UNDERSTOREY VEGETATION AND IT'S RELATION WITH THE REGENERATION OF *QUERCUS SEMECARPIFOLIA* IN LANGTANG NATIONAL PARK AND BUFFER ZONE, CENTRAL NEPAL

A THESIS

SUBMITTED FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE MASTER'S DEGREE IN BOTANY

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DECLARATION

I hereby declare that the work presented in this dissertation is a genuine work done originally by me and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATION

This is to recommend that the Master's thesis entitled **"Understorey vegetation and its relation with the regeneration of *Quercus semecarpifolia* in Langtang National Park and Buffer Zone, Central Nepal"** is carried out by Namrata Yadav under our supervision. The entire work is based on original scientific investigations and has not been submitted for any other degree in any institutions. We therefore, recommend this thesis work to be accepted for the partial fulfillment of M.Sc. Degree in Botany.

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LETTER OF APPROVAL

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Namrata Yadav

ACRONYMS AND ABBREVIATIONS

DBH	Diameter at Breast Height
GPS	Global Positioning System
SPSS	Statistical Package on Social Science
LNP	Langtang National Park
BZ	Buffer Zone
DNPWC	Department of National Parks and Wildlife Conservation
IVI	Important Value Index
F	Frequency
RF	Relative Frequency
D	Density
RD	Relative Density
RA	Relative Abundance
A	Abundance
OM	Organic Matter
MelGyn	Melamchighyang

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Understorey vegetation is as important as overstorey vegetation in forests as it facilities overall regeneration and has crucial role in nutrient cycling. Understorey vegetation largely affects the regeneration of dominant tree species in forests, but little is known about such impacts. In this context, this research work was carried to assess the impacts of understorey vegetation on regeneration of *Quercus semecarpifolia*, and the effects of environmental factors on understorey vegetation and regeneration in Langtang National Park and its buffer zone of Central Nepal. Altogether, 308 plots of 1m×1m for shrubs and 77 plots of 1m×1m plots for herbs were used for data collection from which 160 plots were established in the national park and 148 plots were established in the buffer zone for shrubs species. Similarly, 40 plots were established at the National Park area and 37 plots were established at buffer zone areas for the herb species. Importance Value Index (IVI) of herbs and shrubs species, p-value and correlation of understorey vegetation with seedlings and saplings of dominant tree species, and soil attributes was analyzed. A total of 17 species of shrubs belonging to 12 families were recorded inside the national park and 29 species of shrubs belonging to 14 families in the buffer zone area. Similarly, altogether 30 species of herbs belonging to 17 families were recorded inside the national park and 30 species of herbs belonging to 18 families in the buffer zone area. Simpson's index of diversity and Shannon-Wiener index of diversity of shrubs species inside the national park were found to be 0.9069 and 2.523, while those values for buffer zone were found to be 0.887 and 2.517, respectively. Similarly, Simpson's index of diversity and Shannon-Wiener index of diversity of herb species in the national park were found to be 0.9415 and 3.0849, respectively while those values for buffer zone were found to be 0.9201 and 2.9849. There was no significant correlation between understorey species richness and organic matter content, soil pH and soil nutrients (N, P, K) and also the relationship was not observed between understorey vegetation with the seedling and sapling of *Quercus semecarpifolia*.

Key words: *Ground vegetation, species richness, Quercus semecarpifolia, Nepal*

CHAPTER 1: INTRODUCTION

1.1 Background

Understorey vegetation plays an important role in the ecosystem as they act as drivers of over story succession and nutrient cycling, habitat conservation and regeneration (Hart & Chen, 2006). The development and organization of understorey vegetation depends on climate, soil and other biotic factors (Mishra *et al.,* 2013). The understorey vegetation is the underlying layer of vegetation in a forest or wooded area, especially the trees and shrubs growing between the forest canopy and the forest floor. Plants in the understorey comprise an assortment of seedlings and saplings of canopy trees together with specialist understorey shrubs and herbs (Kaufmann *et al*., 2007). Tree species composition plays an important role in forest ecosystems. Understorey vegetation is influenced by over story composition and structure on the basis of available resources such as light, water and soil nutrients and other physical characteristics of the litter layer (Barbier *et al*., 2008).

Nepal occupies about 0.1% of the global area but harbors over 3% of the world's known flora. A total of 284 flowering plants are endemic to Nepal. The number of known species in Nepal is: 6,073 angiosperms; 26 gymnosperms, 534 pteridophytes; 1,150 bryophytes; 365 lichens; 1,822 fungi and 1,001 algae (GoN 2014). Whereas, according to Tiwari *et al.* (2019) the existing checklists for Nepal record some 6000 species of flowering plants and about 530 ferns. However, the botanical experts estimate that numbers may go up to 7000 when the poorly known remote regions are fully explored. These include both understorey and overstory vegetation.

The floristic diversity of Langtang is considerably rich. Langtang, the closest Himalayan Park from capital city Kathmandu was established by the Government of Nepal in 1976. The recreation center has a region of 1,710 sq. km and reaches out over pieces of Nuwakot, Rasuwa and Sindhupalchowk districts. The elevation of this park ranges from 1000 m to 7245 m (Jones & Fox, 2014). Langtang National Park is the consolidating purpose of Eastern and Western Himalayan Biotic Provenance. It speaks to the precisely mid Himalayan biological system on the globe. The Himalayas are a veritable home of environmental and natural assorted variety.

The Himalayas are a veritable home of ecological and biological diversity. Langtang harbors a maximum number of rare and threatened plants having narrow endemism. In addition to this, the Langtang Valley and Gosaikunda valley are the areas for type specimens of different endemic and endangered flora (Måren & Sharma, 2018).

LNP covers the varieties of vegetation as it extends from the sub-tropical region to the alpine region. The Park's rich vegetation is characterized by Sal (*Shorea robusta*) forest in the southern section of park and it is gradually taken over by hill forest (2000-2600 m) consisting of Chirpine (*Pinus roxburghii*), Rhododendrons and Nepalese alder (*Alnus nepalensis*). The temperate zone (2600-3000m) is covered mainly by oak forest fading to old growth forest of silver fir, hemlock, and larch in the lower sub–alpine zone (3000–3600m). The Nepalese larch (*Larix nepalensis*), the only deciduous conifer in the region, is found in the park and few places elsewhere. *R. arboretum, R. barbatum, R. campanulatum,* scrubs of *R. lepidotum* are some of the different species of Rhododendron found throughout these zones. Tree species such as birch, silver fir, sorbus and twisted *Rhododendron campanulatum* are found near the tree line. All the 4000 m elevation, Juniper and Rhododendron shrubs (*R. anthopogon*) slowly dissolve into the expansive alpine grassland meadows (DNPWC, 2021).LNP is the consolidating purpose of Eastern and Western Himalayan Biotic Provenance. It speaks to the precisely mid Himalayan biological system on the globe. The Himalayas are a veritable home of environmental and natural assorted variety. The Himalayas are a veritable home of ecological and biological diversity. Langtang harbors a maximum number of rare and threatened plants having narrow endemism. In addition to this, the Langtang Valley and Gosaikunda valley are the areas for type specimens of different endemic and endangered flora (Måren & Sharma, 2018).

Due to the expanding human population all over the world, the impact on the forest has influenced the forest resources which lead to disturbance in the forest ecosystem because of which both diversity and regeneration and dominance of tree species are influenced. There are a few specialists whose reviews have clarified the connection among unsettling influence and species richness; however the examinations which clear up how disturbance impacts stand structure, species composition and regeneration of tree species are very limited. Past studies indicate that due to disturbance in the forests; conditions become unfavorable for existing species and fail to reestablish themselves (Halpern & Spies, 1995). The growing pressure of populations on central Himalayan regions and their existing forests has depleted the good forest cover; consequences are seen as frequent landslides and floods, respectively in the hill and plains. Besides these many species have become threatened and are on the verge of extinction. Therefore, the delicate relationship between man and forest has been shattered which needs a sound policy for their conservation management and sustainable development through appropriate knowledge and strategies (Haines-Young & Potschin, 2010).

1.2 Rationale

Understorey vegetation accounts for the majority of plant species diversity and serves as a driver of overstory succession and nutrient cycling (Liu, Chen, & Yang, 2018). However, it is influenced by structure and composition of overstory vegetation as it modifies the resources such as light, water and soil nutrient and the litter layer also affects the understorey vegetation (Barbier *et al*., 2008). The understorey vegetation of the protected and unprotected forest is different to each other in terms of vegetation composition and species richness. According to Dutta and Devi (2013) human impact in the forest may cause reduction in understorey vegetation and ultimately cause change in the soil attributes.

Rich diversity of LNP supports richness in its NTFPs diversity Bhattarai & Vetaas (2003) which contributes a major component of understorey vegetation. Many studies have been done in tree species in LNP but literature survey shows that not many researches related to the understorey vegetation focusing on national parks and buffer zones. So this study tried to find out the richness of understorey vegetation and the impact of disturbance in the understorey vegetation and the relation between understorey vegetation and regeneration. Langtang region has attracted national and international tourists for a long time. Many families are involved in the tourism industry mainly along the famous trekking routes. Whereas, a majority of people are farmers and they depend upon forest resources to fulfill their daily demand. So, this study will definitely help in providing information regarding the status of understorey vegetation and its impact on regeneration of *Q. semecarpifolia*. This study will also help us to know about the effect of environmental factors on the composition of understorey vegetation and its relation with regeneration of *Q. semecarpifolia*. It will be helpful to the forest managers to adopt best forest management strategies to protect the vegetation.

1.3 Hypothesis

- Composition and diversity of understorey vegetation is different in LNP and its buffer zone area.
- There is no impact of understorey vegetation on regeneration of *Q. semecarpifolia*.

1.4 Research Questions

- What is the diversity of herbs and shrubs species of LNP and its buffer zone area?
- What is the effect of microsite conditions such as soil attributes and regeneration on understorey vegetation?

1.5 Objectives

General Objective

- To study and compare the vegetation composition and community structure of understorey vegetation in LNP and its buffer zone.

Specific Objectives

- To find out the species composition and richness of understorey vegetation along the altitudinal gradient.
- To study the relationship between herbs and shrubs richness with the regeneration of *Q. semecarpifolia*.
- To study the effects of soil attributes on understorey vegetation along the altitudinal gradient.

1.6 Limitations

- Inaccessibility of wider study area due to extremely difficult mountain terrain.
- Time restriction to field visit due to COVID-19 pandemic.

CHAPTER 2: LITERATURE REVIEW

2.1 Vegetation Composition and Community Structure

Ilorkar (2003) reported 16 species of shrubs and 44 species of herbs in along the altitudinal gradient in Navegaon national park (Maharashtra). Similarly the study conducted of Himalayan forests of Pakistan found 24 different communities and 4 monospecific forest vegetations in 184 sampling stands Ahmed *et al.*(2006). Hussain *et al*.(2010) conducted a study in Central Karakuram National Park where they recorded five stands dominated by trees and eight stands of bushes. Similarly, the study carried out in Chitral shows complex mosaic of trees, herbs and shrubs vegetation with a wide range of vegetation types. Among the 10 tree communities, 3 monospecific stands, while 9 communities were of herbs and shrubs were recorded (Khan *et al*., 2012).

Goncharenko & Yatsenko (2020) recorded 18 syntax within 7 classes, 7 orders, 8 alliances, and 3 new associations were allocated (*Aristolochio clematitis-Populetum nigrae, Galio aparines-Aceretum negundi, Dryopteris carthusiana-Pinetum sylvestris*) in the forest of Kyiv urban area showed .Similarly, The study of Nitraria retusa (Forssk.) Asch shrub along the Egyptian Red Sea coast aims at analyzing the phytosociological behavior and size structure in relation to the environmental gradients which showed five vegetation groups Shaltout *et al*. (2003). Phytosociology of communities on roadsides is significant in the identification of the degree of tolerance of species, because the method in general, is considered efficient and appropriate to assess the ecological potentials of plants in natural communities. Floristic survey and phytosociological analysis of Kottayam District of Kerala, showed 85 species belonging to 27 families differently tolerant to the stressful environment, which included exotics as well as medicinal plants (Ray & George, 2009).

According to Siccama *et al*. (2006), the herbaceous layer at Hubbard Brook where the herb-shrub layer responded in several ways to the elevation complex gradient. Species diversity increased by 50% and productivity tripled in the higher portions of the ecosystem coincident with a decrease in the productivity of the over story. Increased productivity in the herb-shrub layer resulted from more luxuriant growth of species distributed throughout the ecosystem rather than from increased species diversity. Khan *et al*. (2012) focused on the quantitative survey in 184 sampling stands in different climatic zones of Himalayan forest of Pakistan where many communities showed similar floristic composition but in different quantitative values. Khan *et al*. (2012) made study in forest and non-forest vegetation of Chitral where complex mosaic of herbs, shrubs and tree vegetation with wide range of vegetation type was reflected due to wildlife grazing and human use and results disclosed that many conifer and broad leaved forests were in bad condition due to anthropogenic factors. Bhat (2017) studied herbaceous plant community in Yusmarg Forest of Kashmir region to study human impact to the herb community and results showed that there is low grazing pressure and average human impact on normal distribution of herb species which may cause reduction in herbaceous community in next few decades in the forest ecosystem.

Dutta & Devi (2013) investigated the plant population structure in two disturbed tropical forests in Assam Province on the basis of which they concluded that illegal felling and over-exploitation of forest resources may lead to species-specific changes in the population structure and can alter the future structure and composition of the forests. The study carried out by Borah *et al*. (2014) at forests of Bhuban hills in south Assam, India revealed that the species richness, species diversity and density has declined due to anthropogenic disturbances. Kharkwal & Rawat (2010) conducted an extensive sampling for vegetational analysis in different forest sites between 1600 and 2600 m above sea level in Kumaun Himalaya. Among the sampling sites, total density of tree, shrub and herb species ranged from 10 to 28.6 individuals, 1.8 to 21.7, and 28.1 to 103.7 respectively. The total abundance-frequency (AF) ratio of tree, shrub and herb species across the sampling sites varied from 0.23 to 1.25, 0.25 to 1.79 and 3.4 to 27.3, respectively. The abundance-frequency ratio in the present study showed contagious distribution patterns in tree, shrub and herb species.

