Draft Report

Preparation of land use maps, vegetation cover; and biodiversity status report Upper Teesta – Kanchedzonga Landscape, Sikkim

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Cover Photo: Kanchendzonga National Park and **Singba Rhododendraon Sanctuary**, Sikkim
Photo Credit: Raj Arya, Dharmendra Lamsal, Moumita Chakraborty and Ugen Tashi Bhutia

Project Team: IORA ECOLOGICAL SOLUTIONS PVT LTD.

ACRONYMS

Acronym	Expansion
ATREE	Ashoka Trust for Research in Ecology and the Environment
BR	Biological Richness
CV	Coefficient of variation
DN	Digital Number
DI	Diversity Index
FEWMD	Forests, Environment & Wildlife Management Department
GBPNIHESD	Govind Ballabh Pant National Institute of Himalayan Environment and Sustainable Development
GIS	Geographical Information System
GLCM	Grey Level Co-occurrence Measures
GPS	Geographical Positioning System
HNBGU	Hemawati Nandan Bahuguna Gharwal University
ICAR	Indian Council of Agricultural Research
JFMC	Joint Forest Management Committee
LULC	Land Use and Land Cover
NGO	Non-Government Organisation
NRSC	National Remote Sensing Centre
RS	Remote Sensing
SBSAP	State Biodiversity Strategy and Action Plan
SD	Standard deviation
SFD	Sikkim Forest Department
ToA	Top of Atmosphere
TEV	Total Economic Value
UNDP	United Nations Development Programme
VI	Vegetation Index

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CHAPTER 1

INTRODUCTION

Mountains occupy 24% of the global land surface area and are home to 12% of the world's population. Mountains have an ecological, aesthetic, and socioeconomic significance, not only for those living in the mountain areas but also for people living beyond them (ICIMOD, 2011)[1]. About 10% of the world's population depends directly on mountain resources for their livelihoods and wellbeing, and an estimated 40% depends indirectly on mountain resources for water, hydroelectricity, timber, Biodiversity and niche products, mineral resources, flood control, and recreation (Schild 2008)[2]. As per India's State of Forest Report 2015, total forest and tree cover in Sikkim is 47.80 % of the total geographical area. About 5841.39 sq. Km. or 82.32% of the total geographical area is under the administrative control of the State Forest Department. The forest area is divided into Reserve forest and Protected forests. The reserved forest area constitutes 93.3% of the total forest area. Sikkim forests are rich in Biodiversity with diverse flora and fauna spread across its length and breadth.

In Sikkim, the forest is one of the richest natural resources and has been the major land use in the State. Around 82.31% of the total geographical area of the State is under the administrative control of the State Forest Department. Management of these biodiverse resources, especially in the North District of Sikkim has remained a key force in shaping human attitude towards sacred conservation and sustainable utilization of natural resources. Sacred landscape, forests and groves are patches of vegetation traditionally protected by local communities which form excellent examples of in-situ biodiversity conservation. Considering the vast significance of these resources, IORA has applied geospatial as well as ground based approach for its mapping. Six biodiversity indicators (Spatial, Phytosociological, Economic, Social, Physical and Ecological) have been integrated to stratify the Biological Richness of the landscape. This will finally, identify and quantify indicators for monitoring the ecological health of various land use areas over time.

1.1 Biodiversity in Sikkim

1.1.1 Review of Existing Biodiversity in Sikkim Landscape

Land plays a vital role in the economy of Sikkim, with more than 64% of the population dependent on agriculture. Further, 89% of the State's population is rural and involved in land-based activities. Sikkim is known for its rich Biodiversity. According to FSI (ISFR, 2017),[3] 47.13 % of the states are under the green cover. The state houses over 400 species of flowering plants, 300 species of ferns and its allies, 11 species of oaks, eight species of tree ferns, 40 species of primulas and 20 species of bamboos. On the other side, a faunal wealth of Sikkim includes 144 species of mammals, 600 species of birds, 400 species of butterflies Of these 19 species of mammals, 11 species of birds and 65 species of plants are

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[1] ICIMOD (2011) Framework for Valuing Ecosystem Services in the Himalayas. Technical Report

[2] Schild A (2008) 'The case of the Hindu Kush-Himalayas: ICIMOD's position on climate change and mountain systems.' Mountain Research and Development 28(3/4): 328-331

[3] FSI (2017): India State of Forest Report. Ministry of Environment and Forests and Climate Change, Govt of India.

threatened and endangered. Covering just 0.2% of the geographical area, Sikkim Himalayas show tremendous biological diversity as summarized below:

Table 1: Status of Biodiversity

Wild Biodiversity at a glance	Approx. Nos.	Wild Biodiversity at a glance	Approx. Nos.
Flowering Plants	4500	Mammals	144
Orchids	500+	Birds	550
Rhododendrons	36	Butterflies	600+
Bamboos	20	Fishes	48
Ferns and Ferns allies	362	Mounting & Peaks	28
Tree Ferns	9	Glaciers	21
Primulas	30	Lakes and Wetlands	227
Oaks	11	Rivers and Streams	< 104

Source: www.sikkimforest.gov.in

The total recorded forest area in the State is 5765.10 Km^2, i.e., 50.04% out of which 2173 Km^2 or 30.62 % of the total geographical area of the State is under wildlife protection, which is perhaps the highest in the country. Considering the biological richness, Khangchendzonga Hills were notified as Biosphere Reserve in February 2000, spread over North and West districts encompassing 1784 sq. Km of Khangchendzonga National Park and 835.92 sq. Km over four buffer zones totaling an area of 2619.92 Km^2. Sikkim is gifted with rich Biodiversity and various natural resources with over 500 species of orchids, 28 mountain peaks, 21 glaciers, 553 lakes and wetlands, one national park, and six wildlife sanctuaries.

1.1.2 Presence of Biodiversity: Ecoregion wise

1.1.2.1 Trans-Himalaya

The region above 4600m altitude is identified as trans-Himalaya. It has a characteristic cold desert environment partially or fully covered by snow, ice, and glaciers. This ecoregion is identified as the headwaters of many rivers, of which the major river is Teesta, which originates from Tso Lhamo plateau. Major cover types within this ecoregion include snow and glaciers, cold desert, wetlands, and high altitude pastures. The pasturelands comprise plants of the genera Stipa, Elymus, Carex, Kobresia, Pedicularis, Lonicera, etc. Among the faunal Biodiversity, the globally endangered snow leopard (*Panthera uncia*), Tibetan argali (*Ovis ammon hodgsoni*), Tibetan gazelle (*Procapra picticaudata*), southern kiang (*Equus kiang polyodon*), Tibetan wolf (*Canis lupus chanco*), Tibetan sand fox (*Vulpes ferrilata*), red fox (*Vulpes vulpes*), and globally vulnerable black-necked crane (*Grus nigricollis*) are important species found in this ecoregion. This ecoregion has not yet been included in the protected area network of the State and is perhaps the most eco-sensitive as it contains mostly endangered species. The region has a short four-month growing season in summer during which grasses, sedges, and medicinal herbs grow abundantly, supporting a host of insect fauna as well as the wild and domestic herbivores, larks, and finches. This time of the year, the ecoregion embraces a small number of nomadic Tibetan tribe called 'Dokpas' who herd yak, sheep, and pashmina goats on the pasturelands with no permanent settlements. As this region forms the international border with Tibet (China), a large number of Defence establishments exist. Closure of the border to transhumance over the last three decades has led to intense grazing pressure by both the domestic and wild herbivores on the land. The area also suffers from the presence of landmines causing casualties among yak, Nayan, kiang, and Tibetan wolf. The existence of feral dogs is a significant hazard in this region.

1.1.2.2 Alpine

The ecoregion ranges from 3600m – 4600m MSL, characterized by seasonal snow, extending up to the lower limits of the glaciers, mountain cliffs, alpine pastures, and transhumance. The major constituents of this ecoregion are glacial moraines, alpine meadows/scrublands, sub-alpine forest, few agro-pastoral ecosystems, wetlands, settlements (military & civil) and river/streams. Virtually, alpine scrubs and grasslands dominate the alpine meadows and pastures (Fig 1). Common plant species are *R. thomsonii*, *R. anthopogon*, and *R. setosum*, *Rhododendron niveum*, *Juniperus spp.*, *Aconitum spp.*, *Eriophyton spp.*, *Pedicularis spp.* The region is also home to many medicinal herbs like *Rheum nobile*, *Saussurea simpsonianan, Ophiocordyceps sinensis, Rubus ellipticus*, *Osbeckia nepalensis* etc. It is important to note that over-extraction of some of the medicinal herbs in the region has resulted in the degradation of the ecosystem and continue to pose an immense threat to their survival rate. Faunal species of this area include *Panthera uncia* (snow leopard), *Pseudois nayaur* (blue sheep), *Canis lupus chanco* (Tibetan wolf), *Vulpes vulpes* (red fox), and *Lophophorus impejanus* (Himalayan monal). This region has a very little resident human population, mainly Bhutias with pastoral herding livestock like yak, dzo (cow-yak hybrid) and domestic cattle. This region is protected by two wildlife sanctuaries, i.e. Shingba rhododendron sanctuary and one national park, namely Khangchendzonga National Park (North and West) (Annexure I).

1.1.2.3 Temperate & Sub Alpine

Seasonal snow, mountain cliffs characterize the middle mountains, and heavy precipitation comprises the temperate and the sub-alpine forests with an altitudinal range between 2400–3600 m. The lower reaches of the ecoregion is dominated by temperate broadleaf and coniferous forest. The significant tree species found in this forest type include *Castonopsis hystrix*, *Lithocarpus pachyphylla*, *Tsuga dumosa*, *Picea smithiana*, *Abies densa*, *Rhododendron arboreum*, *R. campanulatum*, *R. barbatum* and *R. falconeri*. Some of the important faunal presence in this ecoregion are *Ailurus fulgens* (red panda), *Panthera pardus* (leopard), *Neofelis nebulosa* (clouded leopard), *Ursus thibetanus* (Asiatic black bear), *Capricornis thar* (Himalayan serow), *Hemitragus jemlahicus* (Himalyan tahr) *Moschus moschiferos* (musk deer), *Tragopan satyra* (satyr tragopan), *Ithaginis cruentus* (blood pheasant), Fire-tailed Sunbird, *Lophura leocomelanos* (Blue Magpie, kalij) and few species of reptiles and amphibians are characteristic.

Fish species Brown Trout - *Salmo trutta fario* (River Trout) has been introduced in high altitude lake and river systems. *Hippophae spp* (Wild Seabuckthorn) a deciduous shrubs from the family Elaeagnaceae is another altitude shrub, some of which is collected for medicinal uses and as a dye. Potato and cabbage are grown as cash crops. Subsistence farming of wheat, barley, and maize is carried out while beans, peas, some apple, peach, and pear are grown on homesteads. Some cattle rearing is practiced with stall fed hybrid milch cows, and the rest graze in forest areas. Farm trials of exotic Lilies are new to this region. Wool from sheeps at higher altitudes is being utilized in the handloom and cottage industry for making blankets, rugs, and carpets use. Dwarf Rhododendron leaves are used for burning as incense—many wild edibles like *Arisaema sp.* Tubers, 'Khendu', and mushrooms are collected from the forest floor. The principal settlement area in this region is at Lachen and Lachung, and the township of Chungthang.

Figure 1: Diagrammatic Representation of Biodiversity Based on Ecoregion

1.2 Socio-Economic status

Sikkim is a small landlocked state that became part of the Indian union in the year 1975. The State is divided into four districts and nine subdivisions for administrative purposes. North district accounts for 60% of the geographical area of the State, while east district accounts for over 45% of its population. East district of Sikkim is much ahead in terms of development index. A few indicators of the north district as follows (Table 2):

Table 2: Key indicators of North Sikkim

Key Indicators	Total	Key Indicators	Total
Area (sq. km.)	4226	Rural Population	39065
Districts (no.)	1	ST Population	65.70%
Subdivision (no.)	2	SC Population	2.25%
Zila- Panchayat wards (no.)	30	Population density (sq. km.)	10
Gram panchayat units (no.)	20	Total literacy rate	78.01%
Gram panchayat wards (no.)	108	Literacy rate (Males)	83.30%
Towns (no.)	1	Literacy rate (Females)	7.10%
Household (no.)	8873	Total main workers	39.39%
Population	43709	Marginal workers	14.05%
Urban Population	4644	Non-workers	46.56%

(*Source: Census, 2011*)

North district has a large rural population and majority of the population (46.56%) is unemployed and largely dependent on forests for their livelihood.

2.1.1.1 Livelihood Practices:

Agriculture practices and adaptation in the State are highly variable in time and space due to various altitude and agro-climatic situations (Table 3). Agriculture is the primary activity of the people in Sikkim. Farming has been a challenge due to small and fragmented occurrence of natural calamities like landslides, floods and earthquake. The low productivity is seriously characterized by two important features viz. land holding size and socio-economic condition of the farmers.

Table 3: Agriculture crop pattern at different altitude

Altitude	Zaid/Summer crops	Kharif crops	Rabi crops
1500-3000 ft.	Maize, Vegetables, paddy etc.	Paddy, Maize, Millet , Soya bean etc.	Wheat, Barley, Buckwheat, Rice-bean, Vegetables
3000- 5000 ft.	N/A	Maize, Paddy , Soya bean, Finger millet etc.	Wheat, Barley, Buckwheat, Rice-bean, Rape and Mustard
5000 ft. and above	N/A	N/A	N/A

(Source: Food Security and Agriculture Development Department, Govt of Sikkim)

On the other side, the congenial temperate climate and the temperate vegetation existing in State are highly favourable for exotic, highly productive livestock. Moreover, the high altitude landowners have a traditional pastoral economy passed on from one generation to generation with their typical livestock such as yaks, sheep, mountain goats, pigs, and poultry.

Agriculture along with livestock rearing is the main occupation in the State. Over 80% of the farmers in the State own livestock and earn supplementary incomes from them. The livestock in Sikkim available in the high-altitude areas such as yaks, sheep and local goats known as "Chengra" predominate. The species of livestock are cattle, buffalo, yak, sheep, pig, mules, dog, rabbit and fowl. A comparative decadal analysis between 1997 and 2007 shows the trend in the growth of cattle population (Table 4):

Table 4: Comparative figure of livestock census (1997-2007)

Species of livestock	1997	2007	Annual Growth (in percent)	Decadal growth (in percent)
Crossbred Cattle	52303	91289	(+)7.45	(+)74.53
Indigenous Cattle	90721	71852	(-)2.0	(-)20.79
Buffalo	1970	243	(-)8.76	(-)87.66
Yak	4781	6468	(+)3.5	(+)35.28
Sheep	5023	4879	(-)0.28	(-)2.8
Goat	82938	110120	(+)3.2	(+)32.77
Pig	26975	38390	(+)4.23	(+)42.31
Poultry	223262	255882	(+)1.46	(+)14.61

(Source: Census, 2011)

Tourism is one of the major sectors that boosts the state economy (Table 5). The tourism sector has been accorded priority as it is deemed one of the significant revenue earning and employment-generating sectors. It is the fastest growing industry; there has been tremendous growth in standard and quality of service, infrastructural development, and competitive promotional packages.

Table 5: Domestic and Foreign Tourist arrival and its Annual Growth

Year	Domestic Tourist	Annual Growth	Foreign tourist	Annual Growth
2005	347650	21.26	16518	22.1
2006	421943	21.37	18049	9.26
2007	465204	10.25	17837	-1.17
2008	512373	10.13	19154	7.38
2009	615628	20.15	17730	7.43

(Source: Tourism & Civil Aviation Department)

CHAPTER 2

AIMS AND OBJECTIVE OF THE STUDY

The study aims to discern and prioritize regions in Upper Teesta –Kanchedzonga landscape with varying biodiverse resources in order to understand the relationship of regional Biodiversity with local and global influences. The study encompasses features from spatial and non-spatial domain, which will facilitate an all-inclusive sustainable management of highland Biodiversity in North Sikkim. Consequently, to assess the present status of significant biodiversity hotspots and evaluate major threats to them, which cover a vast expanse of reserved forest, protected areas, natural and anthropogenic habitats.

Figure 2: Map of the Study Area

2.1 OBJECTIVES

The objectives of the study are Identifying and mapping various types of land use in the Kanchendzonga-Upper Teesta landscape and establishing indicators to monitor its health. The study will consider the following parameters:

1. Socio-legal/ownership categories - local communities, PA/non-PA, government/military/paramilitary forces
2. Biodiversity characterization - vegetation types and dominant species
3. Economic value (both subsistence and commercial)
4. Intensity of use of the landscape – both Quantification and mapping

The study follows a three-pronged approach to achieve its objectives:

1. Extensive review of supporting secondary literature and information.
2. Consultation with experts pertaining to the area on assessment of biodiversity.
3. Consultation with community members to understand their dependency on various species in order to map and assess their economic value.

This approach has helped in identifying and mapping of land use and land cover along with the biodiversity in the landscape. The entire study has been divided into the objectives and each objective has been discussed in detail under the Chapter -3 - Mapping and Analysis of The Land Use and Land Cover and Biodiversity. The analysis has been divided into sub-sections and each sub-section has been discussed with methodology and results along with the maps. Under sub – section 3.1 – discusses methodology for land use and land cover mapping; sub – section 3.2 – details out the Mapping of Land Use based on Socio-Legal/Ownership; sub – section 3.3 – focusses on Biodiversity Characterization - Vegetation Types and Dominant Species and its mapping; while sub – section 3.4 – provides details Mapping along the economic value and finally, under sub – section 3.5 – provides list of Health Indicators needed for the Assessment of Biodiversity. In the last chapter (chapter 4) based on this study and field surveys conservation priorities have been discussed.

The report also has list of Annexures with field photographs and list of species under tree, shrubs and herbs categories noticed in the landscape along with maps.

CHAPTER 3

MAPPING AND ANALYSIS OF THE LAND USE AND LAND COVER AND BIODIVERSITY

3.1 Identifying and Mapping Various Land Use Types in the Landscape

The land use pattern in Sikkim is largely governed by its topography and climate, especially in the field of agriculture and forestry. The changes of land use/land cover pattern over a period control the pressure on land. Geospatial technology is an excellent tool for mapping and monitoring, land use and other natural resources including agriculture and forests. Producing accurate and up-to-date thematic maps is essential for many local to global scale studies. Thematic maps are usually produced using various classification techniques which have been applied by various authors to derive a meaningful information (Lu and Weng, 2007; Xie, Sha, and Yu, 2008; Tso and Mather, 2009) that supports livelihood as well as conservation of the natural resources. Considering the significance of these resources and to effectively promote sustainable land and forest management in alpine pastures and forests in high range Indian Himalayan ecosystems that secure sustainable livelihoods and ensures conservation of globally significant Biodiversity and threatened species, mapping of these resources becomes critical. To identify and map these land use in the Kanchendzonga National Park and Singba Rhododendron Sanctuary, a detailed methodology and results have been discussed and presented in the sections below.

3.1.1 Methodological Approach for Classification

Identification and mapping of land use types in the landscape was done using the analysis based on satellite data supported with field assessments. Land use types involved classes as per Level-III classification scheme of National Remote Sensing Centre (NRSC), ISRO.

3.1.1.1 Field based assessment

Preliminary fieldwork was conducted to collect training sets for land use classes, phytosociological and socio-economic data in the landscape. Detailed surveys were carried out in several villages of west and north districts. We visited the reserve forest zones of Yuksom and Khangchendzonga National Park in West Sikkim and Chungthag, Lachen Valley, Tso Lhamu, Lachung valley in North district. In addition to this, various village have been surveyed to collect training sets for land uses and conduct socio- economic surveys. Data was collected across different forest types found in the Eastern Himalayas in Sikkim. The forest types of Sikkim have been categorized based on the Champion and Seth system of classification and elevation gradients as follows -

a) Broad leaf forest at the elevation range of 1000-3000m;
b) Mixed coniferous forest at the elevation range of 3000-4000m; and
c) Alpine scrub at the elevation range above 4000m.

Further, at each elevation range the plots were laid for trees, herbs and shrub. Based on the stratified random sampling method, all together a total of 60 plots were laid in the entire forest zones. For the number of trees in each 10*10 and 20* 20 m plots (plots varied in size because of the difficult tarries in the selected sites), for shrubs species, 5*5m plots and for herbs 1*1m plots were laid for the species count in each forest types. At high altitude, all plots for shrubs were 10*10m whereas for herb, it was 1*1m plots and we counted the number of herbs in each plot. Furthermore, we incorporated secondary data which included the data collected by the State Forest Department in the year 2010 (Tambe & Rawat, 2010) and plot data provided by Forest department.

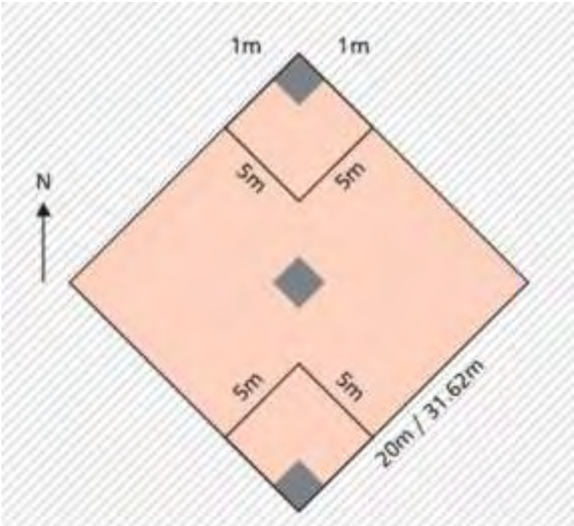


Figure 3: Plot Layout

3.1.1.2 Remote Sensing assessment

Satellite images of IRS, Resourcesat-2, and LISS-IV sensor were procured from NRSC, ISRO. The spatial resolution of the acquired images was 5.8 meters (Table 6), which was consistent with the mandated scale of mapping on 1:10,000. The datasets were of leaf on (peak growth) season to avoid any phonological variations required for delineation of different vegetation types. The digital elevation model (DEM) was utilised in this study for niche modelling to delineate natural vegetation types (Fig 4).

Table 6: Remote sensing data specifications

S.N	Sensor	Spatial Resolution (m)	Tile No.	Data acquisition date	Source
1	LISS-IV, Resourcesat-2	5.8	106/51D	14-11-2018	NRSC
2	LISS-IV, Resourcesat-2	5.8	107/51C	26-10-2018	NRSC
3	LISS-IV, Resourcesat-2	5.8	107/51D	19-11-2018	NRSC
4	LISS-IV, Resourcesat-2	5.8	107/52A	11-01-2018	NRSC
5	LISS-IV, Resourcesat-2	5.8	107/52C	26-10-218	NRSC
6	LISS-IV, Resourcesat-2	5.8	107/52B	01-12-2018	NRSC
7	LISS-IV, Resourcesat-2	5.8	107/52C	25-12-2018	NRSC
10	ALOS PALSAR DEM	12.5	-	2012	USGS

A. Satellite Data Pre-Processing

I. Carried out atmospheric correction of individual georeferenced images to remove haze or cloud cover on the image
II. The atmospherically corrected image was calibrated for radiometric correction to Top of Atmospheric reflectance (ToA). This was done to remove the effect of different solar illumination arising due to the time difference between satellite image acquisitions.
III. Then, the individual images were mosaicked to create a larger image and maintain the same analytical geographical extent in all images.

B. Creation of Classifier "Ruleset" Construction

I. A hybrid classification scheme (supervised and unsupervised) was employed to generate land use land cover map (LULC). Unsupervised classification was used to minimize the effect of subjectivity.
II. A rule-set was defined to supervise the image. The rule-set contained existing/ground-truth training samples along with the high-resolution Google Earth image.
III. The ruleset followed the parametric rule i.e. Maximum likelihood and considered statistical parameters of the pixels that were available in training samples.

