. Similarly, majority of water body area during pre ban period belonged to alder forest (17.5 percent), forest blank (13.8 percent), and agriculture (6.8 percent) in post ban image.

Table4.7 : Change in Area (in %) in the various classification types

Classification Types		Scrub	Agriculture	Barren Land	Water body	Settlement
Post Ban Image				% change		
Upper Hill	Open	13.46	8.19	12.37	4.36	2.06
Himalayan Wet Temperate Forests	Degraded	7.98	8.25	14.95	6.00	7.69
Alpine Scrub	Open	11.09		2.57	0.13	
	Dense	1.28		1.18		
Sub Alpine Thicket		8.27	0.88	6.25		
Moist Temperate	Open	0.15	0.01	0.29	0.17	
	Degraded	0.01	0.23		0.08	
Thicket		10.25	4.15	1.98	2.98	0.51
Middle Hill	Open	0.65	2.55	0.11	2.26	
Forests	Dense	0.99	3.93	0.04	0.63	
	Degraded	0.14	0.46			
	Scrub	0.01	0.42		0.42	
Scrub		1.20	1.11	1.32	0.34	
Alder Forests	Open	0.12	1.77		6.83	15.38
	Dense	0.64	2.72		8.39	19.48
	Degraded	0.05	0.60		1.64	35.38
	Scrub	0.02	0.22		0.67	2.06
Forest Blank		5.97	15.74	19.98	13.88	
Agriculture		0.94	3.04	0.37	6.04	14.36

4.5 ISSUES AND LIMITATIONS

Non availability of LISS III images of the same season was a major limitation faced during GIS analysis. LISS III image captured in 2004-08 was in February and March while the 1998 image was captured in September. In addition, half of the post policy implementation classified image was captured in 2004 while the other half was captured in 2008 thus different time intervals area considered for the same study site. Difference in detailed level of the classification is a major issue faced during Summary analysis. The forest type classified image obtained for 1998 was broadly classified with 14 classes while the same study site was classified into 50 classes in the year 2004-08. Hence a new composite image was obtained by reclassifying, accuracy assessment through GPS points and merging of equivalent classes. (Tambe, Arrawatia, & Sharma, 2011). However, difference in climatic and natural factors like sun angle, atmospheric conditions, ground moisture conditions, aspect and slope have not been addressed which impede determination of actual change on ground. (Washington -Allen, Ramsey, Norton, & West, 1998)

4.6 CONCLUSION

The above change detection techniques complement the findings of the filed survey focusing on regeneration. Even though various limitations were faced, results of the detection techniques point towards change in landscape: from barren land to existence of vegetation. Rate of change for restoration is less as indicated by the area increased and decreased (Table 4) or transformed (Table 7). Higher rate of transformation is observed near lower elevations and fringe areas of sanctuary while a lower transformation trend was not observed at higher elevations. The pace of transformation was also indicated by the various images highlighting changes as per various threshold values. Hence, this analysis is indicative of changing land use pattern in the study site. Landscape monitoring can be accurately and easily done, provided remote sensing images can be acquired yearly and belong to the same season.

CHAPTER 5 SOCIO-ECONOMIC AND LIVELIHOOD DIMENSION

5.1 INTRODUCTION

In the Himalayan mountainous region of Sikkim, the lifestyles and the livelihoods of the local communities are intertwined with the surrounding natural resource endowments. Pastoral and agro-pastoral lifestyles are pre-dominant in these regions and the people depend on the forests and the alpine pastures for their sustenance and livelihood needs. Besides the forests form an integral constituent of their cultural heritage. As per the government records, each of the 907 villages in the State is a forest fringe village. (DFEWM, Sikkim, 2011). For such a resource rich State with high forest dependent population, any policy prescription that induces a change in the access to these ecosystems, would indirectly affect the socio-economic fabric of the region. Thus the actual impact of the grazing exclusion policy cannot be ascertained without understanding the impacts that it has on the local lifestyles and livelihood strategies. The significance of this aspect is for several reasons: first, the social component is important for assessing successful proliferation of the intended outcomes of the conservational policy i.e. grazing exclusion. Second, peoples' perceptions of the impact of a ban are as important, if not more important, than its actual impact. The sustainability of any changes depends on the policy being either enforced or incentive compatible with the local community. Third, the social component may help to develop a more robust strategy if credible historical data based on peoples' recollections can be gathered. Such data must be handled with care, but it could help us do some limited before-and-after comparisons, which would in turn strengthen confidence in our results.

In this chapter, our main objective was to understand the change in lifestyle and livelihood pattern introduced in the study region post policy implementation. The key aspects studied under socio-economic dimension include livelihood strategies, resource use, wildlife conflicts and perception of the local community on the changes post policy implementation. To develop an in-depth understanding of the grazing exclusion policy, we studied evolution of pastoral practices in the area, livestock composition and population change dynamics over the years, fodder and firewood preferences, distribution of key species before the imposition of grazing ban across forest types through discussions with local communities. Also, resource maps were prepared for the forest types depicting important grazing areas and water sources. Thus, a rich repository of information was generated through these participatory methods and household surveys.

5.2 MATERIALS AND METHODS

We surveyed the fringe villages in and around the study sites in BRS and KBR to understand the forest dependence pattern in the region. BRS is surrounded by more than 30 fringe villages comprising of above 5000 households with around 288 herder households. (Sikkim Forest Department, 2008). The sanctuary forms international boundary with Nepal on the east side while it is bordered by villages along other sides. Constrained due to vast area of KBR, our study site was limited to villages in south west region of KBR. In all 120 households across 8 villages were surveyed for the study. The villages were so chosen so that they were spread across altitudinal gradients and spatially distributed across the study sites. The four selected villages in BRS were: Upper Mukrung, Begha, Buriakhop and Bhareng and the fringe areas selected in the buffer areas of the KBR comprised of Chongri and Sangkhola (Sindrabong), Tasenthang, Barseybung and Nambu.

The target stakeholders for the study were ex-herders. However the grazing ban policy also impacted the non-herder households as they were also dependent on the forests for fodder, fuelwood, timber, NTFPs and medicinal herbs. By studying the two groups we were able to comprehend differential impacts of the policy across the two household categories. A stratified approach was adopted to select the sample households. With the help of local resource persons a list of all ex-herder households in the area was made and then they were asked to categorize them into rich, average and poor categories based on their perception. Similarly this was done for the non – herder households. They were further stratified on spatial scale, so that households in proximity of the forests and those that were more than 1-2 km from the periphery of the forests were also included. The sampling intensity was almost more than 80% (of the ex-herder population) in KBR buffer zone, where small settlements are spread across the area. In other settlements, a sampling intensity of above 30% (based on ex-herder population) was adopted. The settlements closer to the forests especially in Chongri and Sangkhola comprised mostly of ex-herder households and the number of non-herder households was insignificant. In such cases the non herder households were covered from Nambu area, a larger settlement area with a sizeable number of herder populations as well. The sampling plan is given in table 5.1. Data on socio-economic characteristics of the households was documented through structured interviews.

Table 5.1: Sampling plan for socio-economic survey

Village	Location	Herders	Non-Herders
Barseybung	KBR	2	3
Begha	BRS	8	8
Bhareng	BRS	10	10
Buriakhop	BRS	12	12
Chongri/Sindrabung	KBR	7	0
Nambu	KBR	4	8
Sangkhola/Sindrabung	KBR	3	3
Tasenthang	KBR	4	6
Upper Mukhrung	BRS	10	10
Total		**60**	**60**

Focused Group Discussions: Meetings with the members of Eco-development Committees (EDC) and Joint Forest Management Committees (JFMC) were convened at both the study sites. The experienced and elderly ex-herders in the selected villages were invited to these meetings to provide detailed information on the historical timeline for livestock population, and mapping of *goath* locations, resource mapping for the area etc. Pair-wise ranking of preferences for fuelwood and fodder species was also documented during these discussions.

Figure 5.1: Focused Group Discussion and Resource Mapping exercise for socio-economic data collection

5.3 RESULTS

5.3.1 CHARACTERISTICS OF SAMPLE POPULATION

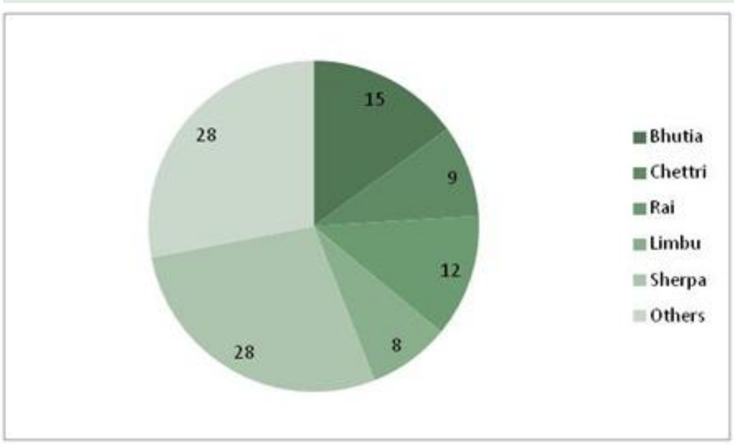


Figure 5.2: Distribution of ethnic group across sample

Though Sikkim is not densely populated, there exists a rich blend of cultures and traditions, co-existing in peace. Buddhism and Hinduism are the predominant religions practiced in the State. The fringe villages of BRS and KBR have a diverse mix of ethnic groups. In the sampled population, the predominant ethnic communities were Bhutia, Chettri, Rai, Sherpa and Limbu as can be seen from figure 5.2. Traditionally, the Bhutias were traders and yak herders, Chettris were agro-pastoralists and Limbus were hunter-gatherers (Tambe & Rawat, 2009). Table 5.2 presents the key demographic details of the sampled population. In the sampled population the sex-ratio was observed to be 96 females to 100 males. The region is below state level average with respect to literacy as almost 50% of the sampled population was either illiterate or had received education below primary level. Mostly people in the age group above 40 years belonged to these categories. The literacy rate was found to be higher in the younger generation. Due to the remoteness of the region, the penetration and awareness of educational facilities was low in the region. However, with implementation of various government programs and improvement in road network in the region, educational infrastructure and facilities have improved in the region. This has provided a chance to the households in remote villages to have access to education and it was observed that majority of the children in the sampled population between the age group 3-16 years were mostly in hostels for education purposes. Though in the elder generation, formal education was lacking, it was observed during the study, that they had tremendous knowledge of the medicinal plants and herbs in the region.

Table 5.2 Demographic Details of the sample population

Demographic Distribution	Percentage (%)	Educational Qualification	Percentage (%)
Age		Not Literate	28
< 20 years	30	Primary	23
20 - 60 years	54	Secondary	20
> 60 years	16	Higher Secondary	17
Gender		Graduates	8
Male	51	Lama School	4
Female	49		

5.3.2 ASSET OWNERSHIP

We studied the land-holding pattern, ownership characteristics and asset distribution across the ex-herder and non-herder households. The main aim was to understand if there was a significant difference in the asset ownership pattern across the two groups: ex-herder and the non-herder households post the ban implementation. Table 5.3, figure 5.3 and 5.4 presents a snapshot view of the asset ownership pattern across the categories.

Table 5.3: Distribution of landholding size across sample households

Landholding Size (acre)	Percentage of landholdings (%)
< 1	12
1-2.5	33
2.5-5	29
5-10	19
>10	7

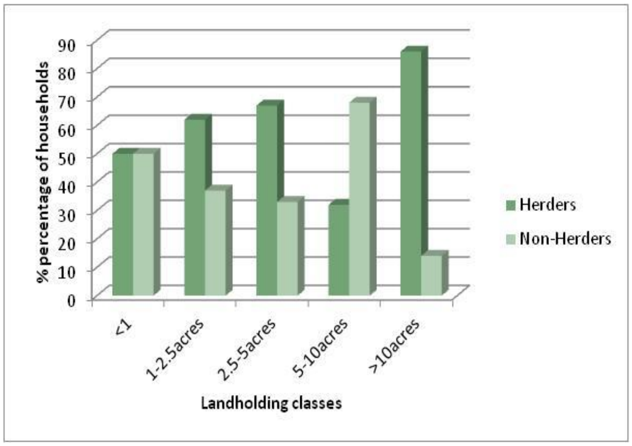


Figure 5.3: Landholding distribution across Herder-Non herder house holds

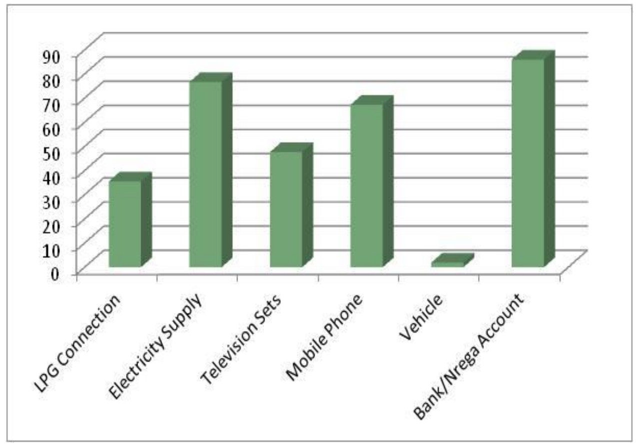


Figure 5.4: Assets ownership status across sample households

Almost 75% of the sampled population belonged to the small and marginal farmers' categories. Practicing agriculture in this area is a challenge due to the mountainous topography of the region. Mostly the agriculture was rainfed and traditional techniques were used. As shown in figure (Figure 5.4) nearly 90 % of the households had an operational bank account which was created by MNREGS. Otherwise, less than 3% of the households accessed financial services otherwise. 75% of the households had access to electricity. Only 35% of the households possessed an LPG collection which indicated that a majority of the population was still dependent on conventional fuelwood use. Most of the households having a LPG connection however used fuelwood only for cooking and heating purposes. This was due to the difficulties in procuring refill in the region and hence most of the LPG owners limited its usage to special occasions. Ownership of motorized vehicles by the sample population was as low as at 2% as the study region was remote and inaccessible and road construction is currently underway. A significant proportion of the population i.e. 67% owned a mobile phone highlighting the penetration of technology to such remote areas.