There are various studies conducted in Nepal. Battarai and Vetaas (2003) studied variation in species richness along a subtropical to warm temperate region in the south-east part of Nepal, between 100m- 1500m to evaluate richness of the different life forms due climatic variation and concluded that richness of herbaceous species, including herbaceous climbers, was unrelated to any of the climate variables. Burzle *et al*. (2017) studied the species composition and ecological tree line vegetation type in Rolwaling valley with the aim to study about differentiate plant communities along the elevation gradient in the treeline ecotone, and to identify factors causing the differentiation of the tree line ecotone vegetation and concluded that species composition is mainly differentiated by soil temperature, nitrogen supply and availability, and soil moisture content. After comparing data obtained from Bajrabarahi and Pashupati Sacred Groves by Shrestha *et al*. (2014), it has been found that local community initiations are more effective in the management system than the government management system for tree diversity conservation in sacred groves of Kathmandu.

The study carried out in Great Xing‘an Mountains of Northeastern China showed functional diversity and trait dispersions of understorey communities and tested how these patterns changed with stand age. Understorey vegetation accounts for the majority of plant species diversity and serves as a driver of overstory succession and nutrient cycling in boreal forest ecosystems. However, investigations of the underlying assembly processes of understorey vegetation associated with stand development following a wildfire disturbance are rare, particularly in Eurasian boreal forests. During the study random patterns of phylogenetic, functional, and trait dispersions were dominant for most of our surveyed plots, indicating that stochastic processes may play a crucial role in the determination of understorey community assembly. The study presented a difference to community assembly and species coexistence theories that insisted solely on deterministic processes. These findings indicated that Eurasian boreal understorey communities may be primarily regulated by stochastic processes, providing complementary evidence that stochastic processes are crucial in the determination of community assembly both in tropical and boreal forests (Liu *et al*., 2018).

2.2 Understorey vegetation and environmental factors

The understorey vegetation is influenced by structure and composition of overstorey vegetation as it modifies the resources such as light, water and soil nutrient and the litter layer also affects the understorey vegetation (Barbier *et al*., 2008). Hussain *et al*. (2010) conducted a study in Central Karakuram National Park where they recorded five stands dominated by trees and eight stands of bushes. Similarly, the study carried out in Chitral shows complex mosaic of trees, herbs and shrubs vegetation with a wide range of vegetation types. Among the 10 tree communities, 3 monospecific stands, while 9 communities were of herbs and shrubs were recorded (Khan *et al*., 2012). Goncharenko & Yatsenko (2020) recorded 18 syntax within 7 classes, 7 orders, 8 alliances, and 3 new associations were allocated (*Aristolochio clematitis-Populetum nigrae, Galio aparines-Aceretum negundi, Dryopteris carthusiana-Pinetum sylvestris*) in the forest of Kyiv urban area showed .Similarly, The study of Nitraria retusa (Forssk.) Asch shrub along the Egyptian Red Sea coast aims at analyzing the phytosociological behavior and size structure in relation to the environmental gradients which showed five vegetation groups Shaltout *et al*. (2003).

The study of communities on roadsides is significant in the identification of the degree of tolerance of species, because the method in general, is considered efficient and appropriate to assess the ecological potentials of plants in natural communities. Floristic survey and phytosociological analysis of Kottayam District of Kerala, showed 85 species belonging to 27 families differently tolerant to the stressful environment, which included exotics as well as medicinal plants (Ray & George, 2009). The study conducted in Wisconsin landscape showed the relation between edaphic and environmental factors and understorey vegetation among 77 plots representing seven major patch types comprising a landscape in northern Wisconsin showed that canopy cover differed in different patch types. Relationships between diversity and site factors were weak overall, but improved when patches were separated by overstory characteristics with soil factors differing in their relative effects on vegetation according to overstory properties. Important site variables influencing vegetation were canopy cover, pH, and forest floor characteristics. Species composition showed greater differences among patch types. These differences occurred primarily between patch types that were less qualitatively similar in terms of overstory (Brosofske *et al*., 2001).

Ugustoa, Upoueyb, & Angerb (2004) conducted a study in the temperate forest, were samples from 26 locations were collected and this study showed that forest management influenced the ground flora more than the tree species did. Number of species and equitability differed little with tree species. Similarly, Dubbert *et al.* (2014) conducted the study in cork-oak woodland in Portugal which showed facilitation and competition between different vegetation layers with large impact on small-scale vegetation development showed facilitation and competition between different vegetation layers with a large impact on small-scale vegetation development

According to the study in northwest Spain, the use of agricultural land for forest plantations has become a common change in biological diversity. Relationships between surface soil properties and the presence of vegetation species were examined in 186 young forest plantations on abandoned agricultural lands in Galicia. The ecological profile method was used to investigate each species and soil variable. Soils under herbaceous vegetation such as *Plantago lanceolata* and *Dactylis glomerata* are shown to have higher levels of calcium and phosphorus and lower organic matter content than those under *Ulex europaeus. Daboecia cantabrica* is associated with shallow soils and *Holcus lanatus* and *Lotus corniculatus*, with deep soils. *Trifolium pratense* is characteristic of soils with high pH and high levels of calcium and magnesium (Zas & Alonso, 2002).

In the Turkana District of northwestern Kenya, trees in an African savanna have positive impacts on herbaceous biomass production and composition, and on soil nutrient status. The study showed vegetation and soil gradients along equi-angular transects radiating from the boles of individual Acacia tortilis trees. Total herbaceous biomass averaged 260 ± 17 (se) g/m^2 at the bole and declined to 95 ± 8 g/m^2 in the tree interspaces. Soil organic carbon and total nitrogen concentrations were greatest (0.72% and 0.083%, respectively) in shallow soils. Transects were also established between tree pairs to assess effects of differential canopy. Grass production averaged 220 ± 21 g / m^2 below overlapping canopies, 150 ± 15 g / m^2 under individual canopies, and 95 ± 8 g / m^2 in interstitial areas. Trees did not influence herbaceous composition beyond tree canopies. It is assumed that shade cast by the tree canopy with subsequent reductions of understorey water stress and temperature and increased nutrient concentrations may be the most important factors affecting understorey soil and vegetation (Weltzin & Coughenour, 1990).

2.3 Understorey vegetation and regeneration of *Quercus semicarpifolia*

The forest tree regeneration depends on seed production, seed size, dispersal mechanisms, understorey tolerance or shade tolerance, resistance to insects and pathogens, biomass production and nutrient requirement (Barnes *et al*., 1998). It consists in the flowering, fruiting and dispersal of the seeds of mature trees, together with the germination of those seeds, seedling establishment and growth (Johnson *et al*., 2002).The presence of a sufficient number of seedling, sapling and tree in forest indicates successful regeneration (Dutta & Devi, 2013). Regeneration is a critical part of forest management, because it maintains the desired species composition and stocking after various disturbances (Khumbongmayum *et al*., 2005).Due to poor seedling recruitment in the understorey vegetation leads to insufficient regeneration (Mori & Takeda, 2004). The successful regeneration of a tree species depends on the ability of its seedlings and saplings to survive and grow (Good & Good, 1972). Successful regeneration is perhaps the single most important step towards achieving long term sustainability of forests (Saikia & Khan, 2013). Environmental factors such as sunlight and litter thickness generally reduces the rate of seed germination and seedling establishment. The reduced canopy cover has a direct effect on seed production, but it may also indirectly affect regeneration through changes in the understorey vegetation and soil properties (Vetaas, 2000). Whereas, the dense canopy of the forest did not promote the satisfactory establishment of oak in the understorey; however the moderate disturbance appeared to benefit the regeneration (Thadani & Ashton, 1995). Besides browsing, growth rate and species composition of the natural regeneration are mainly determined by the light conditions (Ammer, 1996).

Shrestha *et al*. (2013) compared the regeneration density of seedlings and saplings separately between gaps and the understorey in the subtropical *Shorea robusta* (Sal) forest in Chitwan-a dun valley, situated between the crests of the Siwalik ranges in central Nepal and concluded that gap creation promotes tree regeneration by favoring seedling survival and growth and can influence forest management for conservation, as well as for plantations.

According to the study conducted by Tonioli *et al*. (2001) in the forest of Montpellier, France, the effect of herbaceous vegetation on seedling emergence was strongly variable. It is considered that cover by herbs creates a moister environment which facilitates the emergence of seeds of many species of trees. However, there are other examples showing that *Quercus* species are also sensitive to herbaceous competition. According to the study conducted by Dzwonko and Gawronski (2002) herbaceous cover has even more adverse effect on seedling emergence, survival and growth. The study undertaken in moist temperate forest of Mandal-Chopta area in the Garhwal region of Uttarakhand, India showed that seedlings were found to be more prone to competition from herb and shrubs than saplings (Gairola *et al*., 2012).

Seed production is often very limited in the understorey vegetation because of the low resources level. Sometimes the species that blooms under dense canopy may bloom profusely in open canopy and vice versa. Seed production of tree species is highly influenced by wind pollinators.

Microsites suitable for the seed germination and seed establishment are very limited in the forest. Large seeds can be established in the forest understorey as compared to small seeds where the resource is limited and litter is abundant (Antos, 2009).

CHAPTER 3: MATERIALS AND METHODS

3.1. Study area

3.1.1. Location and vegetation

This study was conducted in the Langtang National Park and its buffer zone areas in Helambu Gaupalika, Sindhupalchowk District. Helambu trail area situated in the southern limit of the national park which is located at the latitude of 27°42' 2.768" N and longitude of 85°18' 0.504" E. Total eight sites were studied, among which four sites were studied for that national park and four sites were studied for buffer zones. Sermanthang, Kutumsang, Melamchi Ghyang and Setighyang were selected for the buffer zone whereas two sites in the interval of 500 m in Melamchi Ghyang and two sites Laghang were selected for the national park. Transects were laid down cautiously inside the national park and in buffer zone territory covering *Quercus semecarpifolia* forest in Helambu region as appeared in the accompanying Figure 3.1.

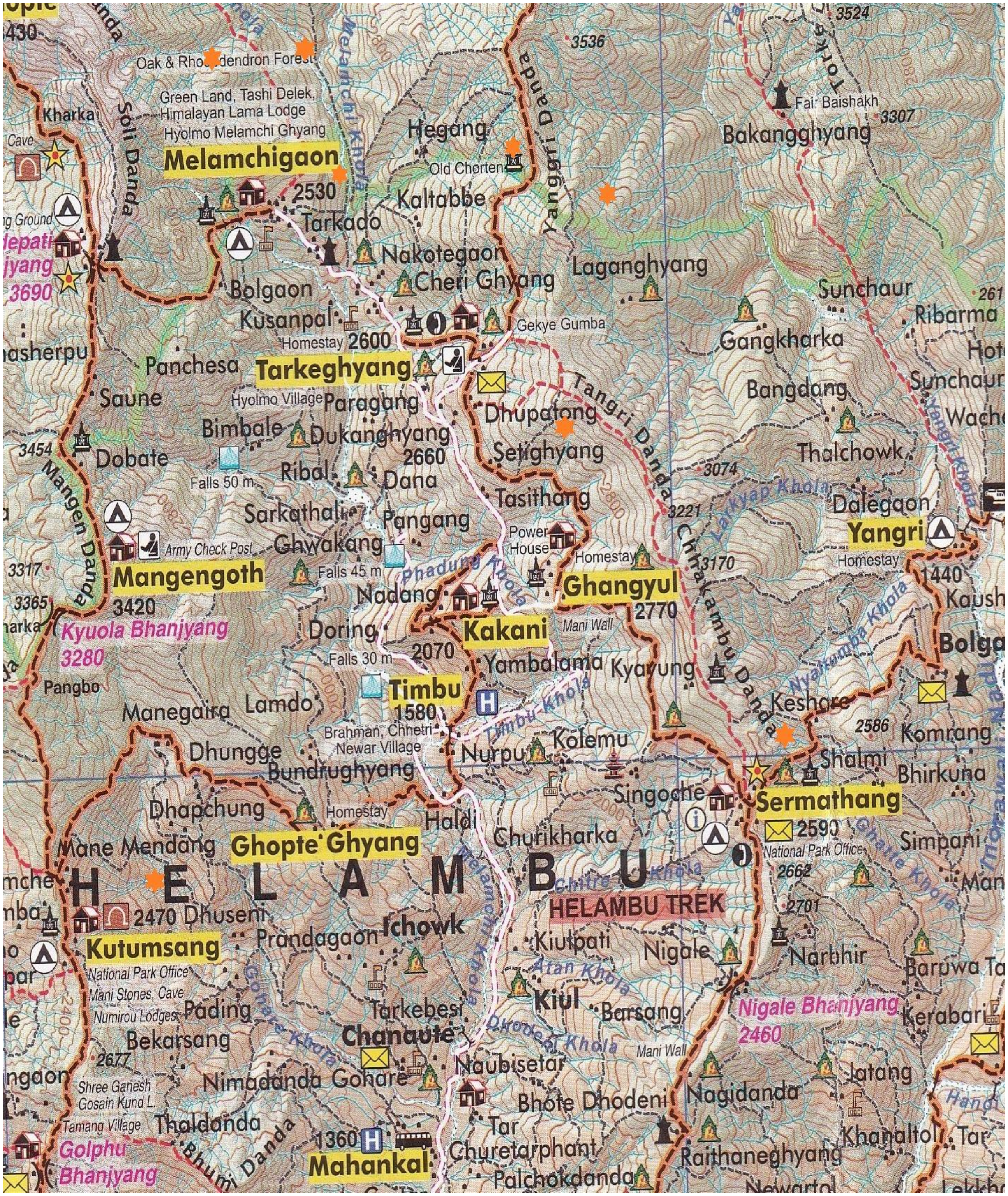

Figure 3.1: Map of LNP and BZ showing study sites marked with red asterisk. (Source: Nepal Map Publisher Pvt. Ltd.)

This research was conducted in the Langtang National Park and its buffer zone. The floristic diversity of Langtang is considerably rich. Langtang, the closest Himalayan Park from capital city Kathmandu was established by the Government of Nepal in 1976. LNP has an area of 1,710 sq. km and reaches out over pieces of Nuwakot, Rasuwa and Sindhupalchowk districts. The elevation of this park ranges from 1000 m to 7245m (Jones & Fox, 2014). Langtang National Park is the consolidating purpose of Eastern and Western Himalayan Biotic Provenance. It speaks to the precisely mid Himalayan biological system on the globe. The Himalayas are a veritable home of environmental and natural assorted variety. The Himalayas are a veritable home of ecological and biological diversity. Langtang harbors a maximum number of rare and threatened plants having narrow endemism. In addition to this, the Langtang Valley and Gosaikunda valley are the areas for type specimens of different endemic and endangered flora (Måren & Sharma, 2018).