C. Hybrid Image Classification, Analysis and Field Validation

I. The classifier iteratively used several supervised classification cycles and validation procedures (ground-truthed points/Google Earth).
II. After each classification step, the training database was density sliced and wherever it required, a knowledge-based approach was applied to derive specific thematic classes with minimum error.
III. Regions with high classification errors were masked out, and additionally, an unsupervised classification *(cluster busting)* was performed to address the effect of subjectivity. Furthermore, the misclassified classes were manually digitized or corrected using google earth as a reference dataset.
IV. The final classified map were spatially filtered using a class-specific filtering approach to remove salt and pepper effects.

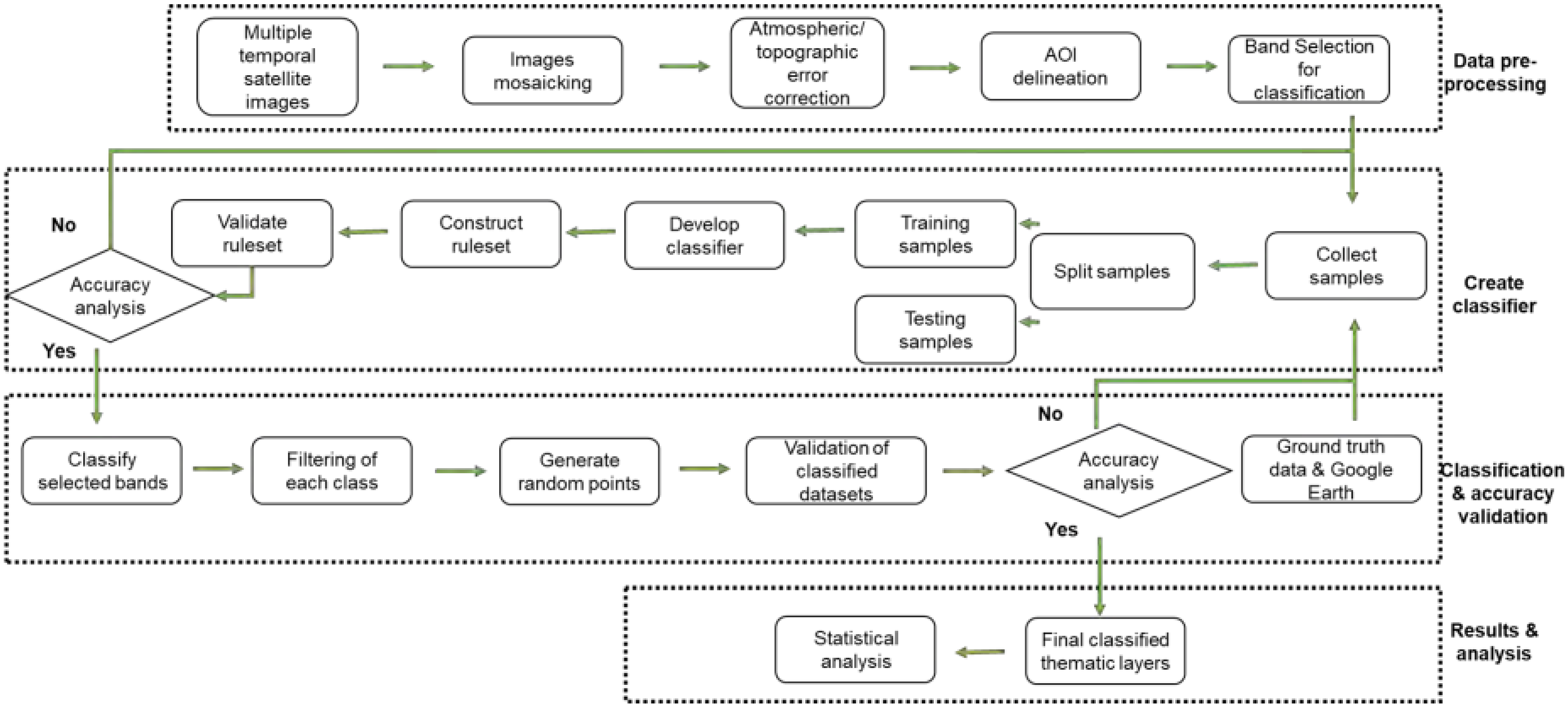


Figure 4: Methodological Flowchart for Land Use and Land Cover Map Preparation

3.1.2 Results

A total of twenty land use types were identified in the landscape. The identified classes included - open broadleaf forest, dense broadleaf forest, open mixed coniferous forest, dense mixed coniferous forest, open scrub, dense scrub, sub alpine thickets, alpine thickets, alpine meadows, morainic scrub, cultivated land, fallow land, bare area, steep rocky area, rural settlements, semi-rural settlements, wetland/lake, glacier, stream, snow cover (Figure, 6, 8 and 10).

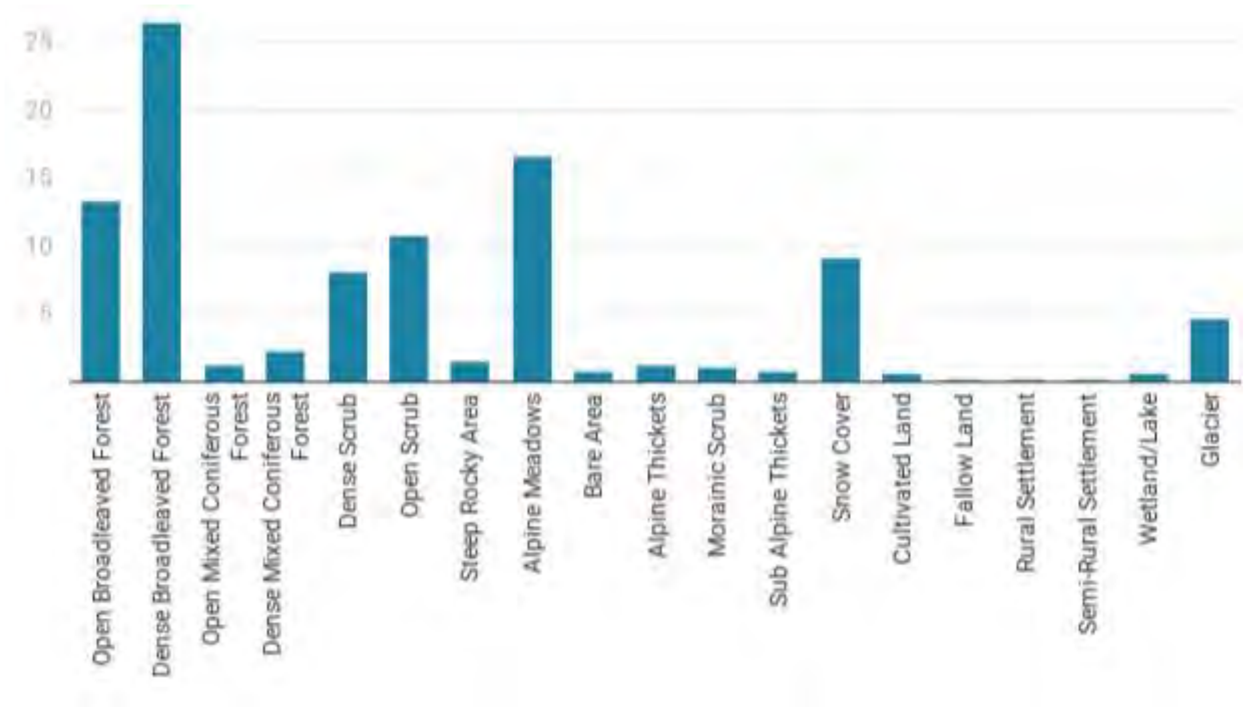


Figure 5: Graph showing Land Use and Land Cover (LULC) statistics of the Project Area

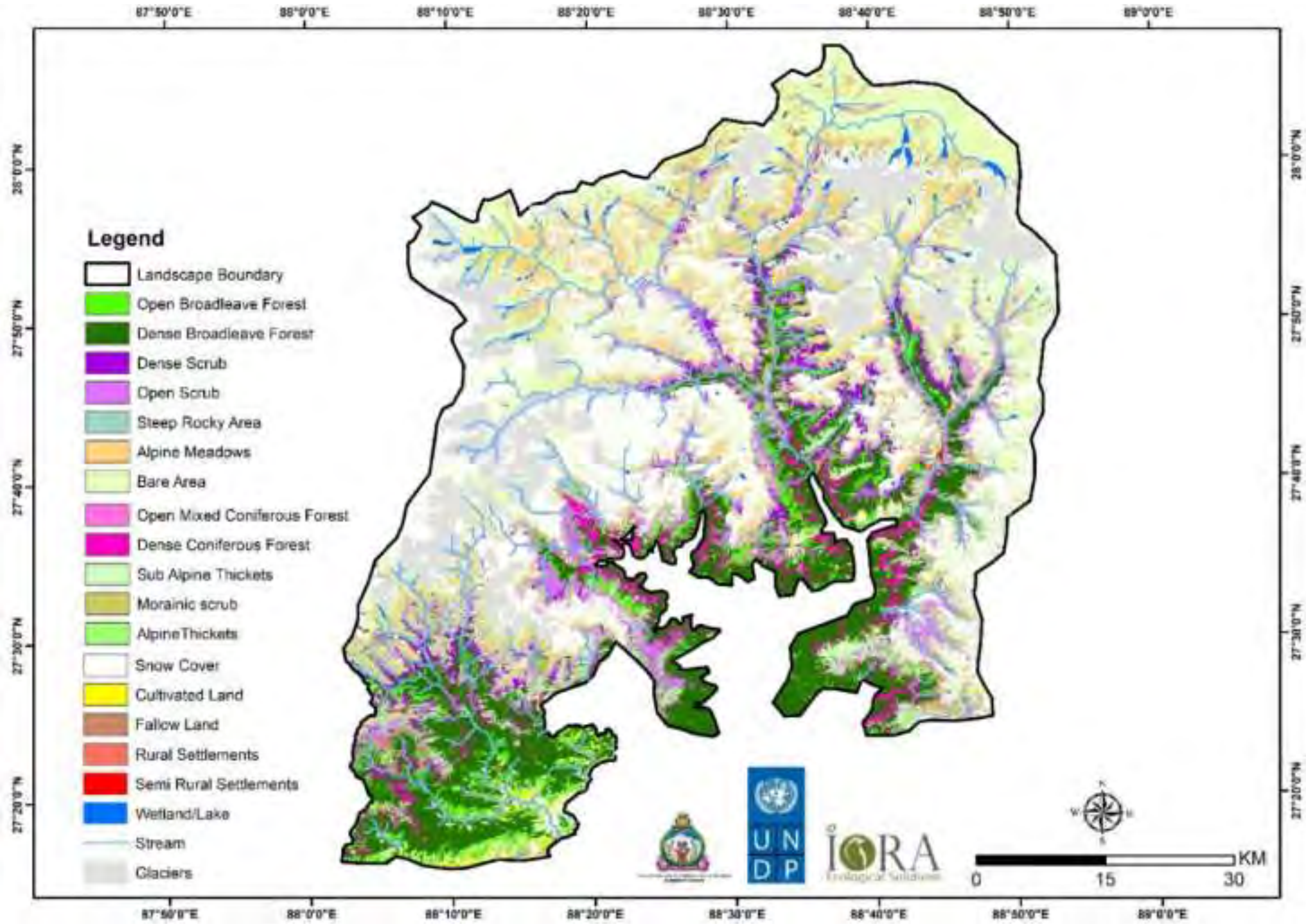


Figure 6: Land Use Land Cover (LULC) Map of the Project Area

Table 7: Area statistics of LU class, Project Area

LULC	Area(Km^2)
Open Broadleaved Forest	612.46
Dense Broadleaved Forest	1216.79
Open Mixed Coniferous Forest	54.98
Dense Mixed Coniferous Forest	106.6
Dense Scrub	370.65
Open Scrub	495.98
Steep Rocky Area	70.44
Alpine Meadows	760
Bare Area	35.36
Alpine Thickets	55.71
Morainic Scrub	45.78
Sub Alpine Thickets	31.56
Snow Cover	420.24
Cultivated Land	26.37
Fallow Land	10.18
Rural Settlement	4.2
Semi-Rural Settlement	7
Wetland/Lake	28.4
Glacier	210.3
Total	4563

Area statistics were calculated to quantify the extent of each land use mapped in the landscape. As shown in the Table 7 (individual analysis for KNP Table 8) and Figure 5,7 9 our analysis showed that the maximum land cover in the landscape is dominated by dense broadleaf forest that occurs on elevation ranging from 2000m to 3600m. Alpine meadows covered the majority of area in the landscape above 4000m. The third dominating class is scrub, which is mainly comprising of Rhododendron and Junipers species.

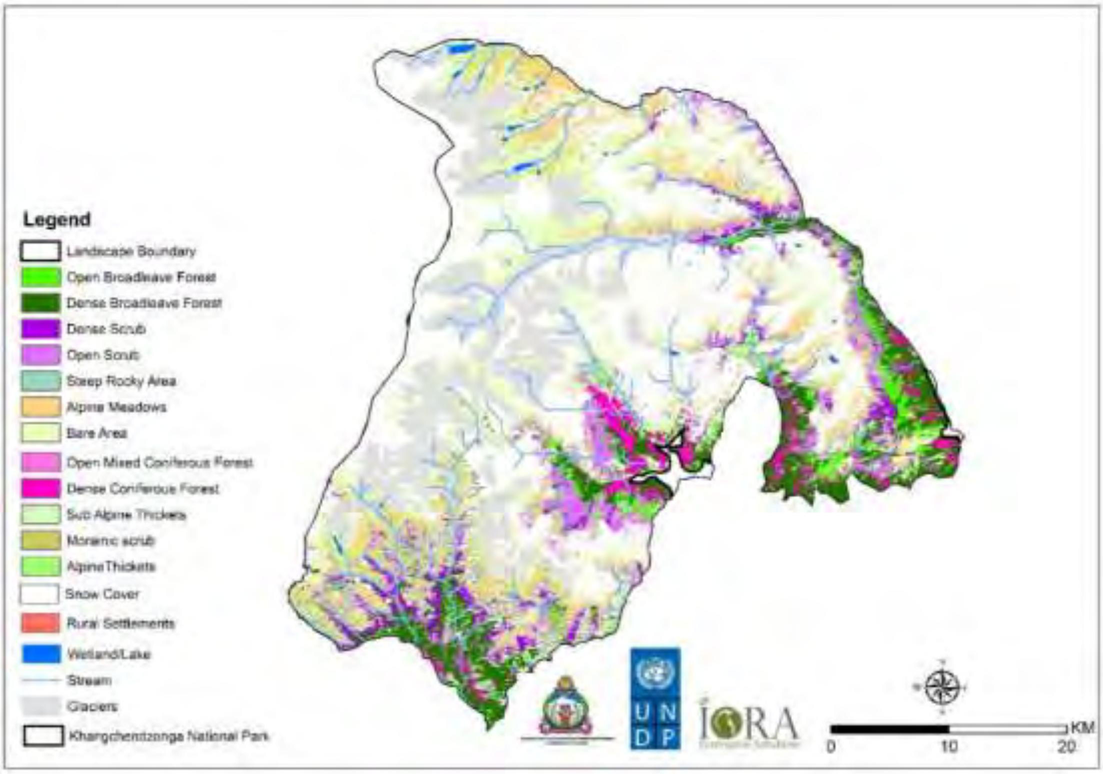


Figure 7: Land Use Land Cover (LULC), Khangchendzonga National Park

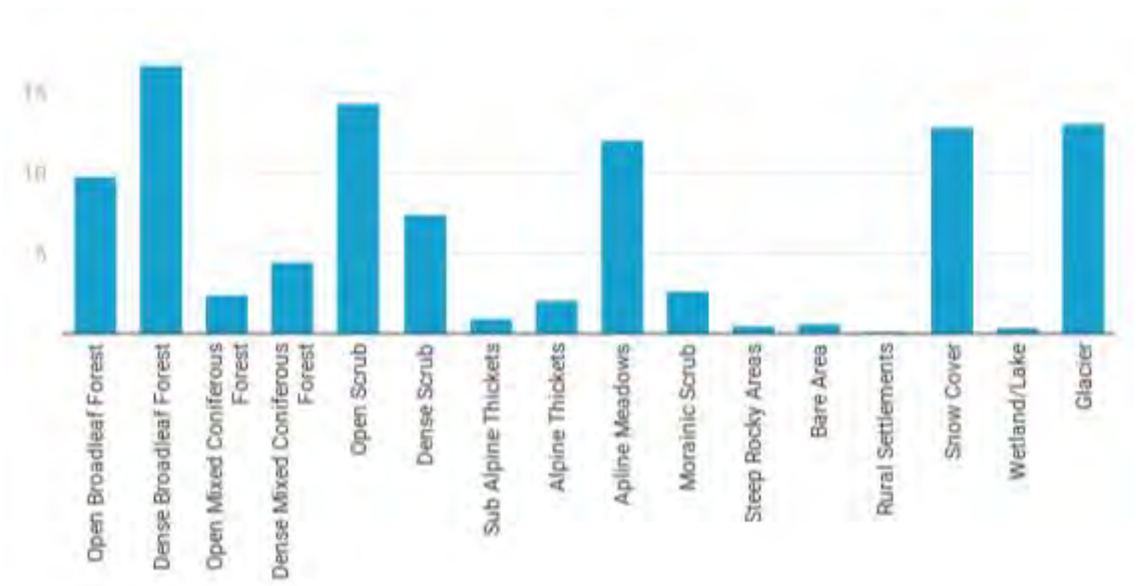


Figure 8: Land Use Land Cover (LULC) distribution (%), Khangchendzonga National Park

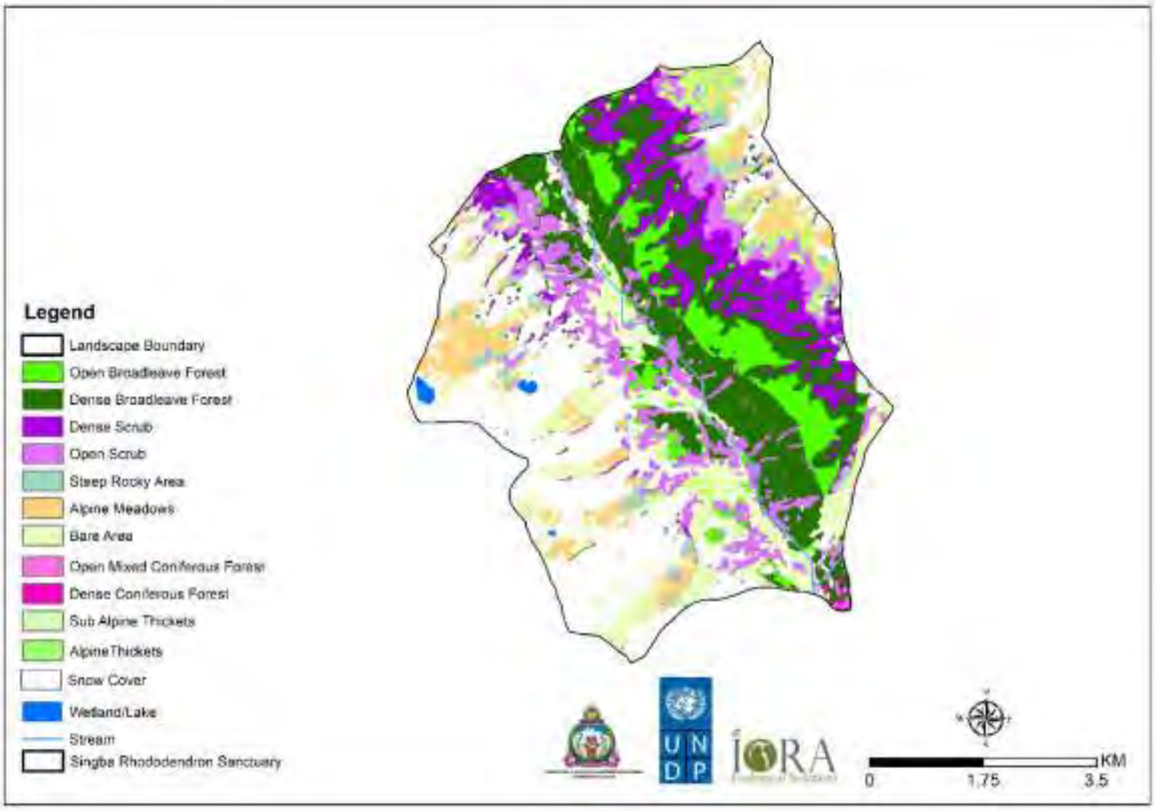


Figure 9: Land Use Land Cover (LULC), Singba Rhododendron Sanctuary

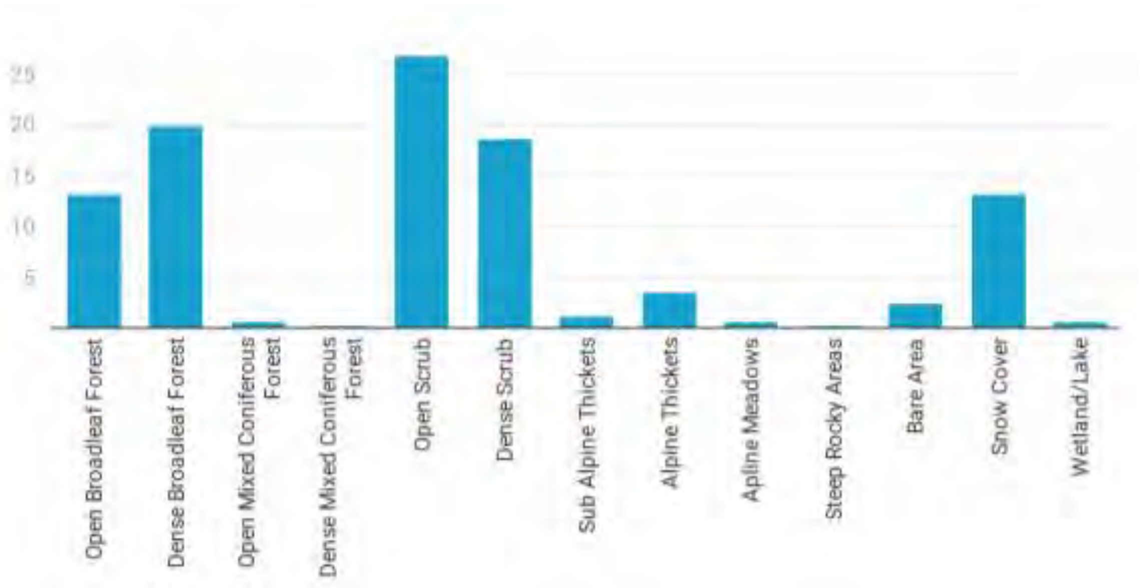


Figure 10: Land Use Land Cover (LULC) distribution (%), Singba Rhododendron Sanctuary

Table 8: Land Use Land Cover (LULC) statistics, Singba Rhododendron Sanctuary

LULC	Area(Km^2)
Open Broadleaf Forest	6.7
Dense Broadleaf Forest	10.3
Open Mixed Coniferous Forest	0.2
Dense Mixed Coniferous Forest	0.1
Open Scrub	10.4
Dense Scrub	7.5
Sub Alpine Thickets	0.2
Alpine Thickets	0.25
Alpine Meadows	0.5
Steep Rocky Areas	0.1
Bare Area	1
Snow Cover	5.6
Wetland/Lake	0.15
Total	**43**

Further, field survey and focus group discussions show that people in the fringe villages were mostly dependent on agri-based livelihood support system.