5.3.3 RESOURCE EXTRACTION

The information on utilization of the forest resources by the herder community, prior to the ban implementation was documented during the structured interviews. This helped in getting a picture of the resource extraction pattern and building an estimate for the levels of extraction from forests before the grazing ban was implemented in the region. Table 5.4 presents a list of fodder and fuelwood species generally used by the herder community when the cow-shed model existed. The discussions with the ex-herders revealed that the fodder & fuelwood consumption was seasonal in nature. On an average, each herder utilized one headload (40 kg) of fuelwood for heating, cooking and making dairy products and used to lop on an average of 2.5 headloads (100 kg) of fodder. The lopping for fodder was done more in the winter season and was done for supplementing the nutritional requirements of the younger calves in the cow-sheds. Besides this trees were cut for building and maintenance of the cow-sheds once in 3-4 years. On an average about 320 kg of timber was required per herder annually. Various medicinal plants and herbs such as Swertia chiraita (chireto), Rubia manjita (majhito), Aconitum ferox (Bikh) etc were used for self medication when required.

Table 5.4 Forest-type wise fuelwood and fodder preferences of the herder community in the pre-ban period

Forest Type	Fodder	Fuelwood
Upper Hill-Himalayan Wet Temperate Forest	*Arundinaria maling*	*Quercus lamellose*
	Quercus pachyphylla	*Viburnum cordifolium*
	Ilex dipyrena	*Quercus thomsonian*
	Shefflera impresa	
	Litsaea polyantha	
Moist temperate Forest	*Thamnocalamus aristata*	*Abies webbiana*
	Osmanthus suavis	*Rhododendron hodgsonii*
Sub-alpine forest	*Rhododendron Spp*	*Abies webbiana*
	Betula alnoides	*Tsuga (brunoniana) dumosa*

Besides, we also documented the current resource utilization pattern and source of energy and fodder through interviews with ex-herder households and non-herder households to understand the change induced in resource utilization pattern. It was observed that the above anthropogenic pressures on forests existing earlier due to the cow-shed model were removed effectively. Now the ex-herders and non herder families utilize the vegetation in and around their land-holdings to meet these requirements. Some of the households having less land-holding size had to sometimes purchase fodder and fuelwood from outside. Some people now make an arrangement in which they take lease trees on other farms to fulfill their resource needs. Also the policy has affected the non-herder households also as now they cannot freely collect fuelwood and fodder from forests that they used to do earlier.

5.3.4 COMPARISION OF LIVELIHOOD STRATEGIES - PRE AND POST GRAZING BAN

In the agro-pastoral model of the region, the pastoral activities contributed to a substantial proportion of income and agriculture was mostly subsistence in nature. The main source of income for the herders in the pre-ban period was from the sale of livestock products i.e. butter(ghee), cheese(churpi), milk to local dairies, sale of calves (mainly the females), sale of adult livestock for meat and wool. They were issued “*pattas*” for grazing their livestock in forests for a nominal fee depending on the herd size. With the grazing exclusion policy implementation, the situation changed considerably. In this section we compare the livestock dependent livelihood income for the herder community pre-and post the grazing ban implementation. Table 5.5 and 5.6 present a snapshot of the key economic traits associated with per unit livestock owned before and after the grazing ban.

Table5.5: Average net annual income per livestock unit before grazing ban

Income generating activities	Description	Cow	Urang	Sheep	Buffalo
Daily Milk Production	(liters/day)	3	2	0.25	2.5
Production Months	(no.)	8	7	4	8
Average Annual Milk Production	(liters)	720	420	30	600
Average Annual Dairy Products Production	Butter (kg/year)	7.2	7	0.6	
	Market Price (Rs/kg)	70	70	70	
	Hard Cheese (kg/year)	9.6	7		
	Market Price (Rs/kg)	85	85		
Average Annual Income from dairy products	(Rs)	1320	1085	42	
Average Annual Income from calves	Average no. of calves sold	3	1	10	1
	Market Price (Rs/unit)	1715	1715	55	2500
	Income	5145	1715	550	2500
Average Annual Income from the sale for meat	Average no of adult livestock sold for meat	1	1	4	1
	Market Price (Rs/unit)	3250	3500	500	4300
	Income	3250	3500	2000	4300
Average Annual Costs per livestock unit	Salt requirement (kg/year)	14.4	12.5	4.8	6
	Market Price (Rs/kg)	3	3	3	3
	Feed requirement (kg/year)	9.6	9	0	5
	Market Price (Rs/kg)	8	8	8	8
	Caretaker's Salary 3000-5000 p.a*				
	Annual Cost	120	109.5	14.4	58
Average Annual Income per livestock unit		**9595**	**6190.5**	**2577.6**	**6742**

Source : Primary survey

*Note: An annual salary of Rs 3000-5000 was paid to the caretaker. This was besides the food, stay and other support.

In the pre ban period, the sampled households owned cows, buffaloes, yak-cow cross breeds and sheep. The herd size in the sample population was, on an average, 20 – 30 per herder. Mostly the cow variety owned was of the local breed 'Siri' that is well adapted to hilly terrain, but is comparatively lower on productivity scale than the cross-breed varieties. The lactation period for cows was on an average 8 months and for Urang 6 months. Dairy products made out of milk were stored and sold once or twice a month to local traders. The local traders mostly used to visit the cattle-sheds in the forests and collect the products, and further sale them to the whole-sale traders in the market. Income from the sale of dairy products and meat contributed nearly 60% and 20% to the total income of herders. Cost was mostly incurred for salt and feed and in some case for care-taker salaries. The average annual net-income was Rs 25,688.64 per herder.

Table5.6: Average net annual income per livestock unit post grazing ban

Income generating activities	Description	Cow
Daily Milk Production	(litres/day)	3.25
Production Months	(Nos.)	9
Average Annual Milk Production	(litres/ pa)	877.5
Average Annual Dairy Products Production	Butter (kg/year)	4
	Market Price (Rs/kg)	75
	Hard Cheese (kg/year)	4
	Market Price (Rs/kg)	225
	Milk supplied to the Dairy Farm (Litres/year)	675
	Market Price (Rs/Lit)	12.25
Average Annual Income from dairy products		9468.75
	Average Number of calves sold	1
	Market Price (Rs/unit)	2220
	Income	2220
Average Annual Income from the sale for meat	Average Number of adult livestock sold for meat	1
	Market Price (Rs/unit)	3250
	Income	3250
Average Annual Costs per livestock unit	Salt requirement (kg/year)	14.4
	Market Price (Rs/kg)	6
	Feed requirement (kg/year)	18
	Market Price (Rs/kg)	18
	Fodder Requirement (Grass)	768
	Market Price	10
	Total Cost	8090.4
Average Net Annual Income from a livestock unit		6848.35

Source: Primary survey

This model changed completely after the grazing ban. High milk yielding varieties of cows viz. *Jersey* and its cross breeds replaced 'Siri' across many of the sampled- households. These are stall-fed. Since the herd size has reduced to average 3-4 units per household, making of milk products (*churpi* and *ghee*) for sell has reduced significantly. Now the milk is used mostly for self consumption and the excess is sold to local dairies. Income from sale of dairy products and sale of meat constitutes approximately 65% and 30% of the income from livestock. The average annual net income from livestock was calculated to be Rs 11,104/- per household.

5.3.5 COMPARISION OF LIVELIHOOD STRATEGIES – EX-HERDER AND NON HERDER

There is a shift in the livelihood strategies post the grazing ban implementation. Earlier the-herders practiced agriculture mostly for subsistence needs. Now with the grazing exclusion, people have reverted to agriculture as the main stay for income generation. In this section we present an overview of the key economic traits of agricultural production in the region and then present a comparison of agricultural income between two groups of households – herders and non herders. This is to highlight the financial position of the ex-herder household relative to other groups of the local communities.

Table 5.7: Average production and income across variety of crops in the region

Crop	Yield per unit Input	Average Production costs	Average Production of a household	Market Price	Average Annual Income
	(kgs per headload*)	(Rs/kg)	(Kgs)	(Rs/kg)	
Cardamom	18 (per acre)	280	45	750	33,750.00
Potato	170	650	450	16	7,200.00
Peas	470	275	215	30	6,450.00
Corn**	450 (per acre)	265	80	20	1,600.00

Source : Primary survey; * 1 headload = 40kgs ** Most of corn production is held for self-consumption

Figure 5.5: Household classification into income classes

Potato, peas and maize are the staple crops of this region. At lower altitudes, (below 7000 feet msl), cardamom is the main cash crop of the region. Most of the high altitude villages thus have a limited scope for agricultural income. Potato is mostly used for self consumption and the excess is sold in the market. Corn produced in the region is mostly for self consumption and fodder and feed requirements of the livestock. Peas are partly used for self consumption and the rest are sold after drying. Table 5.7 presents the economics of agricultural production in the region. The costs incurred include labour costs and cost for readying the soil. The costs incurred from family labour not been considered in the calculations. Market price of crops and cost incurred for agricultural activities were estimated based on quotes provided by the sample households. Cardamom was the most profit yielding crop, but in the past 2 years due to proliferation of some crop disease, the production of cardamom has been drastically hampered in the region. Besides this, production of seasonal vegetables has been taken up by many households. Cabbage is one of the prime vegetables that is grown and sold in markets.

Some have built green-houses around the vegetables to protect from wild animal attacks. It was observed that people are adapting to the policy environment and are establishing themselves to a predominant agrarian economy.

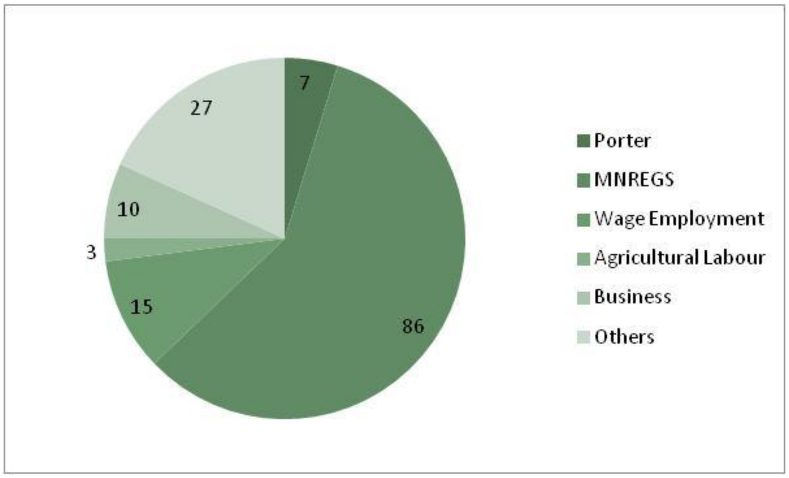


Figure 5.6: Income Generation Activities (all values in %)

Fig 5.5 divides the sample population into broad income classes, to assess income levels of ex-herders and non herders post policy implementation. The income classes represented in the above figure consider only agricultural income of a household. The classification highlights that the agricultural income of the ex-herder households is comparable to other non-herder households across various income categories. Rather there were very few non herder households in the high income category. It was observed that ex-herder households are doing reasonably well to earn a living from agricultural activities, though the income from agricultural activities is lower than their earlier income from livestock rearing. It was observed that the households of earlier livestock care-takers and ex-herders with less herd size and low land holding were the ones that were the most affected by the policy prescription.

5.3.6 ALTERNATIVE LIVELIHOOD STRATEGIES

The livelihood of all the ex-herders and non-herders has been impacted due to the grazing exclusion policy implemented in 1998. People have adopted a number of alternative livelihood strategies that are available in the region. One of the most important sources of seasonal income in the region was found to be MNREGS. The scheme provides atleast 100 days of employment to 86% of the sample population. 27% of the sampled population and their families were found to be associated with government and private jobs at hospitals, hotels and schools in the nearby towns. (Figure 5.6)

The implementation of grazing exclusion has paved way for the introduction of other means of livelihood such as tourism related activities. The altitudinal and climatic characteristics of the region, and its natural beauty attracts tourists every year, with prime attraction being trekking activity. Revenue generated was accounted during two seasons of the year viz. summer and winter. The annual income from trek groups, entry fees, home stays, tenting and kitchen equipment, animals charges, porter and guide charges and tips was estimated to be Rs 2,00,000/- in KBR. This was collected and accounted for both Indian and foreign tourists. The average annual income from Indian tourists was calculated to be Rs 85,000/- and that from foreign tourists Rs 1,20,000/- This information was collected from the Sindrabung Kanchendzonga Eco-friendly Society (SKES) for the annual income registered in their office. This organization has been established to promote eco-tourism in KBR.

The corresponding annual revenue from tourism (only entry fees) for the BRS was recorded to be Rs 70,000/-. (Sikkim Forest Department. Management Plan of Barsey Rhododendron Sanctuary, West Sikkim. Gangtok, DFEWM, Government of Sikkim., 2008). It was mainly Indian tourists from Bengal, and nearby states, who visited the BRS. During our consultations with the EDC and JFMC members in FGD's it was observed that there was no organization similar to the SKES which had been established to promote tourism in BRS.

There is a great opportunity for introducing skilled based employment generating activities in the region. Bamboo is an abundant resource found in the region. This with other NTFP species can be used to generate additional avenues of income for the local communities.

5.3.7 WILDLIFE CONFLICTS

The villages that were surveyed were in close proximity to the sanctuary. Hence, these villages experienced high rates of crop damage due to animals' entering the fields. . Therefore, net agricultural income of each household was subjected to damage caused by animals. This section tries to capture the differential losses in agricultural income due to wildlife incidences between the two groups of households viz. herders and non-herder households.

It was observed during the FGD, that 50% of the herder households, and 70% of the non-herder households felt that the damages due to animal incidence have begun only post implementation of grazing exclusion policy. It was also stated in the FGD's that there has been an increase in the entry of animals into the villages since the implementation of the grazing exclusion policy, except for the wild boar (which used to enter the villages even in the pre-ban period). Moreover, over 70 % of the households interviewed, agreed to damages due to wild boar intrusion in their field and perceived an increase in wild boar incidences post ban implementation.