3.1.2. Climate

The climate of the LNP is diverse due to variation in altitude and topography. A thirty-year climatic data (1990-2020) was analyzed, which was taken from the meteorological station of Dhunche. Mean annual temperature was 15.29℃. The monthly maximum temperature (24.35℃), the highest, was found in May and minimum temperature (2.89℃), the lowest, was found in December. The average annual precipitation was recorded to be 154.60 mm with highest rainfall in the month August (529.12 mm) and the least in the month November (8.81 mm). Upper range of the study site was covered by seasonal snowfall. This snowmelt water is the main source of soil moisture for forests in this region. However rainfall and snow feed groundwater are the main source of soil moisture for forests in the middle and lower range (Figure 3.2).

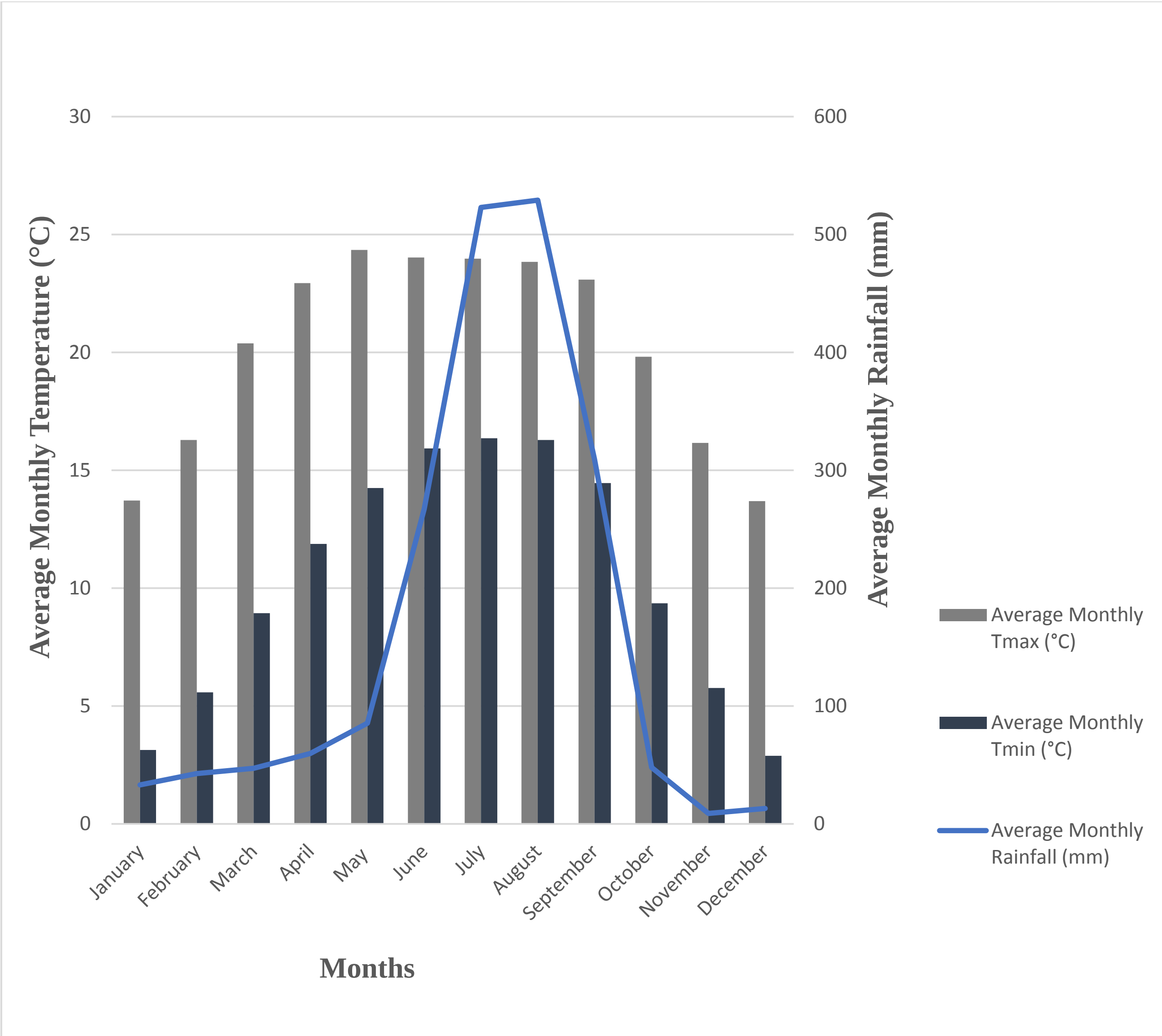

Figure 3.2: Thirty-year (1990-2020) average monthly maximum (Tmax) and minimum (Tmin) temperature and precipitation recorded at Dhunche weather station (1097 m a.s.l.), Rasuwa (Source: Department of Hydrology and Meteorology, Government of Nepal).

3.2 Methods

3.2.1 Vegetation sampling

Vegetation sampling was done in the national park and buffer zone of Helambu region from October 2019 to April 2021. Sampling was done in vertical transects in the *Quercus* dominant forest. Sampling was done using circular plots of 10 m radius. Within each sampling plot four plots of 1m×1m were established for sampling shrubs on four sides and one plot of 1m×1m was established at the center for sampling of herbs. Altogether, 308 plots of 1m×1m for shrubs and 77 plots of 1m×1m plots for herbs were used for data collection.

In each 10m radius plots, basal diameters, crown cover, height of shrubs were measured. Similarly, the number and cover percentage of herbs were recorded. The altitude, latitude, longitude, aspect, canopy cover, litter depth, number of tree species, forest types were also recorded.

3.2.2 Plant collection and identification

The collected plants were identified using the plant field guide book Polunin and Stainton (1984) and the Supplement Volume (1988) . Later, they were confirmed with Hara et al. (1978). Local names of all unidentified plants of herbs and shrubs species encountered in the study area were collected, and were tagged and pressed using herbarium press. Other field notes like color of the flower (if available), fruit, fragrance or any special features regarding the plants were noted carefully. Photographs of plants were also taken for future use. Pressed plant specimens after drying were mounted on a herbarium sheet of 16.5” × 11” using glue and labeled in accordance with Press et al. (2000). Help was taken from the department to identify the collected plants and were also compared with specimens at National Herbarium and Plant Laboratories, Godawari, Lalitpur (KATH).

3.2.3. Soil

For a detailed analysis, soil samples were collected from each sampling plot in each elevation. In each sampling plot 4 soil samples (10 cm depth) collected each from 4 corners and a single sample from the center with the help of trowel, were mixed and sieved to form a single soil sample; 77 such samples were collected, air dried, and stored in plastic bags for laboratory analysis.

3.2.4. Laboratory works

Soil pH, organic matter (OM) content, soil texture and 3 macronutrients (Nitrogen, Phosphorus and Potassium) was determined in the air-dried soil samples at the Agriculture technology center, Lalitpur. For each soil sample pH, organic carbon, nitrogen, phosphorus and potassium was estimated by following procedure described by Gupta (2000) and Zobel et al. (1987).

3.2.4.1 Soil pH

A measured quantity of soil was shaken with a convenient volume of water or salt solution under consistent condition and the pH of the suspension is determined electronically on a direct pH meter, using a glass electrode with a saturated potassium chloride (KCl)- calomel reference electrode. A 1:2.5 soil water ratio is used.

3.2.4.2 Organic carbon

For the organic carbon determination, Walkley-Black method is used. Oxidizable organic matter in the soil was oxidized by chromic acid in the soil was oxidized by chromic acid in the presence of sulphuric acid, the reaction being facilitated by the heat of dilution when 2 volume of conc H_2SO_4 are mixed with 1 volume of potassium dichromate ($K_2Cr_2O_7$) solution. The excess chromic acid is determined by titration with ferrous ammonium sulphate solution and the quantity of the substance oxidized is calculated from the amount of dichromate reduced.

3.2.4.3. Total Nitrogen (%)

For this analysis, the Kjeldahl method was used. Organic matter was oxidized by treating soil with boiling concentrated Sulphuric acid. Nitrogen in the organic compounds is converted into ammonium sulphate during oxidation and ammonium ions in the soil are also trapped in the acid but nitrate and nitrite ions are lost. To include nitrate, salicylic acid and sodium thiosulphate was added. The digestion of the soil with sulphuric acid was facilitated by using sodium sulphate (raises boiling point) and copper sulphate (catalyzes the reaction). The digested solution liberated ammonia on treatment with alkali, which is collected in boric acid solution and titrated with standardized dilute acid using a mixed indicator.

3.2.4.4. Available Phosphorus (%)

Sodium bicarbonate ($NaHCO_3$) at pH 8.5 solution is used as phosphorus extractant for the soils having a pH above 5.5 and NH_4F-HCL (Bray and Kurtz No. 1) extractant for the soils below a pH of 5.5. If the soil has pH >5.5 the modified Olsen's method is used.Activated Charcoal is used during extraction to avoid interference of organic matter during color development.

3.2.4.5. Available Potassium (%)

The potassium content in the leaching extract is made with 1N ammonium acetate at pH 7.0. The soil extract is measured by aspirating in a Flame Photometer after calibrating with standards.

3.3. Data management and analysis

3.3.1. Numerical Analysis

3.3.1.1. Community Structure

The field data was used to calculate frequency, density and importance of herb and shrub species following the method described by Zobel et al. (1987) with some modifications.

Frequency (F)

Frequency is the proportion of sampling units containing the species.

$$\text{Frequency (\%)} = \frac{\text{Number of quadrats in which an individual species occurred} \times 100}{\text{Total number of quadrats sampled}}$$

Relative frequency (RF)

Relative frequency can be obtained by comparing the frequency of occurrences of all the species present.

$$\text{Relative Frequency (RF, \%)} = \frac{\text{Frequency of individual species} \times 100}{\text{Sum of the frequencies of all species}}$$

Density (D)

Density is the number of individuals per unit area.

$$\text{Density} = \frac{\text{Total number of individuals of a species in all plots}}{\text{Total number of plot studied} \times \text{Size of the plot } (m^2)}$$

Relative density (RD)

Relative density can be obtained by comparing the density of occurrences of all of the species present.

$$\text{Relative Density (RD, \%)} = \frac{\text{Density of individual species} \times 100}{\text{Total density of all species}}$$

Abundance

Abundance is the total number of individual species

$$\text{Abundance (A)} = \frac{\textit{Total no.of individual species}}{\textit{Total no. of quadrat in which species occurred}}$$

Relative Abundance (RA) $= \frac{\textit{Abundance of individual Species}}{\textit{Total abundance of all species}} \times 100\%$

Importance Value Index (IVI)

Relative frequency, Relative density, and Relative basal area each indicate a different aspect of the importance of a species in a community. Therefore, the sum of these three values should give a good overall estimate of the importance of a species. This sum is called the importance value.

IVI =RF +RD + RA

Where,

IVI = Importance Value Index of species

RF = Relative Frequency of species

RD = Relative Density of species

RA = Relative Basal Area of species

Shannon Diversity Index (H')

The Shannon index (Shannon & Weiner, 1949) is one of the most employed variables for the estimation of species diversity; for its determination is employed the formulation:

$H' = -\Sigma\ Pi.\ln(Pi)$

Where,

H' = Species Diversity Index

Pi = proportion of the species

Pi = ni / N

N = total importance value of plants

Simpson's Diversity Index

Simpson's diversity index given by Simpson (1949) is an accepted and often used calculation of plant diversity within a habitat. Within a sample area all plants of all species are counted. The diversity is then calculated using the following equation $D = \Sigma\ (ni/N)^2$

Where,

D = Simpson's Dominance Index

N = total importance value of plants

ni = importance value of each species

3.5.2. Statistical analysis

Variation among community attributes and the environmental variables were analyzed by correlation. Statistical Package for Social Sciences (SPSS, version 16), R-Studio and Microsoft Excel were used for all statistical analyses.

CHAPTER 4: RESULTS

4.1 Understorey vegetation composition

A total of 17 species of shrubs belonging to 12 families were recorded inside the national park and 29 species of shrubs belonging to 14 families in the buffer zone area. Family Asteraceae, Berberideceae, Rosaceae was found to be the dominant family inside the national park with 4 species each followed by Lauraceae and Thymelaeaceae with 2 species each while Berberidaceae was found to be dominant in the buffer zone with 4 species followed by Rosaceae and Thymelaeaceae.

Similarly, altogether 30 species of herbs belonging to 17 families were recorded inside the national park and 30 species belonging to species of herbs belonging to 18 families in the buffer zone area. Family Asteraceae and Rosaceae was found to be the dominant family inside the national park with 4 species each followed by Gentianaceae with 3 species while Asteraceae and Rosaceae was found to be dominant in the buffer zone with 4 species followed by Cryophyllaceae and Gentianaceae.

Table 4.1 : Vegetation Composition of Understorey Vegetation

Species	Site	Family	No. of Species	Dominant Family
Shrubs	LNP	12	17	Asteraceae, Berberideceae, Rosaceae
Shrubs	BZ	14	29	Berberidaceae
Herbs	LNP	17	30	Asteraceae, Rosaceae
Herbs	BZ	18	31	Asteraceae,Rosaceae

4.2 Understorey Species Diversity

Simpson’s index of diversity and Shannon-Wiener index of diversity of shrubs species inside the national park were found to be 0.9069and 2.523 respectively while those values for buffer zone were found to be 0.887 and 2.517 respectively.

Simpson’s index of diversity and Shannon-Wiener index of diversity of herbs species, in the national park were found to be 0.9415and 3.0849 respectively while those values for buffer zone were found to be 0.9201 and 2.9849 respectively which are given in the table below:

Table 4.1: Diversity of Understorey Vegetation

Species	**Site**	**Simpson's Index**	**Shannon-Weiner Index of Diversity**	**Evenness**
Shrubs	LNP	0.093	2.523	0.8908
Shrubs	BZ	0.1134	2.521	0.7567
Herbs	LNP	0.0584	3.0849	0.9070
Herbs	BZ	0.0798	2.9849	0.87761

4.3 Understorey Community Structure

4.3.1 Community Structure of Shrubs Species

The forest inside the national park and buffer zone were found to be of mixed type comprising *Quercus semecarpifolia*, *Quercus lamellosa*, *Abies spectabilis*, *Prunus cerasoides* and other tree species. Different species of herbs and shrubs were found in the national park and buffer zones.

The most dominant shrubs species in the national park was *Berberis asiatica* (IVI 30.41) followed by *Daphne bhoula* (IVI 29.58), *Berberis kumaonensis* (IVI 27.55), *Myrica* (IVI 27.37), *Berberis wallichiana* (IVI 21.86) where as the most dominant shrubs species in the buffer zone was *Edgeworthia gardneri* (IVI 38.36) followed by *Berberis wallichiana* (IVI 37.889) , *Sarcococca saligna* (IVI 33.97), *Hypericum uralum* (IVI 25.54).