3.1.2.1 Dependency on agricultural field

Majority of the people in the region cultivate cardamom as it is one of the important cash crop (Fig 11). Local people also cultivate green vegetables and potato for commercial purpose but not in the huge amount.

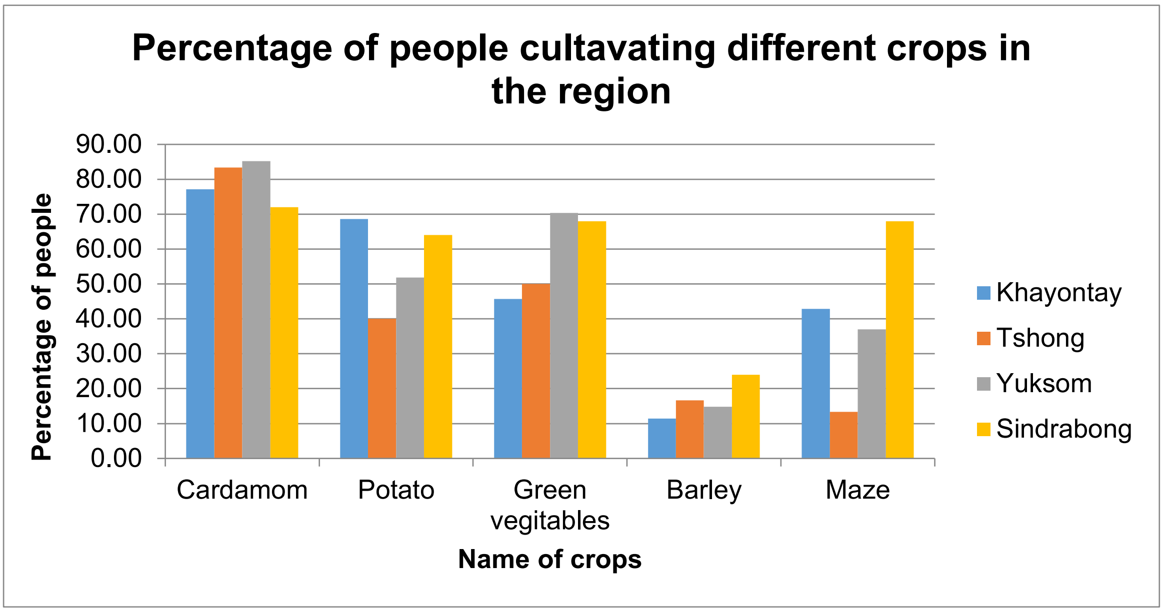


Figure 11: Graph Showing Dependency on Agricultural field

3.1.2.2 Land Use ownership

Majority of the villages surveyed have their own land for cultivation and approximately 28% households in these villages have leased cultivable land (Fig 12) and their main occupation is agriculture based and tourism is the second major occupation in these area (Fig 13).

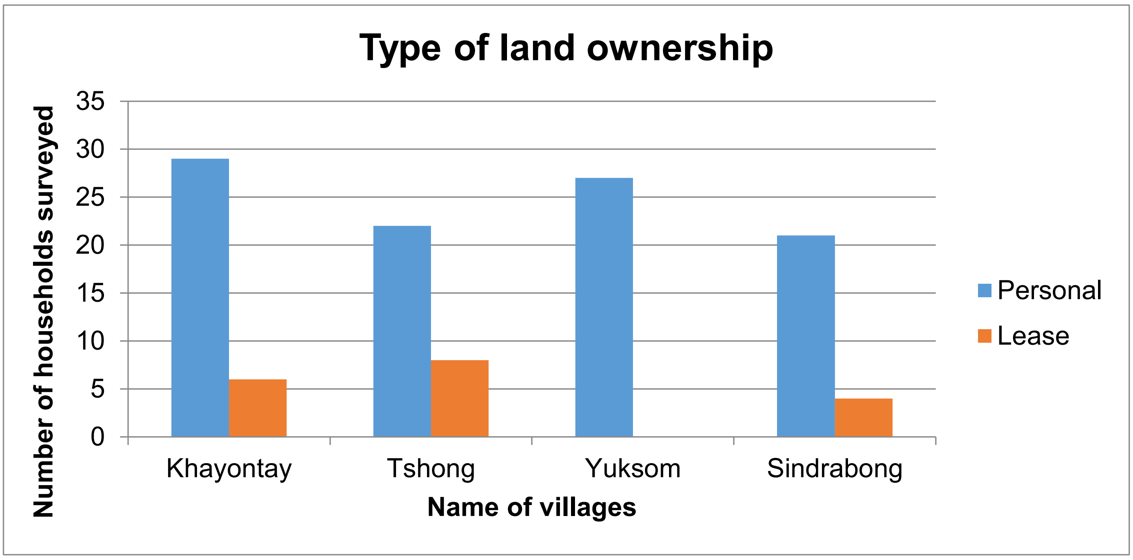


Figure 12: Graph Showing Land Use Ownership

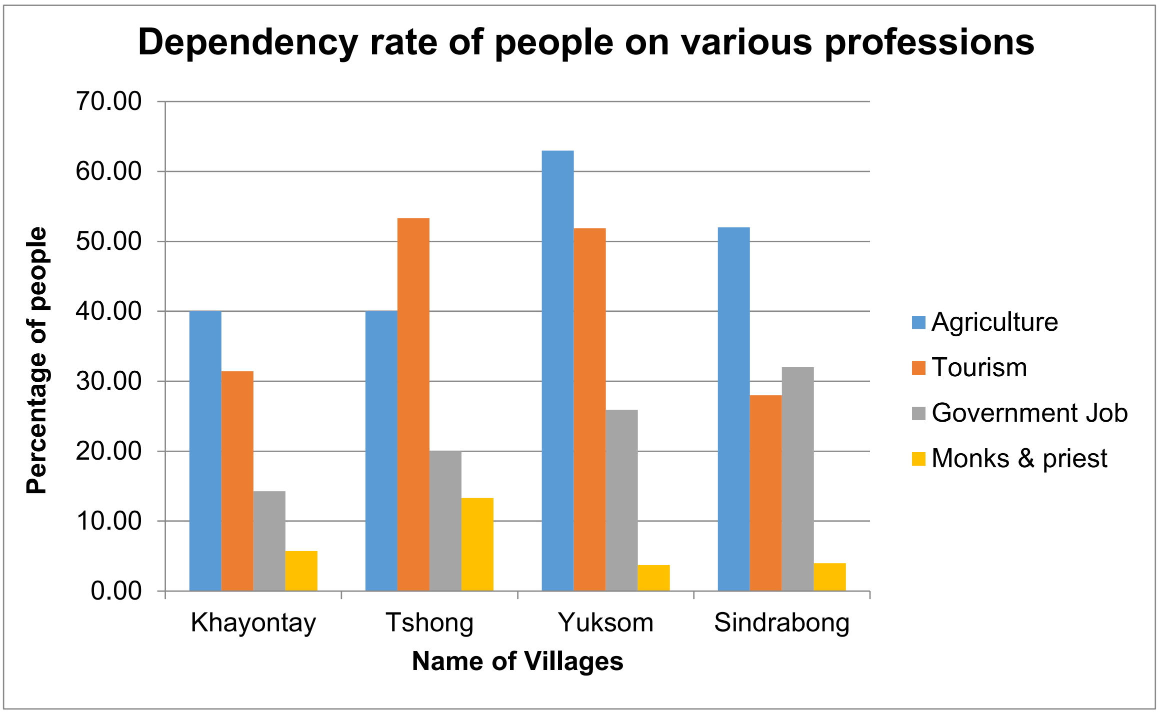


Figure 13: Graph Showing Profession of various household

3.2 Mapping Land Use by Socio-Legal/Ownership

In order to categories, land use types identified and generated under objective 1 of were then utilized to map the distribution of land use by socio-legal/ownership categories. The administrative boundaries were obtained from various state government departments (Table 9) to map the socio-legal boundaries around the land use in the project landscape.

Table 9: Details of Administrative Boundaries

S.N	Administrative Boundary	Source
1	Village Boundary	Rural Development Department, Sikkim
2	Protected Area	Forest And Environment Department, Government of Sikkim
3	Reserved Forest	Forest And Environment Department, Government of Sikkim

3.2.1 Methodology

3.2.1.1 Spatial extraction of LULC by administrative boundaries

The composite LULC layer was spatially overlaid on administrative boundaries e.g., village boundary, protected and reserved forest boundary. Following which, each land use class falling within the specified administrative boundary was extracted using spatial analyst tool in GIS environment (Fig 15, 16 and 17).

3.2.1.2 Quantification of extent of each land use type

After extracting the land use layer for each administrative boundary, area statistics were computed using tabulation method (Fig 14 and Table 8). This method defined the limit and calculated unique values of each land use within the boundary.

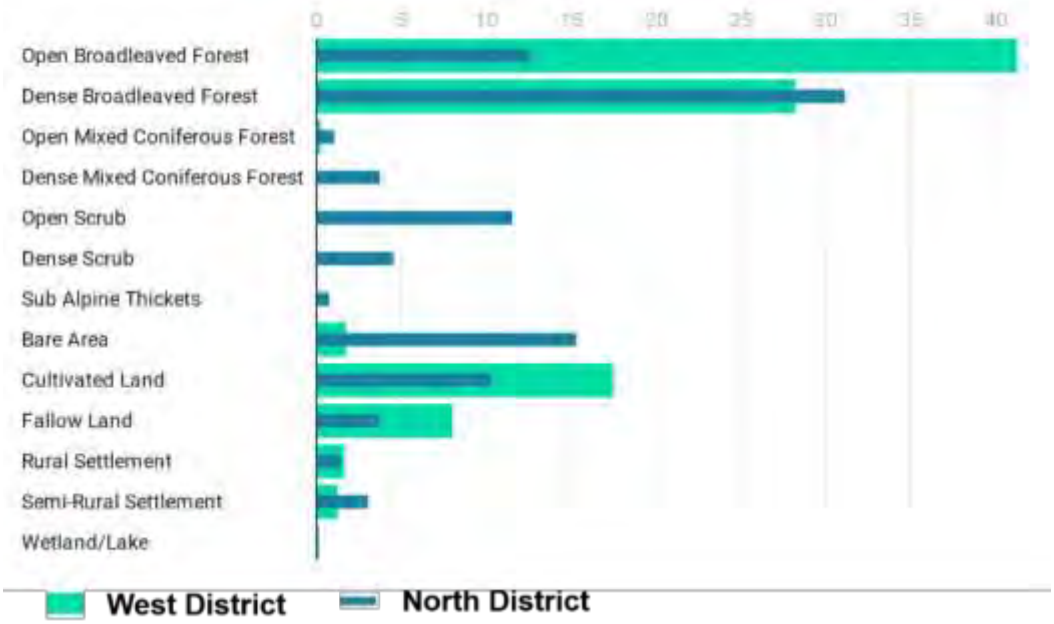


Figure 14: Land use Land Cover (LULC) distribution (%), Villages in the Project Area

3.2.2 Results

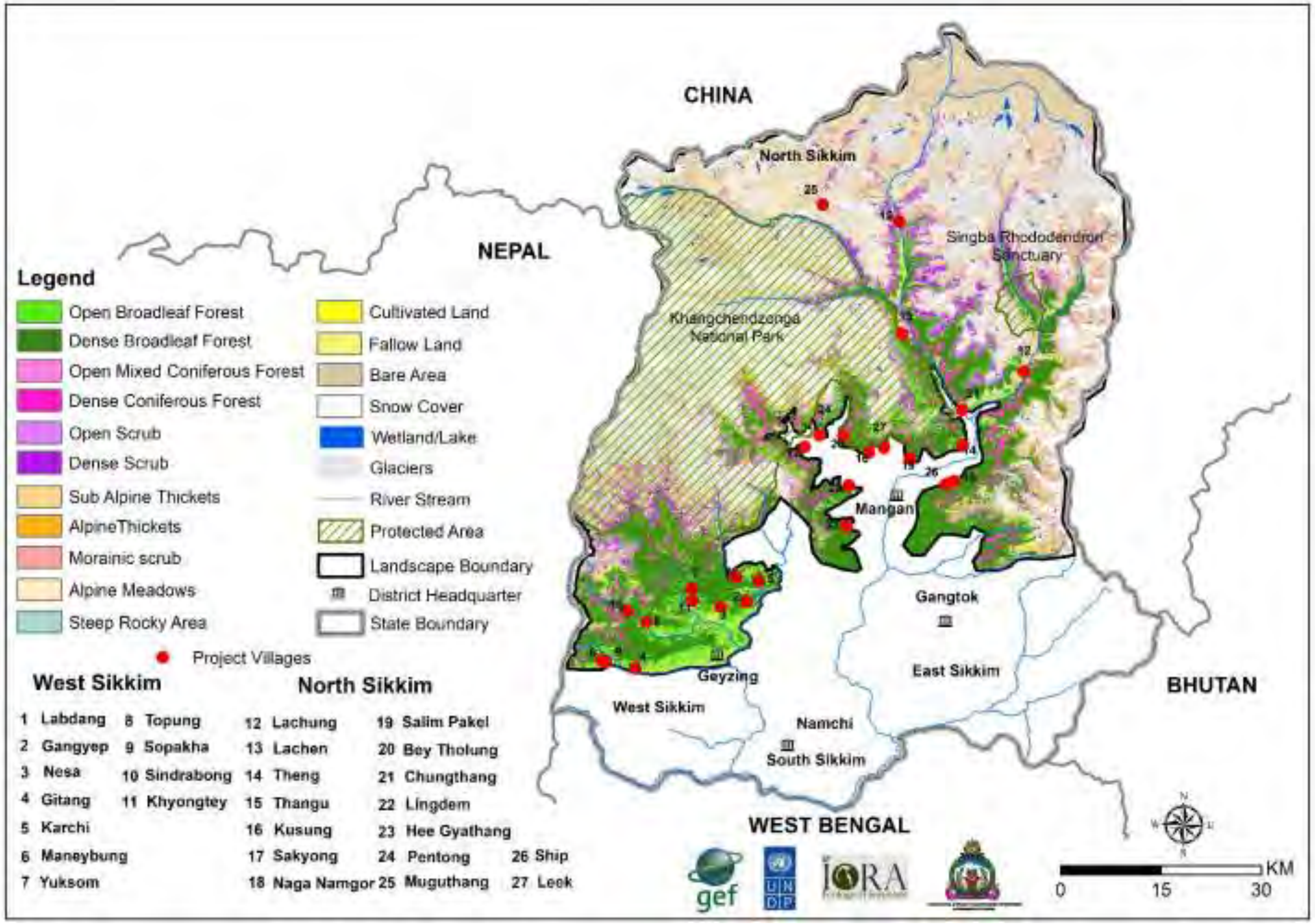


Figure 15: Demarcated boundaries of PA, RF and Villages overlaid on the LULC around the Project Area

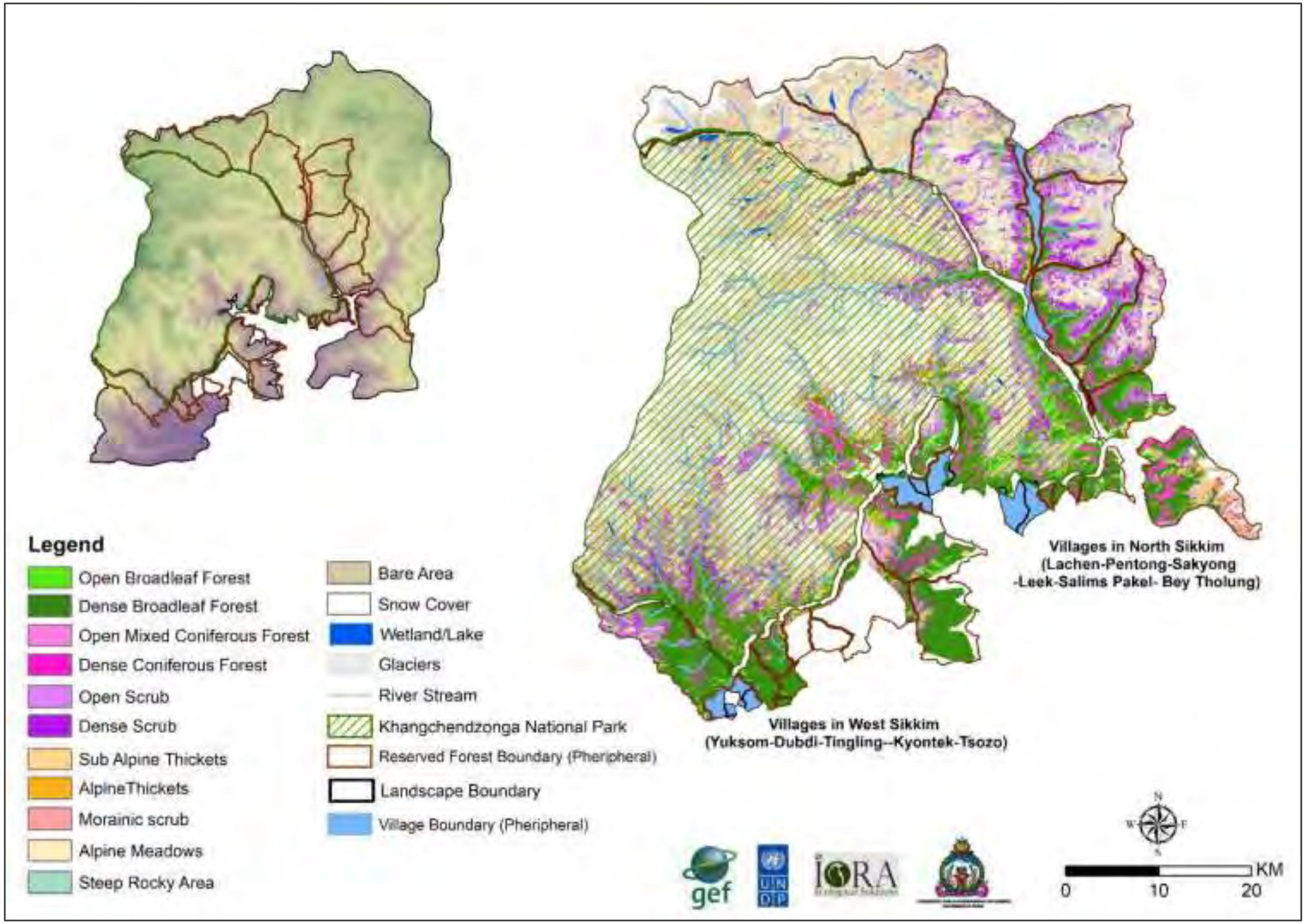


Figure 16: Villages boundary overlaid on the LULC around Kanchendzonga National Park

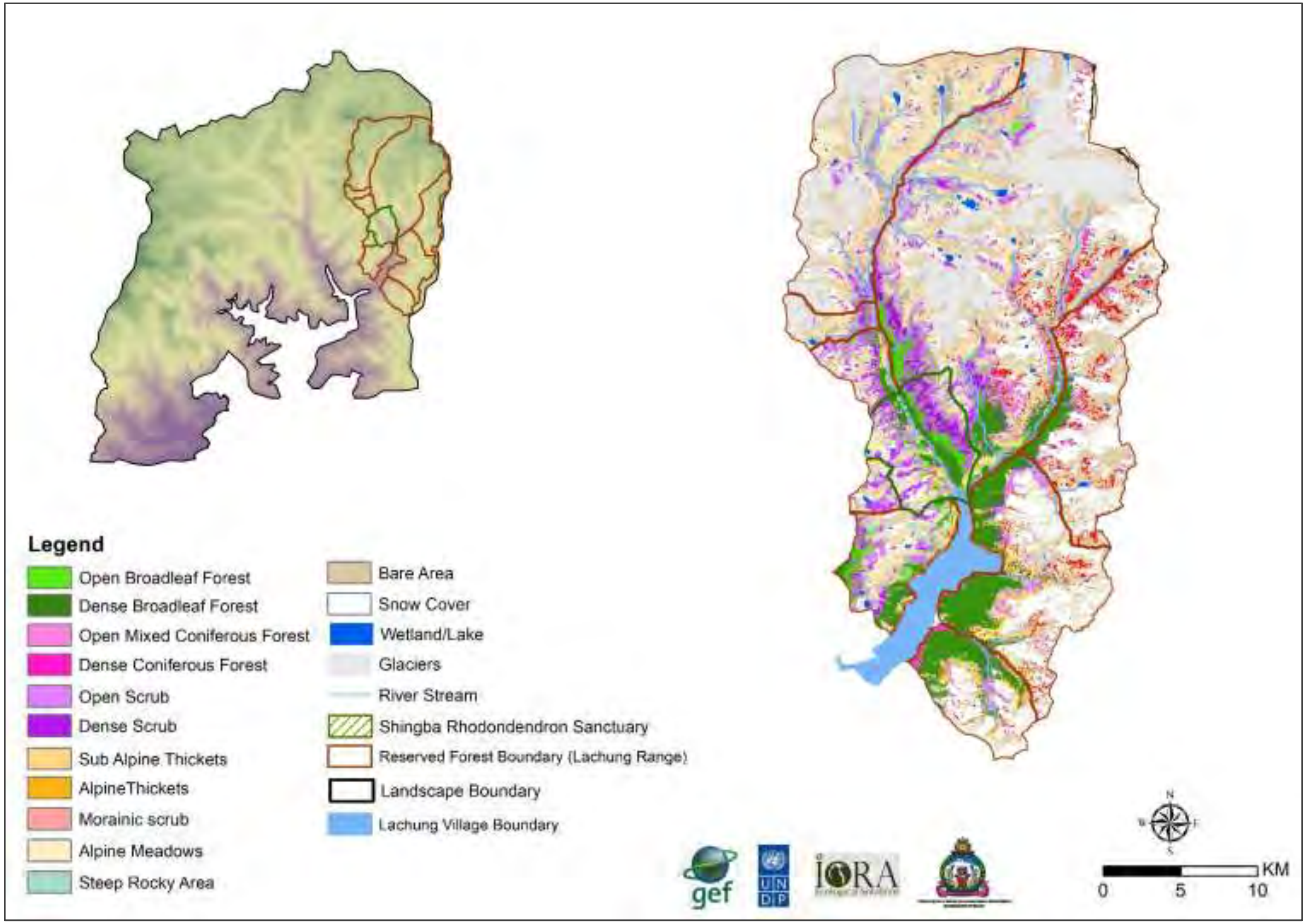


Figure 17: Villages boundary overlaid on the LULC around Singba Rhododendron Sanctuary

3.3 Mapping by Biodiversity Characterization - Vegetation Types and Dominant Species

A phytosociological analysis is a system for classifying plant communities, their composition, and the relationship between the species in a community. Phytosociological analysis is a method to apply a sample plot sizes to describe and measure plants and classify the strong importance of the dominant species within the sample plot. The standard plot sampling and species sorted in hierarchal order (CONCENÇO, G. et al, 2013)[4]. To understand the complex vegetation diversity pattern and composition of the vegetation habitat of an ecological landscape, we calculated abundance, occurrence, species diversity index and similarity index.

3.3.1 Methodology

The field study was conducted in the sampled locations in Kanchedzonga National Park, Singba Rhododendron Sanctuary and surrounding areas to understand the complex vegetation diversity pattern and composition of the vegetation habitat of an ecological landscape in terms of patch size, patch shape, patch slope and patch neighborhood characterization of vegetation need to be classification.