Table 5.8: Classification of sample population in various loss categories

Income Loss (as a percentage of agricultural income)	% of sample population
<15	16.88
Between 15 and 30	23.38
Between 30 and 45	31.17
Between 45 and 60	19.48
>60	11.81

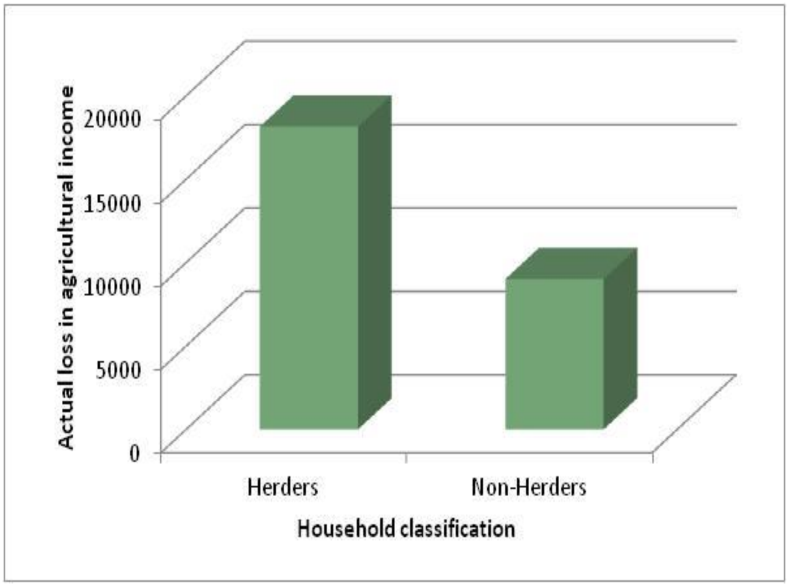


Figure 5.7: Monetary losses incurred due to wildlife incidences

Based on our consultations with the communities in various villages, we could understand the correlation between distance of a household from the forest area and their loss in crop. In villages like *Buriakhop*, we recorded higher damages in households which were higher in altitude, implying proximity to BRS and lower damages in households farther from the forests. Similar was the case in *Bhareng*, and *Upper Mukrung*. It can be said that within 0-0.5kms periphery of the sanctuary forest, nearly 70% of the crops are damaged by the animals, between 0.5-1.5kms; approximately 40-60% of the agricultural produce were damaged. Likewise, it can be inferred that more the distance from the forest, lesser the damage. Also, varying degrees of damage were recorded across different villages.

As shown in (figure 5.7), the average loss incurred by a herder household was recorded to be Rs 18,150/- per annum, and that by a non-herder was Rs 9,017/- . This variation could merely be effected due to the varying landholding sizes that herders and non-herders owned. Upon classification of the sample population as per various income loss as a percentage of agricultural income (Table 5.5), it is observed that maximum households belong to the category with losses ranging from 30 to 45 percent. Approximately 12 percent of the households incurred losses over 60 percent of their agricultural income while most of the households incurred damages upto 30 percent. Upon discussions over this issue during FGDs, villagers stated wild life incidence during pre-ban era also. However, these were limited to animals like porcupine, deer and sometimes wild boar. Post ban implementation, discussants stated the incidences have increased in frequency as well as intensity. Majority of the incidences occur during harvest season of respective crops: deer comes during months of May-June for peas while bear is commonly cited in month of August-September during corn harvest. Damages due to animals like porcupine, rabbit and sometimes monkey were also revealed but these are very less as compared to damages caused by wild boar. Damages due to wild boar occurred during sowing as well as harvesting of potato, a staple crop in the region. Unearthing of sowed potato and digging of ripped potatoes by wild boar is the leading factor in loss of income from agriculture.

5.4 PERCEPTIONS ON IMPLEMENTATION OF THE BAN

In addition to the household questionnaire, households were also asked opinionated questions to gauge their perceptions on impacts of grazing exclusion policy across various dimensions A specific close ended questionnaire, with Likert scale (options ranging from strongly agree, agree, no opinion, disagree and strongly disagree) was designed for ex-herders. The main objective of this exercise was to assess perception, of ex-herders, on the grazing exclusion policy impacts as well as willingness to participate in development of an alternate livestock management system along with the State Forest Department. . In addition to this, some open ended questions on changes induced post ban were also included in the survey to provide additional supporting information on perceptions of local communities (ex-herders and non herders) on the issue. Described below are the main points from this exercise.

5.4.1 ECOLOGICAL BENEFITS

The main objective of the restrictive policy was to protect habitats for the dwindling wildlife population by providing a chance for the degraded forest ecosystems to recover from degradation. Sample population, involving ex-herders and non herders, agreed to attainment of this objective as they noted an increase in density of forests in the study region. During our interactions, some ex- herders stated that earlier large openings could be seen on side sloping hill forests and now these same areas have been covered by dense vegetation and that its difficult to recognise their earlier routes. In addition, over 47 percent of the sample population strongly agreed that water quality in local streams, which originate from the sanctuary, has improved. The local population noted that earlier when the cattle-

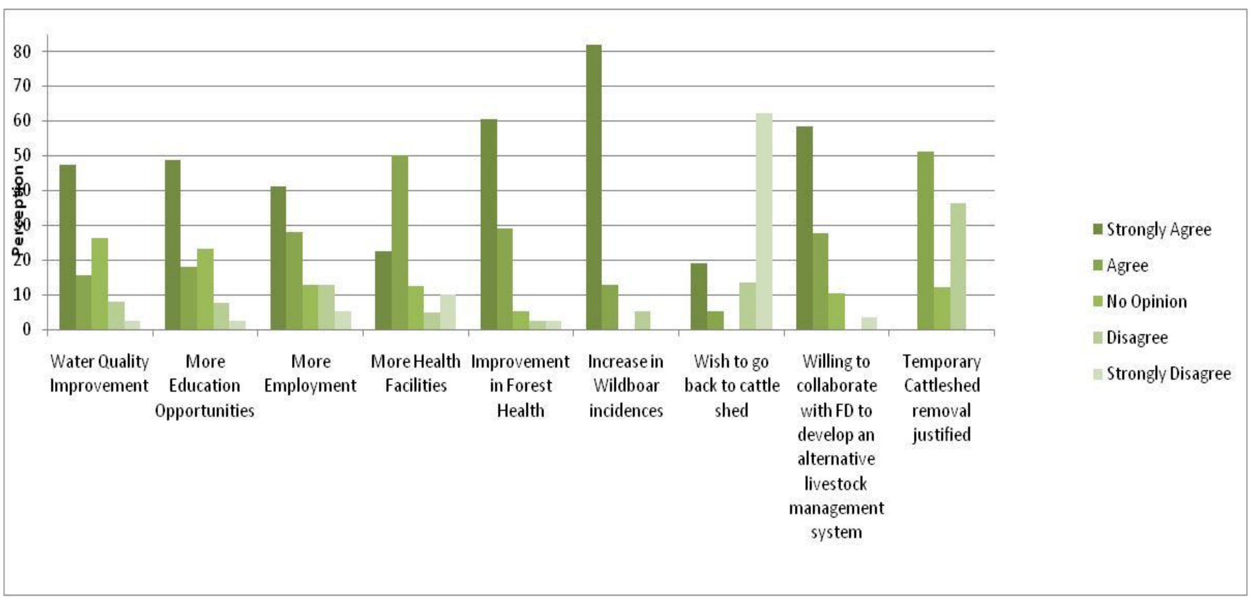


Figure 5.8 : Perception (in terms of %) of sampled population

sheds existed in forests, the local streams usually would be contaminated by animal droppings and eroded organic matter. Post imposition of restrictions, absence of such contamination has led to a perceived increase in water quality in local streams. Moreover some of them mentioned instances of revival of springs or improvement in stream flow at places like *Thulo Dhaap*, *Kalijhaar* and *Aaley chowk*. A minor population also observed decline in population of birds post grazing ban, citing non availability of animal dung which was used as feed by birds in the forests, as the foremost reason.

5.4.2 SOCIAL BENEFITS

With respect to change in employment opportunities, contrasting opinions were documented among ex-herder and non herder groups. Ex-herder community identified an increase in employment opportunities as an economic impact of the policy while non herders stated no changes in employment avenues in the local economy. One of the potential reasons for this could be that mostly ex-herder groups associated with JFM or EDC are more involved in activities related to the newly introduced nature based tourism in the region. Overall, 48 percent and 41 percent of the sample strongly agreed to more education and employment opportunities while only half of the sample perceived enhancement of health facilities post ban implementation (Figure 1). While ex-herder groups stated a decline in their household income post the restriction policy, both the affected groups pointed to MNREGS as the major employment providing opportunity in the region. Also even though both groups agreed to a gradual increase in prices of various dairy products, fodder and fuel wood they did not associate this price rise to resource access restrictions. Post cattle shed eviction, most of the ex- herders were contended to stay and work in the villages and the areas close by (or nearby areas), in contrast to the strenuous and grueling life in forests.

5.4.3 CONFLICTS AND OPPORTUNITIES

A notable increase in number of wildlife sightings, in close proximity to human settlements, was noticed as a major impact of closing up of forests.. Over 85 percent of the sampled population stated that there has been an increase in crop damage incidences by wild boar and other animals in the fringe villages. Upon further probing, approximately 62 and 65 percent of ex-herders believed that non availability of sufficient food and restricted movement inside forests due to dense undergrowth have resulted in an increase in frequency of wildlife straying near habitations. 85 percent of the ex-herders also considered ban on hunting of wild animals as a key reason for increase in man-animal conflict in the region.

The opinions of ex-herders and non herders differed on the issue of whether the removal of cattle-shed was justified. Overall, approximately 52 percent of the sampled population justified the move while 12 percent of them had no opinion about removal of the cattle shed from forests. 50 percent of the ex-herders interviewed did not agree to removal of cattle sheds while only 23 percent of the non herders agreed to this. High dependence on forests for day to day activities and higher income from livestock in the *gothwala* system were major reasons for endorsing an agro-pastoral lifestyle in forests. 60 percent of the non herders interviewed justified removal of cattle sheds but approximately 16 and 8 percent of the interviewed non herder and ex-herder population had no opinion about this action. Reasons for justification of cattle shed removal included ecological benefits like better regeneration of forests and increase in water quality. Middle aged ex-herders, age less than 55, emphasised on various social benefits of the policy too like educational opportunities and prospect of living with other family members in village. However, elderly ex-herders, approximately above the age of 55, asserted that if given an opportunity and better personal health condition, they would like to stay in temporary cattle shed inside forests even now.

5.5 CONCLUSION

The details from the household survey provide insights into the magnitude of the livelihood impact associated with the policy implementation. It was observed that not only herders were impacted but also the non herder group was impacted though to a less extent. Amongst the herder group, caretakers and people with less land ownership were the most impacted. Earlier mostly people used to practice subsistence agriculture and now they focus on doing agriculture for livelihood. Other livelihood options such as MNREGS and eco-tourism have been introduced of late. Eco-Tourism is gaining importance in the region, as the villages have become more accessible now. Also the access to education and health facilities such as hospitals and PHC has improved from the past. The villages have been introduced to better yielding crops varieties and livestock varieties which have resulted in higher economic returns. Though, the associated costs have also gone up considerably due to restriction on the free access to forest resources. There has been an increase in the instances and intensity of the damage caused by wild animals to the crops and this calls for finding a solution to the emerging issue. A need for livestock management system and need for improving the management of reserved forests for the community needs has been corroborated during the study. Thus, the perceptions and information captured from the socio-economic survey can be used as an input for further policy refinement.

CHAPTER 6
CLIMATE CHANGE MITIGATION THROUGH GRAZING EXCLUSION POLICY

6.1. INTRODUCTION

Forest ecosystems assume significance in addressing climate change associated challenges by playing a vital role in maintaining the carbon balance of the atmosphere. Interestingly, on one hand they form one of the largest terrestrial carbon sinks and on the other, deforestation constitutes 20% of the anthropogenic GHG emissions worldwide (IPCC-WGI, 2007). Thus, their role in international climate mechanisms has been limited. Issues such as uncertainty of activities, non – permanence[12], leakage, establishing additionality and practical difficulties in measurement, reporting and verification were the leading cause for concern. (WWF Position Paper, 2009). However, recognizing the potential of forests and land use measures to reduce net carbon emissions by the equivalent of 10-20% of projected fossil fuel emissions through 2050 (UCS, 2005), Bali Action Plan inducted an international framework to halt deforestation. Reducing Emissions from Deforestation and Degradation (REDD), was inducted at the 13th Conference of Parties in 2007. Inclusion such as the REDD encourages and provides an opportunity to conservation-centric government policies, ultimately resulting in carbon abation and forest enhancement, to participate and benefit from the growing carbon market. Successful mitigation of climate change through REDD requires effective forest governance. (FAO and ITTO, 2009) Adaptive policies, developed through a bottom up approach, not only ensure stringent compliance to conservation centric policies, but also provide clarity on issues such as forest rights and access. (Bushley, 2010) Such forest management policies counter degradation of forest ecosystem and also enhance the capacity of stocking territorial carbon in them.

In India, Sikkim is one of the most pro-active states in leading the implementation of conservation policies. With over 80% of its geographic area notified as recorded forest area (FSI, 2009) and over 30% of its area under protected area networks, Sikkim is recognized as a key conservation hub. It is home to a variety of flora (4500 species) and fauna (150 species of mammals & 550 species of birds & 600 types of butterflies) - such rich diversity in a relatively small landmass puts forward considerable challenge in terms of governance. The issue is compounded by the fact that a high percentage of total population is forest dependent in the State[13]. For such a resource rich mountainous State, maintaining the health of natural resources also helps in minimizing the loss due to recurring natural disasters such as landslides

[12] Defines the risk of reversal of emissions removed by sinks through natural disasters

[13] As per the government records, each of the 907 villages in the State is a forest fringe village. (DFEWM, Sikkim, 2011)

and sinking areas. Realising the need for maintaining the balance between development and environment, Sikkim State government has launched a number of eco-friendly policies and initiatives in the last two decades to achieve the twin goals of conservation and sustainable development.