Some of the shrub species were found in both national park and buffer zone .The important value index of some of species found in both national park and buffer zone is given below.

Table 4.3.: Importance Value Index (IVI) of some shrub species

SN	Species	IVI in National Park	IVI in the Buffer Zone
1.	*Berberis asiatica*	30.41	3.561
2.	*Berberis kumaonensis*	27.55	10.908
3.	*Berberis wallichiana*	21.86	37.889
4.	*Daphne bhoula*	29.58	11.607
5.	*Edgeworthia gardneri*	6.67	38.369
6.	*Hypericum uralum*	7.56	25.538
7.	*Lindera pulcherrima*	14.61	4.724
8.	*Mahonia nepalensis*	5.765	9.78
9.	*Pyracantha crenulata*	16.1	7.085
10.	*Sarcococca saligna*	17.57	33.977

4.3.2 Community Structure of Herbs Species

The most dominant herbs species in the national park was *Cyperus rotundus* (IVI 28.77) followed by *Cynodon dactylon* (IVI 20.24), *Rubia manjith* (IVI 18.58) , *Smilax aspera* (IVI 15.49148) *Fragaria virginiana* (IVI 15.005), *Rumex nepalensis* (IVI 14.719) and *Anaphalis margaritacea* (IVI 12.75) whereas the most dominant herbs species in the buffer zone was *Cyperus rotundus* (IVI 41.62) followed by *Fragaria* sp (IVI 14.55), *Fragaria virginiana* (IVI 14.39), *Smilax* sp (IVI 13.83), *Strobilanthes tomentosa* (IVI 13.13) , *Rumex nepalensis* (IVI 12.85 and *Aconitum spicatum* (IVI 12.81).

Some of the herb species were found in both national park and buffer zone .The important value index of some of species found in both national park and buffer zone is given below.

Table 4.4.: Importance Value Index (IVI) of some herb species

SN	Species	IVI in National park	IVI in Buffer zone
1	*Anaphalis busua*	11.313	9.099
2	*Anaphalis margaritacea*	12.75	12.251
3	*Cirsium falconeri*	6.545	7.737
4	*Cyperus rotundus*	28.772	41.620
5	*Drymaria cordata*	7.453	8.596
6	*Fragaria virginiana*	15.004	14.399
7	*Hedera nepalensis*	12.742	10.182
8	*Rumex nepalensis*	14.719	12.856
9	*Smilax aspera*	15.491	13.833
10	*Strobilanthes tomentosa*	11.086	13.129

4.4 Understorey vegetation and environmental factors

4.4.1. Soil pH

The forest soil of LNP and its buffer zone was strongly acidic in the study area. The soil pH in the buffer zone ranged from 3.01 to 4.18 and the pH inside the national park ranged from 3.33 to 4.51.The soil inside the national park was less acidic in comparison to the buffer zone. The *p*-value for correlation between pH and shrub species richness was found to be 0.669 and 0.192 in LNP and BZ respectively. Similarly, the *p*-value for correlation between pH and herb richness were 0.326 and 0.005 in LNP and BZ respectively. These results show that there is no significant relation between soil pH with shrubs richness in both LNP and BZ and herb richness in LNP but there is significant relation between soil pH and herb richness in BZ (Figure 4.1).

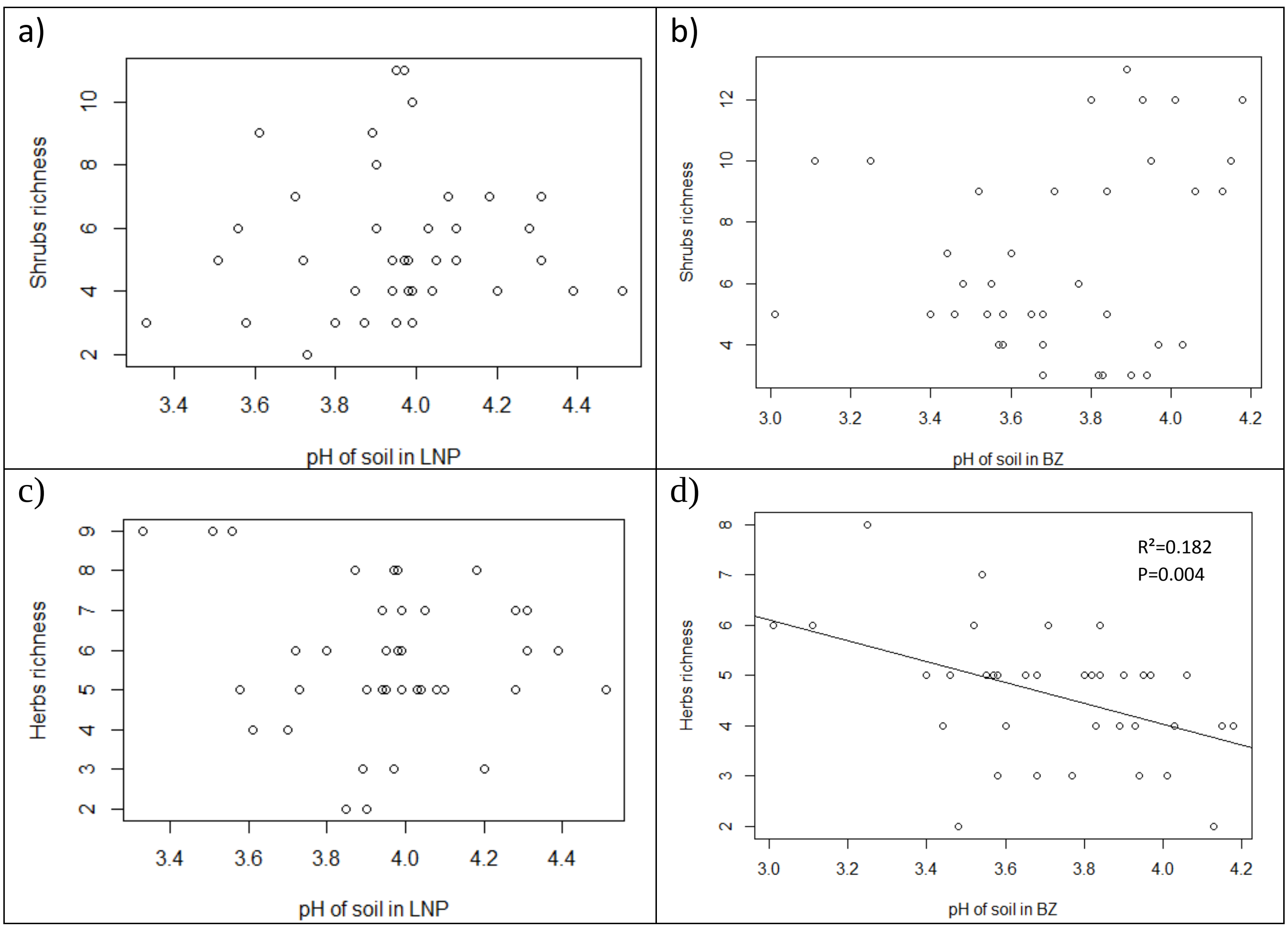

Figure 4.1.: Understorey vegetation and its relation with soil pH

4.4.2. Soil Organic Matter

The total organic matter contained in the soil ranged from 5.87 to 25.11 in the study site. The soil organic matter in the LNP ranged from 6.74% to 20.98% and in the buffer zone ranged from 5.87% to 25.11%.

The *p*-value for correlation between the organic matter content in the soil and shrub richness were 0.666 and 0.137 in LNP and BZ respectively. Similarly, the *p*- value for correlation between soil pH and herb richness were 0.104 and 0.215 in LNP and BZ respectively. These results show that there is no significant relation between soil pH with shrub and herb richness in both LNP and BZ (Figure 4.2).

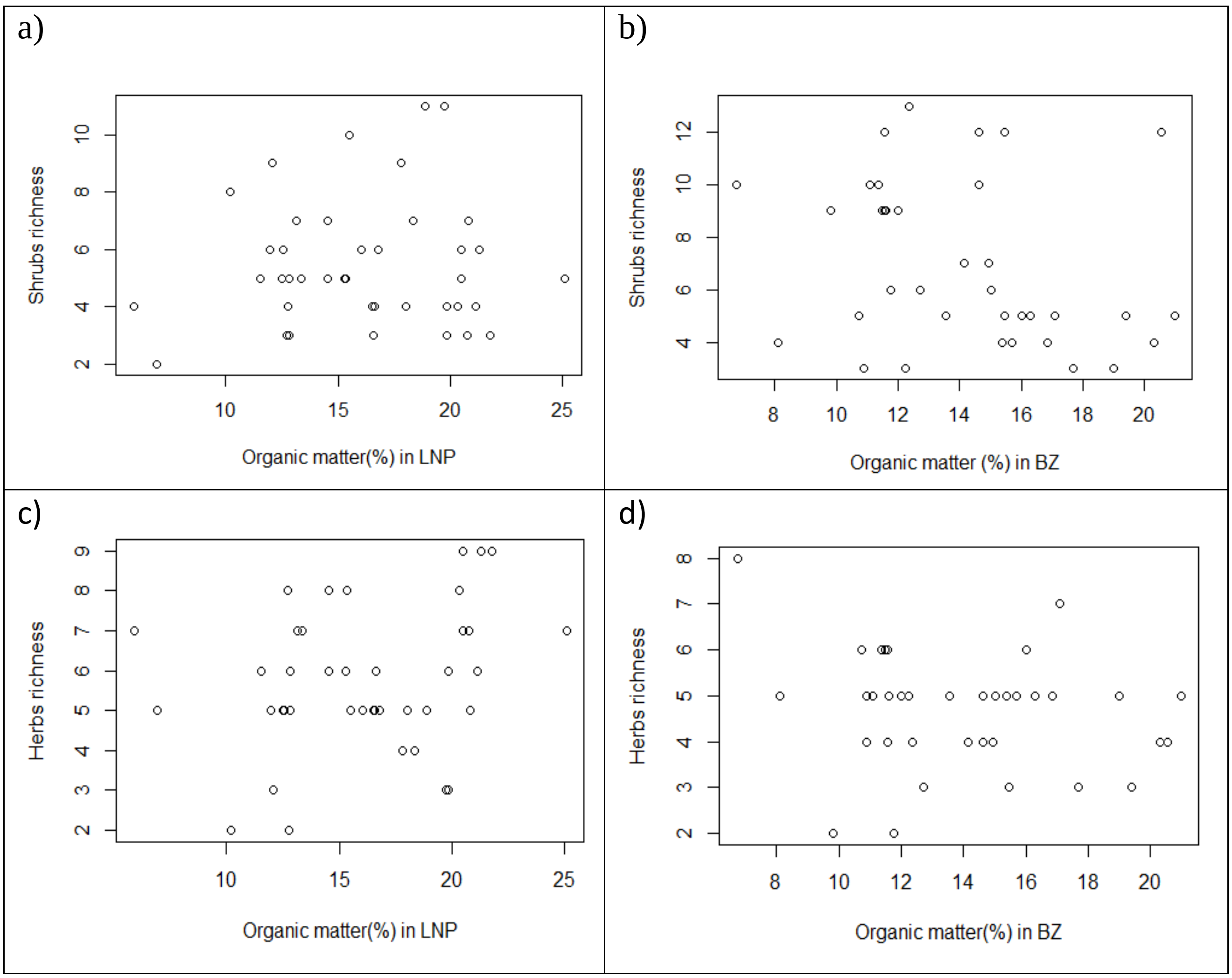

Figure 4.2.: Understorey vegetation and its relation with soil organic matter (%)

4.4.3. Soil Nitrogen

Nitrogen is added to soil naturally from nitrogen fixation by soil bacteria and legumes and through atmospheric deposition in rainfall. The total available nitrogen in the soil ranged from 0.24 to 1. The *p*-value for correlation between soil nitrogen and shrub richness were 0.737 and 0.118 in LNP and BZ respectively. Similarly, the *p*- value for correlation between soil pH and herb richness were 0.069 and 0.234 in LNP and BZ respectively. The results show that there is no significant relation between soil pH with shrub and herb richness in both LNP and BZ (Figure 4.3).

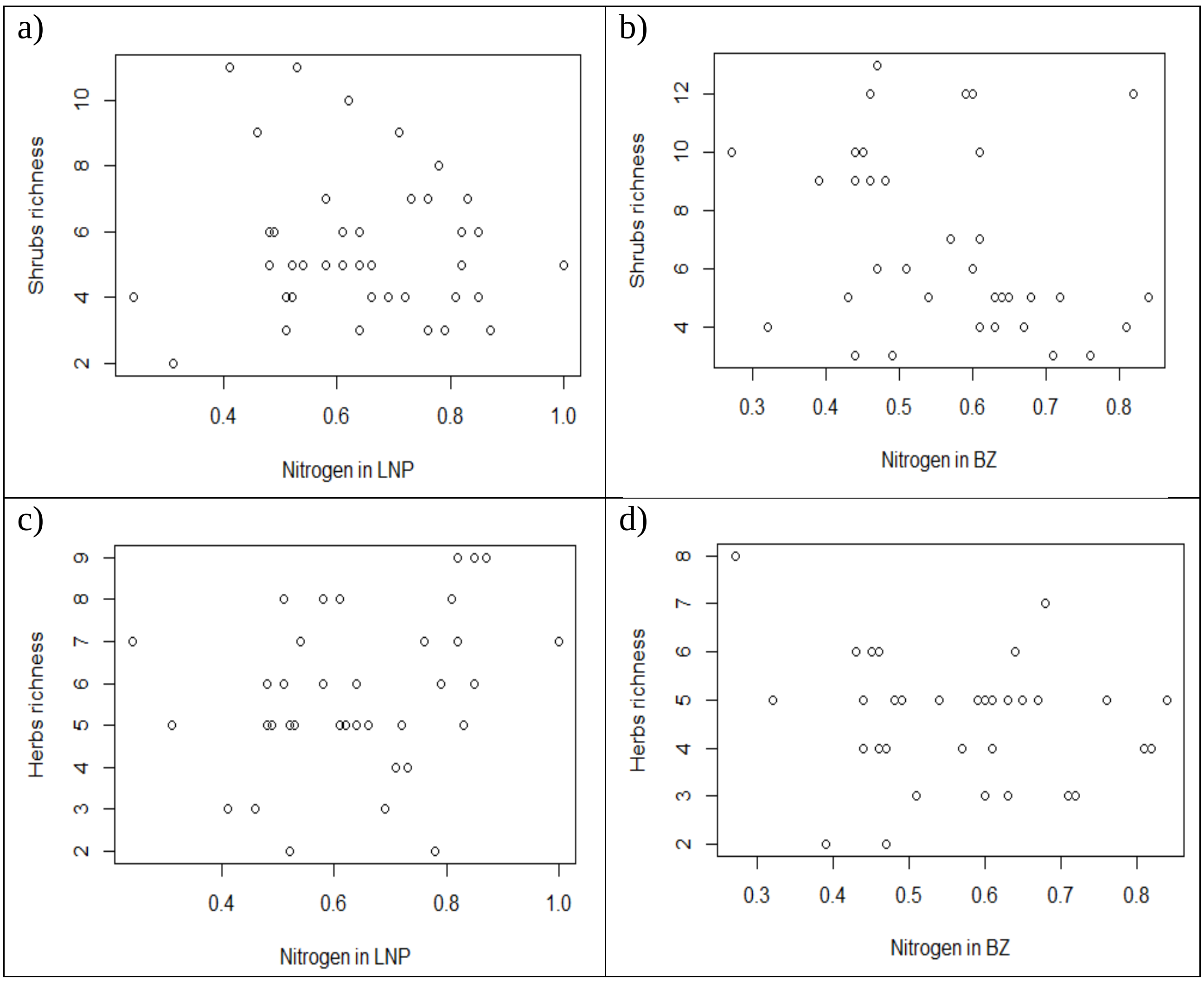

Figure 4.3.: Understorey vegetation and its relation with soil nitrogen

4.4.4. Soil Phosphorus

The total available phosphorus in the soil ranged from 23.03 to 549.12.The soil phosphorus in the LNP ranged from 35.93 to 357.48 and inside the buffer zone ranged 23.03 to 549.12.The *p*-value for correlation between the phosphorus content in the soil and shrub richness in the LNP and BZ were 0.579 amd 0.012 respectively. Similarly, the *p*-value for correlation between soil phosphorous and herb richness were 0.311 and 0.462 in LNP and BZ respectively. These results show that there is no significant relation between soil pH with shrub in LNP and herb richness in both LNP and BZ but there was a significant relation between soil phosphorous and shrub richness in BZ (Figure 4.4).