3.3.1.1 Field Sampling

The vegetation strata proportions were utilized for determining the sample plots using area weighted stratified random sampling technique with probability proportionate to stratum size. The sampling analysis will include Cochran's formula to calculate sample size.

$$\frac{n_0 = Z^2 \rho(1-\rho)}{e^2} \quad \text{………………… Eq. 1}$$

Where:

n_0 = sample size

Z = critical value of desired confidence level

p = estimated proportion of population which has the attribute in question

q = (1-p) estimated proportion of an attribute that is present in the population

e = desired level of precision

This formula is modified for smaller population as:

$$n = \frac{n_0}{1+\frac{(n_0-1)}{N}} \quad \text{……………….. Eq. 2}$$

where,

n_0 is the sample size derived from eq. 1 and N is the population size.

[4] Concenço, G., M. Tomazi, I.V.T. Correia, S.A. Santos, and L. Galon 2013.Phytosociological Surveys: Tools for Weed Science? Planta Daninha 31(2): 469–482

Sample size has been calculated with Z value at 90% confidence level, ± 5% precision level and assuming maximum variability is at 50%. This covers all the characteristic of land use.

3.3.1.2 Sample Design

The on-ground sampling analysis has involved a nested quadrate approach to evaluate trees (20m * 20m), (31.62m * 31.62m), shrubs/saplings (5m * 5m), herbs/seedlings (1m * 1m), climber/lianas/epiphytes in each stratum (Fig. 3). In each sample plot, the circumference at breast height (CBH) of each tree with CBH >= 30cm has been recorded. Trees with CBH > 17m and < 30cm was treated as a sapling and those with CBH < 17m as seedlings. In the case of shrubs, the CBH has been measured about 30cm above the ground. The total number of seedlings of various species has been counted along with a recording of the average girth (1.4m) of each species. The inventorization technique followed National Working Plan Code (NWPC 2014) depending on the terrain, the plot size varied from 20m*20m to 10m*10m (Table 10).

For arid steppe areas in Tso Lhamo plateau, a nested quadrate of size 10m*10m has been used due to terrain inaccessibility. The total number of tillers of each shrub species was counted along with biophysical data, field data included information on cover type, locality, aspect, slope, geo-coordinates, signs of disturbance and altitude.

Table 10: Enumeration and collection of floral data in the landscape

Landscape	Major Floral composition	Sampling method	Plot size	Information
Forest fringe areas	Wet Temperate forest, East Himalayan mixed Coniferous, East Himalayan Sub-alpine Birch, Scrub	Stratified random	31.62m * 31.62m	Trees : CBH, Species Name
				Shrubs/Sapling : No., Species Name
				Herbs/Seedling: No., Species Name
				Climber/Lianas/Epiphytes: No., Species Name
Khangchendzonga National Park	Buk Oak Forest, East Himalayan Mixed Coniferous, East Himalayan Sub-alpine Birch Forest, Scrub	Stratified random	31.62m * 31.62m / 20m * 20m	Trees : CBH, Species Name
				Shrubs/Sapling : No., Species Name
				Herbs/Seedling: No., Species Name
				Climber/Lianas/Epiphytes: No., Species Name
Shingba Rhododendron Sanctuary	East Himalayan mixed Coniferous, East Himalayan Sub-alpine Birch, Scrub	Stratified random	31.62m * 31.62m / 20m * 20m	Trees : CBH, Species Name
				Shrubs/Sapling : No., Species Name
				Herbs/Seedling: No., Species Name
				Climber/Lianas/Epiphytes: No., Species Name
Tso-Lhamu Plateau	Scrub, East Himalayan Sub-alpine Birch	Simple random	10m * 10m	Shrubs/Sapling : No., Species Name
				Herbs/Seedling: No., Species Name
				Climber/Lianas/Epiphytes: No., Species Name

A total of 92 plots were laid in the landscape to analyse the biodiversity character in the landscape. Out of 92, 42 plots were laid in temperate, 30 in sub-alpine and 20 in alpine. 46 plots were laid in west district. During the field survey, a total of 125 plant species were identified and recorded from the sampled area, of which 55 were non-woody herbs and grasses, and 38 were woody trees, and a variety of shrubs species were identified (35 identified). To analyze phytosociological character of the community in various vegetation types in the project area, MS excel and R Core Team 2017 (R©) was used.

The species count data was used for each tree, shrubs and herbs to find out the most abundant species across different forest types. Based on the data collected from the different field sites, highest species occurrence was derived for each forest type. Further, the three most ***Abundant species*** of herb, shrub and trees was calculated by counting the density of occurrence of the trees in each forest types. The species ***Frequency of occurrence*** based on the number of trees, shrubs and herbs across different forest types was also calculated using R as the average number of trees, herbs and shrubs species found in each forest types and plotted with standard error distribution.

A diversity index is a quantitative measure that reflects the number of different species and how evenly the individuals are distributed among those species. Typically, the value of a diversity index increases when the number of types increases and the evenness increases. One of the commonly used index to understand the species diversity is Shannon wiener index, which was used for calculating diversity of trees, shrubs and herbs in each forest types. The Shannon-Weiner index (Barnes et al. 1998) derived from information theory is primarily based on measuring uncertainty and the degree of uncertainty in predicting the species of a random sample and is related to the diversity of a community. If a community has low diversity (dominated by one species), the uncertainty of prediction is low; a randomly sampled species is most likely going to be the dominant species. However, if diversity is high, uncertainty is high. It was computed as:

$$\text{Shannon Index (H)} = -\sum_{i=1}^{s} Pi\ln pi \text{ ....Eq. 3}$$

Where 'P' is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), 'ln' is the natural log, Σ is the sum of the calculations, and 's' is the number of species.

Further, to calculate the similarity among of the presence of species in various forest categories, Jaccard similarity index (sometimes called the Jaccard similarity *coefficient*) has been used. This index compares members for their shared presence in two sets of vegetation. It's a measure of similarity for the two sets of data, with a range from 0% to 100%. The higher the percentage, the more similar the two populations, although it's easy to interpret, it is extremely sensitive to small samples sizes and may give erroneous results, especially with very small samples or data sets with missing observations. For our data we have used Jaccard similarity index to understand the similarity between different forest types within the composition of herb, shrub and trees. The similarity between three forest types, using the formula for Jacquard similarity index:

$$J = (\text{set 1, set 2}) = |1 \cap 2| / |1 \cup 2| \text{.........Eq. 4}$$

where, J is the Jacquard Index = (number of objects in common) / (total number of objects). Compared the number of common species in different forest types and divided by total number of species. Generally, the values of Jacquard's Index ranges from 0 to 1, which was multiplied by 100 to get the percentage. Figure 18 gives the details of the methodology flow used in the analysis to derive diversity index.

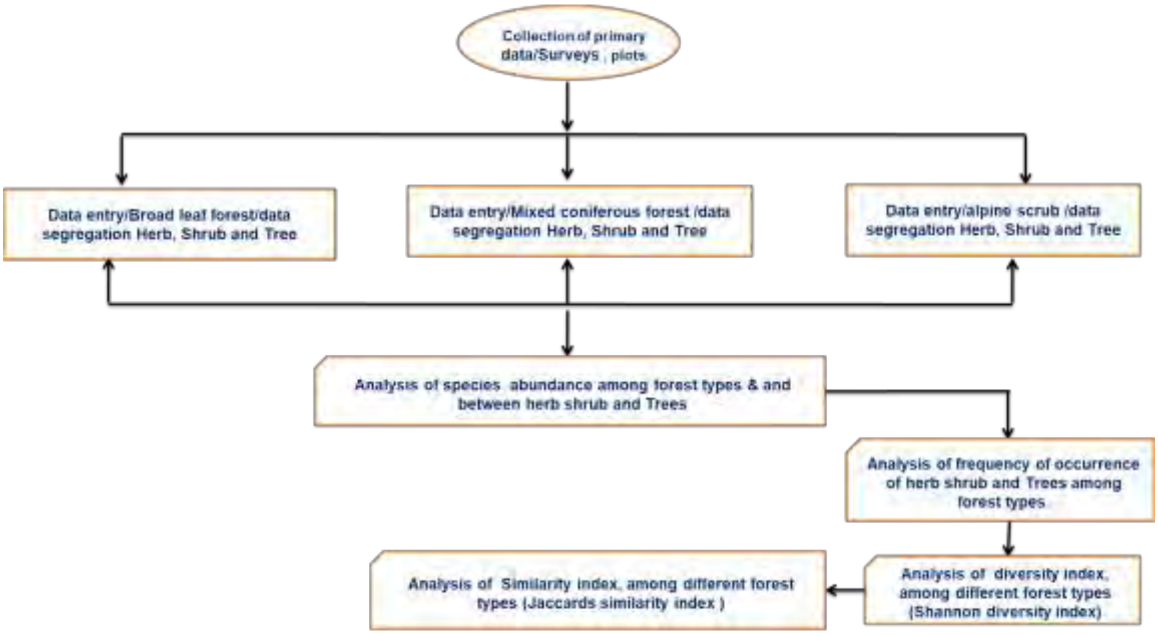


Figure 18: Methodology flowchart for diversity index analysis

3.3.2 Results

3.3.2.1 Species abundance

Abundance is perhaps the most important ecological quantity necessary for understanding the dynamics of populations and for decision-makings in biological management and conservation, for example assessing extinction risk of endangered species (Mace & Lande 1991; Maceet al.2008), monitoring invasive species (Veldtman, Chown & McGeoch 2010) and managing species populations, particularly threatened species (Tosh, Reyers & van Jaarsveld 2004; Figueiredo & Grelle2009). In practice, however, data on species abundance are often not available or too expensive to collect. In such cases, distribution data have to be used as an approximate surrogate for abundance (Wilsonet al.2004; Cardilloet al.2008;Maceet al.2008). Here the number of most abundant species of herbs, shrubs and trees in different types of forest in Sikkim Himalayas was analysed, which is explained in the figures 19-22. The species co-existence of herbs, shrubs and trees in each forest types was also assessed .

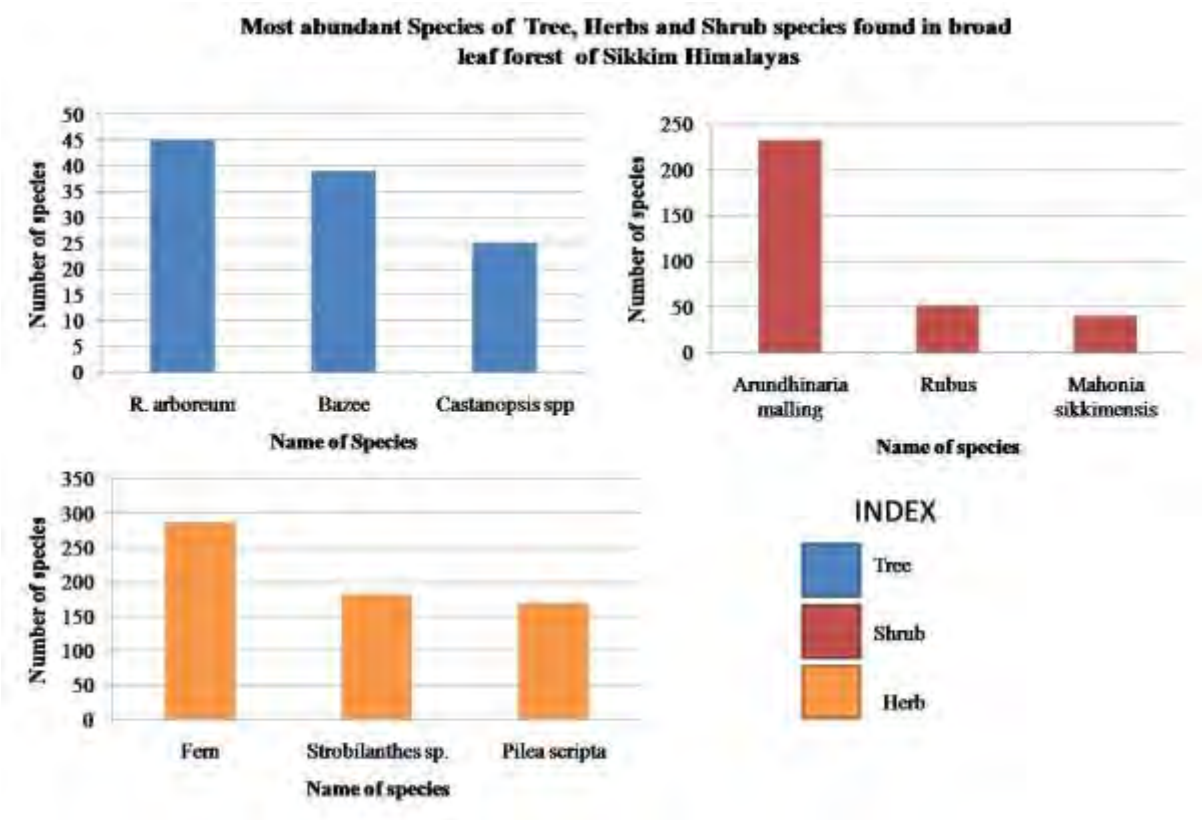


Figure 19: X axis represents name of species and y axis represent number of species , shows the three most abundant species of herb (Orange), shrub (Red) and tree (Blue) found in Sikkim Himalayas, It also shows the co-existence of herb, shrub and tree in broad leaf forest

Species abundance graph shows that *Rhododendron arboreum*, was the most abundant tree in broad leaf forest followed by *Bazee* (Local name), and *Castanopsis species*. Besides, fifty-eight numbers of tree species were noticed under temperate broad leaf forests. Among these some of the economically important tree species are *Alnus nepalensis, Eurya acuminate, Juglans regia, Magnolia champaca* and *Tsuga demosa*. In terms of shrubs, *Arundinaria maling* (gamble) has been the most abundant species found in broad leaf forest followed by *Rubes sp.* and *Mahonia sikkimensis*. Total number of 31 shrub species has been reported from the broad leaf forest (Table for the list of species is given in the Annexure II). There were around 68 species of herbs are found among them the most abundant was the species of pteridophyte's followed by *Strobilanthes spp. and Pilea scripta*. Other species of herbs are given in the Annexure II. We have also observed the species co-existence like herb species pteridophyte's *Strobilanthes spp. and Pilea scripta* are mostly found under the canopy of *Rhododendron arboretum*, *Castanopsis sp*, *Arundinaria maling*, *Rubes spp.* and *Mahonia sikkimensis.*

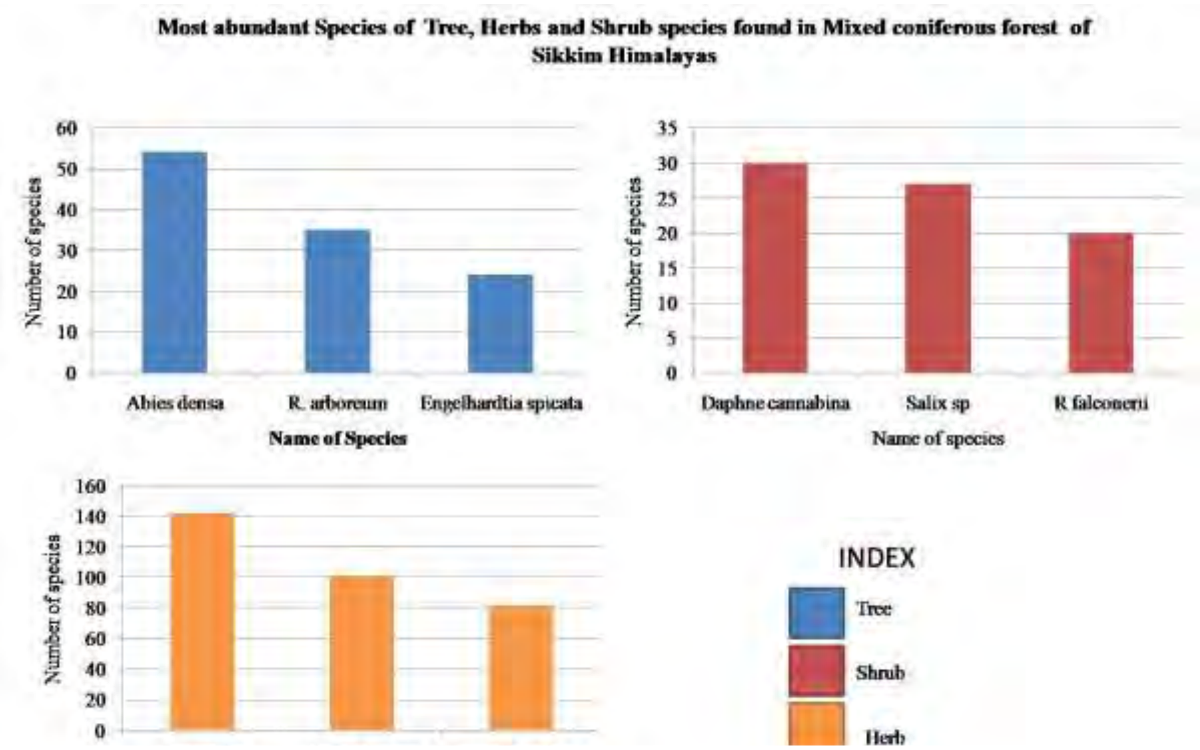


Figure 20: X axis represents name of species and y axis represent number of species , shows the three most abundant species of herb (Orange), shrub (Red) and tree (Blue) found in Sikkim Himalayas, It also shows the co-existence of herb, shrub and tree in mixed coniferous forests

In the Mixed coniferous forest, *Abies densa* has been seen as the most abundant tree followed by *Rhododendron arboretum* and *Engelhardia spicata*. There were a total of forty species of trees found in the temperate forest zone (list of other species are given in the Annexure II). The three most abundant shrub species found in the temperate forest where *Daphne cannabina, Salix spp.* and *Rhododendron falconerii*. Beside these, there were total number of 25 species of shrubs found in the region (Annexure II). Among the fifty-three number of herbaceous plants, *Potentilla sp* was the most abundant species followed by species of *Anaphalis* and *Prunela vulgaris* (Annexure II).

The total number herb species found in the Alpine zone were twenty-three with *Anaphalis spp*. being the most abundant species followed by *Aconogonum molle, Cassioppe fastigiata,* and *Primula kingi* (Annexure II). Among the shrub species, *Juniper sp.*(Sang) was the most abundant species in alpine scrub followed by *Rhododendron nivale* and *Salix sp*. It was observed that the abundance of herbs were higher in alpine scrub as compared with shrub species.

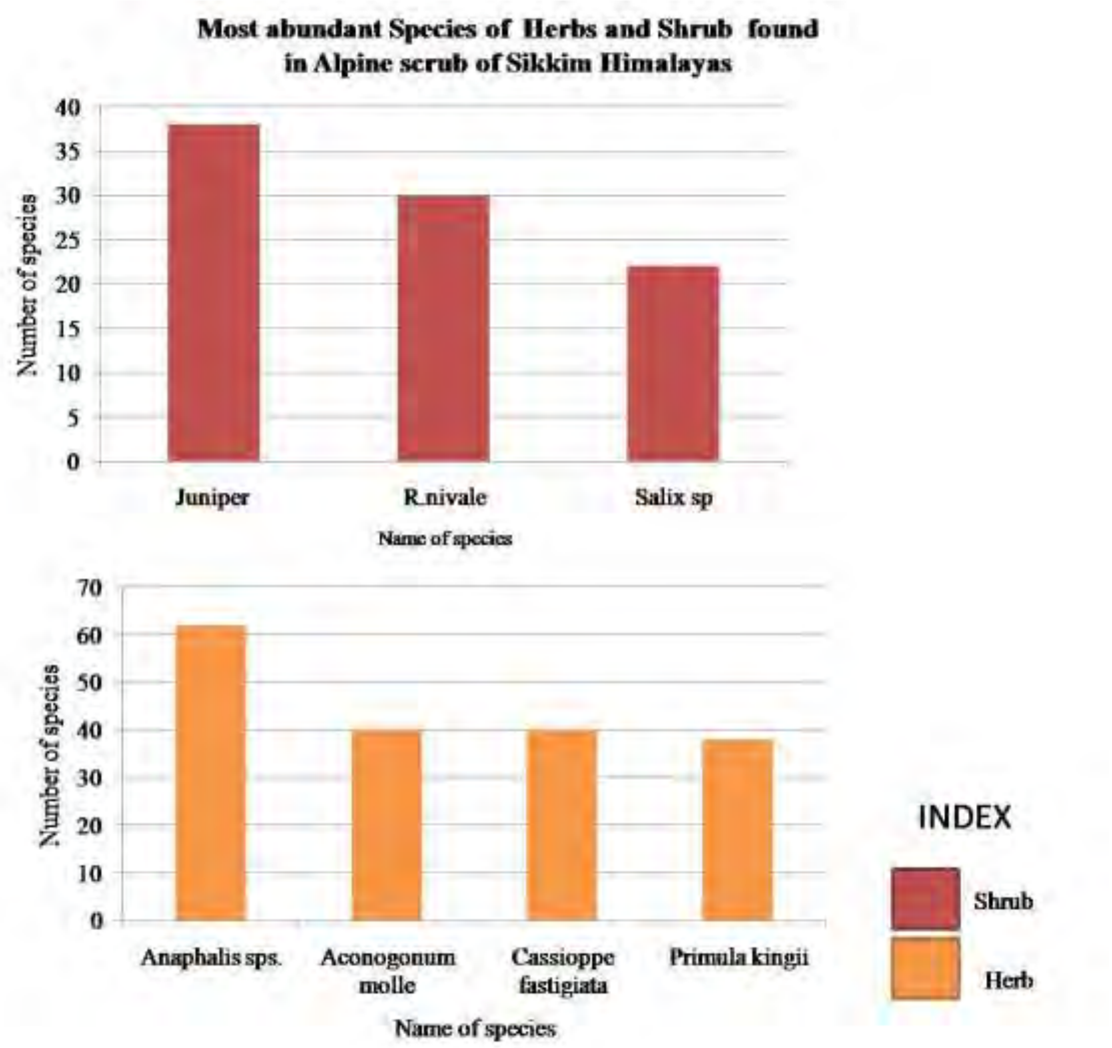


Figure 21: Abundance of herbs and shrub species in the Alpine Scrub region in the Project Area

(X axis represents three different types of forest Y axis represents average number of species occurrence and colour's represents herb (blue), shrub (red) and Tree (Green). It shows that there is no significant difference in frequency of occurrence)

3.3.2.2 Species occurrence

The frequency of occurrence of trees, herbs and shrubs in each forest types was calculated and the result shows that the occurrence of herb in broad leaf forest was higher having average number of 25 herbs in each plots followed by shrubs which was fifteen and trees with five in number in each plot. In the mixed coniferous forest also, the occurrence of herbs was higher at 22 in numbers followed by trees having eight number per plot and lowest was shrubs with five species per plot. Alpine scrub has 12 number of herbs per plot and 7-8 number of shrubs per plot (Fig 22).