Grazing exclusion policy was one such challenging initiative implemented in 1998. Considering the high dependence of the local communities on the forest areas for subsistence needs such as fuelwood, fodder, timber and livelihood dependency on livestock rearing, policy implementation was a formidable task. The aim of the policy was to restore forest ecosystems and is recognized as a decisive policy measure contributing to mitigating climate change.

The main focus of this chapter is to highlight the net positive impact on forest carbon stocks by the introduction of grazing exclusion policy in the State of Sikkim. The case is developed based on our field work in Barsey Rhododendron Sanctuary (BRS) in the West District of Sikkim. The case compares two alternative scenarios: (i) Forest carbon stocks in the absence of the grazing exclusion policy (ii) Forest carbon stocks with implementation of the grazing exclusion policy.

6.2. STUDY SCENARIOS

The government of Sikkim introduced conservation policy banning open grazing of domestic livestock in reserved forests, plantations and water sources in 1998. Following the ban on grazing, the process of cow-shed removal was started in Barsey Rhododendron Sanctuary and by 2004; the policy was successfully implemented in the protected area. There was a reduction of about 93% in the livestock population units grazing in the study area. (Tambe, Bhutia, & Arrawatia, 2005) The decline in anthropogenic pressure on the forest resources is supposed to improve the condition of the degraded forest landscape and contribute in enhancing the forest carbon stock. The chapter attempts to quantify this change in forest carbon stocks that can be attributed to the policy implementation. The chapter develops two scenarios and compares them to highlight the change in forest carbon stocks due to the introduction of the grazing ban policy in BRS.

6.2.1. SCENARIO 1: WITHOUT POLICY DIRECTIVE ON GRAZING EXCLUSION

In developing this scenario, we make projections for the forest carbon stocks in BRS for 2010, presuming that the grazing ban intervention had not been implemented for that area. The dynamics of livestock population variation over the last seven decades in BRS reveal that the livestock pressure was maximum around the late ninety's. Moreover around the same time, in 1998, there was detailed forest inventory survey conducted by Forest Survey of India in the West and South districts of Sikkim. BRS was one of the areas where plots where laid for the FSI inventory exercise. Around this time, the grazing pressure in BRS had also been established. Thus, looking at data availability, 1998 was chosen as the base year for developing this scenario. The projections are based on the assumption that in the absence of the policy directive on grazing exclusion, the grazing pressure would have remained constant over the next decade.

This scenario develops estimates for the growing stock in BRS for the year 2010, taking baseline growing stock from FSI 1998 survey. Change in forest carbon stocks from 1998 to 2010 is estimated as below:

$$C_t = C_{t-1} + C_i - C_l \quad \text{-- equation 1}$$

Where, t varies from 1999 to 2010

C_t = forest carbon stock at time period t
C_i = increment in forest carbon stock due to mean annual increment
C_l = losses in forest carbon stock due to anthropogenic pressures
t = year

6.2.2. SCENARIO 2: WITH POLICY DIRECTIVE ON GRAZING EXCLUSION

Following the Sikkim government notification on banning grazing in forest areas, the intervention was implemented in BRS by 2004 as discussed earlier. The baseline remains the same for both the scenarios. In this scenario, the estimates for the forest carbon stocks in BRS for the year 2010 are developed based on the primary data collected through intensive field survey during November- December 2010. The estimates generated from this scenario can be treated on the lower side as data has been collected from areas that were earlier subjected to grazing pressure. And undisturbed areas have not been covered in the survey.

The objective of constructing the two scenarios is to capture the policy impact of the grazing ban implementation in BRS. The first scenario captures the growing stock (2010) of degraded forests as it assumes that the disturbances do not cease to exist even after 1998. The second scenario captures the actual growing stock for 2010 based on field data, which reveals the removal of anthropogenic pressure from BRS after policy implementation in 1998. This difference in forest stocks in both the scenarios is emphasized by taking their respective carbon stocks into consideration. Thus, the potential and scope of forest cover to act as carbon sinks if conserved is also highlighted.

6.3. MATERIALS AND METHODS

6.3.1. STUDY AREA

Barsey Rhododendron Sanctuary lies in the south-west corner of the West district of Sikkim with an area of 104sq. km. The major significance of the sanctuary is the presence of a wide variety of *rhododendron species* and that it is home to some of the rare Schedule I species including Red Panda (Sikkim Forest Department, 2008). BRS is surrounded by more than 30 fringe villages comprising of above 5000 households. (Sikkim Forest Department, 2008). In addition to stray cattle grazing in forest fringes, the sanctuary was home to 288 herders and 5,370 cows, 370 buffaloes, 506 yaks and 135 sheep. Prior to the ban, *pattas* (permits) were given to herders for grazing their livestock. Herders followed an agro-pastoralist lifestyle with establishing permanent *goaths (*cattle-sheds), in the forests and practicing mostly subsistence agriculture in the villages. In the forest, vegetation in and around the cattle-shed would be cleared to create *kharka* (open space for grazing). In the adjacent areas, trees would be heavily lopped for fodder and cut for firewood and timber. The movement of the herders depended upon availability of fodder, water, livestock type and was seasonal in nature. From mid of 1970s to late 1990's, there was an increase in the livestock population and rise in the number of heavy livestock types such as yak, and yak-cow hybrids. With livestock density as 61 livestock / km^2 and cattle shed of density of 4.5 / km^2, the sanctuary was immensely degraded due to the anthropogenic activities. (Tambe, Bhutia, & Arrawatia, 2005).

6.3.2. FIELD SURVEY

We conducted extensive field surveys during Nov – Dec 2010. Data on vegetation and soil parameters was collected in the field while qualitative data was collected on hydrological and wildlife aspects. The study area was stratified into 4 broad categories based on the forest type:

1. Upper Hill-Himalayan Wet Temperate Forest (Oak and dwarf bamboo dominated)
2. Moist temperate forest (Mixed coniferous)
3. Sub-alpine forest (Birch/Fir & Rhododendron forests)
4. Sub-Alpine scrub (Rhododendron & scrub thickets)

Ten plots were laid in each of the forest type zones within 1 ha radius of the cow-shed locations, except for the sub-alpine scrub forest where quadrants were laid. In all, 30 plots of 0.1 ha each and 20 1 m^2 quadrants were laid. The methodology prescribed by the Forest Survey of India was followed for collecting vegetation data from the plots. (FSI, 2002). A detailed inventory on important vegetation attributes such as canopy cover, regeneration, girth at breast height, tree height etc was prepared. (Refer to Chapter 3 for details)

The consumption data for average fuelwood, fodder and pole requirements were collected through *Focused Group Discussions* with Joint Forest Management Committee and Eco-Development Committee members, and *Household Surveys* of 60 herder households in the fringe villages of the sanctuary.(Refer to Chapter 5 for details) Annual requirements of the herder population alone, was considered for this study.

6.3.3. SECONDARY INFORMATION

The average growing stock estimates were adopted from the FSI, Interim Report, (1998).

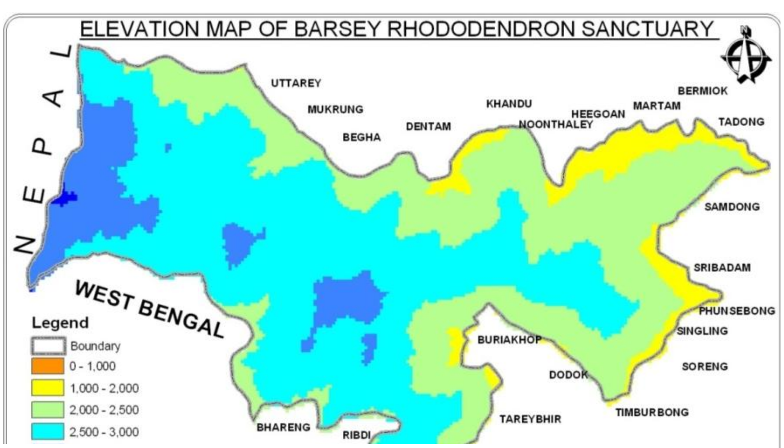


Figure 6.3.1: Elevation map of Barsey Rhododendron sanctuary (DFEWM, Sikkim, 2011)

AREA CALCULATION

We used a LISS III classified image for calculating area under each of the forest type. The image classified on the basis of altitude was taken from the Management Plan of the sanctuary as developed by the state forest department. The image was divided into six classes namely: 0-1000m, 1000-2000m, 2000-2500m, 2500-3000m, 3000-3500m and 3500-4000m. (Figure 6.1) Arc GIS (version 9.2) was used to calculate the area under each altitude class, these area estimates were utilized for further estimation of carbon stock.

6.3.4. METHODOLOGY FOR ESTIMATION OF GROWING STOCK

The study measures the impacts of grazing exclusion policy by considering four variables, i.e. Pre-ban growing stock, mean annual increment, anthropogenic pressures and post ban growing stock. The baseline growing stock for the year 1998 is estimated based on average volume of growing stock values obtained from Forest Survey of India, Kolkata, interim report (1998). The growing stock in the year 2010 is estimated based on the plot level data obtained during the field surveys. Local allometric equations given in table 6.1 were utilized for calculating volumes of different tree species. Thus, the methodology for calculating the baseline and current growing stock are both based on FSI technique. State level Mean Annual Increment (MAI) estimate of 0.767 Mm3 (FAO 1998), as provided by the Food and Agriculture Organization report 1998, was adopted for this study. Activities causing loss of carbon stock, collectively taken as anthropogenic pressures, include lopping for fuelwood & fodder, poles for maintenance and construction of cow-sheds and free grazing of domestic livestock in forest areas. Field based primary data was used for calculating carbon loss due to anthropogenic pressure and post-ban growing stock as in 2011.

Table 6.31 : Allometric Volume Equation (FSI, 1998)

Form Class	Local Allometric Equation
I	V/D^2= 0.001559 +0.06674/D2 - 0.02039/D
II	V/D^2= 0.0012897 + 0.25564/D2 - 0.030418/D
III	V= 0.12652 - 0.018037 D + 0.000956D2
IV	V/D^2= 0.001184 + 0.1812/D2 - 0.02348/D
Estimation of Bamboo biomass (Hairiah K., Sitompul, Noordwijk, & Palm, 2001)	
W = .131 (D^ 2.28)	

METHODOLOGY FOR ESTIMATION OF CARBON EQUIVALENT

Methodology, prescribed by the Indian Council of Forestry Research and Education, was adopted to calculate carbon content of growing stock of trees and to estimate the loss in carbon stock due to anthropogenic pressures. As soil carbon estimates for the baseline are not available, the paper limits itself to biomass carbon, stored in forest vegetation, to highlight change in territorial carbon stock due to grazing ban.

Methodology to estimate Carbon Content

Forest Carbon Stock = Biomass Carbon + Soil Carbon

(The paper assess only biomass carbon in order to highlight policy impact)

Biomass Carbon = Above Ground Biomass (AGV) + Below Ground Biomass (BGV)

Above Ground Volume (AGV) (Mm3) = Growing Stock (Mm3) * Biomass Expansion Factor (1.575)

Below Ground Biomass (BGV) (Mm3) = Above Ground Volume (AGV) * Root-Shoot Ratio (0.266)

Total Biomass (Volume) (Mm3) = ABV + BGV

Biomass of Trees (Million Tonnes) = Total Biomass*Wood Density (0.7116)

Other Vegetation (Million Tonnes) = Biomass*Ratio (0.015)

Total Forest Biomass (TFB) (Million Tonnes) = Biomass (Tree) + Other Vegetation

Dry Weight of Biomass (Million Tonnes) = TFB*0.8

Carbon Equivalent of Biomass (Million Tonnes) = Dry weight of Biomass*0.4

Source: (Kishwan, Pandey, & Dadhwal, 2009)

Biomass carbon includes above-ground as well as below-ground biomass; where below-ground is a derived as a product of *the root-to-shoot ratio* [14] and above-ground biomass. For the baseline, average volume per hectare was considered from the FSI interim report. However, documented *dbh* at plot level was used in local allometric volume equations to estimate the above ground volume for estimating growing stock for 2010. These estimated growing stocks (in m^3) were multiplied by the national biomass expansion factor to obtain above ground volume (AGV) and subsequently below ground volume (BGV). Conversion from biomass (in terms of volume) to biomass (in Tonnes) was done by assuming mean wood density as 0.7116. Even though the study doesn't include carbon stock assessment of forest litter and dead trees, carbon pool of other vegetation (on the forest floor biomass) was incorporated to calculate the Total Forest Biomass (TFB). Further carbon equivalent of biomass was estimated considering the dry weight of TFB. (Refer box)

[14] ratio of belowground biomass to aboveground biomass of a tree species

6.4. RESULTS

6.4.1. SCENARIO 1: WITHOUT POLICY DIRECTIVE ON GRAZING EXCLUSION

6.4.1.1. ESTIMATION OF BASELINE

The estimation of baseline growing stock is a prerequisite for the calculation of change in carbon stocks. Table 6.2 presents an overview of the growing stock assessment for the West district of Sikkim according to the FSI 1998 report. The FSI study had divided the forests into reserved and unreserved categories, which were further divided into 4 stratums based on the altitude. The paper has adopted the estimates developed for the reserved forests in West Sikkim. As most of the area in BRS lies above 2000m hence the values for stratum III and IV only were utilized for this paper. The area of BRS lying below 2500m was multiplied by growing stock estimates under stratum III while for area between 2500-3500m stratum IV estimates were used. Above 3500m, the tree line starts diminishing and subalpine thickets start dominating. In BRS 0.202 sq. km of area lies above 3500m and it has been excluded for the growing stock estimations.