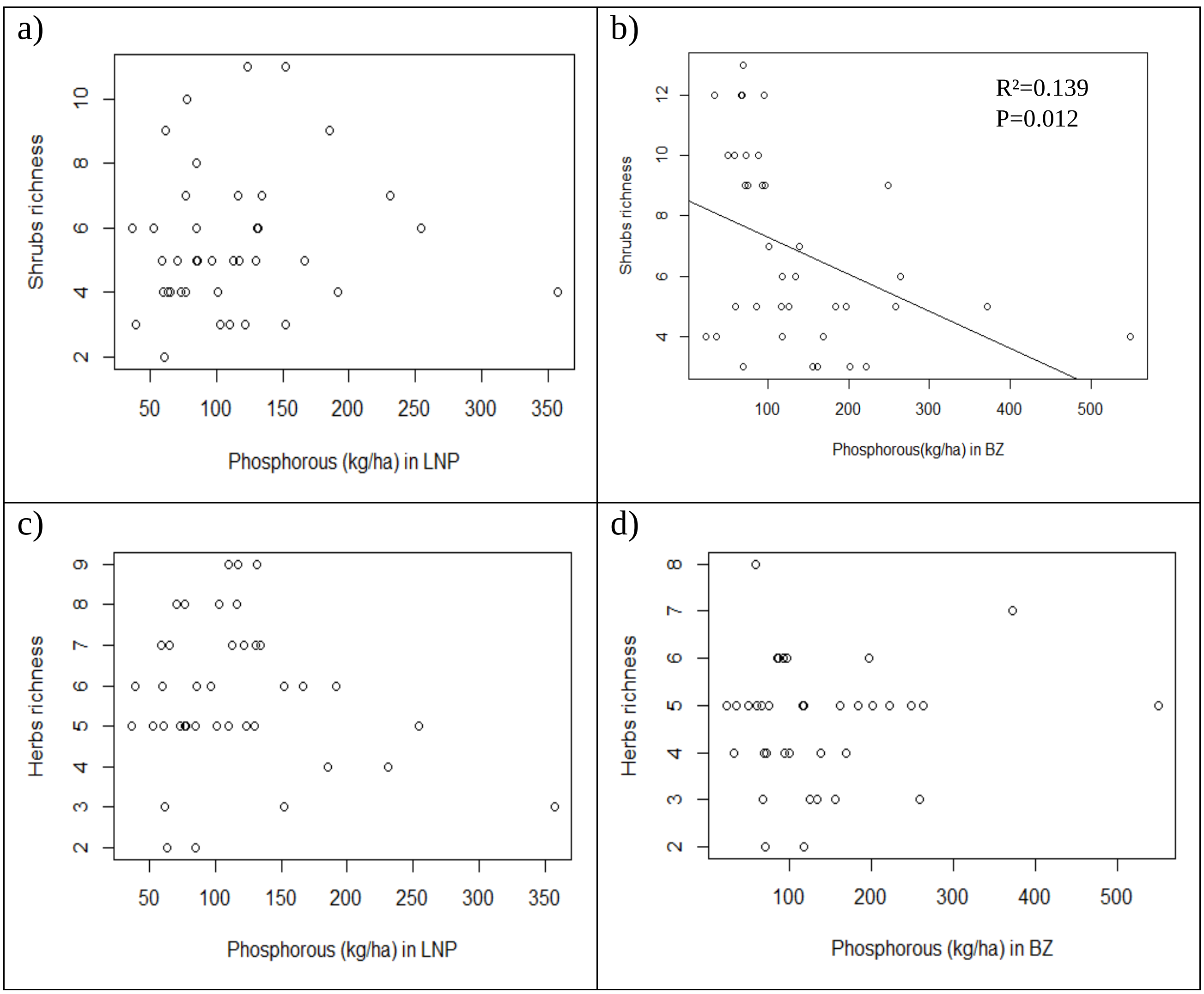

Figure 4.4.: Understorey vegetation and its relation with soil phosphorous

4.4.5. Soil Potassium

The total available potassium in the soil ranged from134 to 763.8.The soil phosphorous in the LNP ranged from 174.2 to 763.8 and inside the buffer zone ranged 134 to 673.8. The *p*-value for correlation between the phosphorus content in the soil and shrub richness in the LNP and BZ were 0.024 and 0.401 respectively. Similarly the *p*-values or correlation between the phosphorus content in the soil and herb richness in the LNP and BZ were 0.008 and 0.052. The obtained result showed significant relation between potassium content in the soil and shrubs species in LNP and with herb richness in both LNP and BZ but there was not significant relation between soil potassium and shrub richness in BZ (Figure 4.5).

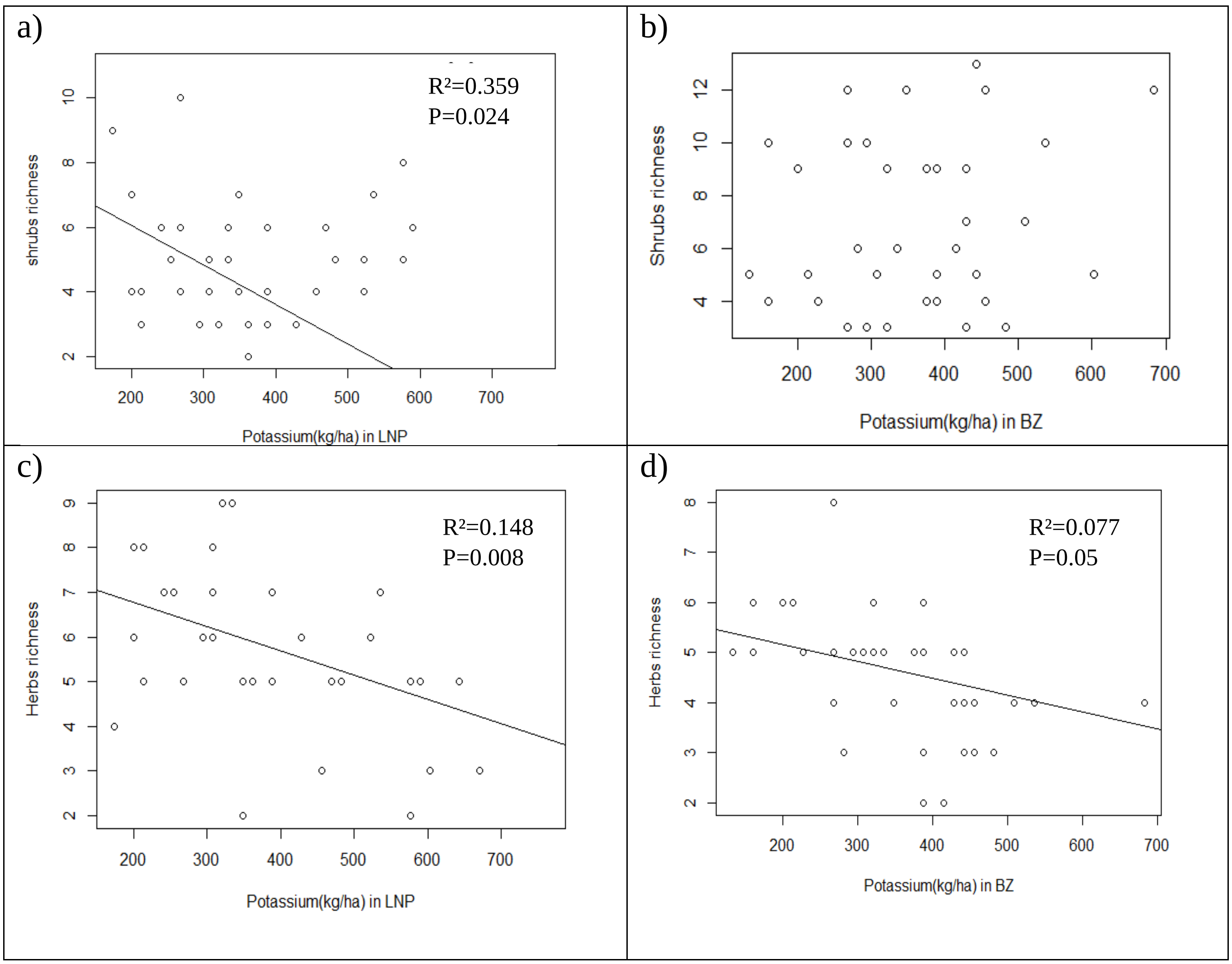

Figure 4.5.: Understorey vegetation and its relation with soil potassium

4.5. Understorey vegetation and regeneration of *Quercus semecarpifolia*

4.5.1. Regeneration of *Quercus* semecarpifolia seedling

The *p*-value for correlation between *Quercus semecarpifolia* seedling and shrub richness were 0.273 and 0.183 in LNP and BZ respectively and the *p*-value for correlation between regeneration of Quercus seedling and herb richness were 0.761 and 0.191 respectively. The obtained result shows that there was no significant relation between *Quercus* seedling with shrub species and herb species in both the national park and buffer zone (Figure 4.6).

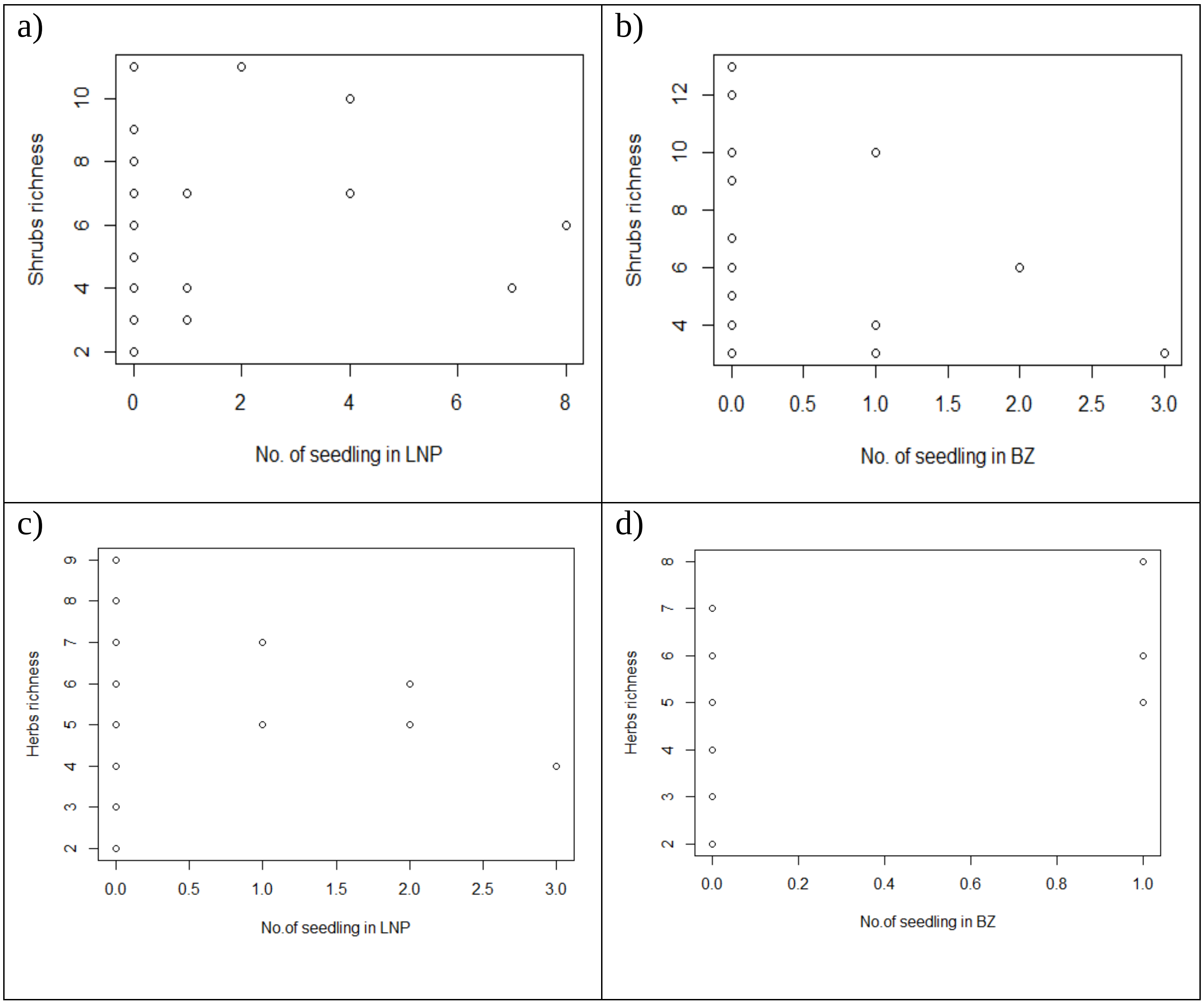

Figure 4.6.: Understorey vegetation and its relation with *Quercus semecarpifolia* seedling

4.5.2. Regeneration of *Quercus semecarpifolia* sapling

The *p*-value for correlation between *Quercus semecarpifolia* sapling and shrub richness in the LNP and BZ were 0.761 and 0.596 respectively. Similarly, the *p*-values for correlation between *Quercus semecarpifolia* sapling and herb richness in the LNP and BZ were 0.755 and 0.689 respectively The obtained shows that there was no significant relation between *Quercus* sapling with shrub and herb species in both the national park and buffer zone (Figure 4.7).