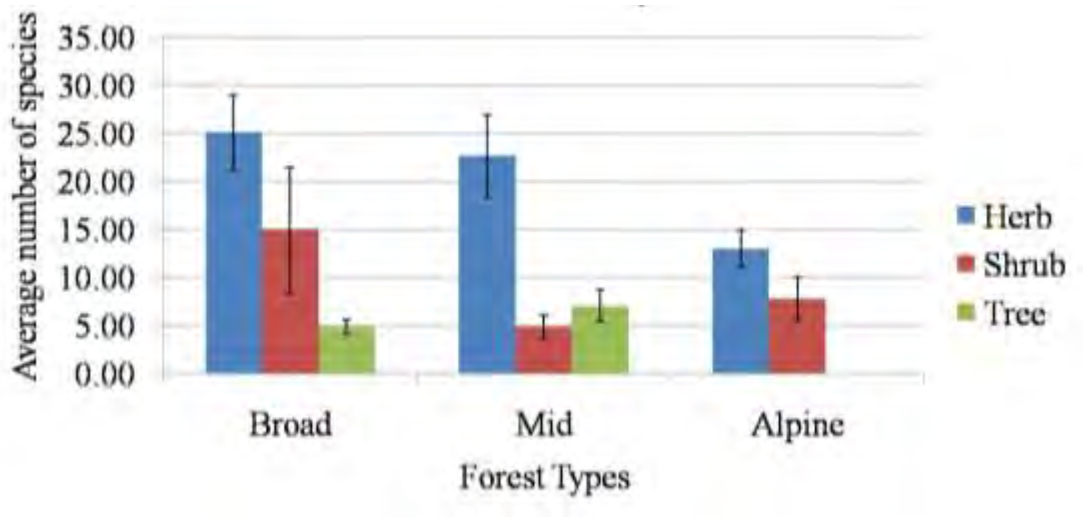


Figure 22: Average number species in temperate, sub-alpine and alpine forests

3.3.2.3 Shannon-Wiener Diversity Index

Biodiversity is one of the primary focus in this landscape, but quantifying the species diversity of ecological communities is complicated. To assess the diversity Shannon's wiener Index was calculated (Eq. 3) based on the plot data (Table 11).

Table 11: Shannon –Wiener Index of Tree, Shrub and Herb in 3 different types of forest in Sikkim Himalayas

S. No	Forest Types	Shannon –Wiener Index		
		Tree	Shrub	Herb
1	Temperate Forest	3.59	2.23	3.69
2	Sub Alpine Forest	3.44	3.00	3.47
3	Alpine Scrub	-	2.39	3.22

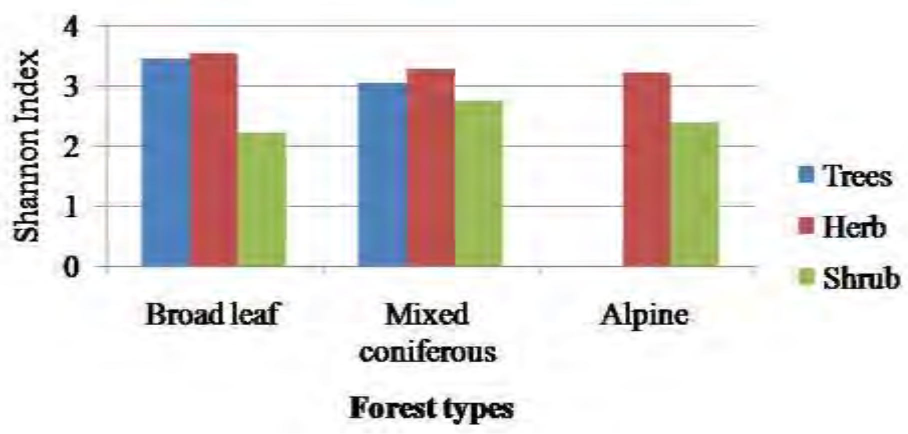


Figure 23: Shanon-Weiner Diversity Index based on broad forest categories

Typical values of Shannon wiener index is generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4 (Table 12). The Shannon index increases as both the richness and the evenness of the community increase. The results shows that there is higher diversity of herbs and trees (Fig 23), which is above three in all the forest types in comparison with the shrub species, which is low.

Table 12: Summary of results on abundance and diversity of Herb shrub and Tree in three different types of forest in Sikkim Himalayas

Results on Abundance and diversity						
Forest types	**Herb**		**Shrub**		**Tree**	
	Abundance	Diversity	Abundance	Diversity	Abundance	Diversity
Temperate	79	3.69	33	2.24	65	3.59
Sub Alpine	70	3.47	41	3.01	54	3.44
Alpine	23	3.22	21	3.39	-	-

The higher number of herb species and/or high diversity index in case of herbs may be attributed to the season i.e. spring season during which the field survey was done. During winters and in summers, this number decreases. The analysis indicates that forests of Sikkim Himalayas are highly diverse in terms of herbs and trees whereas there is little less diversity in case of shrub species.

3.3.2.4 Jaccard's similarity index

To undertsand the similarity in the species across three forest types a comparison of biodiversity levels in all the three broad forest category was done using the Jaccard's similarity index (Eq. 4). Jaccard's index of similarity is a fraction of species shared between the samples. To assess the similarity, a comparison was done for the species shared between three different kinds of forest found in the landscape (Table 13).

Table 13: Table shows Jaccard's similarity index in three forest types

	Alpine Vs Temperate Temperate Vs Alpine	Alpine Vs Sub-Alpine Sub-Alpine Vs Alpine	Temperate Vs Subalpine Sub-Alpine Vs Temperate
Herb	2.31	2.89	6.94

Shrub	1.09	6.52	4.35
Tree	*	*	14.65

Results of our similarity index showed that there is higher similarity of trees 11% in broad leaf forest and mid altitude forest, which is somewhat obvious because they shared the

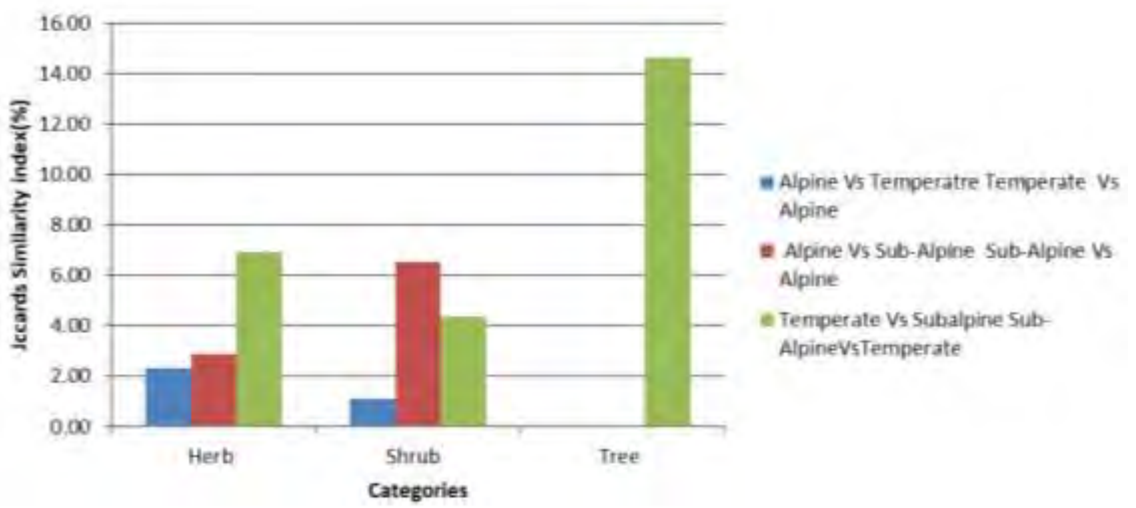


Figure 24: Jaccards Similarity index of Herb, Shrub and Tree in three different types of forest in Sikkim Himalayas

same kind of landscapes and rainfall pattern in both types of forest are mostly the same. In terms of herbs and shrubs also broad leaf forest and mid altitude forest shared the higher number of species. species similarity between broad leaf forest and alpine forest showed that there is 4.55% similarity in herbs and 8.69% similarity in shrubs which is bit low as the landscapes they share are far different from each other and weather patterns also varies in these landscapes (Table 14). Similarity index between mid-altitude forest and alpine forest showed that there is 8.45% similarity in terms of herbs and 9.70% similarity in terms of shrubs species this might be because mid altitude forest also share some characteristics of alpine scrubs as they share the same boundary (Fig 24).

Results

Table 14: Phytosociological structure across different vegetation categories

Categories	Abundance	Occurrence	Diversity	Jaccard's
Broad leaf (Herb)	Pteridophyte's (fern's) most abundant herb species, followed by *Strobilanthes sp* and *Pilea scripta*	Average number of twenty five herbs occur in each plot	Highest Diversity of Herbs in comparison to other forest types (3.53) , also comparison with Tree and Shrub	1. Very low similarity in herbs between Broad leaf and alpine. (4.55%) 2. High similarity between herbs of broad leaf and coniferous forest (10.65%)
Broad leaf (Shrub)	*Arundinaria maling* most abundant shrub species, followed by *Rubes sp.* and *Mahonia sikkimensis*	Average number of fifteen shrubs noticed in each plot	Diversity of Shrubs was low in comparison to herbs and trees (2.21), it was also low in comparison to other forest types	1. 8.96% similarity in shrubs between broad leaf and alpine forest.. 2. 9.03% similarity in shrubs between broad leaf and coniferous .

Categories	Abundance	Occurrence	Diversity	Jaccard's
Broad leaf (Tree)	*Rhododendron arboreum,* was the most abundant tree followed by *Bazee* (Local name), and *Castanopsis species*	Average number of Five Tree's occur in each plot	Tree diversity was high in comparison with mixed coniferous forest (3.44), and with herb it was low but with shrub it was high	1. Absence of trees in alpine scrub. 2. 11% similarity in trees between Broad leaf and coniferous forest.
Mixed coniferous (Herb)	*Potentilla sp* was the most abundant species of herb followed by *Anaphalis* and *Prunela vulgaris*	Average number of twenty two herbs occur in each plots	Diversity of herbs was high in comparison with shrubs and trees (3.27), it was high with alpine but low with broad leaf forest.	1. 10.65% similarity between in coniferous and broad leaf. 2. 8.45 % similarity between coniferous and alpine forest
Mixed coniferous (Shrub)	*Daphne cannabina,* was most abundant species followed by *Salix sp, and Rhododendron falconerii*	Average number of five shrub occur in each plots	Shrub diversity was low in comparison with trees and herbs (2.74), but it was high in comparison with broad leaf and alpine forest	1. 9.7% similarity between coniferous and alpine forest. 2. 9.09% similarity between coniferous and broad leaf forest. .

Categories	Abundance	Occurrence	Diversity	Jaccard's
Mixed coniferous (Tree)	*Abis densa* was a most abundant tree followed by *Rhododendron arboretum and Engelharditia spicata*	Average number of eight trees occur in each plots	Diversity of tree was low in comparison with mixed coniferous forest (3.04), also low in comparison with herbs but high with shrub	1. No trees at alpine scrub 2. 11% similarity between broad leaf and coniferous.
Alpine Scrub (Herb)	*Anaphalis sp* was the most abundant species followed by *Aconogonum molle, Cassioppe fastigiata,* and *Primula kingii*	Average 12 number of herbs per plot	Diversity of herb was low in comparison with other two forest types, but was high in comparison with shrub	1. 4.55% similarity in between alpine and broad leaf forest. 2. 8.45% similarity in between alpine and coniferous forest.
Alpine Scrub (Shrub)	*Juniper (Sang),* was the most abundant shrub species found in alpine scrub followed by *Rhododendron nivale and Salix sp.*	Average 7-8 number of shrubs in average per plot	Diversity of shrub was almost the same with other forest types, but low in comparison with herb	1. 8.96% similarity in between alpine and broad leaf forest. 2. 9.7% similarity in between alpine and coniferous forest.

3.4 Mapping along economic value

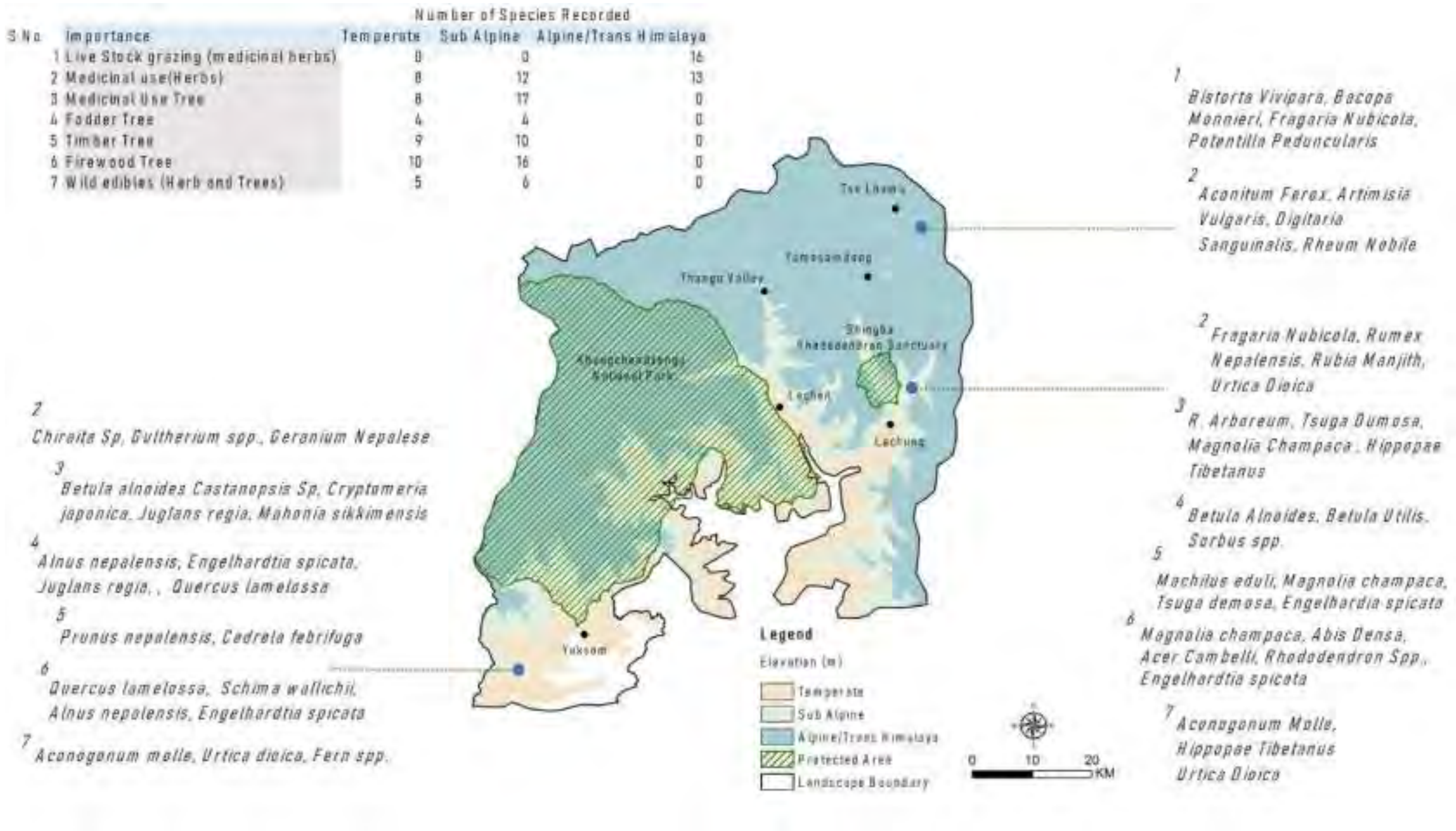
Land use system in the Himalayas support a large diversity of socio-economic needs in sustainable way and in many different climatic conditions. Environmental and agro-ecological functions of trees (soil protection, water control, soil fertility maintenance, conservation of biodiversity, etc.) as well as their various functions of production (wood, food, fodder, medicines, etc.) are remarkably expressed in forest ecosystems. In project area, the importance of species lie along the subsistence use by indigenous people as the majority of the landscape is protected area.

3.4.1 Methodology

A semi-structured questionnaire was prepared to examine rural households in the Upper Teesta Landscape. As a part of stakeholder consultation, socio-economic survey were conducted to assess the social profile of the people, their dependency on forests for various importance needs like *livestock grazing, medicinal herbs, medicinal tree, fodder tree, timber tree, firewood tree, wild edibles*. Additionally, observational field data were recorded to assess the needs during the field survey. A key focus was to collect quantitative information on key impact indicators for the vegetation health assessment i.e. - persons engaged in collection of forest resources (NTFP, fuel wood etc.); harvesting pattern; time and distance travelled/spent on collection of resources.

3.4.2 Results

The primary field information was spatially plotted to create map based on the elevation profile (temperate, sub alpine & alpine/trans Himalaya) and the importance (Fig 25). Dominant species were put on the map and a table (Table 15) of all the species recorded during the field was prepared.



S No	Importance	Number of Species Recorded Temperate	Sub Alpine	Alpine/Trans Himalaya
1	Live Stock grazing (medicinal herbs)	0	0	16
2	Medicinal use(Herbs)	8	12	13
3	Medicinal Use Tree	8	17	0
4	Fodder Tree	4	4	0
5	Timber Tree	9	10	0
6	Firewood Tree	10	16	0
7	Wild edibles (Herb and Trees)	5	6	0

Figure 25: Dominant species based on elevation and importance

Table 15: Importance of Species at Different Altitudinal zones

Importance Value	Temperate	Sub -Alpine	Alpine
Livestock grazing			*Anaphalis sp, Artemisia vulgaris, Bistorta Vivipara,* Bacopa monnieri, *Cynodon dactylon, Cassioppe fastigiata, Fragaria nubicola, Pedicularis Sp, Potentilla peduncularis, Primula sikkimensis, Primula glomorata, Primula denticulate, Rheum Nobile, Aconogonum molle.*
Medicinal Herb	*Chiraita Sp, Ammmomum subulatum, Gultherium sp, Geranium Nepalese* (+ 5 Species)	Bacopa monnieri, *Aconogonum molle, Fragaria nubicola, Rumex nepalensis, Rubia manjith,* Urtica dioica (+7 Species)	Bacopa monnieri, *Aconitum ferox, Artimisia vulgaris, Digitaria sanguinalis, Heracleum wallichii,, Houttuynia cordata, Persicaria nepalensis, Potentilla Sp, Piper boehmeriifolium, Prunella vulgaris, Heracleum nepalense, Rheum Nobile*
Medicinal Tree	Betula alnoides, *Pieris ovalifolia, Castanopsis Sp, Cryptomeria japonica, Erythrina indica, Juglans regia, Magnolia doltsopa, Mahonia sikkimensis*	*R. Arboretum, Rhododendron fulgens, Terminalia Sp, Tsuga dumosa, Prunus nepalensis, R. Thomsonii Schima wallichii, magnolia champaca , R. Berbatum, R. Falconerii, R. Grandii. Hippopae tibetanus, Prunus nepalensis, Cedrela febrifuga, Exbucklandia populnea, Betula alnoides, Betula utilis, Sorbus sp, Vibernum, Schima wallichii*	

Importance Value	Temperate	Sub -Alpine	Alpine
Fodder Tree	*Prunus nepalensis, Cedrela febrifuga, Exbucklandia populnea,*	*Betula alnoides, Betula utilis, Sorbus sp, Vibernum, Schima wallichii*	
Timber Tree	*Alnus nepalensis, Cryptomeria japonica, Engelhardtia spicata, Juglans regia, , Quercus lamelossa, Quercus lineate, Saurauia nepalensis, Spondias axillaris, Schima wallichii*	*Juniperus recurva, Machilus eduli, Magnolia doltsopa, Magnolia champaca, Pieris Formosa, Tsuga demosa, Macaranga denticulate, Engelhardia spicata*	
Firewood Tree	*Quercus lamelossa, Quercus lineate, Saurauia nepalensis, Spondias axillaris, Schima wallichii, Alnus nepalensis, Eurya acuminate, Engelhardtia spicata, Machilus edulis, Symplocos theifolia,*	*Machilus eduli Magnolia doltsopa, Magnolia champaca, Pieris Formosa, Abis Densa, Acer Cambelli, Acer caudatum, Rhododendron Sp, Pieris ovalifolia, Q. Glauca, Hippopae tibetanus, Erythrina indica, Eurya acuminate, Engelhardtia spicata, Brassatopsis mitis, Pieris ovalifolia*	
Wild edibles (Herb & Trees)	*Aconogonum molle, Ammmomum subulatum, Urtica dioica, Fern sp, Prunus sarosides, Choerospondias axillaris*	*Aconogonum molle, Hippopae tibetanus Urtica dioica, Fern sp, Gultherium sp,*	*Rheum Nobile, Aconogonum sp,*

3.5 Health Indicators for Assessment of Biodiversity

The sequential changes in the nature of biodiversity at various levels constitutes the health of a landscape. The changes are usually attributed to natural or anthropogenic factors, which are the composites of multiple processes. In a study (FAO, 2016), have tried the quantification of the indicators for the assessment of the health of the land use and faced numerous technological and financial challenges. Therefore, it is imperative to develop a set of indicators to achieve an efficient monitoring system that integrates spatial science and ecology driven by the users living and working in the landscape. To develop a common platform for stakeholders and to understand the changes and the nature of changes, an easy adoption and implementation approach should be developed. The approach should define each indicator and its associated continuum metrics. Our approach is broadly defined in two categories based on its implementation process.

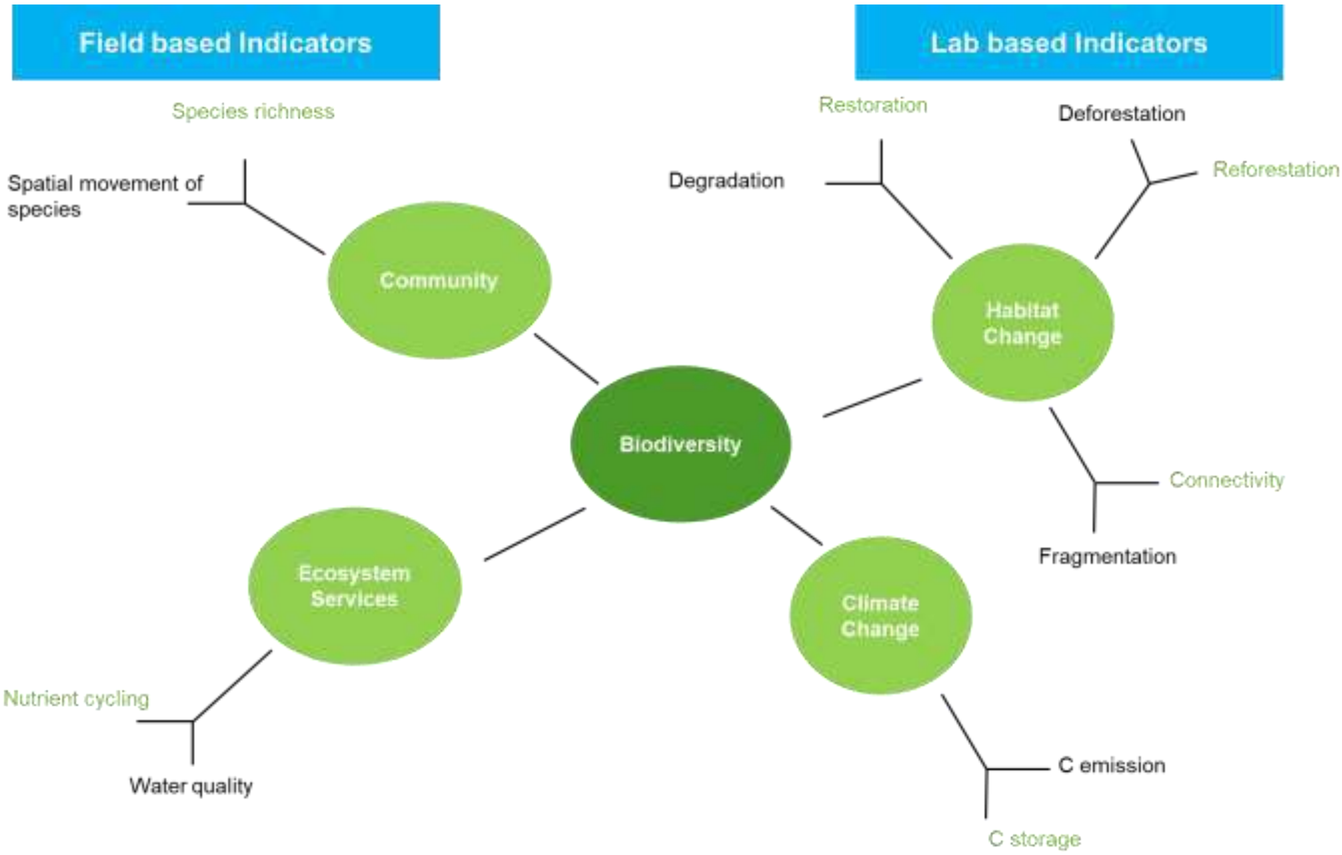


Figure 26: Diagrammatic representation of Health Indicator Assessment

3.5.1 Habitat Change Analysis

Context: Intensification of land uses have resulted in changes in land cover which are driven by various factors like agriculture, developmental purposes, livestock production, tourism etc. Changes in land use can lead to the destruction or modification of Biodiversity. Biodiversity also gets affected due to natural phenomenon like landslides or any aberrant weather conditions. The project landscape consists of various ecoregions and the pathways/drivers of change in the regions varies greatly.