Table 6.2: Baseline volume estimates adopted for the study site (FSI, 1998)

Stratum	Altitude (m)	Volume (m^3/ha)	Stems per Hectare
I	≤ 900m	66.813	144.999
II	901 to 1800m	111.266	287.307
III	1801 to 2400m	130.196	190.811
IV	≥ 2400m	283.047	270.714

From the LISS image, the estimated area in BRS was 54.055 sq.km under stratum III and 85.14 sq.km under stratum IV. The total volume of growing stock was calculated by multiplying average volume per hectare by area. It was estimated at 0.704 Mm^3 for stratum III and 2.410 Mm^3 for stratum IV. The total forest biomass after converting the growing stock to biomass stood at 4.484Mt. From the above, the net accumulation of carbon in the forest stock was projected at 1.435Mt for the year 1998. Form the findings of the FSI report; it is observed that, the forests in stratum III were dominated by *Quercus spp*. that contributed the most (37.89 percent) while the stratum IV was predominated by *Abies* species (45.15 percent). In both the stratums, mature trees (over 60cm diameter) majorly contribute to the volume (63 to 65 %). The forests in stratum III correspond to the upper hill Himalayan wet temperate forests while, the forests in stratum IV cover the moist temperate and sub-alpine forest types. This estimated carbon stock is used as the reference level to detect change in carbon stock level.

6.4.1.2. ESTIMATION OF LOSS OF CARBON DUE TO ANTHROPOGENIC PRESSURE

Forest ecosystem presents a unique case: when conserved or managed sustainably, they act as sink for carbon, while when degraded or destroyed they turn into sources of carbon dioxide emission. The rapid increase in anthropogenic pressure in BRS was a significant factor contributing to degradation. The livestock population in BRS increased from just over thousand in 1960's to over 6000 livestock units in 1990's[15], an increase of over 250%. This led to intensification of the human activities in the sanctuary, resulting in clearing up of the forested areas for constructing cattle-sheds and grazing areas. This human induced pressure in terms of extraction for fuel wood, construction and lopping for fodder was the main factor contributing to the forest degradation and resulting in diminishing the value of the forest carbon stock. Table 6.3 lists the livestock pressure in BRS for the year 2000. These values have been adopted in this paper for estimating the grazing pressure.

To estimate the carbon loss, a consumption based approach has been adopted. Information on activities contributing to extraction of the resource was documented through interviews with the herders. There were about 288 herders practicing pastoralism in BRS around the year 2000 (Tambe, Bhutia, & Arrawatia, 2005). The discussions with the herders revealed that the preferred species for fuelwood were *Arundinaria maling* (malingo), *Quercus spp* (bante), and Viburnum cordifolium (asare) in the temperate forests while *Abies densa* & *Rhododendron spp* were mostly used at the higher altitudes. The mean consumption of fuelwood by herder was 40kgs d^{-1} (1 head load)[16] for cooking and heating purposes. The average requirement of a herder was 21 metric tonnes $year^{-1}$.

Table 6.3: Livestock pressure in Barsey Rhododendron Sanctuary (Tambe, Bhutia, & Arrawatia, 2005)

Livestock	Population	Months grazed inside forest
Cow	5370	8
Buffalo	370	8
Yak	506	12
Sheep	135	12

Lopping of trees for fodder constituted another cause for loss in tree stock leading to loss in forest carbon. Lopping was mostly done for providing fodder to the young calves in the cattle sheds and to supplement the fodder requirements of livestock, especially in winter when ground availability of fodder declines. Some of the preferred species lopped for fodder were *Thamnocalamus Aristata* (Raat Ningale), *Arundinaria maling* (malingo), *Quercus spp* (bante), Litsaea polyantha (pahenley), *Ilex dipyrena*

[15] Information from focussed group discussions with local communities

[16] For the purpose of calculations, 1HL has been taken as 40kgs and 1 Peel as 12HL.

(lissey)and *Sorbus Cuspidata* (Teiga).The average fodder requirement of a herder was 90kgs d^{-1} (2.5 head loads) Net demand for fodder per herder was 33 metric tonnes $year^{-1}$. Herders also required poles for maintenance and construction of the cattle sheds. Species like *Viburnum cordifolium* (asare) and in higher altitudes *Abbies densa* (Silver Fir) and *Tsuga Dumosa* (hemlock) were utilized for this purpose. The herder on an average required 92 tonnes $year^{-1}$, for the purpose of constructing and repairing his cattle shed.

Table 6.4: Carbon losses due to various disturbances

Disturbance	Consumption (Tonnes p.a.)	Biomass Equivalent (Tonnes p.a.)	Carbon equivalent (Tonnes p.a.)
Fuelwood	6165.504	9710.669	3107.414
Fodder	9642.24	15186.528	4859.689
Timber (poles)	92.16	145.152	46.449
Grazing	100371.600	100371.600	17263.915

Besides lopping, another source of biomass loss to forests was in the form of livestock grazing freely in the forests. To estimate this loss, the average daily consumption of green fodder for a cow has been adopted as 60 kg. The other livestock such as yaks, sheep etc have been converted to *equivalent cow units,* which are multiples of this average cow consumption. For the purpose of calculation, they were taken as cattle/cow=1, buffalo=2, yak=1, and sheep=0.5 (Paljor, 1998).

The total average annual biomass extraction for a herder amounted to 33 metric tonnes of fuelwood, 52 metric tonnes of fodder, and 145 metric tonnes of poles. These annual estimates were then converted into their biomass equivalents using standard biomass expansion factors and further converted into their carbon equivalents by applying the carbon content conversion factor of 0.4 to them. Displayed in table 6.4 are the corresponding losses in the stocks of carbon due to lopping for fuelwood, fodder and grazing. The contribution of grazing to the loss of carbon stocks was estimated to be 68%[17] as compared to fuelwood and fodder which were at 12% and 19% respectively.

6.4.1.3. PROJECTION OF STOCK OF CARBON

As per methodology, the forest stocks in 2010 were estimated by taking the baseline stocks of 1998 and deducting the losses in carbon due to anthropogenic pressure from them and adding the natural regeneration of forest stocks every year. For this, the *MAI of 0.353 t/ha/yr* reported at the state level has been adopted. This was an addition of 4920.3963 tonnes of carbon per annum to the growing stock every year. By adopting equation 1, the carbon stock for 2010 for BRS was estimated to be 1.17 Million tonnes. The calculations indicate a reduction from 1.43 Million tonnes of carbon in 1998 (baseline year) at a rate of 22.054 thousand tonnes per annum. This continuous decline, over 12 years, suggests that the rate of removal of biomass to be higher than the associated natural regeneration and growth. Such

[17] The loss of carbon due to grazing was estimated after considering the seasonality in grazing of the different types of livestock

projections with constant anthropogenic pressure eventually predict role reversal of trees- from carbon stocks to sinks. (Bhat & Ravindranath, 2010)

6.4.2. SCENARIO 2 - WITH GOVERNMENT INTERVENTION

This scenario quantifies the effectiveness of grazing exclusion policy, in terms of carbon stocks. A positive change in sequestered territorial carbon levels points towards increase in forest biomass- a direct result of undisturbed natural regeneration. A negative change indicates continuation (or acceleration) of degradation activities resulting in higher carbon loss as compared to sequestration. Field based forestry inventory data is used to calculate the growing stock and its carbon equivalent for 2010, 12 years into the policy intervention. Based on the field inventory data, an average volume per hectare for each of the forest type- upper hill Himalayan wet temperate, moist temperate and sub alpine is estimated by taking an average of total volume in each of the ten plots laid.

Table 6.4: Volume, Biomass and Carbon Stock estimation in 2010

Forest type	Average Volume (m^3 per ha)	Forest Biomass Equivalent (Million Tonnes)
Upper Hill Himalayan Wet Temperate	189.462	1.474
Moist Temperate	233.659	2.317
Sub -Alpine	603.760	1.173

Most of the bamboo documented during the field survey had dbh in the range of 3-7cm, indicating rapid regeneration at the study site. The study adopted a diameter-dry weight relationship to estimate the growing stock for bamboo (Hairiah K. , Sitompul, Noordwijk, & Palm, 2001). Carbon stored in bamboo forms 7% of the total carbon stock in the study site with maximum contribution of approximately 16 % in the wet temperate zone. In addition to bamboo species, *Quercus* species contribute upto half of the above ground volume in the wet temperate forests while *Litsaea polyantha* and *Rhododendron* species contribute 18.20% and 7.27% respectively. In the moist temperate zone there was a mix of broadleaved species with coniferous. There was dominance of coniferous (*Tsuga dumosa, Abies densa)* and *Rhodendron species,* adding upto 50% percent of the above ground volume. Some of the prominent broadleaved species were *Acer cambelli* (4.53%), *Osmanthus suavis* (6.79%), and *Quercus spp.* (9.73%). In the sub-alpine region, *Rhododendron spp.* were conspicuous owing to the luxuriant regeneration and contributed about 46.76% to the above ground volume. The regions had *Abies densa* (39.63%) is the other dominant species of the zone.

The stock of biomass of wet temperate, moist temperate and sub alpine forests was 1.474 Mt, 2.317 Mt and 1.173 Mt respectively (Table 6.5). Total Forest Biomass, inclusive of enumerated trees as well as other forest floor biomass, for the site is estimated at 5.059 Million tonnes while the carbon equivalent for same is 1.755 Million tonnes. The estimates show that there was an increase of about 320 thousand tonnes of carbon over the baseline in the BRS. Table 6.6 presents the comparative scenario. The augmentation in the forest carbon stock can be attributed to the effective implementation of grazing exclusion policy in the BRS.

Table 6.46 : Change in forest carbon stock between 1998 and 2010

Item with description	Factor	1998	2010
Growing Stock of Sanctuary (Mm^3)		3.114	3.513
Mean Biomass Expansion Factor (EF)	1.575		
Ration (Below to Above Ground Biomass) – RBA	0.266		
Above Ground Biomass (Volume) AGB=GS*EF		4.904	5.533
Below Ground Biomass - AGB*RBA		1.305	1.472
Total Biomass (TGB) AGB + BGB		6.209	7.005
Mean Density – MD	0.7116		
Biomass in Metric Tonnes = Growing Stock (Mm3) * MD		4.418	4.984
Ratio (Other Vegetation to Tree Biomass)	0.015		
Total Forest Biomass in Mt (Trees + Herbs + Shrubs) - TFB		4.484	5.059
Dry Weight in Mt (TFB*80%) - DW [18]		3.927	4.387
Stock of Carbon in Mt (DW*40%)		1.435	1.755

6.5. DISCUSSION

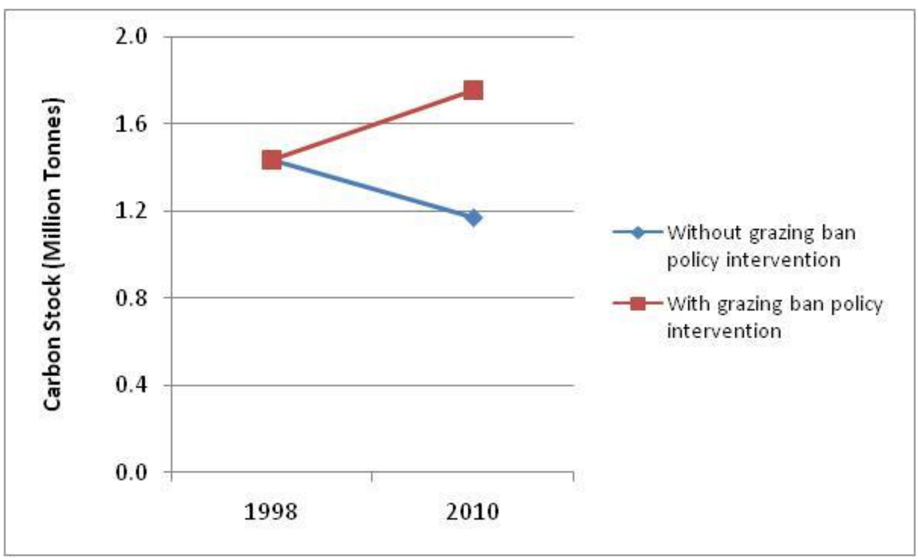


Figure 6.5: Comparison of scenarios -forest carbon stocks with and without grazing exclusion policy

This chapter reveals the impact of the grazing exclusion policy in terms of enhancement of the forest carbon stock on a relatively finer scale. Figure 6.2 presents a comparative account of with and without policy intervention. It is observed that the difference between with and without policy intervention scenarios amounts to about 585 thousand tonnes of carbon. This translates to 2142[19] thousand tonnes of carbon di-oxide equivalent. (Assuming an average price of the offsets in the forest carbon market scenario at \$4.6/tCO2e[20], it can be valued at Rs 45.33[21]

[18] DW(2010) is inclusive of the dry weight of bamboo species

crores.) This change indicates active role played by forests in enhancing carbon sink and sequestering carbon which would have been absent if grazing exclusion had not been implemented. This conservation promoting policy has improved carbon sequestration, considered as a low cost abatement option. Value of this carbon sequestrated is not limited to the geographic area of study site but rather is a contributor to global reduction in net carbon emissions. (Richards & Anderrson, 2001). Usually such studies are either designed at a broad regional scale based upon country or landscape level estimates or are micro-level site specific & data intensive studies, requiring time series data for longer time intervals. In either case data availability is a crucial factor. In the absence of the detailed longitudinal data, the case has been developed with limited information and scope. The estimates should be treated carefully and are indicative in nature. The intention behind developing this case using a available information was to highlight the significance of the impacts generated by the policy instrument and to showcase them by developing a case study. Currently the working plan is being developed for the state of Sikkim for which intensive forest inventories are been conducted across all the districts. This data can be utilized along with the data from earlier forest inventories in the State (1988 or 1998) by Forest Survey of India to develop a picture of forest carbon stock change at the State level. Such an exercise will help in establishing the presenting a holistic picture of the policy measures and create a useful data repository for climate change related topics. Not only can such study contribute towards decision making on relevant policy issues, but by combining this data with socio-economic indicators, it is possible to establish program effectiveness and creating useful information for strengthening policy performance.

Sikkim with its effective implementation of conservation promoting policies has been able to reverse the trend of forest degradation. It has great potential in leading India's initiative on international conservation funding mechanisms. Efforts have to be made for creating linkages between its policy measures on conservation to the international mechanisms of climate funding by creating necessary frameworks This is great opportunity to utilize the State's internal institutional frameworks and prepare for playing a larger role by participating in global efforts of establishing market mechanisms to support initiatives on reducing forest loss and degradation.