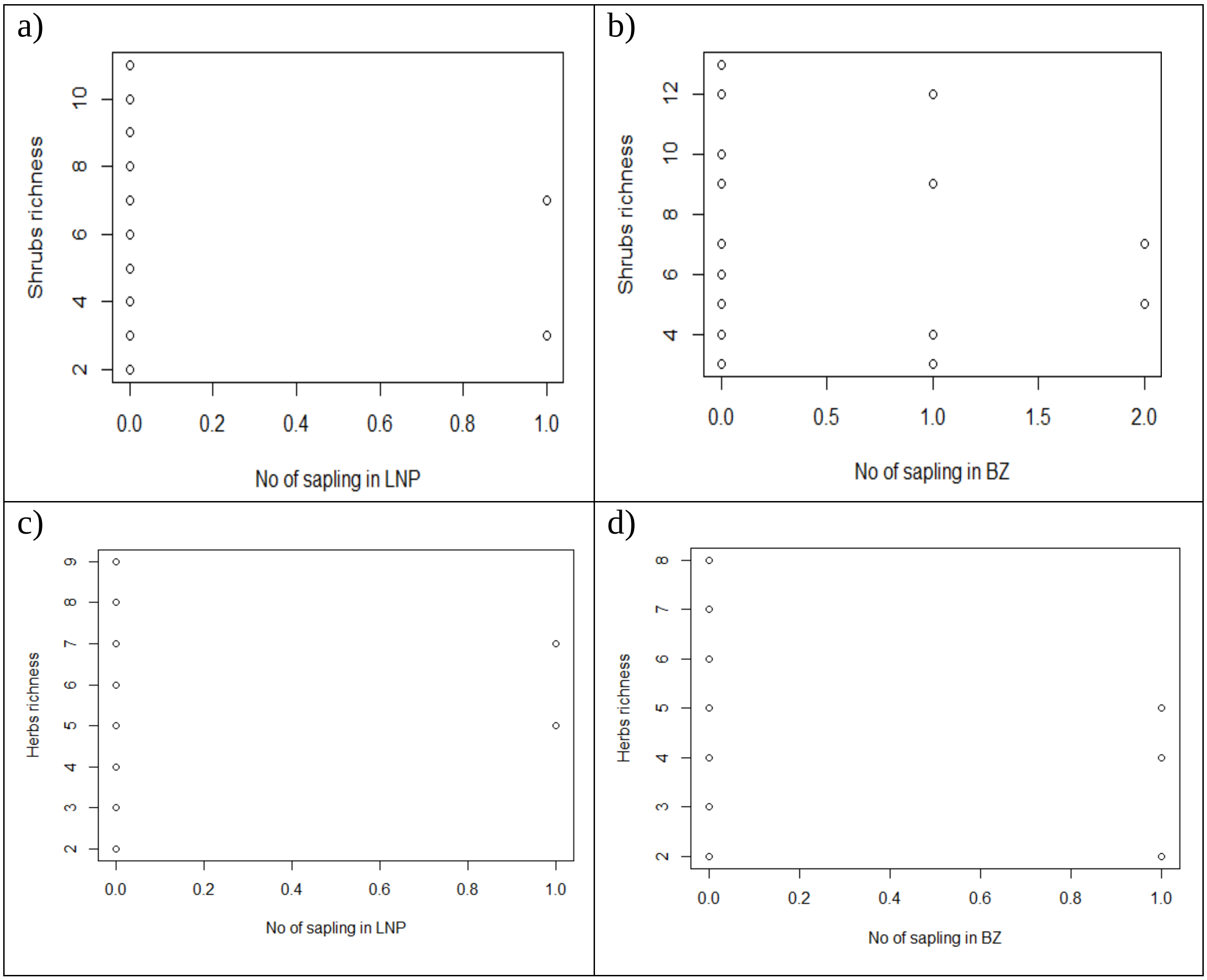

Figure 4.7.: Understorey vegetation and its relation with *Quercus semecarpifolia* sapling

CHAPTER 5: DISCUSSION

5.1. Understorey vegetation composition

The protected forests have intact habitats and show least anthropogenic disturbances (Khan *et al.,* 2019). Numerous studies have shown that forest management practices affect vegetation composition when compared to either intact forests or forests abandoned for at least a few decades (Nagaike *et al*., 2005; Odor *et al*., 2009; Horvat *et al.*, 2017; Kaufmann *et al.*, 2017). Borah *et al.* (2014) recorded 75 and 56 tree species from undisturbed forest and disturbed forest respectively at Barak Valley, Southern Assam, which shows that species richness (diversity) was higher in undisturbed area than disturbed area. Same result was obtained by Lalfakawma *et al.* (2009) as they also obtained higher tree species in undisturbed forest (32) than disturbed forest (17) at Lunglei district, Mizoram, North-East India. The study conducted by Måren & Sharma (2018) in the Langtang area showed higher species richness within protected areas. Khan *et al.* (2019) conducted a similar study in the forest of Sathan Gali, District Mansehra, KP, Pakistan and reported more species diversity than unprotected forest. However, the results obtained by this study are different from the above findings. In this study,.17 species of shrub species were found in the national park and 29 species of shrub were found in the buffer zone which means species richness higher in the disturbed area (buffer zone) than the national park (undisturbed area).Similar research was conducted by Muthuramkumar *et al*., (2006) in the Western Ghats of India showed that the trees species diversity in the unprotected forest was less as compared to the protected forest but the understorey vegetation of the unprotected forest was higher in comparison to the protected forest. A similar result was shown in the study conducted by Upadhaya *et al.* (2006) which supports this study. The result obtained by this study shows that the buffer zone has more species in comparison to the national park. This might be because the BZ area is intermediately disturbed resulting in higher diversity than NP (Willig & Presley 2018).

5.2. Species Diversity

Species diversity is one of the most important measures of community structure and it has been related to succession, climate, stability and primary productivity (Rahbek, 2005; Singh & Rawat, 2012). The study carried out in the disturbed and undisturbed area of Florida showed that the value of Shannon-Weiner diversity was higher in the undisturbed area than the disturbed area (Ahoo & Anlalhriatpuia, 2009). Similar study was conducted by Lalfakawma *et al*., 2009 and Borah *et al*. 2014) where the value of Shannon-Weiner diversity showed that the diversity was higher in the undisturbed area than the disturbed area.

But this study shows that there is no difference in value of Shannon-Weiner diversity of shrubs species in both LNP and BZ which is similar to the result of (Decocq *et al*., 2004), where there was no significant difference was found between the two silvicultural systems in the shrub layer, despite of significant differences for light and water resources. In this study, Shannon Weiner index for herbs was slightly higher in LNP as compared to the BZ though the number of species is more in the buffer zone. This might be due to the fact that the diversity of the tree layer can influence the diversity of the herb layer by modifying resource availability and environmental conditions relevant to herb layer plants (Beatty, 2003; Barbier et al., 2008). This result is quite different from the result of Vockenhuber *et al*. (2011), because their results have shown that forest stands with higher tree diversity were characterized by higher herb layer species richness. But some previous studies exploring tree diversity effects on the herb layer have shown mixed results, while some studies detected positive relationships between tree and herb layer diversity (Ingerpuu *et al*., 2003; Mölder *et al*., 2008) and some found no effect (Ewald, 2002; Borchsenius et al., 2004; Houle, 2007).

5.3. Understorey vegetation and environmental factors

The species distribution is mainly determined by the environmental variables such as soil nutrients and climatic factors (Austin, 2007).In this study we focused on the soil pH, soil nitrogen, soil phosphorous, soil potassium and soil organic matter. All these factors contribute in creating microenvironment of the plant species that influence their survival and growth Naqinezhad *et al.*, 2013). The forest soil of LNP and BZ was acidic. The acidic nature of soil in present study might be due to the high rainfall (Figure 1). The soil pH in the LNP is higher than

BZ but there was no significant relation between the soil pH and understorey species in both LNP and BZ. This result is similar to the research of Biyogue (2016) which was conducted in the savanna ecological zone in northern Ghana. In his research, low soil pH values recorded in the unprotected forest sites. According to his research, this could be attributed to an advanced stage of removal of basic cations from the surface of the soils under these forests as a result of the effect of anthropogenic activities which led to the loss of nutrients mainly through, grazing, bushfires, and logging.

This study also shows that the organic matter in the national park is higher than the buffer zone which is similar to the research of Biyogue, (2016); Teshome *et al.,* (2013). The low organic matter/organic carbon contents in the unprotected forest sites was probably due to insufficient inputs of organic matter in the soils of these forests as a result of constant removal of organic matter through, grazing, logging and bushfires (Biyogue, 2016) and sufficient nutrient cycling in the protected forest (Teshome *et al.*, 2013).But according to the study of Biyogue (2016), organic matter has significant relation with species which is not found in this study. In this study there is no significant relation between soil organic matter and understorey species.

5.4. Understorey vegetation and regeneration of *Quercus semecarpifolia*

The number of seedling of *Quercus semecarpifolia* herb plot were 17 and shrub plot were 39 whereas the number sapling in herb plots were 5 and in shrub plots were 11. Among which, 12 seedlings and 2 sapling of *Q. semecarpifolia* were found in the national park and 5 seedlings and 3 saplings where found in the herb plot in the buffer zone. Similarly, in case of shrubs species, 29 seedlings and 2 saplings were found in the national park whereas, 10 seedling and 9 saplings were found in the buffer zone. This shows that the number of seedling were more in the national park (undisturbed) in comparison to buffer zone (disturbed) which is similar to the study conducted by Gairola *et al*. (2012) where he reported the overall regeneration of trees in the forest had a greater contribution of middle and understorey species as they are better adapted to grow under the shady conditions. In contract to which Forget (1991) reported that many non-pioneer species can establish in understorey, forest edges and gaps. In all the forest types there were dense canopy cover, not many invasive or pioneer species could invade and grow inside. Although there were few invading species in this forest, but few forest types had high percentage of seedlings and saplings of invasive species.

Increased canopy disturbance in this forest seems to facilitate a very dense herbaceous field layer and a dense thicket of shrubs in very open sites (Vetaas, 1997). Both seedlings and saplings are rare in such sites, and competition with the sub-canopy shrubs and herbaceous vegetation may play an important role as suggested by several other studies (Lorimer *et al*., 1994; Negi & Naithani, 1995; Crow, 1988). But in this study there is no significant relation between the understorey species with seedling and sapling of *Q. semecarpifolia.*

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The forests studied both in national parks and buffer zones were of mixed type. Asteraceae and Berberideceae were dominant families of shrubs in both LNP and BZ. Similarly, Asteraceae and Rosaceae were dominant families of herbs in both LNP and BZ. The numbers of herb and shrub species were more in buffer zone than in national park. This may be due to the open canopy in BZ which helps the light to reach ground and promotes understorey vegetation to grow. High canopy openness promotes higher understorey species.

There was no difference in value of Shannon-Weiner diversity index of shrubs species in both LNP and BZ whereas the Shannon-Wiener diversity index for herbs was slightly higher in LNP as compared to the BZ though the number of species is more in the buffer zone. This may be due to the similar species in both LNP and BZ and also, there was not much difference in elevation of the study sites.

Microsite conditions such as organic matter, pH and nutrients content in soil (N, P, and K) showed positive correlation with the shrub and herb species but the values were insignificant. This indicates that soil nutrient plays important role in the shrubs and herbs growth and organic matter adds the soil where it supports the rooting during the germination.

This study was carried out in the *Quercus semicarpifolia* dominant forest and regeneration of its seedling and sapling increases its competition with the herb and shrub species. The number of seedling of *Q. semicarpifolia* is more in case of LNP than BZ. However, the better regeneration of seedling inside the national park compared to the buffer zone is the result of controlled human activities. Though, both seedling and sapling showed positive correlation but there was no significant relation with both herb and shrub species national park as well as in the buffer zone.

6.2 Recommendations

On the basis of results and observations, the following recommendations can be given:

- More experimental works are needed at other sites of LNP and its buffer zone to further supplement the result of the present study.

- Seasonal grazing by cattle, slashing, lopping, litter collection, etc. were the main causes of forest disturbance. Thus they should be controlled.