Degradation	Deforestation	Desertification
Temperate & Sub Alpine		Alpine
Forest (Dense)	Forest	Scrub/Meadows/Steppe
Clear cutting, Landslides etc.		Grazing,Drought etc.
↓	↓	↓
Forest (Open)	Other Land Use	Bare Area/Less Scrub

Figure 27: Pathways of changes in habitat

Pathways potentially cause fragmentation of the habitat into isolated patches and consequently disturbs the overall connectivity of the landscape. Pathways are also attributed to changes in ecological succession of habitats with low conservation values.

Indicators: We defined three indicators within this theme, which are:

- Forest degradation & restoration: It is referred to as changes within the forest class that negatively affect the stand or site and, in particular, lower the production capacity and decrease biomass content. The decrease in canopy cover for the trees is generally called forest degradation.
  Restoration of forests is referred to increase in canopy cover or assisted natural regeneration of trees in open patches of forest.

- Deforestation/Reforestation: Deforestation is called permanent removal of forest cover and withdrawal of land from forest use for various purposes
  Reforestation is diversion of any land use to forest land for plantation purpose.

- Forest fragmentation & connectivity: Forest fragmentation is a landscape-level process that consists of two interdependent components: forest loss and spatial pattern changes to which species respond differently. It leads to habitat modification and subdivision of plant and animal populations. Thus, changes in species interactions occur leading to further tree mortality and destruction as observed at the edges of forest fragments. Forest connectivity is considered as function of forest loss. Greater connectivity of forest refers to organized and compact contiguous patches of forest and vice versa.

Methodology: An integrated methodology was defined for each indicator to include spatial assessment as well as field based measurements.

3.5.1.1 Forest degradation & restoration

Vegetation Index (VI) like Normalized Difference Vegetation Index (NDVI) is an indicator that can be remotely sensed by satellites measuring wavelengths of the light absorbed and reflected by vegetation. It gives an indication of the vegetation state of an ecosystem and can thus be used to characterize habitat degradation. Vegetation Index can be further converted into canopy density using field-based measurements (Fig 29). In the present study, we have utilized two time point data for the degradation assessment in the project area (Fig 28).

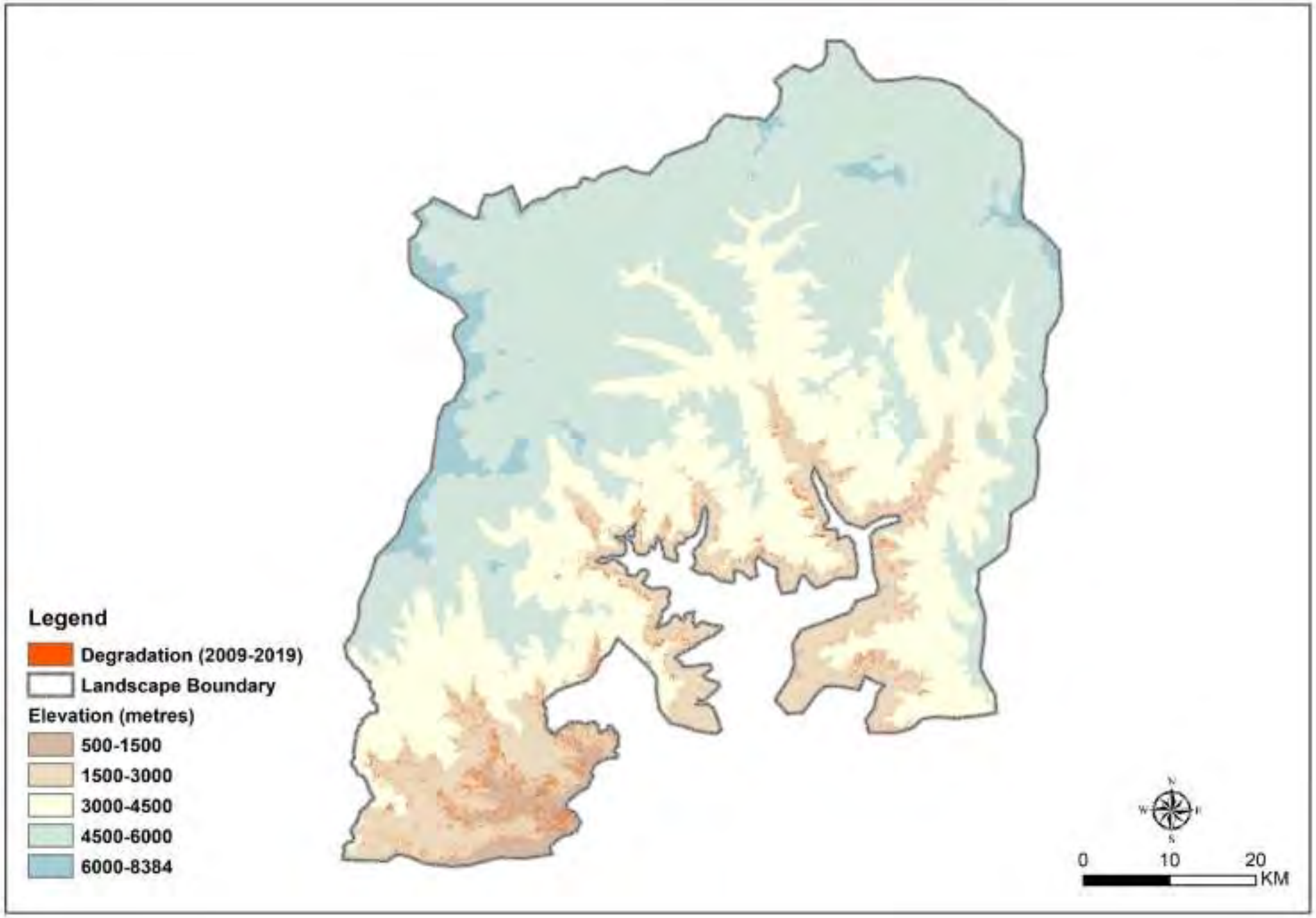


Figure 28: A Degradation Map of the Project Area in Sikkim

Field based measurements can be easily done using a densiometer or a fish eye photographic lens that can be mounted on the stand-alone camera or on a camera of any smart phone.

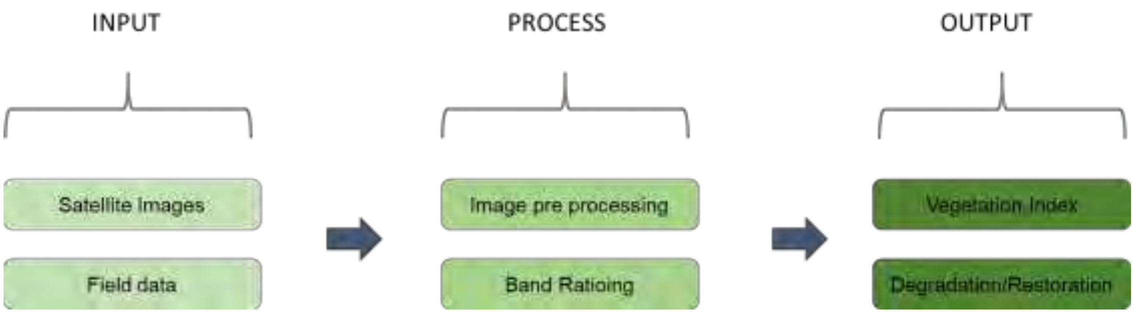


Figure 29: Pathways of changes in Degradation Assessment

3.5.1.2 Deforestation/Reforestation:

Analysis of land use land cover (LULC) over a range of time periods can assist in finding the areas of change in forest land to other land use. As the spatial and temporal coverage of satellite images are continuously improving, it is possible to produce land use land cover at defined time intervals to monitor the forests (Fig 30).

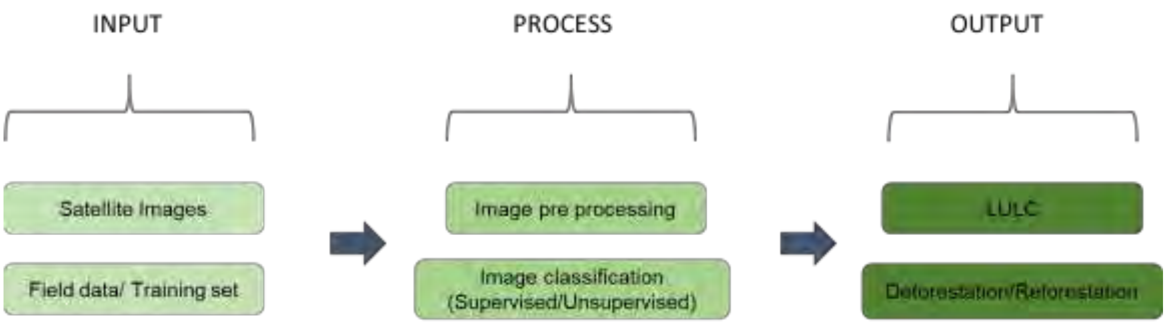


Figure 30: Pathways of changes in Deforestation Assessment

3.5.1.3 Fragmentation Analysis in the Project Area:

Forest fragmentation & connectivity: Fragmentation can be estimated as a function of forest cover obtained from LULC analysis. It can be estimated by comparing multi temporal land cover maps in the landscape fragmentation tool.

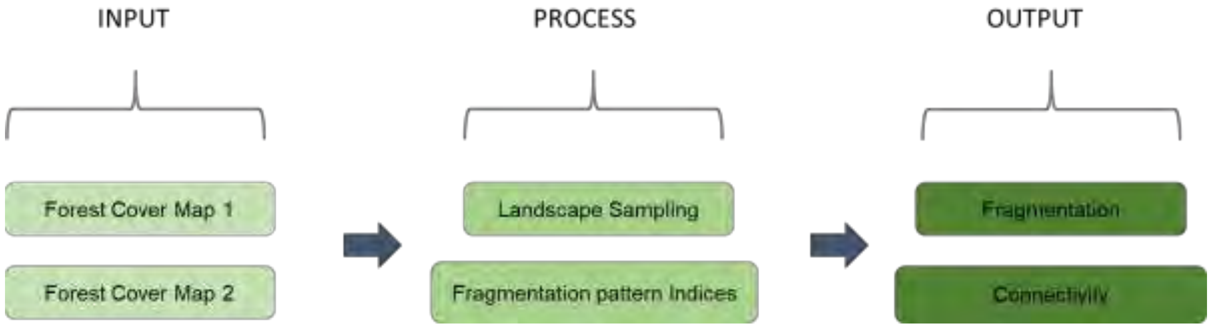


Figure 31: Pathways of Fragmentation Assessment

Table 16: List of Data Availability and Tools for the fragmentation assessemnt

Data	Temporal Coverage	Spatial Resolution	Software
Global Thematic data			
Global LULC	1998-2002, 2003-07, 2008-12, 2015-18	300 meters (CCI, ESA),	Fragstat, Lecos (QGIS), Fragmentation tool (ArcGIS)
GlobeLand30	2000 &2010	30 metres (GLC, China)	Fragstat, Lecos (QGIS), Fragmentation tool (ArcGIS)
MODIS LULC	2000-2010	500 metres (NASA)	Fragstat, Lecos (QGIS), Fragmentation tool (ArcGIS)
Satellite data			
Landsat Series	1972 - Current date	60 metres (1-5 MSS) & 30 metres (TM, ETM+, OLI)	ArcGIS, Erdas Imagine, QGIS
Sentinel Series	2016 - Current date	10 metres	ArcGIS, Erdas Imagine, QGIS, SNAP

Fragmentation increases the vulnerability of patches to external disturbances with consequences for the survival of these patches and of supporting Biodiversity (Nilsson and Grelsson, 1995). Fragmentation was computed as the value of continuity of vegetation cover using the Landscape Fragmentation Tool (LFT) developed by NASA EPA (Fig 31). The value was used in conjunction with the total proportion of vegetation cover in the landscape to produce an index. The forest fragmentation index classified the vegetation cover into four classes i.e. patch, edge, perforated and core. The core category was further divided into small core, medium core, and large core based on the area of the core tract. The main categories were defined based on the grid size that was set to be 100 metres. The input layer for the fragmentation index was categorized in two classes i.e. vegetation and non-vegetation cover. The details of the four classes are listed below:

Core pixels were any vegetation pixels that were more than 100 meters from the nearest non vegetation cover pixel-

a. small core patches had an area of less than 250 acres
b. medium core patches had an area between 250 and 500 acres
c. large core patches had an area greater than 500 acres

Patch pixels were within a small vegetation fragment that did not contain any core vegetation pixels. Perforated and edge forests are with 100 meters of non-vegetation pixels but were part of a tract containing core pixels:

- edge pixels were along the outside edge of the vegetation tract
- perforated pixels were along the edge of small vegetation gaps

The vegetation fragmentation index comprised two parts. The first is the total vegetation proportion (TVP):

$$TVP = \frac{Total\ \ vegetation\ cover}{Total\ non\ vegetation\ cover} \text{ ....Eq. 5}$$

The TFP was used as a general value to provide a basic assessment of vegetation cover in the region as a non-linear relationship between the amount of forest in a region and the level of forest fragmentation. The TFP ranged from 0 to 1.

The second component of the index was to measure the vegetation continuity (VC) within the region. The VC value examined only the vegetated areas within the region:

$$VC = \frac{Weighted\ vegetated\ area}{Total\ vegetation\ area} \times \frac{Area\ of\ largest\ interior\ vegetation\ patch}{Total\ vegetation\ area} \text{ ....Eq. 6}$$

The VC measured specifically utilized the results from the vegetation fragmentation model. Weighting values for the weighted vegetated area for each fragmentation class were derived from median TVP values as shown by the equation below. The area of each fragmentation class was then multiplied by the weight.

$$WVA = (1.0 * core) + \left(0.8 * (perforated) + (0.5 + edgel) + (0.2 * patch)\right) \quad \dots \dots . \text{Eq. } 7$$

The analysis shows that majority of the forest is under low fragmentation category (Table 17 and Fig 32).

Table 17: Forest category wise Fragmentation Percentage

Land Use Class	High	Medium	low
Broadleaved Forest	10	45	60
Mixed Coniferous Forest	2	6	25
Scrub	55	30	10
Alpine Meadows	20	2	0
Alpine Thickets	2	7	2
Sub Alpine Thickets	1	10	3
Morainic Scrub	10	0	0

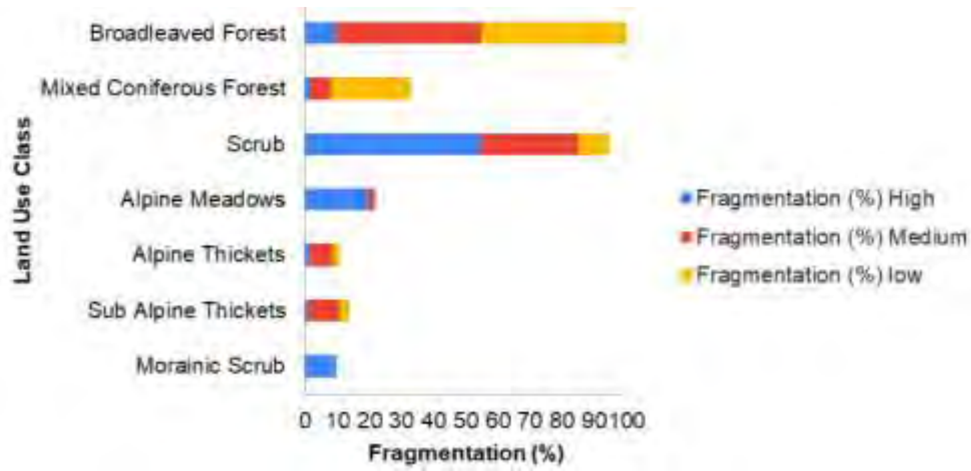


Figure 29: Fragmentation (%) in various Land Use classes

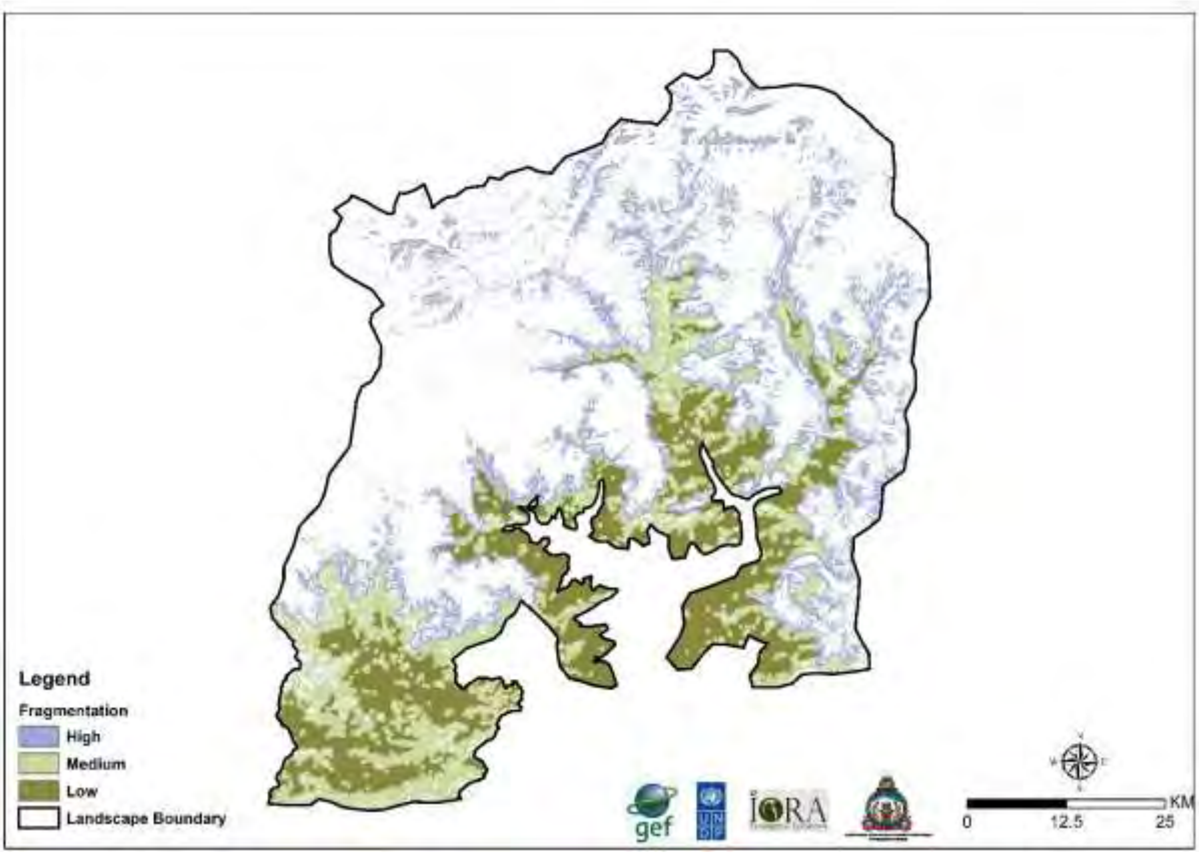


Figure 30: Map Showing Fragmentation in the Project Area

3.5.2 Climate Change Analysis

Context: Forests play a crucial role in regulating global climate by regulating carbon cycle and contain a substantial proportion of the world's terrestrial Biodiversity. Deforestation and forest degradation in the tropics and sub-tropics have a large negative impact on terrestrial Biodiversity, and thus on the provision of those ecosystem services that are most closely linked to Biodiversity. One of the key supporting services provided by forests is carbon removal from the atmosphere (sequestration) and the long-term storage of this carbon in the form of biomass, dead organic matter and soil carbon pools. In past few decades increase in deforestation and degradation have resulted in large scale carbon emission. As climate change tends to worsen due to the rise in atmospheric CO_2 concentrations may temporarily affect plant photosynthetic activity and net ecosystem productivity (NEP) (Cramer et al., 2001; Long et al., 2004). Regular monitoring of carbons stock on spatial scale in different carbon pools can aid in estimation of carbon emission and sink to identify specific land use areas.

Indicators: We considered two indicators to identify the potential risk to Biodiversity linked with climate change:

Carbon Storage: It is the ability of a forested ecosystem to sequester or remove CO_2 from atmosphere in the form of biomass through photosynthesis. The estimation of present biomass in forest carbon pools defines the present carbon storage/stock of the landscape.

Carbon Emission: Carbon emission is the process of adding CO_2 concentrations in the atmosphere by removal of biomass in the forested areas. Temporal monitoring of carbon stocks (compare carbon stock of different time points) on spatial scale can assist in estimation of carbon emission in the landscape.

Methodology: Satellite based measurement can be integrated with field data to generate carbon stock maps for user defined interval to quantify changes in carbon stock and also vulnerable areas of change:

- Carbon Storage:
  A forest carbon estimates the carbon stock by relating canopy density layer derived from NDVI with forest biophysical attributes such as forest cover and biomass.
  The model includes a stratified vegetation layer representing different forest cover types. Each stratum is represented using the pair-wise values of forest plot biomass and the co-located canopy pixels in geographic terms. These pairs are used as an input to either an OLS regression or a simple relationship (linear or nonlinear) for statistical correlation. The resulting equation can be used as a calibration algorithm to compute forest carbon values from the canopy density value. Existing field biomass data can be utilized for statistical correlation (Fig 31).

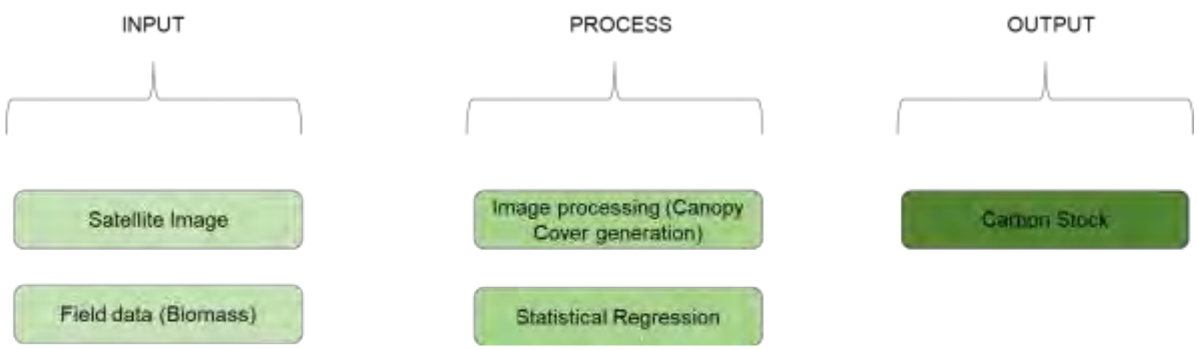


Figure 31: Pathways for Carbon Stock Assessment

- Carbon Emission:
  Carbon Emission can be estimated as a function of change in carbon stocks over two time-points (T1 & T2). Detailed methods to calculate the net balance of carbon emissions and removals are described in the Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance (IPCC, 2003) and the 2006 IPCC Inventory Guidelines (IPCC, 2006). The forest carbon map of two time-points can be created using the above mentioned step and can be run through a change detection algorithm to identify emissions (Fig 32).