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[19] Based on the carbon dioxide to carbon ratio of 44 /12

[20] The average price for offsets across the primary forest carbon markets were \$3.8/tCO2e in 2008, \$4.5/tCO2e in 2009, and \$5.5/tCO2e in 2010 (Diaz, Hamilton, & Johnson, 2011)

[21] Conservative estimate taking 1\$ equivalent as Rs 46.

CHAPTER 7
POLICY IMPACTS AND WAY AHEAD

7.1 INTRODUCTION

'Policy impacts' is a broad term and its usage is common particularly in the program evaluation sphere. There are various methodologies by which policy impacts can be established. In quantitative impact assessment studies, usually policy impacts are defined during the design of the study and quantified. In real life programs in emerging country like India, usually evaluations are done as an addendum. The quantitative designs are too complex to execute in field and mostly qualitative evaluations is the only way further. In such studies establishing policy impacts is a crucial step. For evaluations of developmental programs, establishing impacts is relatively uncomplicated as the outcomes and impacts can be studied by quantifying the change in outcome variables mostly socio-economic in nature. In case of environmental programs the problem gets escalated due to data availability issues and collecting information on environmental variables is relatively challenging and resource intensive job. In India, the stress on monitoring the programs and doing evaluations is yet in the emerging stage. Designing a research studies to examine program evaluations can help provide useful insights on outcome, impacts and policy effectiveness. The insights can be used to strengthen the policy impacts.

We have developed a framework for analyzing the policy impacts for the grazing exclusion policy. The framework helps in getting a consolidated view of the policy on various dimensions: environmental as well socio-economic. One of the key objectives of this section is to present this framework that can be utilized to evaluate policy impacts for conservation program evaluations, for research studies based on qualitative study design. Also we put forth thoughts on taking forward the conservation work being done in the State. We do this by developing an in-depth case study of forest carbon stock increase based on the information collected through extensive primary work in the study area. To conclude, we provide suggestions and recommendations that would help in further

In this study we had the opportunity of looking at the policy implementation of the grazing exclusion policy in Sikkim. The main purpose of this chapter is to consolidate the findings from the year long work in the region and present the learning's and provide recommendations for further intensification of the policy impacts. Since the study area had a relatively confined scope, the findings and recommendations provided in this section are limited for the study region.

7.2 POLICY IMPACTS – EVALUATION MODEL

7.2.1 FRAMEWORK COMPONENTS

The framework is comprised of four key components. The components are so identified that each captures a significant dimension on which a policy can have an impact. Each component is characterized by a set of indicators that bring out critical aspects of that dimension. The four dimensions are listed below

Table 7.1: Identified Policy Impact Parameters for grazing exclusion policy

Parameter	Indicator	Description	Nature	Scale Range
Ecosystem	Regeneration	Percentage of plots showing adequate regeneration	Positive	Medium
	Habitat Invasion	Percentage of plots having any of the invasive species above threshold	Negative	Low
	Wildlife Population	Percentage of plots showing signs of wildlife presence	Positive	High
	Hunting Incidences	Percentage of sample agreeing to existence of hunting practices before the ban	Positive	Medium
	Water	Percentage of the agree to enhancement of the water quality and sources after the ban	Positive	Medium
	Soil Erosion	Percentage of the plots having thick humus layer and floor vegetation	Positive	Medium
	Forest Disturbance	Percentage of plots with presence of cow dung	Positive	Medium
	Forest Density	Percentage of plots with medium dense and dense canopy	Positive	Medium
	Canopy layers	Percentage of plots with more than three canopy layers	Positive	Medium
Economic	Income from Livestock	Percentage of herders whose income have reduced post ban implementation	Negative	High
	Livelihood Diversification	Percentage of the herders adopting other livelihood strategies	Positive	Medium
	Loss	Monetary loss due to animal incidences as a percentage of agricultural income	Negative	Medium

Parameter	Indicator	Description	Nature	Scale Range
Access to Services	Price rise	Percentage of people agreeing to price rise post ban implementation	Negative	Medium
	Access to education	Percentage of the sample indicating benefit in access to educational facilities	Positive	Medium
	Access to Health care	Percentage of the sample indicating better access to health facilities	Positive	High
	Employment Opportunities	Percentage of the sample citing increase in employment opportunities post grazing ban	Positive	Medium
Participatory Process	Access to Natural Resources	Percentage of herders who want an alternative grazing management system	Negative	Medium
	Cultural	Percentage who agree to removal of cattle sheds from forests	Positive	Medium
	Equity	Percentage of the herders who have received compensation	Positive	Medium
	Inclusive Approach	Percentage of herders belonging to any forest conservation institution (EDC/ JFMC/Farmer group/Dairy)	Positive	Low
	Effective Implementation	Percentage of herders who sold livestock either to forest department or in Nepal, post ban implementation	Positive	Medium

The table 7.1 lists the indicators and describes the verifiers used for measuring the indicators. The analysis done is based on the information generated through the sample population households and sample sites. For evaluating the performance of each indicator a standard qualitative scale is used. The indicator performance is judged on a -low -medium -high scale. The indicators developed are classified as positive or negative based on the verifier description. Following scale is used to categorize the results into low, medium and high.

Table 7.2 Policy Impact Evaluation scale

Category	Range
Low	Less than 30%
Medium	Between 30 and 70 %
High	More than 70%

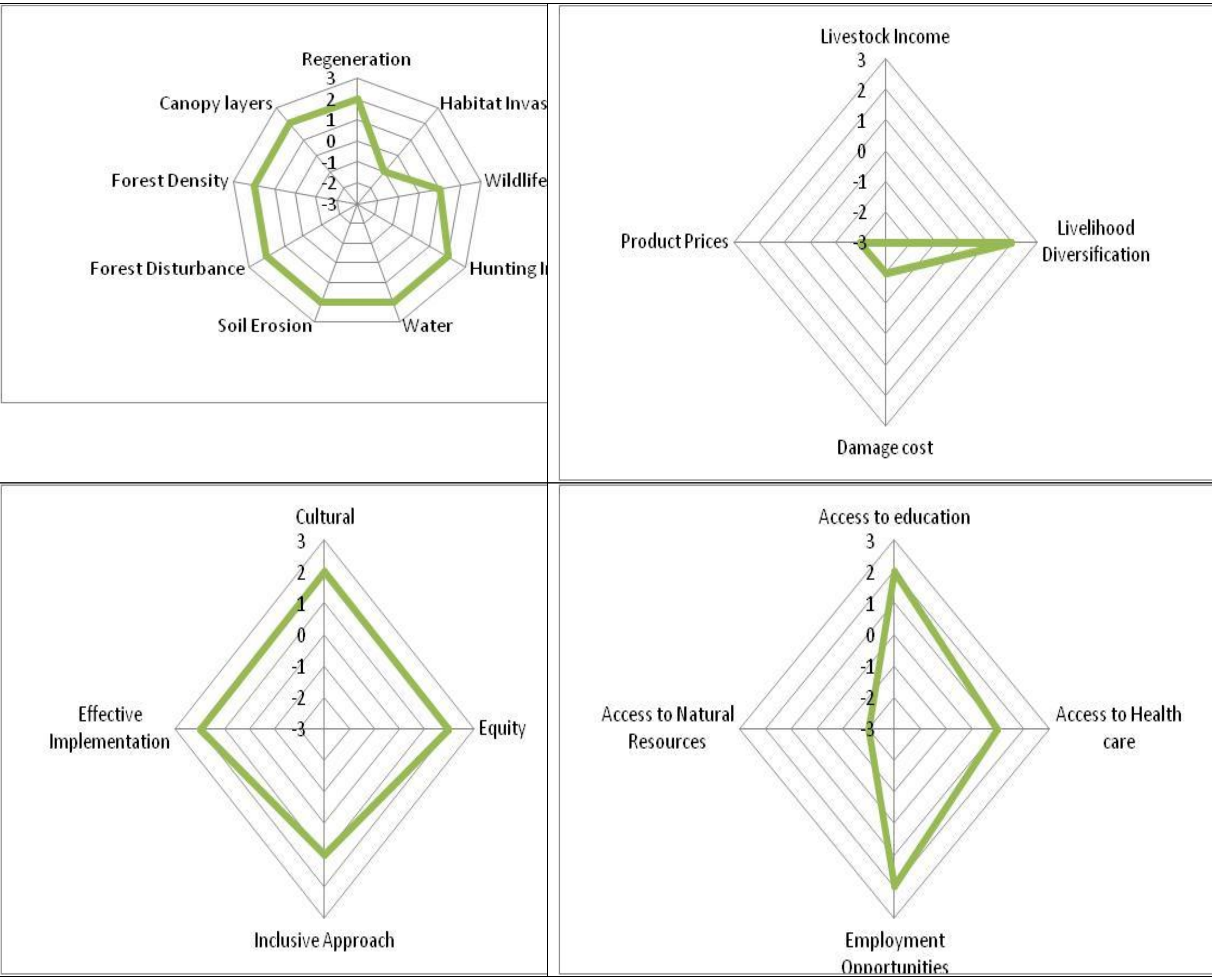

Figure 7.1: Policy Impact on various aspects (Ecosystem, Economic, Access to Services and Participatory Process)

The policy impact matrix presents a consolidated view of the grazing exclusion policy on some vital elements of the forest ecosystems. From the figure 6.1, it is observed that the policy had a positive bearing on nearly all aspects of ecosystem health except for a low negative impact on invasive species. This indicates that post policy implementation there has been intensive growth of some vegetative species that can lead to inhibiting regeneration of other species. An example of this is the extensive distribution of Arundaria maling and Viburnum cordifolium in certain pockets of the BRS and KBR. It is suggested that further surveys should be conducted in such areas to study the gregarious nature of the succession vegetative growth and appropriate habitat management plans be developed. On other aspects, such as canopy layer, forest density and regeneration, the policy shows a net positive influence. This can be attributed to the decline in the key drivers of forest degradation: lopping, cutting and grazing. As these activities have stopped, the process of opening up of forest canopies has reduced. This resting period post grazing exclusion has provided the much needed chance for the ecosystems to show recovery. The policy had a high policy impact on incidences of forest disturbance particularly in BRS where we observed only one particular instance of recent felling. On the other hand, the policy implementation was found to be less effective in KBR, as there continue to be some grazing pressure. We found that these instances were concentrated in the Nayapatal and Dungdang areas. All the observed incidences are day grazing and are low in pressure. Overall there has been a high positive influence of the policy there is a considerable reduction from the previous disturbances and pressures on the forests. We discern that there has been a positive effect on the forest soils in terms of reduction in soil erosion. The forest floor was mostly covered by thick vegetation, even in the scrub areas which earlier had high animal grazing, thus causing reduction in the erosion process. The effect of grazing exclusion policy on wildlife population and hunting incidences are based on the perception of the local communities and the sighting incidences during the surveys. The matrix shows that the policy impacts need to be strengthened on the economic dimensions. Local communities perceive price rise in milk related products and fodder and fuelwood items. Also they perceive that there has been an increase in the incidences of wildlife population causing damage to the area. Thus strategies to tackle these problems should be designed. More or less people agree to the ban on grazing made them to adapt a lifestyle that provided them opportunity to stay close to the family and seem to prefer this over the rigorous lifestyle in the forests. Also they agree that now their access to health and education services has improved. But their access to natural resources for fodder and fuel wood have considerably reduced. Only some of the villages covered during the survey had reserved forests for their fodder and fuelwood requirements and thus they strongly felt that their access to the forest resources has been curtailed. Also most of them felt the need for development of livestock management system in the region.

The results of this analysis process are tightly tide to the study location and use the perception of the participants. Hence the results are applicable only for the studied area.

7.3 POLICY OPTIONS AND WAY FORWARD

7.3.1 CONCLUSIONS

1. A detailed forest inventory of the earlier grazing disturbed areas was prepared along with the information on soil characteristics. Also an ecological database was created from this inventory using ecological analysis software packages. Use of such tools can further help in developing an understanding of the relationships between different ecological variables. Initiatives such as these can be used to generate a rich repository of ecological information at the State level.

2. The locations of the degraded areas were marked using GPS. Such spatial information can be used to study the spatial distribution of the degradation within the forest areas and give a comprehensive picture of the disturbance regime. Disturbance hot-spots can be identified and appropriate strategies can be developed to address the issues within these areas. This spatial information can be combined with the ecological data and comprehensive models can be developed for studying the effects of conservation policies on the forest health.

3. The perception of the local community on the impacts of the grazing exclusion was documented. Mostly they appreciate the positive policy impacts on the ecosystem however cited the loss in livelihood income. Also the incidences of wildlife damages to crops have increased post policy implementation. A focused study needs to be carried out to understand effective solutions to minimize this issue and design appropriate strategies to tackle them. Also the need to develop a livestock management system using participatory approach was identified.

4. A comprehensive approach is vital for understanding the influence of the conservation policies. The policy impact matrix developed lists the critical ecological, social and governance aspects that are influenced by the policy. The model indicates that the ecosystem impacts show positive trends while the socio-economic aspects need further strengthening. Livestock income was substantially and further policy level initiatives are needed to strengthen the alternative livelihood options introduced such as ecotourism. The policy impact matrix has the potential for being further developed and used for policy impact evaluations of conservation interventions.

7.3.2 WAY AHEAD

1. Habitat management plans for the grazing affected areas need to be developed taking variation of forest types into consideration. The profuse regeneration of some species such as *Arundaria Maling* and *Viburnum spp*. needs to be studied further.

2. Efforts should be made to supplement the regeneration of the key species such as Quercus that has as the regeneration seems by for ex-situ conservation zones within these areas could be delineated or in-situ conservation techniques be adopted

3. Developing a rich repository of vegetation information by digitizing the data collected in the field level exercises – working plan.

4. Development of livestock management systems in the community forests areas using participatory approach,

5. For the working plan of the state intensive forest inventories have been conducted across all the districts. This data can be utilized along with the data from earlier forest inventories in the State (1988 or 1998) by Forest Survey of India to develop a picture of forest carbon stock change at the State level. Such an exercise will help in establishing the presenting a holistic picture of the policy measures and create a useful data repository for climate change related topics.

