VEGETATION STATUS, COMPOSITION AND STRUCTURE OF MALIKA FOREST, BAGLUNG, WESTERN NEPAL

A THESIS

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

BY

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Symbol NO.: Bot 074/549

TU Registration NO.: 5-2-0053-0386-2013

SUBMITTED TO

DEPARTMENT OF BOTANY

AMRIT CAMPUS

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KATHMANDU, NEPAL

NOVEMBER, 2022

DECLARATION

I, Nisha Gaire, hereby declared that this dissertation entitled "VEGETATION STATUS, COMPOSITION AND STRUCTURE OF MALIKA FOREST, BAGLUNG, WESTERN NEPAL" is my original work and all other sources of the information used are duly acknowledged. I have not submitted it or any of its part to any other universities for any academic award.

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RECOMMENDATION

This is to certify that the M.Sc. dissertation work entitled **"VEGETATION STATUS, COMPOSITION AND STRUCTURE OF MALIKA FOREST, BAGLUNG, WESTERN NEPAL"** has been completed by Ms. Nisha Gaire under my supervision. This entire work was accomplished on the basis of candidate's original research work. To the best of my knowledge, the work has not been submitted to any other academic degree. I hereby recommend for acceptance of this dissertation as a partial fulfillment of the requirement of Master's Degree in Botany at the Institute of Science and Technology, Tribhuvan University, Nepal.

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LETTER OF APPROVAL

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ACKNOWLEDGEMENT

I would like to express my very great appreciation to my respected supervisors Dr. Biva Aryal for their invaluable time, suggestions and guidance throughout my dissertation work. The deepest gratitude and sincerest thanks go to our respected teacher as well Co-Supervisor Prof. Dr. Kanta Poudyal for their impressive tutelage, constructive criticism and intellectual support who all contributed to this academic tenure.

I am thankful to Head of Department Associated Prof. Dr. Shila Singh for her academic and administrative supports. I am also grateful to Assistant Prof. Dr. Laxmi Joshi Shrestha (Coordinator M.Sc. Botany Program) for providing necessary help and valuable suggestions during this study. I want to thank Prof Dr. Mukesh Kumar Chettri for intellectual support. My thanks also go to all the academic and administrative staff of college name for their direct and indirect support and help. I would also like to appreciate the authorities of National Herbarium and Plant Laboratories (KATH), Godawari for allowing permission to assess the herbarium specimens and Department of Survey for providing necessary data.

I am very grateful to my friend Pratima Acharya and Prerana Khadka for their valuable suggestions, constant help and inspiration during the field visit and desk-study. Lastly, I am greatly indebted to my whole family especially to my husband Mr. Shiva Sharma, for his overall support and inspiration throughout this research.

Nisha Gaire

November, 2022

LIST OF ACRONYMS AND ABBREVIATION

ANOVA	Analaysis of Varience
BA	Basal Area
C	Coverage
D	Density
DBH	Diameter at breast height
DHM	Department of Hydrology and Meteorology
F	Frequency
FGD	Focus Group Discussion
GoN	Government of Nepal
GPS	Global Positioning System
Ha	hectare
IVI	Important Value Index
Kg/ha	Kilogram per Hectare
NPK	Nitrogen Phosphorus Potassium
p	Level of significance
RBA	Relative Basal Area
RC	Relative Coverage
RD	Relative Density
RF	Relative Frequency
Sq .km	Square kilometer
USDA	The United States Department of Agricultures
VDC	Village Development Committee
WFP	World Food Programme

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ABSTRACT

There is the importance of structurally diverse forests for the conservation of biodiversity and provision of a wide range of ecosystem services. The frequency, diversity, density, IVI, Carbon stock and soil nutrient factors of two altitudinal range i.e 1600-2000m and 2000-2400m were quantify to investigate the vegetation diversity of Malika Community Forest. Systematic random sampling was applied for vegetation analysis. Circular quadrat method was used in the field for the observation. The altitude wise collected data was divided into two altitudinal range (1600-2400m). Altogether 70 main quadrats were studied from these two altitudes. For Tree species, altogether 140 quadrats (70X2) were laid for shrub species and 210 quadrats (70X3) for herb species were laid. Circular plot of $10m^2$ radius were laid for the study. Number of seedlings and saplings were also recorded within main plot. Community structured was studies by using vegetation quantitative characters (frequency, density, IVI), carbon stock analysis and regeneration. Total 16 soil samples were prepared for laboratory analyses which were collected from center of each quadrat. For soil analysis both physical as well as chemical parameters like the N, P, K, soil pH, organic matter and soil texture of the soil were tested. In the present study, the tree species diversity decreased from lower to highest altitudes. Between two altitudinal range, the highest frequencies among shrubs was of *Rubus ellipticus* in lower altitude and of *Prunus* sp in upper altitude whereas *Artemisia indica* and *Cynodon dactylon* which was 34% in lower altitude whereas *Stellaria media* and *Cyperus rotundus* has highest frequencies (42%) in upper altitude among herbs and highest frequency was of *Pinus* among trees. The highest diversity was found among herbs species i.e H=2.97 in low altitudinal range whereas highest diversity in shrubs species in upper altitudinal range of 2000-2400m i.e, H=2.66. In the studied area the highest IVI for herbs was of *Stellaria media, Arisaema toftuosum, Ageratina adenophora. Dicranopteris* and for shrubs the highest IVI was of *Lyonia ovalifolia* and *Rhus javanica.* Among the tree species *Pinus roxburghii* scored highest IVI recorded as from 2000-2400m. The density of seedlings and saplings of *P. roxburghii* were highest in both altitudes. The highest carbon stock was reported in *P. roxburghii*. The tree and shrub species richness increased from lower to higher altitudes.