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ANNEXES

Annex 1: Importance Value Index (IVI) of Shrubs in the Buffer Zone (Sermanthang)

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Hypericum uralum*	0.0075	35.09	0.275	2.45	3.636	9.89	47.43
2	*Swertia pericarifolia*	0.0001	0.29	1	8.90	1	2.72	11.91
3	*Berberis wallichiana*	0.0026	12.28	0.428	3.81	2.33	6.351	22.45
4	*Artemisia gmelinii*	0.0008	3.80	0.538	4.79	1.85	5.055	13.65
5	*Ageratina adenophora*	0.0004	1.75	0.5	4.45	2	5.443	11.65
6	*Rubia manjit*	0.0001	0.58	0.5	4.45	2	5.443	10.48
7	*Pyracantha crenulata*	0.0003	1.46	0.8	7.12	1.25	3.402	11.98
8	*Heracleum* sp.	0.0001	0.58	0.5	4.45	2	5.443	10.48
9	*Dichrocephala integrifolia*	0.0005	2.34	0.5	4.45	2	5.443	12.23
10	*Buddleja asiatica*	0.0005	2.34	0.625	5.56	1.6	4.355	12.26
11	*Rubus eliptica*	0.0008	3.80	0.46	4.11	2.166	5.897	13.81
12	*Smilax aspera*	0.0012	5.56	0.736	6.56	1.357	3.6941	15.81
13	*Neolitsea pallens*	0.0013	6.43	0.5	4.45	2	5.4439	16.33
14	*Dryopteris cochleata*	0.0016	7.31	0.68	6.05	1.470	4.0029	17.36
15	*Synotis* sp.	0.0005	2.05	0.857	7.63	1.166	3.1756	12.85
16	*Aconogonum molle*	0.002	10.53	0.416	3.71	2.4	6.5327	20.77
17	*Rubus calycinus*	0.0005	2.63	0.666	5.93	1.5	4.0829	12.65
18	*Aeracema*	0.0001	0.58	0.25	2.23	4	10.887	13.70
20	*Hedera nepalensis*	0.0001	0.58	1	8.90	1	2.7219	12.21
	Total	0.0213	100.00	11.24	100.	36.74	100.00	300.0

Annex 2: Importance Value Index (IVI) of Shrubs in the Buffer Zone (Kutumsang).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Daphne bhoula*	0.0031	8.47	0.23	6.72	4.37	9.960	25.164
2	*Rubia manjit*	0.0002	0.484	0.5	14.7	2	4.553	19.757
3	*Synotis sp*	0.0044	12.11	0.24	7.06	4.16	9.486	28.658
4	*Mahonia nepalensis*	0.0019	5.326	0.273	8.02	3.66	8.348	21.703
5	*Berberis wallichiana*	0.0125	34.14	0.15	4.38	6.71	15.28	53.811
6	*Berberis kumaonensis*	0.0002	0.484	0.5	14.7	2	4.553	19.757
7	*Dryopteris cochleata*	0.0041	10.89	0.22	6.54	4.5	10.24	27.683
8	*Edgeworthia gardneri*	0.0076	20.58	0.12	3.46	8.5	19.35	43.396
9	*Drepanostachyum intermedium*	0.0013	3.632	0.33	9.81	3	6.83	20.275
10	*Smilax aspera*	0.0012	2.905	0.33	9.81	3	6.830	19.549
11	*Heracleum sps*	0.0003	0.968	0.5	14.7	2	4.553	20.242
	TOTAL	0.0368	100	3.39	100	43.92	100	300

Annex 3: Importance Value Index (IVI) of Shrubs in the Buffer Zone (Melamchighyang).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Daphne bholua*	0.0088	29.15	0.1972	4.01	5.071	11.12	44.278
2	*Sarcococca saligna*	0.012	39.43	0.1666	3.38	6	13.15	55.961
3	*Berberis kumaonensis*	0.0021	6.981	0.2941	5.97	3.4	7.452	20.406
4	*Pyracantha crenulata*	0.0007	2.258	0.0909	1.84	11	24.11	28.215
5	*Mahonia nepalensis*	0.0005	1.642	0.875	17.7	1.142	2.505	21.915
6	*Aconogonum molle*	0.0023	7.597	0.2162	4.39	4.625	10.14	22.125
7	*Lindera pulcherrima*	0.0006	1.848	0.5555	11.2	1.8	3.945	17.074
8	*Berberis wallichiana*	0.0027	8.829	0.2790	5.66	3.583	7.854	22.351
9	*Myrica sp*	0.0001	0.205	1	20.3	1	2.192	22.703
10	*Berberis asiatica*	0.0003	0.821	0.5	10.1	2	4.384	15.358
11	*Dryopteris cochleata*	0.0003	0.821	0.25	5.07	4	8.767	14.665
12	*Zanthoxylum sp*	0.0001	0.410	0.5	10.1	2	4.384	14.947
	Total	0.0304	100	4.9247	100	45.62	100	300

Annex 4: Importance Value Index (IVI) of Shrubs in the Buffer Zone (Setighyang).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Lindera pulcherrima*	0.0025	4.239	0.439	7.77	2.277	5.417	17.43
2	*Berberis asiatica*	0.0023	3.929	0.5	8.8	2	4.756	17.538
3	*Myrica sp*	0.0033	5.58	0.44	7.86	2.25	5.351	18.804
4	*Pyracantha crenulata*	0.0011	1.861	0.555	9.83	1.8	4.28	15.97
5	*Daphne bholua*	0.012	19.95	0.181	3.21	5.514	13.11	36.283
6	*Gaultheria fragrantissima*	0.0034	5.688	0.327	5.79	3.055	7.266	18.748
7	*Debregeasia salicifolia*	0.0103	17.16	0.204	3.62	4.882	11.61	32.404
8	*Zanthoxylum sp*	0.0022	3.723	0.5	8.85	2	4.756	17.33
9	*Artemisia gmelinii*	0.0057	9.514	0.195	3.46	5.111	12.16	25.133
10	*Hypericum uralum*	0.0015	2.482	0.625	11.1	1.6	3.805	17.35
11	*Berberis kumaonensis*	0.009	15.51	0.186	3.30	5.357	12.74	31.5
12	*Drepanostachyum falcatum*	0.0021	3.619	0.4	7.08	2.5	5.945	16.647
13	*Mahonia nepalensis*	0.001	1.75	0.588	10.4	1.7	4.042	16.215
	Total	0.0604	100	5.648	100	42.04	100	300

Annex 5: Importance Value Index (IVI) of Shrubs in the National park (Mel GhyNP1).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Dryopteris cochleata*	0.0023	8.18	0.297	10.14	3.35	6.25	24.57
2	*Pyracantha crenulata*	0.0030	8.53	0.244	8.336	4.08	7.60	24.47
3	*Sarcococca saligna*	0.0056	15.6	0.166	5.673	6	11.17	32.52
4	*Berberis kumaonensis*	0.0055	15.5	0.258	8.796	3.86	7.20	31.51
5	*Zanthoxylum Sp*	0.0016	4.70	0.259	8.825	3.85	7.18	20.711
6	*Daphne sp*	0.0006	1.742	0.3	10.21	3.33	6.2	18.16
7	*Lindera pulcherrima*	0.0015	4.35	0.24	8.16	4.16	7.75	20.28
8	*Berberis asiatica*	0.0008	2.264	0.23	7.85	4.33	8.069	18.189
9	*Drepanostachyum falcatum*	0.012	33.79	0.103	3.509	9.7	18.06	55.370
10	*Myrica sp*	0.0007	1.916	0.272	9.283	3.67	6.82	18.02
11	*Gaultheria fragrantissima*	0.0008	2.264	0.2307	7.855	4.33	8.069	18.189
12	*Mahonia nepalensis*	0.0003	1.043	0.33	11.34	3	5.586	17.978
	Total	0.0358	100	2.937	100	53.7	100	300

Annex 6: Importance Value Index (IVI) of Shrubs in the National park (Mel Ghy NP2).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Berberis kumaonensis*	0.0042	12.27	0.191	6.427	5.23	9.521	28.22
2	*Gaultheria fragrantissima*	0.0021	6.317	0.371	12.49	2.69	4.9	23.705
3	*Edgeworthia gardneri*	0.0088	25.63	0.134	4.498	7.47	13.61	43.73
4	*Myrica sp*	0.0096	27.97	0.148	4.989	6.74	12.26	45.23
5	*Debregeasia salicifolia*	0.0025	7.4	0.171	5.739	5.86	10.66	23.802
6	*Lindera pulcherrima*	0.0015	4.51	0.32	10.75	3.13	5.68	20.95
7	*Pyracantha crenulata*	0.0017	5.054	0.214	7.204	4.66	8.49	20.75
8	*Dryopteris cochleata*	0.0001	0.541	0.33	11.21	3	5.46	17.209
9	*Berberis wallichiana*	0.0004	1.26	0.285	9.605	3.5	6.37	17.24
10	*Sarcococca saligna*	0.002	5.776	0.156	5.253	6.4	11.65	22.67
11	*Berberis asiatica*	0.0006	1.985	0.363	12.2	2.75	5.006	19.21
12	*Daphne bhoula*	0.0004	1.263	0.285	9.605	3.5	6.371	17.24
	Total	0.0346	100	2.974	100	54.9	100	300

Annex 7: Importance Value Index (IVI) of Shrubs in the National park (Laghang NP1).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Berberis wallichiana*	0.0033	13.87	0.1132	2.797	8.83	17.74	34.41
2	*Gaultheria fragrantissima*	0.0013	5.497	0.333	8.236	3	6.024	19.75
3	*Berberis kumaonensis*	0.0003	1.308	0.4	9.883	2.5	5.02	16.21
4	*Dryopteris cochleata*	0.0001	0.523	0.5	12.35	2	4.016	16.89
5	*Daphnea*	0.0031	13.08	0.2	4.941	5	10.04	28.07
6	*Berberis asiatica*	0.0076	32.19	0.2113	5.223	4.73	9.5	46.92
7	*Myrica sp*	0.0018	7.85	0.3	7.412	3.33	6.693	21.95
8	*Drepanostachyum falcatum*	0.003	14.66	0.2142	5.294	4.67	9.37	29.32
9	*Rubus niveus*	0.0010	4.450	0.2941	7.267	3.4	6.827	18.54
10	*Lindera pulcherrima*	0.0008	3.403	0.23	5.70	4.33	8.701	17.807
11	*Hypericum uralum*	0.0001	0.523	0.5	12.35	2	4.016	16.89
12	*Pyracantha crenulata*	0.0005	2.094	0.25	6.177	4	8.032	16.30
13	*Zanthoxylum Sp*	0.0001	0.523	0.5	12.35	2	4.016	16.89
	Total	0.0238	100	4.0471	100	49.8	100	300

Annex 8: Importance Value Index (IVI) of Shrubs in the National park (Laghang NP2).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Berberis wallichiana*	0.007	14.9	0.125	3.74	8	14.21	32.855
2	*Gaultheria fragrantissima*	0.003	8.882	0.225	6.76	4.43	7.86	23.510
3	*Berberis kumaonensis*	0.004	10.17	0.183	5.48	5.46	9.703	25.356
4	*Dryopteris cochleata*	0.002	3.725	0.53	16.1	1.86	3.29	23.144
5	*Daphne sp*	0.004	9.169	0.203	6.08	4.92	8.746	23.996
6	*Berberis asiatica*	0.008	18.19	0.212	6.36	4.71	8.356	32.916
7	*Myrica sp*	0.003	6.017	0.285	8.55	3.5	6.22	20.788
8	*Drepanostachyum falcatum*	0.005	10.61	0.243	7.28	4.11	7.304	25.187
9	*Rubus niveus*	0.002	4.871	0.323	9.68	3.09	5.49	20.048
10	*Lindera pulcherrima*	0.002	4.012	0.214	6.41	4.66	8.291	18.717
11	*Hypericum uralum*	0.002	4.155	0.241	7.23	4.14	7.36	18.741
12	*Pyracantha crenulata*	0.002	2.86	0.25	7.48	4	7.106	17.456
13	*Zanthoxylum Sp*	0.001	2.43	0.294	8.81	3.4	6.041	17.281
	Total	0.043	100	3.34	100	56.3	100	300

Annex 9: Importance Value Index (IVI) of Herb in the Buffer zone (Sermanthang).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Swertia paniculata*	0.001	0.830	0.250	4.164	4.00	6.798	11.793
2	Cuscuta sp	0.001	0.207	1.000	16.658	1.00	1.700	18.565
3	*Anaphalis margaritacea*	0.011	8.921	0.357	5.949	2.80	4.759	19.629
4	*Anaphalis bhuswa*	0.010	8.299	0.231	3.844	4.33	7.365	19.508
5	*Aconitum spicatum*	0.002	1.867	0.571	9.519	1.75	2.974	14.360
6	*Strobilanthes tomentosa*	0.011	8.714	0.292	4.859	3.43	5.827	19.399
7	*Drymaria cordata*	0.007	5.602	0.286	4.759	3.50	5.948	16.309
8	*Rumex nepalensis*	0.013	10.996	0.231	3.844	4.33	7.365	22.205
9	*Frageria* sp	0.019	15.975	0.333	5.553	3.00	5.099	26.626
10	*Cyperus rodentous*	0.031	25.519	0.184	3.060	5.44	9.253	37.831
11	*Satyrium nepalensis*	0.001	0.415	0.500	8.329	2.00	3.399	12.143
12	*Arisaema concinnum*	0.001	1.037	0.333	5.553	3.00	5.099	11.689
13	*Ainsliaea latifolia*	0.009	7.054	0.235	3.920	4.25	7.223	18.196
14	*Hydrocotyle* sp	0.003	2.282	0.200	3.332	5.00	8.498	14.111
15	*Stellaria patens*	0.001	0.415	0.500	8.329	2.00	3.399	12.143
16	*Achyranthes aspera*	0.001	0.622	0.333	5.553	3.00	5.099	11.274
17	*Boehmeria platyphylla*	0.002	1.245	0.167	2.776	6.00	10.197	14.218
	Total	0.121	100	6.00	100	58.84	100	300

Annex 10: Importance Value Index (IVI) of Herb in the Buffer zone (Kutumsang).

SN	Species	D	RD	F	RF	A	RA	IVI
1	Boehmeria platyphylla	0.002	4.138	0.167	4.63	6	4.14	12.91
2	*Achyranthes aspera*	0.001	2.069	0.333	9.27	3	2.07	13.41
3	*Anaphalis margaritacea*	0.001	3.448	0.600	16.68	1.67	3.45	23.58
4	*Anaphalis bhuswa*	0.002	4.828	0.429	11.91	2.33	4.83	21.57
5	*Cyperus rotendus*	0.006	15.862	0.174	4.84	5.75	15.86	36.56
6	*Impatiens urticifolia*	0.003	8.276	0.333	9.27	3	8.28	25.82
7	*Eragostis* sp	0.002	4.138	0.500	13.90	2	4.14	22.18
8	*Hydrocotyle*sp	0.008	20.690	0.267	7.41	3.75	20.69	48.79
9	*Achyranthes bidenata*	0.004	10.345	0.267	7.41	3.75	10.34	28.10
10	*Frageria* sp	0.005	13.793	0.250	6.95	4	13.79	34.54
11	*Primula* sp	0.005	12.414	0.278	7.72	3.6	12.41	32.55
	Total	0.036	100	3.597	100	38.85	100	300

Annex 11: Importance Value Index (IVI) of Herb in the Buffer zone (Melamchighyang).

S N	Species	D	RD	F	RF	A	RA	IVI
1	Rumex nepalensis	0.002	4.11	0.33	12.51	3.00	4.11	20.73
2	*Cirsium falconeri*	0.002	3.65	0.38	14.07	2.67	3.65	21.38
3	*Cyprus rotendus*	0.014	25.11	0.16	6.14	6.11	25.11	56.37
4	*Fragaria virginiana*	0.011	19.63	0.16	6.11	6.14	19.63	45.38
5	*Stellaria media*	0.003	5.94	0.23	8.66	4.33	5.94	20.53
6	*Smilex*sp	0.003	4.57	0.50	18.76	2.00	4.57	27.89
7	*Potentilia*	0.009	15.53	0.12	4.41	8.50	15.53	35.46
8	*Ivy* sp	0.001	2.28	0.40	15.01	2.50	2.28	19.58
9	*Aconitum* sp	0.005	9.13	0.20	7.50	5.00	9.13	25.77
10	*Trifolium repens*	0.006	10.05	0.18	6.82	5.50	10.05	26.91
	Total	0.055	100.00	2.66	100.00	45.75	100.00	300.00

Annex 12: Importance Value Index (IVI) of Herb in the Buffer zone (Setighyang).