6. The current eco-tourism model needs to be strengthened so that the benefits of eco-tourism are more equitably distributed. Also capacity building programs should be organized so as to develop the understanding of responsible tourism for the involved people Also strategies need to be developed for more boosting the responsible tourism in the region.

7. The scope of current study was local in nature. To develop an understanding of the overall policy impacts across Sikkim a state-wide study is essential. It will help understand the policy effectiveness and influence across the region.

   The purpose of carrying out evaluation of conservation policies was to provide the policy makers with meaningful and reliable information on the outcomes and impacts achieved by the policy on ecosystems as well as on the local communities. The quantitative designs of impact assessments are statistically more robust and establish casualty but in real life conservation projects, it is difficult to implement such designs. Also in certain cases it is difficult to create treatment and control groups. In low data environment, using alternative design options and frameworks using mix method approach as presented in the paper offer useful insights on policy relevant parameters. The presented framework integrates qualitative and quantitative techniques, and it serves as an effectual approach to program evaluation for conservation interventions. The quantitative techniques provide the necessary logical base and ascertain the relationships statistically while the qualitative techniques help in substantiating the findings of the study. Thus it presents a feasible methodology for assessing impacts in the absence of detailed longitudinal ecological or socio-economic data.

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ANNEXURES

Table 1: Control site selection matrix

Control Site Selection Parameter	Basic Description	Number of Cowsheds	Altitude (m)	Vegetation Types	Livestock (type and pressure)	Population density	Travel time (How to get there?)
Barsey-KNP	An extension of Barsey Rhododendron Sanctuary in the KNP range	No number in particular	Same altitudinal range as Barsey Rhododendron Sancturay as it is an extension	Same variation as in Barsey Rhododendron Sanctuary	Day grazing still going on	Similar to Barsey due to day grazing	Going ahead of Barsey as in same direction
Assam Lingzay	Comes under Ranipool Range, Bhusuk 3 area and Compartment 1 of Yali Reserve Forest	1 in Bhusuk 3 area while 2 in Yali RF. The ban was implemented from 2000-06.	Oak forest (from 2133-2700m) in Bhusuk	Same variation as in Barsey Rhododendron Sanctuary	In a cattle shed, 20 and above cattle but only cows	Herders have moved out after ban but sparse cattle sheds present	From Assam Lingzay to Nartam followed by a 2hr trek to reach Bhusuk
Rachila	Inside Pangulakha sanctuary i.e. Tri junction of Bhutan, West Bengal and Sikkim	Either 1 or 2	3000	Same variation as in Barsey Rhododendron Sanctuary	No data	Due to migration, population pressure is same as BRS (the site is also a tri-junction)	3 day trek to reach the site through Pangulakha sanctuary (road from Rangila to Nathang via Padamchen)

Table 2: GPS points of vegetation plots in KBR and BRS

Plot Number	Chowk Name	Longitude (E)	Latitude (N)	Plot Number	Chowk Name	Longitude (E)	Latitude (N)
P1	Nayapatal	88.0996667	27.3652000	P31	Dodwa	88.0446167	27.2303917
P2	Nayapatal	88.1005667	27.3658000	P32	Dodwa	88.0434667	27.2298500
P3	Nayapatal	88.0987833	27.3673000	P33	Dodwa	88.0435444	27.2428000
P4	Nayapatal	88.0953500	27.3683833	P34	Dodwa	88.0533083	27.2432389
P5	Nayapatal	88.0971833	27.3681500	P35	Dodwa	88.0420250	27.2297750
P6	Gombey Chowk	88.1013833	27.3673167	P36	Thulodhaap	88.0545500	27.2475833
P7	Gombey Chowk	88.1010667	27.3686167	P37	Thulodhaap	88.0546667	27.2484667
P8	Gombey Chowk	88.1011667	27.3706500	P38	Thulodhaap	88.0520000	27.2480667
P9	Gombey Chowk	88.1016833	27.3710167	P39	Thulodhaap	88.0516833	27.2466000
P10	Gombey Chowk	88.1014333	27.3719333	P40	Thulodhaap	88.0533083	27.2432389
P11	Bis chowk	88.0960000	27.3692667	P41	Asthal	88.1373167	27.2095667
P12	Bis chowk	88.0957333	27.3693500	P42	Asthal	88.1143333	27.2116667
P13	Sailiy chowk	88.0876667	27.3722667	P43	Asthal	88.1129167	27.2085500
P14	Sailiy chowk	88.0856333	27.3724667	P44	Taal	88.1088833	27.2049000
P15	Lower raatapani	88.0819000	27.3760333	P45	Taal	88.1088750	27.2048972
P16	Saily Chowk	88.0843500	27.3781333	P46	Buriakhop	88.1389917	27.2079472
P17	Lower Ratapani	88.0832500	27.3800667	P47	Buriakhop	88.1366000	27.2083500
P 18	Dungdang	88.0867333	27.3852000	P48	Buriakhop	88.1346000	27.2078667
P19	Dungdang	88.0886500	27.3862333	P49	Barsey	88.1411833	27.2100167
P20	Dungdang	88.0899000	27.3896333	P50	Barsey	88.1373167	27.2095667
P21	Dungdang	88.0872333	27.3872000	P51	Bhareng	88.1051667	27.1802806
P22	Ratapani	88.0878000	27.3875500	P52	Bhareng	88.1051667	27.1807667
P23	Chattubari	88.0757167	27.3921833	P53	Bhareng	88.1039000	27.1814500
P24	Chattubari	88.0748667	27.3932667	P54	Bhareng	88.1026278	27.1824028
P25	Chattubari	88.0746667	27.3933500	P55	Bhareng	88.1002944	27.1829583
P26	Chattubari	88.0752500	27.3937500	P56	Bhareng	88.0935861	27.1866222
P27	Ratapani	88.0777333	27.3921667	P57	Bhareng	88.0903639	27.1865250
P28	Phedi	88.1009833	27.3758000	P58	Bhareng	88.0917556	27.1858944
P29	Phedi	88.1023833	27.3755167	P59	Bhareng	88.0925861	27.1870917
P 30	Phedi	88.1027028	27.3780528	P60	Bhareng	88.0906306	27.1874278

Table 3: List of enumerated species (with and without scientific names)

S No.	Local Names	Scientific Names	S No.	Species without scientific names

S No.	Local Names	Scientific Names	S No.	Species without scientific names
1	Gobre Salla	Abies webbiana	1	Aani munjing
2	Lalgeri	fragaria nubicola	2	Ajambari Herb
3	Kapasi	Acer cambelli	3	Akhtin Kadha
4	Lekh Kapasi	Acer pectinatum	4	Armule jhar
5	Thotaney	Aconogonum molle	5	Barkha Jhuna
6	Sissi	Actinodaphne sikkimensis	6	Bhalu poinle
7	Ilamey Jhar	Ageratum conyzoides	7	Charkuney Herb
8	Laali	Amoora wallichii	8	Chaypathey herb
9	Bukiphul	Anaphalis adnata	9	Chebre kadha
10	Bonso	Arthraxon microphyllus	10	Chile Korlinge
11	Malingo	Arundinaria maling	11	Chothroke kadha
12	Budhi okhoti	Astilbe rivulus	12	Forsani Kadha
13	Chuthrey	Berberis aristata	13	Gaay kadha
14	Berberies	Berberis spp.	14	Gaun Jhar
15	Saur	Betula alnoides	15	Ghode kadha
16	Bhujapat	Betula utilis	16	Ghui Poinle
17	Chattu	Bupleurum spp.	17	Harey Shrub
18	Harkatey	Carex nigra	18	Himali sothar
19	Aankhley	Chirita urticifolia	19	Jade sothar
20	Lekh Katus	Corylus Ferox	20	Jalthangne Herb
21	Kagati	Daphne cannabina	21	Jale kadha
22	Kuro jhar	Desmodium laxiflorum	22	Jat Lissey
23	Panchphal	Dillenia indica	23	Jhow Herb
24	Abhijal	Drymaria cordata	24	Kaancho Paate
25	Sothar	Dryopteris cochleata	25	Keebu Herb
26	Gagleto	Elatostema sessile	26	Khekya Herb
27	Setikhat	Endospermum chanensis	27	Khorsane kadha
28	Kurkurejhar	Equesetum debile	28	Kunche Jhar
29	Shimjhar	Eupatorium odoratum	29	Kupurdante herb
30	jhingune (sano or lekh)	Eurya acuminata	30	Lakhali Badam
31	Khanakpa	Evodia meliaefolia	31	Lare Singjane
32	Aiselo Kadha	Fragaria nubicola	32	Leese Kudo
33	Kaligedi	Gaultheria nummularoides	33	Lekh Abisalejhar
34	Gentinum	gentinum trachophyllia	34	Lekh Dubo
35	Bhangre sisno	Girardinia diversifolia	35	chijimire Herb
36	Chipley Jhar	Gonostegia hirta	36	Male jhar
37	Nashe jhar	Hemiphragma heterophyllum	37	Mandalay Herb
38	Gulpha	Holboellia latifolia	38	Mushroom Spp.
39	Lissey	Ilex dipyrena	39	Neero paate
40	Suire buki	Juncus Spp	40	Perey Lora
41	Dhupi	Junipereous recurva	41	Phurmang Herb

S No.	Local Names	Scientific Names	S No.	Species without scientific names
42	Kesari Buki	Kobresia capillifolia	42	Pinnese Jhar
43	Dum	Lagenaria Siseraria	43	Potadhar Herb
44	Ghurpis	Leucoseptrum canum	44	Sangley Herb
45	Barsey Jhar	Ligularia mortonii	45	Sano majhito
46	Poinle	Litsea polyantha	46	Sathrenu Herb
47	Lampati	Litsea khasyana	47	Setho bukki
48	Mahaguru	Lomatogonium species	48	Sunbeli Herb
49	Moss layer	Moss Layer	49	Theethe jhar
50	Nagbeli	Lycopodium clavatum	50	Theki Phal
51	Angeri	Lyonia ovalifolia	51	Tiktikey jhar
52	Bhaise kawala	Machilus spp.	52	Tiktikey sothar
53	Ghoge chanp	Magnolia campbelli	53	Tiware Herb
54	Yellow Poppy	Meconopsis dhwojii	54	Yame Herb
55	Mirmire jhar	Micromeria biflora	55	Zing Jango
56	Sirlinge	Osmanthus suavis	56	Zingane Shrub
57	Fern	Osmunda claytomiana		
58	Ghode Dubo	Pennisetum clandestinum		
59	Doodhe jhar	Phleum alpinum		
60	Jaringo	Phytolaca acinosa		
61	Bolu	Pieris formosa		
62	Larim	Piptanthus nepaulensis		
63	Shyamphul	Pleurospermum Spp		
64	Rani thotney	Polygonum polystachyum		
65	Ratnaula	Polygonum viviparum		
66	Namley Jhar	Potentila peduncularis		
67	Primula	primula edgeworthi		
68	Himalayan Cherry	Prunus cornuta		
69	Arupati	Prunus nepalensis		
70	Buk Bajarat	Quercus lamellosa		
71	Bante	Quercus pachyphylla		
72	Phalant	Quercus thomsonian		
73	Khorsane shrub	Ranunculus hirtellus		
74	Khokim	Rheum acuminatum		
75	Rhodo White	Rhododendron		
76	Gurans	Rhododendron arboreum		
77	Lal Chimal	Rhododendron barbatum		
78	Rhodo phal	Rhododendron falconeri		
79	Seto chimal	Rhododendron griffithianum		
80	korlinge	Rhododendron hodgsonii		
81	Thomsonic Rhodo	Rhododendron thomsonii		
82	Pink Rhodo	Rhododendron vaccimioides		

S No.	Local Names	Scientific Names	S No.	Species without scientific names
83	Majhito	Rubia manjita		
84	Putali ghas	Rubus lineatus		
85	Chutrey Kadha	Rubus spp.		
86	Halhaley	Rumex nepallensis		
87	Kalikath	Sarcosperma arboretum		
88	Cheeru	Selinum tenuifolium		
89	Tori phuley	Senecio littus		
90	Bhalu Chinde	Shefflera impresa		
91	Putali jhar	Smilax Rigida		
92	Bokshi kara	Solanum nigrum		
93	Teiga	Sorbus cuspidata		
94	Bhale Chireto	Swertia angustifolia		
95	Chiraito	Swertia chirayita		
96	Lekh Bhale Chireto	Swertia spp.		
97	Kholme	Symplocos laurina (spicata)		
98	Kharane	Symplocos theifolia		
99	Rato Ningale	Thamnocalamus aristata		
100	Thengre Salla	Tsuga dumosa		
101	Nakima	Tupistra nutan		
102	Asare	Viburnum cordifolium		
103	arum	Viburnum mullah		
104	Panchapate	Vitex heterophylla		
105	Wild Orchids	Wild Orchids		
106	Bhale Timbur	Zanthoxylum armatum		
107	Buki timbur	Z. acanthopodium		
108	Bhale Dum	Lagenaria species		
109	Chijimire Herb	Chijimire Herb		
110	Lakhali Ghurpis	Leucoseptrum species		
111	Mayishi kadha	Mayishi kadha		
112	Suerey Harkat	Carex species		
113	Tori Bukki	Tori Bukki		
114	Utis	Alnus nepalensis		
115	Bhimsenpat	Buddlein asiatica		
116	Rhododendron grande	Rhododendron grande		
117	Jhingri	Eurya japonica		
118	kimbu	Morus laevigata		
119	Ghingne	Myrsine semiserrata		
120	Mandane	Acrocarpus fraxinifolius		
121	Dangre salla	Taxus baccata		