Figure 32: Pathways for Carbon Emission Assessment

3.5.3 Field Based Health Indicators

3.5.3.1 Community- Species Richness

Context: Detailed assessment of taxonomic richness requires reliable lists of species. Since generation of detailed lists is difficult in quick assessment, alternative approaches are required. One such approach is to estimate richness at a family or community level than at species level. Local people can often provide very quick and reliable estimates of the species present. In the present study based on survey and the analysis (as detailed below) of abundance a community species richness map was prepared (Fig 33).

Indicators & Methodology:

Measure of Richness:

i) Abundance & Distribution of native floral species; report by Local people through interviews:

Local people, especially representatives of indigenous groups, may have detailed knowledge of the presence, and even the abundance, of species of some groups that are important to them, even though their concept of species may not be consistent with taxonomic orthodoxy. A checklist of species (local names) can be prepared by doing transects or simple quadrate plot. Later, interviews can be conducted provide a very rapid approximation of "species" richness in some groups and more importantly the decline/increase in abundance of some taxa.

ii) Identification of spatial movement of species:

Documenting changes in the spatial position of species, as well as the migration rate between them, may be important for many species (Hanski 1991). In studies, shifting of native species northwards is recorded Sikkim. This could be due to the forest is being fragmented as a consequence of climate change, logging or other human activities and. Roads, shrinking habitat, loss of certain tree species and other similar phenomena can cause important changes to the reproductive structure of a large forest type. The assessment can be undertaken by documenting geo-coordinates and the other topographic parameters i.e. elevation, slope etc. of the occurrence of the species. The collected data can be plotted on the map using GIS software for further analysis.

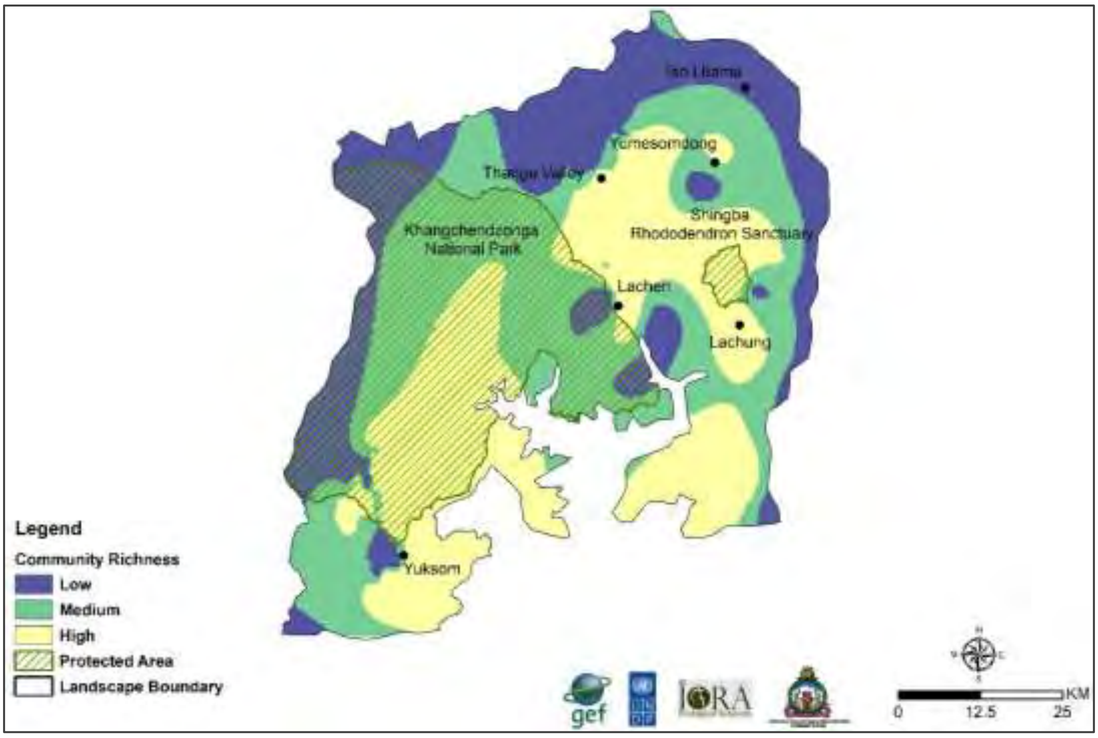


Figure 33: Map showing community richness in the Project Area

iii) Disturbance Index:

The disturbance index was calculated as a function four landscape metrices i.e. fragmentation, juxtaposition, porosity and interspersion. The landscape metrices were supplemented by spatial distribution of major forest types in proximity to roads, villages and landslide prone areas. A buffer of 2-5 kilometre was created around the roads and villages to define the level of disturbance (Fig 34). The disturbance index was computed with a linear combination of the defined parameters based on the probabilistic weightage. The weightages of the parameters were calculated based on the focussed group discussions and field survey. The mathematical equation used for calculating the disturbance index is as follows:

$$DI = \sum_{i=1}^{n} (frag_i * wt_{i1} + Por_i * wt_{i2} + RD\&VD_i * wt_{i3} + Int_i * wt_{i4} + La_i * wt_{i5} + Jux_i * wt_{i6})$$

…………………….Eq. 8

Where, DI= Disturbance index, Frag=Fragmentation, Por= Porosity, Int= Interspersion, Jux=Juxtaposition, RD &VD= Road & Village Density, La= Landslide prone area, wt= weights.

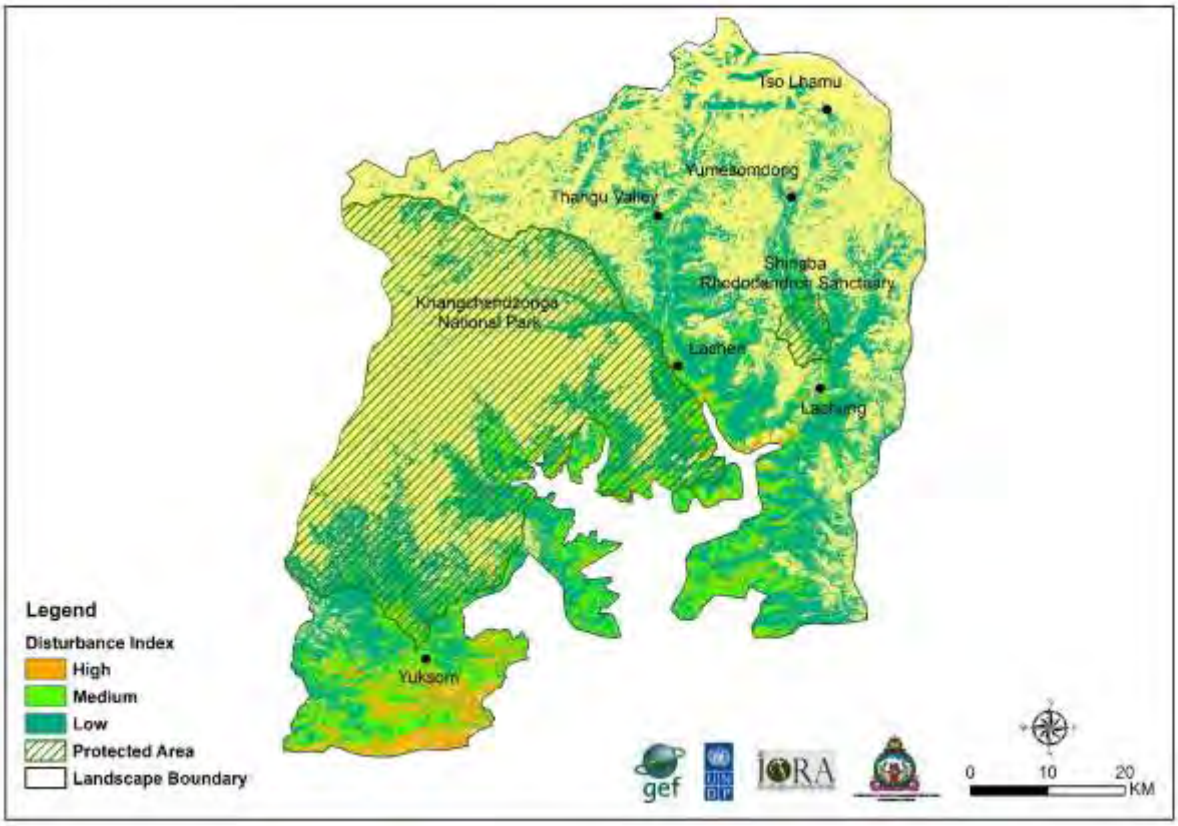


Figure 34: Map showing disturbance index in the Project Area

3.5.4 Ecosystem services: Nutrient cycling & water quality

Context: Diverse ecosystem processes sustain the ability to maintain the community structure and levels of Biodiversity within any system, the services like nutrient cycling and water run off through forest catchment areas are considered here to be the most useful as potential indicators of changes in those services which maintain and shape Biodiversity. Nutrient cycling describes the flow of nutrients, including carbon and nitrogen, as well as potassium, phosphorus, calcium, sodium, magnesium and iron through the ecosystem. As the two services are intimately related, the nutrients can be lost due to run off into the streams and rivers and change the water quality.

- **Nutrient recycling:**

Soil conductivity and pH: Soil conductivity and pH may give an indication of nutrient levels in the soil, although these measures will not identify what those nutrients are. It is important that soil type and parent material are considered when comparative sites are chosen.

- **Water quality:**

Estimation or diversity of aquatic streams floral species & organisms: This indicator is related to the correlation of diversity and abundance of various floral species and organisms with the water quality variables, such as the quantity of suspended organic matter, nutrients, and pollutants in the water. Stream invertebrates are easy to sample, and can be sorted and identified to the family level by technicians with only a moderate level of training. The occurrence of species along with status of water quality at various sites can be documented and further corroborated with scientific literature to derive results.

CHAPTER 4

RECOMMENDATIONS

4.1 Conservation in the Landscape

The Upper Teesta - Kanchendzonga landscape being home to many rare and endangered species, biodiversity conservation has been made a top priority in Sikkim. Kanchenjunga Landscape that encompasses diverse ecological zones and has already been designated under protected area network Kanchenjunga Biosphere Reserve for a better management and conservation of the biodiverse floral and faunal resources. In the year 2001, Sikkim was included in government of India's Action plan for the conservation of Biodiversity. This precipitated in the development of the Sikkim Biodiversity Strategy and Action Plan (2003). The primary emphasis under this plan was to identify potential and availability of biological diversity, both wild and cultivated/domesticated, found in the State's different ecoregions, and outlined strategies and an action plan for their conservation. After nearly a decade, as the scientific knowledge accumulated, stakeholders attained greater awareness and realized the need for improved conservation and management strategies for biological diversity, and the issues and concerns emerged more rapidly than ever before; Government of Sikkim had initiated a thorough revision and update of the 2003 Biodiversity Action plan. At the same time, Japan International Cooperation Agency assisted State Biodiversity Strategy and Action Plan, 2010 was evolved keeping in view all the significance of the biodiversity in the State. In addition, the significant conservation scope for Biodiversity in Sikkim requires a combination of large areas that can serve as population sources and smaller areas that can serve as links or repositories for habitat-sensitive species for which habitat conditions, and not area, is the primary consideration.

Various research to this effect shows that climate change has a remarkable effect on both floral and faunal diversity in Sikkim that might even lead to serious consequences like the extinction of some species (Telwal et al., 2013 and Kumar and Pandit, 2019). Geospatial Mapping and assessment of biodiversity value has a crucial role in identifying key areas for conservation and establishing conservation priorities. Extent and quality of habitat conditions and phytosociological characters are often used as surrogate for biodiversity characterization (Nelson et al., 2011). Remote sensing based assessments are being utilized to generate biodiversity maps and health indicators (Nagendra et al., 2013; Roy et al, 2013).

4.1.1 Conservation Priorities in the Upper Teesta –Kanchendzonga Landscape

A. Conservation of Biodiversity:

Mountain ecosystems across the globe are most vulnerable to the effects of climate change (Dobrowski and Parks, 2016; Pandit, 2017). Historically in Sikkim Himalaya region nearly 4250 plant species (Hooker, 1872) has been reported with almost a third of this diversity were reported above 4000 m elevations. The areas above 4000 m in the Lachen valley has a presence of about 350 vascular plant species, of which nearly 32% are endemic to the Eastern Himalaya (Telwal, 2013). The ecosystems at lower elevations in the sub-tropical and temperate zones are seeing varied land-use and land-cover changes due to the development of roads, hydro-projects driven by deforestation for various uses in the recent past, by unprecedented hydropower development (Pandit et al, 2007; Grumbine and Pandit, 2013). The cumulative effect of factors such as increased fragmentation of montane floras because of human activities, topographic isolation and endemism along with effects of climate change could result in escalation of extinction rates. The situation is further getting aggravated as a result of climate change leading to many species showing a migration towards higher region as has also been presented in a study by Telwal et al, 2013 and has been annexed in this report (Annexure III). Singba (Rhododendron) Wildlife Sanctuary conserves only 3% of top conservation value areas in current and future climates (Kumar and Pandit, 2019) which needs to be expanded by expanding the area under protection in the higher altitude. One such study conducted by Kumar and Pandit in 2019 suggests that the coverage of PA network in Sikkim Himalaya should increase to 43% of the state's geographic area (with the proposed additional geographic area of 896 sq. km) to offset the negative impacts of on-going climate change in the region. This includes designation of three more potential areas as new PAs in the region, i.e. areas around Yumsedong, Lachen, and Chungthang.

B. Human-Wildlife Conflict:

The main conflict animal of Trans-Himalaya is Tibetan Wolf (*Canis lupus chanco*) locally called Chanco and there is least evidence of Snow leopard conflict in past. The feral dogs is another conflict animal introduced by humans especially in defence areas as they feed on defence food waste. Himalayan Black bear, Wild Boar, Monkeys, porcupine have been reported to have affected human life and livelihoods in lower elevation areas.

Issues with Feral dogs: Feral dogs' issues are more prominent in Northern district of Sikkim where the dogs feeding on defence waste are attacking yak calves and other small wildlife species like marmots and pika. Goth Dog is also very ferocious that preys on ground nesting birds and small mammals, which needs to be monitored in order to protect faunal biodiversity.

C. Defence activities:

It is another important issue in the context of Sikkim sharing international boundaries with three countries namely China, Nepal and Bhutan. The defence is the important stakeholders of snow leopard landscape of Sikkim. The proper sensitization and awareness should be done about the landscape and presence of Rare, Threatened and Endangered Species and also the significance of biodiversity in the landscape.

D. Waste Management:

Proper waste management should be followed and community level sensitization should be done as well. It is helpful in checking and monitoring illegal activities in the landscape but Proper waste disposal practices should be followed. A proper Garbage Management Plan to be put in place within KNP and Singba Rhododendron Sanctuary.

E. Tourism activities:

It is boon to the community and local stakeholders but proper carrying capacity should be maintained. Vehicular movement in the pristine landscape should be regulated and monitored. Tourists should be well versed and aware about the landscape and community. Maximum benefits from Tourism should go to local community.

F. NTFP collection:

The collection should be monitored and the products should fetch good market price for livelihood upliftment of community. Proper trainings and support should be given to community for value addition and product development as Sikkim has potential to flourish in global market due to organic branding. Unsustainable collection of firewood from

Rhododendron and Juniper forests in huge quantities. Some of the regulatory provisions to be made on currently heavily overgrazed and clandestine smuggling of medicinal plants and other forest produce from KNP. Yak grazing is not a traditional activity within KNP therefore should be monitored.

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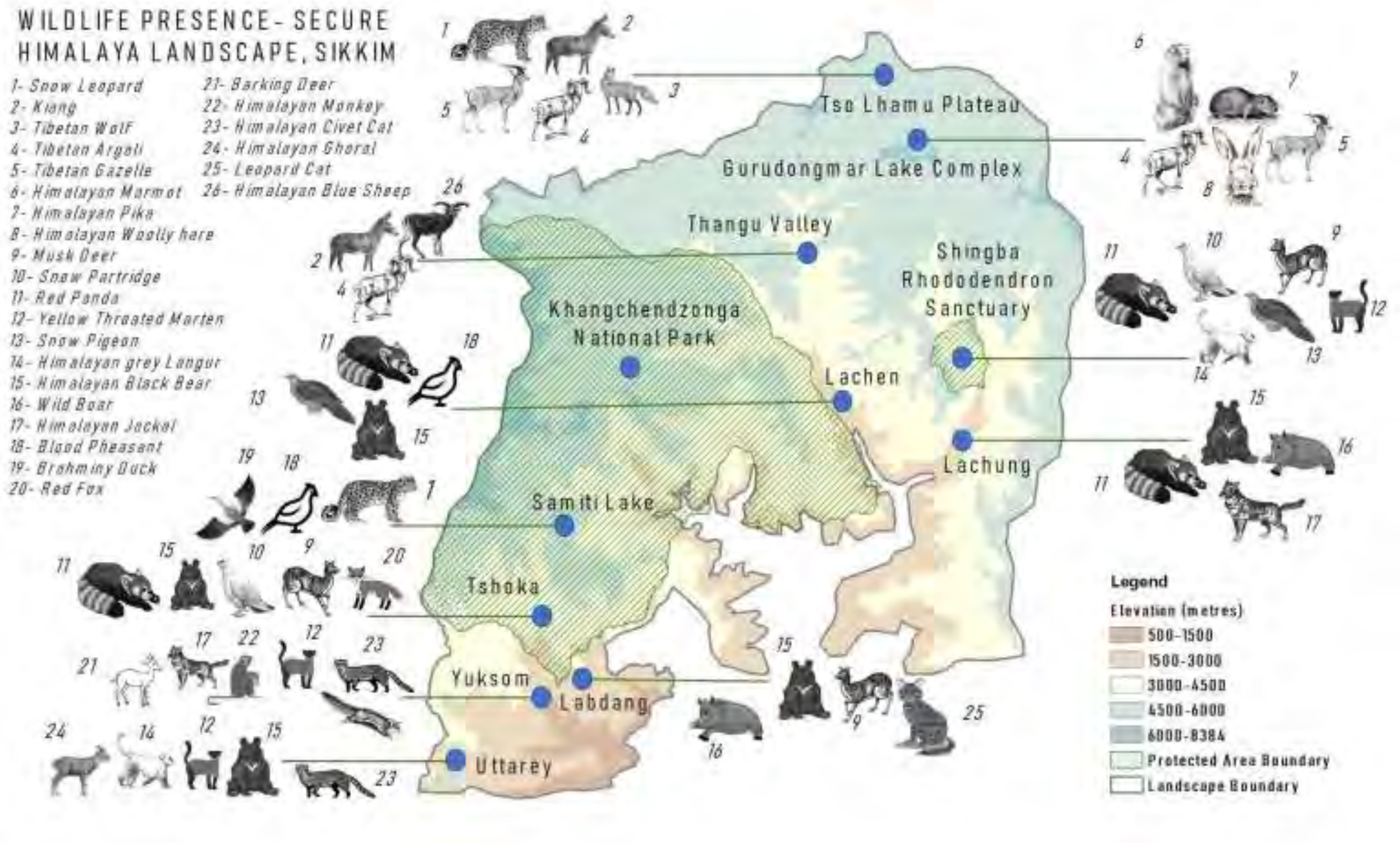
ANNEXURE I:

Presence of Wildlife in the Upper-Teesta Kanchendzonga Landscape



ANNEXURE II
LIST OF FLORA IN THE PROJECT LANDSCAPE

Floral Presence in Temperate forest:

S.No	Herb	Shrub	Tree
1	*Aconogonum molle*	*Eurya acuminate*	*Acer campbelli*
2	*Ammmomum subulatum*	*Actinodaphne sikkimensis*	*Abies densa*
3	*Anaphalis spp*	*Edgeworthia gardenerii*	*Picea spinulosa*
4	*Artemesia vulgaris*	*Mahonia nepalensis*	*Andromeda villosa*
5	*Arundinaria malling*	*Pieris formosa*	*Alnus nepalensis*
6	*Aster sps.*	*Mahonia sikkimensis*	*Pieris ovalifolia*
7	*Austilbe ribularis*	*Maesa chisia*	*Betula alnoides*
8	*Bidens pilosa*	*Euphorbia griffithii*	*Bambusa sp*
9	*Swertia chiriata*	*Berberis sp.*	*Brassaiopsis mitis*
10	*Brahmi sp*	*Rhapidophora decursiva*	*Castanopsis tribuloides*
11	*Carex sps*	*Rubus ellipticus*	*Pentapanax leschenaultia*
12	*Cissus elongate*	*R. companulatum*	*Cupressus*
13	*Cynodon dactylon*	*Rhododendon nivale*	*Leucosceptrum cannum*
14	*Cissus elongate*	*Rubus sp*	*Cryptomeria japonica*
15	*Cucumis sativus*	*Musa sp*	*Docynia indica*
16	*Setaria palmifolia*	*Symplocos theifolia*	*Erythrina indica*
17	*Digitaria sanguinalis*	*Vibernum spp*	*Eurya acuminata*
18	*Elatostema platyphyllum*		*R. arboretum*
19	*Equisetum debile*		*Engelhardia spicata*
20	*Eragrostic sps*		*Hippopae tibetanus*
21	*Asplenium sp.*		*Juglans regia*
22	*Fragaria nubicola*		*Juniperus recurva*
23	*Geranium sp*		*Nyssa sessiliflora*
24	*Geranium nepalense*		*Leucosceptrum cannum*
25	*Elatostema platyphyllum*		*Machilus edulis*
26	*Gerardiana diversifolia*		*Magnolia doltsopa*
27	*Gultherium sp*		*Eriobotrya petiolata*
28	*Carex sp*		*Michelia cathcartii*
29	*Heraclam wallichii*		*Magnolia champaca*
30	*Arisaema sp.*		*Pieris formosa*
31	*Rubia manjith*		*Pieris ovalifolia*
32	*Oxalis corniculata*		*Prunus cerasoides*
33	*Dendrobium sp*		*Quercus lamelossa*
34	*Pedicularis*		*Quercus lineate*
35	*Pilea scripta*		*R. companulatum*
36	*Potentilla*		*R. dalhousie*
38	*Aralia sp.*		*Rhododendron fulgens*

39	*Primula sp*		*Rhododendron hodgsonii*
40	*Prunella vulgaris*		*Saurauia nepalensis*
41	*Rumex nepalensis*		*Spondias axillaris*
42	*Persicaria nepalensis*		*Sorbus cuspidata*
43	*Urtica dioica*		*Schima wallichii*
44	*Strobilanthes sp.*		*Symplocos theifolia*
45	*Laportea terminalis*		*Symplocos theifolia*
46	*Smilax zeylanica*		*Terminalia myriocarpa*
47	*Tupistra nutans*		*Tsuga demosa*
48	*Eupatoraium sp*		*Tetradium fraxinifolia*
49	*Musa sp*		*Quercus lamelossa*
50	*Piper sps*		*Cedrela febrifuga*
51	*Rapidophora sp.*		*Ficus nemoralis*
52	*Rohdea nepalensis*		*Exbucklandia populnea*
53	*Impatiens sp.*		*Macaranga denticulate*
54	*Rosa sericea*		*Engelhardia spicata*
55	*Selaginella*		