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Cyprus rotendus*	0.015	28.780	0.169	6.073	5.900	28.780	63.634
2	*Gentiana capitata*	0.004	7.805	0.250	8.958	4.000	7.805	24.568
3	*Swertia angustifolia*	0.001	0.976	0.500	17.916	2.000	0.976	19.868
4	Potentilla eriocarpa	0.003	5.854	0.167	5.972	6.000	5.854	17.679
5	Imperata cylindrica	0.002	3.415	0.571	20.476	1.750	3.415	27.305
6	*Hedera* sp	0.005	9.268	0.158	5.658	6.333	9.268	24.194
7	*Frageria*sp	0.002	3.415	0.286	10.238	3.500	3.415	17.067
8	Trifolium repens	0.004	6.829	0.143	5.119	7.000	6.829	18.777
9	*Anaphalis margaritacea*	0.007	13.659	0.143	5.119	7.000	13.659	32.436
10	*Swertia*sp	0.003	6.341	0.154	5.513	6.500	6.341	18.196
11	*Smilex*sp	0.007	13.659	0.250	8.958	4.000	13.659	36.275
		0.051	100	2.791	100	53.983	100	300

Annex 13: Importance Value Index (IVI) of Herb in the Buffer zone (Melamchi Ghyang NP1)

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Trifolium repens*	0.004	5.190	0.333	10.474	3.000	5.190	20.854
2	*Cirsium falconeri*	0.005	6.574	0.316	9.923	3.167	6.574	23.071
3	*Imperata cylindrica*	0.005	6.228	0.278	8.728	3.600	6.228	21.185
4	*Drymaria cordata*	0.005	7.266	0.286	8.978	3.500	7.266	23.510
5	*Galium asperifolium*	0.001	1.730	0.200	6.284	5.000	1.730	9.745
6	*Cyperus rotendus*	0.019	26.644	0.130	4.081	7.700	26.644	57.368
7	*Hedera* sps	0.006	7.612	0.136	4.285	7.333	7.612	19.510
8	*Frageria virginiana*	0.006	8.304	0.250	7.855	4.000	8.304	24.464
9	*Potentilla eriocarpa*	0.002	3.114	0.222	6.983	4.500	3.114	13.211
10	*Gentiana capitata*	0.002	2.422	0.143	4.489	7.000	2.422	9.333
11	*Impatiens urticifolia*	0.001	1.730	0.200	6.284	5.000	1.730	9.745
12	*Viola* sp	0.001	1.730	0.200	6.284	5.000	1.730	9.745
13	*Smilex*sp	0.007	9.343	0.185	5.819	5.400	9.343	24.504
14	*Rubia manjith*	0.007	8.997	0.192	6.043	5.200	8.997	24.036
15	*Anaphalis triplinervis*	0.002	3.114	0.111	3.491	9.000	3.114	9.720
		0.072	100	3.183	100	78.400	100	300

Annex 14: Importance Value Index (IVI) of Herb in the Buffer zone (Melamchi Ghyang NP2)

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Geranium nepalense*	0.005	6.04	0.35	9.38	2.86	6.04	21.47
2	*Rumex nepalensis*	0.003	3.63	0.50	13.40	2.00	3.63	20.65
3	*Cynodon dactylon*	0.010	11.48	0.21	5.64	4.75	11.48	28.60
4	*Stellaria patens*	0.003	3.63	0.42	11.17	2.40	3.63	18.42
5	*Aconitum spicatum*	0.002	2.72	0.44	11.91	2.25	2.72	17.35
6	*Cyperus rotendus*	0.019	22.96	0.13	3.53	7.60	22.96	49.45
7	*Ivy* sps	0.004	4.53	0.27	7.15	3.75	4.53	16.21
8	*Frageria virginiana*	0.008	9.97	0.21	5.69	4.71	9.97	25.62
9	*Potentiala*	0.008	9.67	0.09	2.51	10.67	9.67	21.85
10	*Gentiana stipitata*	0.005	5.44	0.22	5.96	4.50	5.44	16.83
11	*Viola* sp	0.003	3.02	0.20	5.36	5.00	3.02	11.40
12	*Smilex*sp	0.004	5.14	0.29	7.88	3.40	5.14	18.16
13	*Rubia manjith*	0.008	9.06	0.17	4.47	6.00	9.06	22.59
14	*Anaphalis triplinervis*	0.002	2.72	0.22	5.96	4.50	2.72	11.39
	Total	0.083	100	3.73	100	64.39	100	300

Annex 15: Importance Value Index (IVI) of Herb in the Buffer zone (Leghang NP1)

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Geranium nepalense*	0.004	8.59	0.43	11.67	2.33	8.59	28.85
2	*Stellaria patens*	0.003	7.98	0.38	10.48	2.60	7.98	26.43
3	*Anemone demissa*	0.005	11.04	0.33	9.08	3.00	11.04	31.16
4	*Ivy* sp	0.006	13.50	0.36	9.90	2.75	13.50	36.90
5	*Cyanodon dactylon*	0.002	3.68	0.17	4.54	6.00	3.68	11.90
6	*Galium asperifolium*	0.002	4.91	0.25	6.81	4.00	4.91	16.62
7	*Smilex*sp	0.004	9.20	0.20	5.45	5.00	9.20	23.85
8	*Anaphalis triplinervis*	0.003	7.98	0.23	6.29	4.33	7.98	22.24
9	*Eragostis*sp	0.002	3.68	0.33	9.08	3.00	3.68	16.44
10	*Rumex nepalensis*	0.004	10.43	0.18	4.81	5.67	10.43	25.67
11	*Swertia paniculata*	0.002	4.91	0.50	13.62	2.00	4.91	23.43
12	Rubia manjit	0.006	14.11	0.30	8.29	3.29	14.11	36.51
	Total	0.041	100	3.67	100	43.97	100	300

Annex 16: Importance Value Index (IVI) of Herb in the Buffer zone (Leghang NP2)

SN	Species	D	RD	F	RF	A	RA	IVI
1	*Gentiana stipitata*	0.003	5.45	0.36	7.78	2.75	5.45	18.67
2	*Fallopia convolvulus*	0.001	1.49	0.67	14.27	1.50	1.49	17.24
3	*Rumex nepalensis*	0.004	8.42	0.18	3.78	5.67	8.42	20.61
4	Galium asperifolium	0.002	3.96	0.50	10.70	2.00	3.96	18.62
5	*Smilex*sp	0.001	1.98	0.75	16.05	1.33	1.98	20.01
6	*Cyanodon dactylon*	0.003	5.45	0.36	7.78	2.75	5.45	18.67
7	Rubia sp	0.002	2.97	0.83	17.84	1.20	2.97	23.78
8	*Anaphalis margaritacea*	0.011	20.79	0.12	2.55	8.40	20.79	44.13
9	*Anaphalis bhuswa*	0.009	17.33	0.14	3.06	7.00	17.33	37.71
10	*Aconitum spicatum*	0.002	4.46	0.44	9.51	2.25	4.46	18.42
11	*Strobilanthes* sp	0.008	16.34	0.18	3.89	5.50	16.34	36.56
12	*Eragostis* sp	0.006	11.39	0.13	2.79	7.67	11.39	25.56
	Total	0.051	100	4.67	100	48.02	100	300

Annex 17: Values of Soil Nutrient, Soil Organic Matter, Soil pH, *Quercus semecarpifolia* seedling and sapling.

S.N	SAMPLE	Ph	N	P	K	OM	Seedlings	Saplings
1	Sermathang	3.25	0.27	58.97	268.0	6.74	3	1
2	Sermathang	3.11	0.45	87.53	160.8	11.35	4	0
3	Sermathang	3.52	0.46	93.06	321.6	11.48	1	4
4	Sermathang	3.44	0.57	100.43	428.8	14.14	1	2
5	Sermathang	3.60	0.61	138.20	509.2	14.96	1	7
6	Sermathang	3.48	0.47	117.93	415.4	11.75	1	6
7	Sermathang	3.54	0.68	371.30	603.0	17.10	1	6
8	Sermathang	3.58	0.63	125.30	442.2	15.45	1	2
9	Sermathang	3.46	0.65	116.09	442.2	16.28	2	1
10	Sermathang	3.68	0.72	257.98	388.6	19.40	0	0
11	Kutumsang	3.68	0.63	549.12	388.6	15.70	2	2
12	Kutumsang	3.55	0.60	263.50	335.0	15.04	8	0
13	Kutumsang	4.03	0.81	168.61	455.6	20.32	1	0
14	Kutumsang	3.97	0.67	23.03	375.2	16.85	6	3
15	Kutumsang	3.68	0.44	161.24	321.6	10.90	4	3
16	Kutumsang	3.90	0.76	222.04	428.8	19.00	3	1
17	Kutumsang	3.01	0.43	85.68	214.4	10.74	2	1
18	Mel Ghy	3.83	0.44	69.10	268.0	10.90	0	0
19	Mel Ghy	3.82	0.49	200.85	294.8	12.23	0	0
20	Mel Ghy	3.57	0.61	117.01	227.8	15.37	4	0
21	Mel Ghy	3.71	0.46	96.74	201.0	11.57	1	1
22	Mel Ghy	3.40	0.54	183.35	308.2	13.55	1	2
23	Mel Ghy	3.84	0.64	197.17	388.6	16.03	0	2
24	Mel Ghy	3.58	0.32	35.93	160.8	8.10	0	0
25	Mel Ghy	3.65	0.84	59.89	134.0	20.98	4	9
26	Mel Ghy	3.77	0.51	133.59	281.4	12.72	0	2
27	Mel Ghy	3.94	0.71	155.71	482.4	17.68	10	0
28	Setighang	4.06	0.48	75.55	375.2	12.01	1	0
29	Setighang	3.84	0.44	248.76	428.8	11.61	1	0
30	Setighang	4.15	0.61	72.79	536.0	14.63	0	0

31	Setighang	3.80	0.59	66.34	268.0	14.63	0	0
32	Setighang	3.89	0.47	69.10	442.2	12.35	1	0
33	Setighang	3.95	0.44	49.75	294.8	11.08	2	1
34	Setighang	4.13	0.39	70.94	388.6	9.81	0	0
35	Setighang	4.18	0.46	33.17	348.4	11.55	1	1
36	Setighang	4.01	0.60	68.18	455.6	15.45	0	3
37	Setighang	3.93	0.82	94.90	683.4	20.55	1	2
38	Mel Ghy NP1	3.70	0.73	231.26	348.4	18.34	24	0
39	Mel Ghy NP1	3.61	0.71	185.19	201.0	17.84	2	0
40	Mel Ghy NP1	4.39	0.85	59.89	241.2	21.15	32	0
41	Mel Ghy NP1	4.18	0.58	116.09	522.6	14.54	0	0
42	Mel Ghy NP1	4.51	0.72	72.79	469.0	18.01	0	0
43	Mel Ghy NP1	3.87	0.51	103.19	294.8	12.72	1	0
44	Mel Ghy NP1	4.28	0.82	130.83	361.8	20.49	0	1
45	Mel Ghy NP1	4.05	0.54	58.97	201.0	13.38	0	0
46	Mel Ghy NP1	4.28	0.64	52.52	335.0	16.03	43	0
47	Mel Ghy NP1	3.99	0.62	77.39	254.6	15.53	32	0
48	Mel Ghy NP2	4.04	0.66	101.35	268.0	16.52	1	1
49	Mel Ghy NP2	3.80	0.79	152.02	388.6	19.83	1	0
50	Mel Ghy NP2	4.31	0.58	96.74	536.0	14.54	8	0
51	Mel Ghy NP2	3.98	0.81	76.47	388.6	20.32	4	1
52	Mel Ghy NP2	3.97	0.61	70.02	361.8	15.37	1	0
53	Mel Ghy NP2	3.94	1.00	112.40	321.6	25.11	3	0
54	Mel Ghy NP2	3.33	0.87	109.64	268.0	21.81	2	0
55	Mel Ghy NP2	3.56	0.85	131.75	482.4	21.31	0	0
56	Mel Ghy NP2	3.51	0.82	117.01	455.6	20.49	2	0
57	Mel Ghy NP2	4.08	0.83	76.47	335.0	20.82	5	4
58	Laghang NP1	3.85	0.52	63.57	308.2	12.75	0	0
59	Laghang NP1	3.73	0.31	60.81	214.4	6.94	0	1
60	Laghang NP1	3.58	0.64	109.64	589.6	16.57	0	0

61	Laghang NP1	3.94	0.24	65.42	268.0	5.87	3	0
62	Laghang NP1	4.03	0.48	254.29	670.0	11.95	0	0
63	Laghang NP1	3.99	0.76	121.62	576.2	20.78	5	4
64	Laghang NP1	3.95	0.51	38.70	308.2	12.82	0	1
65	Laghang NP1	4.20	0.69	357.48	763.8	19.86	3	3
66	Laghang NP1	3.90	0.49	35.93	214.4	12.55	6	0
67	Laghang NP1	4.10	0.52	129.91	576.2	12.48	3	0
68	Laghang NP2	3.99	0.66	191.64	174.2	16.61	0	2
69	Laghang NP2	3.72	0.61	166.76	388.6	15.29	0	0
70	Laghang NP2	3.98	0.46	85.68	308.2	11.51	4	1
71	Laghang NP2	4.31	0.53	134.52	348.4	13.15	6	2
72	Laghang NP2	3.90	0.41	84.76	308.2	10.19	2	0
73	Laghang NP2	3.94	0.51	84.76	428.8	12.82	8	2
74	Laghang NP2	4.10	0.64	84.76	643.2	16.77	0	0
75	Laghang NP2	3.89	0.48	61.73	603.0	12.08	0	1
76	Laghang NP2	3.95	0.76	123.46	522.6	18.91	5	2
77	Laghang NP2	3.97	0.78	152.02	522.6	19.73	2	0

***MelGhy=Melamchighyang**

PHOTOPLATES

Bushes of *Daphne bholua* in LNP

A newly established seedling of *Q.semecarpifolia*

Unsustainable grazing in BZ

Interacting with Local people


Firewood collected by local people from BZ

Rural road construction, a major cause of habitat loss