Table 4: Soil testing report for study sites

Sample No	Chowk Name	pH	Electrical Conductivity	Organic Carbon Content	Available Nitrogen	Available Potassium	Available Phosphorus	Cation Exchange Capacity
			Siemens /metre	%	Kg/ Ha.	Kg/ Ha.	Kg/ Ha.	Cmol(P^+) Kg^{-1}/ meq $100gm^{-1}$
S1	Nayapatal	5.02	0.07	7.3	730.7	358.4	8.03	21.5
S2	Nayapatal	4.77	0.085	5.5	718.1	380.8	27.82	22.5
S3	Nayapatal	4.39	0.064	5.86	755.8	168	19.53	24.5
S4	Nayapatal	4.22	0.106	7.16	853	112	64.6	20.5
S5	Nayapatal	4.57	0.038	4.21	520.6	179.2	17.61	15.5
S6	Nayapatal	4.75	0.07	5.07	840.4	358.2	64.62	15.6
S7	Nayapatal	4.96	0.027	4.03	395.1	123.2	7.48	15.9
S8	Nayapatal	4.56	0.134	4.8	617.8	291.2	9.89	27.7
S9	Nayapatal	6	0.06	6.4	696.2	504	43.44	31.5
S10	Nayapatal	4.56	0.076	6.58	903.2	380.9	54.09	28.4
S11	Bis Chowk	4.57	0.082	3.78	445.3	179.2	50.07	22.5
S12	Bis Chowk	4.59	0.112	7.34	743.2	974.4	83.42	16.6
S13	Sayli Chowk	4.29	0.073	5.79	658.6	132.2	23.91	24.25
S14	Sayli Chowk	4.64	0.043	3.45	304.2	168	4.63	19.5
S15	Raatapani	4.29	0.052	5.11	827.9	201.6	29.02	27.5
S16	Raatapani	3.87	0.008	2.59	1461.4	145.6	30.85	23.4
S17	Raatapani	4.74	0.176	3.16	360.6	476	58.11	24.6
S18	Dung Dang	4.72	0.031	5.07	771.5	313.6	137.01	25.5
S19	Dung Dang	4.8	0.037	3.42	401.4	190.4	45.13	17.2
S20	Dung Dang	4.01	0.072	5.97	862.4	89.6	129.54	16.3
S21	Dung Dang	3.99	0.042	4.74	470.4	190.4	96.75	26.8
S22	Dung Dang	4.3	0.055	3.13	448.4	190.4	15.51	27.9
S23	BigBhaari	4.46	0.058	5.43	482.9	179.2	17.32	12.2
S24	Chattubhari	4.32	0.051	4.3	548.8	235.2	52.55	22.4
S25	Chattubhari	4.41	0.026	3.36	558.2	168	27.72	21.3
S26	Chattubhari	4.09	0.073	3.83	630.3	280	11.99	20.1
S27	Chattubhari	4.05	0.06	5.29	727.5	145.6	40.51	32.5
S28	Yambong	4.29	0.043	5.43	755.8	212.8	30.48	13.75
S29	Yambong	3.72	0.091	3.65	1069.4	212.8	36.25	18.06
S30	Yambong	4.02	0.108	3.92	627.2	156.8	42.38	19.4
S31	Yambong	4.06	0.056	3.94	602.1	123.2	60.77	26.25
S32	Yambong	3.73	0.062	6.19	758.9	313.6	80.06	20.5
S33	Phedi	4.1	0.129	4.7	743.2	123.2	51.31	20.35

Sample No	Chowk Name	pH	Electrical Conductivity	Organic Carbon Content	Available Nitrogen	Available Potassium	Available Phosphorus	Cation Exchange Capacity
S34	Phedi	4.56	0.06	7.02	608.4	168	16.61	20.6
S35	Phedi	5.21	0.14	3.56	558.2	1030.4	95.53	32.5
S36	Dodwa	3.98	0.064	6.51	589.6	324.8	13.32	28.3
S37	Dodwa	4.46	0.045	5.94	558.2	168	20.09	22.4
S38	Dodwa	3.98	0.063	4.14	542.5	190.4	0.53	16.01
S39	Dodwa	4.33	0.056	2.43	326.1	168	3.19	17.06
S40	Dodwa	5.02	0.047	3.4	404.5	515.2	37.05	18
S41	Thulodhaap	4.3	0.156	4.26	583.3	179.2	17.05	22.75
S42	Thulodhaap	3.93	0.125	5.65	1292	235.2	85.31	34.5
S43	Thulodhaap	4.71	0.04	3.74	464.1	313.6	9.32	21.5
S44	Thulodhaap	5.1	0.043	2.48	175.6	649.6	0.92	23.6
S45	Thulodhaap	4.87	0.018	2.8	197.6	112	5.56	23.2
S46	Kalijhar	4.75	0.157	4.01	602.1	2072	120.86	26.75
S47	Kalijhar	4.11	0.117	3.37	573.9	179.2	56.87	19.5
S48	Kalijhar	4.47	0.042	9.3	332.4	100.8	13.59	20.6
S49	Kalijhar	4.39	0.017	1.46	313.6	257.6	2.78	18.7
S50	Kalijhar	4.85	0.017	8.69	225.8	67.2	1.06	18.9
S51	Taal	4.64	0.034	3.2	442.2	212.8	2.13	40.5
S52	Taal	4.21	0.078	3.96	580.2	716.8	38.02	36.6
S53	Taal	3.97	0.09	5.26	755.8	268.8*	4.79	32.7
S54	Taal	4.21	0.046	6.48	517.4	268.8	34.5	25
S55	Taal	3.79	0.197	5.15	1019.2	268.8	48.78	22.1
S56	Buriakhop	4.18	0.047	4.68	492.3	100.8	35.78	60.7
S57	Buriakhop	3.92	0.201	6.21	1329.6	280	41.84	55.8
S58	Buriakhop	3.63	0.143	5.22	1031.7	145.6	57.57	30.5
S59	Buriakhop	4.04	0.027	3.49	382.6	168	2.39	32.6
S60	Buriakhop	4.3	0.076	5.02	487.1	145.6	17.32	31.5
S61	Bhaareng	4.76	0.066	3.78	671.1	179.2	4.01	33.7
S62A	Bhaareng	4.66	0.27	6.17	1727.9	985.6	149.92	24.5
S62B	Bhaareng	4.48	0.441	6.34	1627.6	896	102.09	22.5
S63	Bhaareng	4.14	0.062	6.25	790.3	224	18.12	22.7
S64	Bhaareng	4.15	0.08	6.51	639.7	179.2	34.86	21.02
S65	Bhaareng	4.05	0.048	6.62	696.2	168	2.13	22.5
S66	Bhaareng	4.15	0.061	4.68	370	145.6	34.68	20.7
S67	Bhaareng	3.78	0.172	6.53	659.6	347.2	15.99	19.2
S68	Bhaareng	3.35	0.351	6.21	1176	235.2	24.25	20.2
S69	Bhaareng	3.92	0.098	5.49	1075.6	201.6	21.85	34

Sample No	Chowk Name	pH	Electrical Conductivity	Organic Carbon Content	Available Nitrogen	Available Potassium	Available Phosphorus	Cation Exchange Capacity
S70	Bhaareng	3.87	0.178	6.61	1382.9	425.6	49.04	32.7

Table 5: Pair-wise ranking for Fuelwood preference in Moist Temperate forests (Done in Heegaon)

	Sirlinge	Asare	Baante
Sirlinge		Asare	Sirlinge
Asare			Asare
Baante			
		1st	2nd

Table 6: Pair-wise ranking for Fuelwood species in Upper Hill Himalayan wet temperate forests (Done in Heegaon)

	Katus	Bante	Bajrat	Asare	Phalat	Jhingane	Khorane
Katus		Bante	Bajrat	Asare	Phalat	Jhingane	Khorane
Bante			Bajrat	Bante	Phalat	Bante	Bante
Bajrat				Bajrat	Bajrat	Bajrat	Bajrat
Asare					Phalat	Asare	Asare
Phalat						Phalat	Phalat
Jhingane							Jhingane
Khorane							
		3rd	1st	4th	2nd	5th	6th

Table 7: Pair-wise ranking for Fuelwood species in Moist Temperate forest (Done in Bhareng)

	Pyayong	Korlingo	Silver Fir	Asare	Lissey	Sirlinge
Pyayong						
Korlingo	Pyayong					
Silver Fir	Silver Fir	Silver Fir				
Asare	Pyayong	Korlingo	Silver Fir			
Lissey	Pyayong	Korlingo	Silver Fir	Asare		
Sirlinge	Sirlinge	Korlingo	Silver Fir	Asare	Sirlinge	
	2nd	2nd	1st			

Table 8: Pair-wise ranking for Fuelwood species in Upper hill Himalayan wet temperate forests (Done in Bhareng)

	Bante	Asare	Larim	Sirlinge	Phalat
Bante					
Asare	Asare				
Larim	Bante	Asare			
Sirlinge	Bante	Asare	Sirlinge		
Phalat	Bante	Asare	Phalat	Phalat	
	2nd	1st			

Table 9: Pair wise ranking for Fodder species in Moist Temperate forest (Done in Heegaon)

	Bante	Lissey	Malingo	Bhalu Chinde	Dhengre Salla	Kapassey
Bante		Bante	Malingo	Bante	Bante	Bante
Lissey			Malingo	Bhalu Chinde	Dhengre Salla	Lissey
Malingo				Malingo	Malingo	Malingo
Bhalu Chinde					Bhalu Chinde	Bhalu Chinde
Dhengre Salla						Kapassey
Kapassey						
	2nd		1st			

Table 10: Pair wise ranking of Fodder species in Upper hill Himalayan wet Temperate Forests (Done in Heegaon)

	Kaulo	Bajrat	Jhingane	Malingo	Poinley	Lissey	Kapassey	Phalat	Aarupatey
Kaulo		Kaulo	Kaulo	Malingo	Poinley	Kaulo	Kapassey	Kaulo	Kaulo
Bajrat			Jhingane	Malingo	Poinley	Lissey	Kapassey	Phalat	Bajrat
Black Jhingane				Malingo	Poinley	Lissey	Kapassey	Jhingane	Jhingane
Malingo					Malingo	Malingo	Malingo	Malingo	Malingo
Poinley						Poinley	Poinley	Poinley	Poinley
Lissey							Lissey	Lissey	Lissey
Kapassey								Kapassey	Kapassey
Phalat									Phalat
Aarupatey									
			2nd	1st	1st	3rd			

Table 11: Pair wise ranking done for Fodder species in Moist Temperate forests (Done in Bhareng)

	Tega	Leg Gurpis	Ghoghe chap	Rat Ningale	Sirlinge
Tega					
Leg Gurpis	Tega				
Ghoghe chap	tega	Leg Gurpis			
Rat Ningale	Rat Ningale	rat ningale	rat ningale		

	Tega	Leg Gurpis	Ghoghe chap	Rat Ningale	Sirlinge
Sirlinge	Sirlinge	Sirlinge	sirlinge	Rat Ningale	
				1st	2nd

Table 12: Pair wise ranking of Fodder species in Upper hill Himalayan wet temperate forests (Done in Bhareng)

	Malingo	Liso	Bante	Phalat	Zingane
Malingo					
Liso	Malingo				
Bante	Same	Bante			
Phalat	Malingo	Phalat	Bante		
Zingane	Malingo	Zingane	Bante	Phalat	
	1st		2nd	3rd	

FROM THE FIELD!!!

We are grateful to the local resource persons and field assistants without whose cooperation and help the detailed study would not have been possible. We would like to thank them for their time, efforts and for sharing with us their knowledge of indigenous resources and lifestyle in the region.

The Barsey Team

Mingma Sherpa

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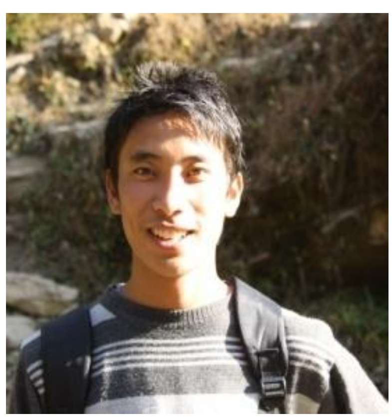


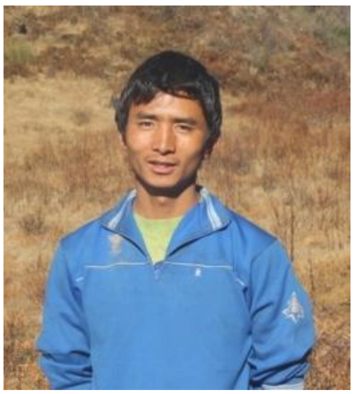
Phurba Dorjee Sherpa

Tashi Doma Sherpa

Lal Bahadur Rai

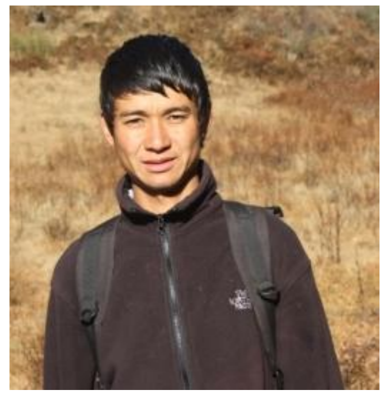
Ganesh Rai

Birbal Chettri

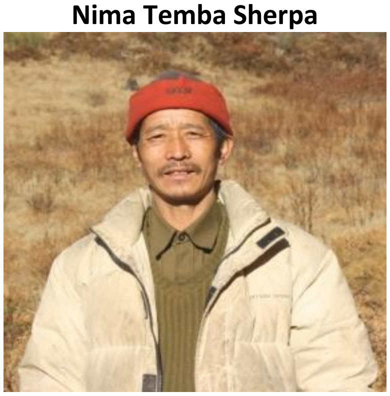


Nima Temba Sherpa

Nima Namgil Sherpa

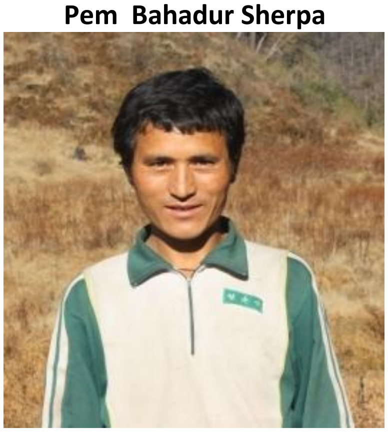


Dorjee Sherpa



Pem Bahadur Sherpa

Nar Bahadur Subba



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