List of Species found in Sub-Alpine forest:

S.No	Herb	Shrub	Tree
1	*Anaphalis sp.*	*Berberis insignis*	*Abies densa*
2	*Anaphalis hookerii*	*Lyonia ovalifolia*	*Acer caudatum*
3	*Arisaema sps*	*Bambusa sp*	*Albizia lebbeck*
4	*Artimisia vulgaris*	*Daphne cannabina*	*Cedrela febrifuga*
5	*Houttuyunia cordata*	*Schefflera impressa*	*Q. lamellose*
6	*Bistorta vivipara*	*Edgewordia gardenerii*	*Beilschmiedia sikkimensis*
7		*Salix sp*	*Betula alnoides*
8	*Bhrami*	*Lycopodum japonicum*	*Castanopsis spp*
9	*Oxalis corniculata*	*Mahonia nepalensis*	*Cryptomeria japonica*
10	*Carex haematostoma*	*R. thomsonii*	*Docynia indica*
11	*Cissus elongate*	*R. anthopogen*	*Juniperous recurva*
12	*Coriaria terminalis*	*Myrsine semiserrata*	*R. grande*
13	*Cynodon dactylon*	*R. wightii*	*Engelhardtia spicata*
14	*Digitaria sanguinalis*	*Rosa sericea*	*Eurya acuminate*
15	*Elatostema platyphyllum*	*Rubus ellipticus*	*Tsuga demusa*
16	*Eupatorium adenophorum*	*Symplocos theifolia*	*Juniperous indica*
17	*Pteris* sp.	*Vibernum sp.*	*Juniperus recurva*
18	*Fragaria nubicola*	*Arundinaria maling*	*Q. glauca*
19	*Lecanthus peduncularis*	*Eurya sp.*	*R. falconerii*
20	*Gaultherium sp.*	*Urtica dioica*	*Litsaea elongate*
21	*Gentiana*	*R. lepidotum*	*Machilus edulis*
22	*Heraclam wallichii*	*R. setosum*	*Magnolia campbelli*

23	*Dryopteris* sp.	*Euphorbia griffithii*	*R. barbatum*
24	*Impatiens sp.*		*Meliosma wallichii*
25	*Juncus sikkimensis*		*Michelia doltsopa*
26	*Juncus himalensis*		*Magnolia champaca*
27	*Rubia manjith*		*Pieris ovalifolia*
28	*Sphagnum sp.*		*Prunus cornuta*
29	*Pedicularis sp.*		*Prunus nepalensis*
30	*Potentilla sp.*		*Quercus lineate*
31	*Oxalis*		*R. arboretum*
32	*Paris polyphylla*		*R. grandii*
33	*Pedicularis siphonantha*		*R. thomsonii*
34	*Persicaria nepalensis*		*Sorbus sp.*
35	*Potentilla fruticosa*		*Rhododendron hodgsonii*
36	*Premula dekinia*		*Quercus lamellose*
37	*Primula sikkimensis*		*Schima wallichii*
38	*Primula sp.*		*Symplocos theifolia*
39	*Primula denticulata*		*Vibernum*
40	*Piper boehmeriifolium*		*Acer cambelli*
41	*Piper nigrum*		*Cinnamomum Sp*
42	*Prunella vulgaris*		
43	*Rubia manjith*		
44	*Selaginella*		
45	*Persicaria capitata*		
46	*Rheum nobile*		
47	*Rumex nepalensis*		
48	*Selaginella*		
49	*Swertia chiriata*		
50	*Artemisia vulgaris*		
51	*Aconogonam molle*		
52	*Begonia sp.*		
53	*Bidens Sp.*		
54	*Cassiope fastigiata*		
55	*Geranium sp.*		
56	*Gerardinia diversifolia*		
57	*Lycopodium veithii*		
58	*Heracleum nepalense*		
59	*Lycopodon japonicum*		
60	*Nephrolepis cordifolia*		
61	*Urtica dioica*		
62	*Phlomis sp.*		
63	*Pilea scripta*		
64	*Rheum emodi*		

65	*Rohdea nepalensis*		
66	*Roscoea purpurea*		
67	*Sphagnum sps.*		

List of species found in alpine scrub:

S.No	Herb	Shrub
1	*Aconogonum molle*	*Berberis sp.*
2	*Anaphalis sps.*	*Juniperous sp.*
3	*Bisorta sp.*	*Sorbus sp.*
4	*Bistorta vivipara*	*Juniperous recurva*
5	*Rheum nobile*	*Salix sp*
6	*Cassioppe fastigiata*	*Rhododendron lepidotum*
7	*Clematis buchananiana*	*R. aerogenesis*
8	*Ephedra sp*	*R. anthopogen*
9	*Fritillaria sp*	*R. barabetum*
10	*Fragaria nubicola*	*R. falconerii*
11	*Gentiana sp*	*R. lepidotum*
12	*Geranium sp.*	*R. setosum*
13	*Caltha sp.*	*R.nivale*
14	*Pedicularis sps.*	*Rhododendron thomsonii*
15	*Perscicaria sps.*	*Salix wallichiana*
16	*Potentilla sps.*	*Sorbus ursine*
17	*Suassurea sp.*	
18	*Primula delinia*	
19	*Primula denticulate*	
20	*Primula glomorata*	
21	*Primula kingie*	
22	*Primula sikkimensis*	
23	*Prunella sps.*	

ANNEXURE III

Table 18: List of the endemic species recorded from the landscape with the historic and recent altitudinal range extents (Source: Telwala et al. 2013)

S.No.	Species	Family	Historical range (m)	Present range (m)
1	*Aconogonon hookeri*	Polygonaceae	4272-5181	4300-5250
2	*Allium macranthum* Baker.	Alliaceae	3500-4500	3917-4500
3	*Allium sikkimense* Baker	Alliaceae	3886-4420	4478-5223
4	*Anaphalis xylorhiza* Schultz-Bip	Asteraceae	3656-5182	4000-5195
5	*Androsace selago* Klatt.	Primulaceae	4267-4572	4209-4570
6	*Anemone demissa* Hook. f. & Thomson	Ranunculaceae	3963-4877	4000-5000
7	*Arenaria ciliolata* Edgew.	Caryophyllaceae	4267-5182	4200-5200
8	*Arenaria densissima* Wall.	Caryophyllaceae	4572-5182	4500-5286
9	*Arenaria glanduligera* Edgew	Caryophyllaceae	4267-5334	4504-5416
10	*Arenaria monticola*	Caryophyllaceae	4572-4877	4656-5552
11	*Arenaria melandroyoides* Edgew.	Caryophyllaceae	4267-5334	4648-5400
12	*Arenaria musciformis* Wall.	Caryophyllaceae	4420-5029	4384-5186
13	*Arenaria polytrichoides* Edgew	Caryophyllaceae	4267-5182	4492-5396
14	*Artemisia biennis* Willd.	Asteraceae	4572-4877	4500-5000
15	*Artemisia campbelli* Hook. f. & Thomson	Asteraceae	3658-4722	3670-4877
16	*Artemsia salsoloides* Willd.	Asteraceae	4572-5182	4500-5200
17	*Aster diplostephoides* Benth.	Asteraceae	4267-4877	4315-5093
18	*Astragalus confertus* Benth	Leguminosae	4267-4877	4548-5248
19	*Berberis angulosa* Wall.	Berberidaceae	3658-4572	3828-4772
20	*Berberis concinna* Hook. f. & Thomson	Berberidaceae	3810-4191	4089-4778
21	*Caltha scaposa* Hook.f.	Ranunculaceae	4267-5182	4200-5350
22	*Campanula aristata* Wall.	Campanulaceae	3957-4724	4328-4907
23	*Campanula immodesta* Hook. f. & Thomson	Campanulaceae	3963-4725	4094-4975
24	*Cassiope fastigata* (Wallich).D.Don.	Ericaceae	3048-4267	3708-4508
25	*Cassiope selaginoides* Hook. f. &Thomson	Ericaceae	3048-3962	3825-4789
26	*Chamaesium novem-jugum*	Apiaceae	3658-4572	3700-4902
27	*Chionocharis hookeri* (C. B. Clarke) I. M. Johnston	Asteraceae	4662-5393	4680-5395
28	*Codonopsis foetens* Hook. f. & Thomson	Campanulaceae	4115-4648	4315-4822
29	*Codonopsis thalictrifolia* Wall.	Campanulaceae	3962-4420	4000-4700
30	*Cortia hookeri Clarke*	Apiaceae	3962-5182	3950-5500
31	*Corydalis cashmeriana* Royle.	Papaveraceae	4267-5182	4700-5240
32	*Cotoneaster microphylla* Wall.	Rosaceae	3352-4572	3700-4572
33	*Cremanthodium decaisnei* Clarke	Asteraceae	4420-4877	4397-5057
34	*Cremanthodium oblongatum* Clarke	Asteraceae	3658-4877	3800-4880
35	*Cremanthodium reniforme* Benth	Asteraceae	3048-4572	3785-4572
36	*Cyananthus incanus* Hook. f. &	Campanulaceae	3963-4877	3988-5125

S.No.	Species	Family	Historical range (m)	Present range (m)
	Thomson			
37	*Delphinium caeruleum* Jacq.	Ranunculaceae	4710-5182	4850-5268
38	*Delphinium glaciale* Hook.f.	Ranunculaceae	4267-4877	4300-5050
39	*Dracocephalum heterophyllum* Benth	Lamiaceae	4500-4877	4789-5192
40	*Elsholtzia eriostachya* Benth.	Lamiaceae	4000-4420	4100-4880
41	*Eritrichium pustulosum* C. B. Clarke	Boraginaceae	3963-5182	4412-5192
42	*Eritrichium pygmaeum* Clarke	Boraginaceae	4267-4750	4207-4750
43	*Erysimum deflexum* Hook. f. & Thomson	Brassicaceae	4267-5259	4330-5259
44	*Euphorbia stracheyi* Boiss	Euphorbiaceae	3658-4877	3873-5520
45	*Euphrasia officinalis* Linn.	Scrophulariaceae	3000-4265	3887-4600
46	*Fragaria daltoniana* J. Gay	Rosaceae	3048-4572	3664-4649
47	*Gaultheria trichophylla* Royle.	Ericaceae	3352-4267	3700-4649
48	*Gentiana detonsa* Fries	Gentianaceae	3962-4267	4044-4951
49	*Gentiana ornata* (G.Don).Griesb	Gentianaceae	4286-4725	4375-4899
50	*Gentiana robusta* King.	Gentianaceae	4267-4877	4507-4900
51	*Geranium collinum* M.Bieb.	Geraniaceae	3658-4268	4100-4556
52	*Hedysarum sikkimense* Benth.	Leguminosae	3962-4876	4552-5016
53	*Hippolytia gossypina* Hook. f. & Thomson	Asteraceae	4419-5182	4500-5250
54	*Juniperus indica* Bertol	Coniferae	4000-4572	3822-4600
55	*Juniperus recurva* Ham.	Coniferae	4000-4572	3955-4649
56	*Lagotis glauca* Gaertn.	Selaginaceae	4267-4572	4300-4900
57	#*Lancea tibetica* Hook. f. & Thomson	Scrophulariaceae	4419-4572	4350-4956
58	*Leontopodium haastioides* Hand.-Mazz	Asteraceae	4420-5182	4645-5418
59	*Lepidium capitatum* Hook.f.&Thomson	Brassicaceae	4200-5486	4500-5552
60	*Lonicera hispida* Poll.	Caprifoliaceae	3962-5182	4000-5000
61	*Meconopsis horridula* Hook. f. & Thomson	Papaveraceae	4420-5029	4495-5351
62	#*Meconopsis simplicifolia* Walp.	Papaveraceae	3500-3658	3850-4656
63	#*Microgynaecium tibeticum* Hook.f.	Brassicaceae	4500-4562	4500-4956
64	*Microula pustulosa* (C. B. Clarke) Duthie	Boraginaceae	3962-5182	4207-5220
65	*Morina nepalensis* D. Don.	Morinaceae	3048-3968	3700-4594
66	*Nardostachys grandiflora* DC.	Valerianaceae	3981-5182	4030-5054
67	*Nepeta discolor* Royle. ex Bentham	Lamiaceae	3963-4876	4500-5000
68	*Onosoma hookeri* Clarke	Boraginaceae	4115-4572	4136-4825
69	*Oreosolen wattii* Hook.f.	Scrophulariaceae	4572-5030	4500-5000
70	*Oxytropis tartarica* Jacq.	Leguminoseae	4000-4572	4507-4916
71	*Parnassia nubicola* Wall.	Scrophulariaceae	3524-4572	4150-4879
72	*Pedicularis integrifolia* Hook.f.	Scrophulariaceae	3657-4344	3978-5086
73	*Pedicularis lachnoglossa* Hook.f.	Scrophulariaceae	3657-4510	3475-4500
74	*Pedicularis longifolia* Rudolph	Scrophulariaceae	4420-4877	4507-4940

S.No.	Species	Family	Historical range (m)	Present range (m)
75	*Pedicularis roylei* Maxim.	Scrophulariaceae	4562-4877	4507-4916
76	#*Pedicularis trichoglossa* Hook. f.	Scrophulariaceae	4572-4752	4500-4700
77	*Phlomis rotata* Bentham ex J.D. Hooker	Lamiaceae	3963-4876	4508-5552
78	*Polygonum sibiricum* Laxm.	Polygonaceae	4420-5182	4745-5211
79	**Ponerorchis chusua* (D. Don) Soo.	Orchidaceae	3048-4114*	4000-4522*
80	*Potentilla fruticosa*	Rosaceae	3352-5182	4209-5250
81	*Potentilla microphylla*	Rosaceae	4267-4572	4507-4916
82	*Potentilla sino-nivea*	Rosaceae	4267-5334	4500-5250
83	*Primula sikkimensis* Hook.f.	Primulaceae	3352-4572	4000-4865
84	*Primula tibetica* Watt	Primulaceae	4496-5182	4438-5400
85	*Pterocephalus hookeri* (C. B. Clarke) Diels	Dipsacaceae	4267-4876	4507-5248
86	**Rheum nobile* Hook.f. & Thomson	Polygonaceae	3962-4572*	4556-4656*
87	*Rheum spiciforme* Royle	Polygonaceae	3962-4876	4125-4813
88	**Rhodiola bupleuroides* Wallich ex Hook.f. & Thomson	Crassulaceae	3200-4542*	4504-5000*
89	*Rhododendron nivale* Hook.f.	Ericaceae	3352-4876	3963-5102
90	*Ribes luridum* Hook. f. & Thomson	Hydrangeaceae	3048-4572	3770-4772
91	*Salix calyculata* Hook.f.	Salicaeae	3352-4267	4200-5000
92	*Salix lindlyeana* Wall.	Salicaeae	3658-4267	4000-4500
93	*Saussurea gossypiphora* Don.	Asteraceae	4267-5182	4606-5000
94	*Saussurea heiracioides* Hook.f	Asteraceae	3657-4267	4485-4836
95	*Saussurea katochaete*	Asteraceae	3963-4877	4050-5560
96	**Saussurea leontodontoides* (DC.)	Asteraceae	3962-5182*	4540-5129*
97	**Saussurea stella* Maxim.	Asteraceae	4445-4876*	4725-4880*
98	*Saussurea tridactyla* Clarke	Asteraceae	4740-5334	4919-5315
99	**Saussurea uniflora* Wall.	Asteraceae	3048-4572*	4256-4902*
100	*Saussurea werneroides* Hook.f.	Asteraceae	4724-5129	4700-5200
101	*Saxifraga aristulata* Hook. f. & Thomson	Saxifragaceae	3962-5182	4438-5248
102	*Saxifraga flagellaris* Willd.	Saxifragaceae	4267-4876	4500-5000
103	*Saxifraga hemisphaerica* Hook. f. & Thomson	Saxifragaceae	4876-5182	4500-5200
104	*Saxifraga hirculus* Linn.	Saxifragaceae	4267-5182	4735-5248
105	*Saxifraga jacquemontiana* Dene.	Saxifragaceae	4267-5029	4700-5248
106	*Saxifraga lychinits aff.*	Saxifragaceae	4267-5029	4428-5400
107	*Saxifraga pallida* Wall.	Saxifragaceae	3810-5106	4250-5220
108	*Saxifraga ramulosa* Wall.	Saxifragaceae	4572-5182	4500-5200
109	*Saxifraga saginoides* J. D. Hooker & Thomson	Saxifragaceae	3048-5486	3730-5552
110	*Sedum fischeri* R.Hamet.	Crassulaceae	4877-5182	4800-5200
111	*Sibbaldia purpurea* Hook.f.	Rosaceae	4267-4877	4200-5010
112	*Silene apetala* Willd.	Caryophyllaceae	3962-4572	4000-4572
113	*Silene caespitella* F. N. Williams	Caryophyllaceae	3657-4267	4485-4902
114	*Silene nigrescens* (Edgeworth)	Caryophyllaceae	4572-4876	4735-4938

S.No.	Species	Family	Historical range (m)	Present range (m)
	Majumdar			
115	*Soroseris glomerata* (Decne.) Stebb	Asteraceae	3658-4268	4248-4926
116	*Stellaria decumbens* Edgew.	Caryophyllaceae	3962-5182	4248-5248
117	*Stracheya tibetica* Benth.	Leguminosae	4267-5182	4570-5348
118	*Swertia multicaulis* Don.	Gentianaceae	4267-4572	4570-4900
119	*Thalictrum alpinum* Linn.	Ranunculaceae	4267-4876	4507-5250
120	*Thlaspi alpestre* Linn.	Brassicaceae	4562-5171	4700-5240
121	*Viola biflora* Linn.	Violaceae	4000-4876	4200-5248
122	*Waldheimia tridactylites*	Asteraceae	4511-5133	4500-5129
123	*Youngia depressa* Hook. f. & Thomson	Asteraceae	4572-4877	4507-4916
124	*Youngia gracileps* Hook.f.	Asteraceae	4572-4877	4507-4965

*These species recorded contraction of range by more than 50 % of their recorded historical range extents.

ANNEXURE IV

Laying out of Sample Plot by the Field Team in the Landscape






Data collection at Khecheopalri lake

Entrance of Khangchedzonga National Park

Tchu-she river towards Sachen

Vegetation in Yuksom –Dzongri Transect

On the way to Tshoka and Kokchorung

Mesmerizing view of Mt. Pandim from Tshoka

Thangsing field site

PLANT SPECIES IN THE LANDSCAPE

Gentiana sino-ornata

Saussurea sp.

Cassioppe sp.

Rhododendron spp.

Rhododendron spp.

Saxifraga sps

Silens nigrescens

Aster sikkimensis

Geranium nepalense

Jacobaea raphhanifolia

Perscicaria capitata

Euphorbia griffithii

Unidentified

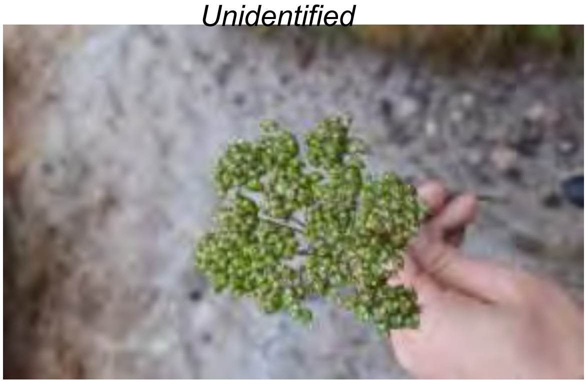
Unidentified

Rhododendron sp.


Osbeckia stellata


Unidentified


Vibernum sps


Heracleum sps.


Berberis sps.


Himalaiella andersonii


Picea spinulosa


Unidentified

Cassiope fastigiata

Gentiana sikkimensis

Gentiania ornata

Aster sps.

Bistorta sps


Bistorta sps


Cassiope sps.


Unidentified


Unidentified


Anaphalis sps


Berberis sps


Satyrium nepalense


Anaphalis sp


Unidentified


Oxalis sp


Unidentified


Cynotis vaga


Unidentified


Hemphragma heterophyllum

Impatience falcifer

Persicaria capitata

Rumex nepalensis

Unidentified

Prunella vulgaris

Vaccinium nummularia


Lycopodium japonicum


Anaphalis margaritaceae


Rubus nepalensis


Unidentified


Rohdea nepalensis


Quercus glauca

Cautleya spicata

Chirita urticifolia

Gerardinia diversifolia

Bidens pilosa

Calceolaria tripartita

Mahonia nepaulensis

Acer stachyophyllum

Quercus lamellosa

Selaginella sps.

Arisaema spp.

Aconogonom molle


R. anthopogen


Acorn of *Tsuga demusa*


Pilea scripta


Acer sp.

FAUNAL PRESENCE IN THE LANDSCAPE

Ungulate Hoof mark

Pellets droppings

Feral dog feeding on cattle

Pug Mark

Fire-tailed Sunbird

Verditer Flycatcher

Dark-rumped Rosefinch (Male & Female)

Golden-naped Finch

White-throated laughing thrush

ANNEXURE V

Key Stakeholder

Key stakeholders based on secondary literature review

Institution/Organization	Location
Forests, Environment and Wildlife Management Department	Sikkim
Department of Science and Technology	Sikkim
Sikkim State Biodiversity Board	Sikkim
Botanical Survey of India, Himalayan Circle	Gangtok
High Altitude Plant Physiology Research Centre, H.N.B. Garhwal University	Srinagar, Uttaranchal
G.B Pant Institute of Himalayan Environment and Development (Sikkim Unit)	Gangtok, Sikkim
North Eastern Space Application Centre	Shillong, Meghalaya
ICAR Research Complex	ICAR Research Complex
Krishi Vigyan Kendra	Sikkim
National Research Centre for Orchids	Pakyong, Sikkim
World Wildlife Fund for Nature, India - Sikkim Unit	Gangtok, Sikkim
Institute of Bio-resources and Sustainable Development	Gangtok
ATREE	Gangtok
Tourism and Civil Aviation Department, Govt of Sikkim	Gangtok
Food Security And Agriculture Development	Gangtok
Local Village Councils, Zumsa	
Other NGO's (Khangchendzonga Conservation Committee (KCC), Ecotourism & Conservation Society of Sikkim (ECOSS), Sikkim Paryavaran Sanarakshan Sangh(SPSS), Green Circle, Sikkim Lepcha Youth Association (SLYA), WWF Sikkim Unit etc.	
Rural Management Development Department	Gangtok, Sikkim

* Local stakeholders and dependent communities on the floral Biodiversity for their livelihoods are major stakeholders.

ANNEXURE VI

DEFINITIONS OF TERMS

Frequency	Frequency is the number of times a plant species occurs in a given number of quadrats. Frequency is usually expressed as a percentage and is sometimes called a Frequency Index. The concept of frequency indicates the probability of finding a species in a series of quadrats examined in an area of interest.
Abundance	
Diversity Index (DI)	DI is quantitative measure that reflects the number of different species and how evenly the individuals are distributed among those species
Shanon	
Jaccard Similarity Index	The Jaccard similarity index is a way to compare populations by determining what percent of organisms identified were present in both populations. It's a measure of similarity for the two sets of data, with a range from 0% to 100%. The higher the percentage, the more similar the two populations.
Richness-Evenness indices	The first two indices are based on information theory. These indices are based on the rationale that the diversity in a natural system can be measured in a similar way to the information contained in a code or message.

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