Key word: Forest structural diversity, altitude, Important Value Index, *Pinus roxburghii.*

CHAPTER 1
1. INTRODUCTION

1.1 Species composition

Species composition refers to the contribution of each plant species to the vegetation. Species composition is the identity of all the different organisms that make up a community. Species composition means, with respect to a stand or other area of land, the species that constitute the plant community within that stand or area. Species composition provides the essential description of the character of the vegetation at a site.

Nepal has rich biodiversity, especially in plant species, because of variability in topography, climate variations and vertical dissimilarities. In Nepal, 118 types of ecosystems have been identified in different physiographic zones with 52 and 38 ecosystems in the middle mountains and the highlands respectively (Maskey, 1995). MFSC/GoN, 2014 enumerated 6,973 species of angiosperm and 26 species of gymnosperm in Nepal.

The Population structure (age or size) of tree species provides valuable information on population dynamics (Dang *et al.,* 2010). Information about population structure is important to understand the mechanism of species coexistence and long-term ecological processes of natural forest (Miura *et al.,* 2001). Population structures declare the dominance status of species and development within the community (Gairola *et al.,* 2014). Although the population structure of plants is described either by age, size or by their life stage (Rabotnov, 1969), the population structure of woody perennial species is often estimated by size class distribution (Saxena and Singh, 1984; Venter and Witkowski, 2010). The population structure and recruitment patterns of forest are influenced by many factors like disturbance, competitive interactions between trees (North *et al.,* 2004).

1.2 Species richness

Structurally diverse forests are important to maintain species-rich communities (Simpson 1949; Brunialti *et al*., 2010; Taboada *et al.,* 2010). A higher diversity

characteristics (shapes and expressions) can lead to higher species diversity by provision of different microhabitats (Recher, 1991; Woinarski *et al*., 1997; Michel *et al*., 2011). The ability of species diversity to quantify forest composition has provided ecologist with the most prominent tool, often used as the scorecard to preserve and restore a forest. Likewise, the size class distribution of forest trees is the prime indicator of forest structure and dynamics, widely used to examine the forest's health, including regeneration (Korner, 2003). Tree diameter is a statistically proven parameter to measure forest carbon stocks (Lee *et al*., 2016). Furthermore, stem density and basal area are an excellent surrogate to estimate forest biomass and carbon.

A proper understanding of forest composition and structure allow foresters, national park rangers, and landowners to maximize forest ecosystem's goods and services by maintaining or conserving a desired structure and composition of the forest at stand and landscape level (Kunwar and Sharma, 2004)..

In Nepal, *Pinus roxburghii* constitute 8.45% of total forest area (DFRS, 2015). It is the dominant species at the study sites, followed by *Rhododendron arboreum.*Understanding of soil chemical reaction and processes is essential for developing innovative resource management strategies, and understanding and regulating the behaviour of the terrestrial ecosystem at regional and global scale (Tale and Ingole, 2015). In study site, lower region of the forest known as *P. roxburghii* forest due to its dominancy along with *Rhododendron arboreum* and *Alnus nepalensis*. Above 2000m mixed type vegetation is found where *P. roxuburghii*, *Rhododendron arboreum*, *Symplocos ramosissima* are dominated.

1.3 Forest Structure

Forests are three-dimensional systems whose bio-physical structure plays major roles in ecosystem function and diversity. Forest structure can be thought of as both a product of forest dynamics and biophysical processes and as a template for biodiversity and ecosystem function. Consequently, understanding forest structure can help to unlock an understanding of the history, function, and future of a forest ecosystem (Waring and Franklin, 1979).

Forest structure comprises trees, shrubs, and ground covers including vegetation and dead woody materials. Based on diameter class, structure can be small, medium, and large trees (Bennett, 2010). Vegetation structure is the organization of individuals in space that constitutes a stand of plants. A forest is a large area dominated by trees where forests provide a diversity of ecosystem services. A forest consists of many components that can be broadly divided into two categories that are biotic (living) and abiotic (non-living) components. Quantitative assessment of the diversity, structure and composition of forest trees are essential, not only to understand forest biodiversity and health but also for designing conservation strategies, which is a significant threat to biodiversity (Bhutia *et al*., 2019).

In Nepal approximately 29% of the total land is covered by forest consisting of 35 forest types along the elevational gradient from 60 m asl to tree line at around 4000 m asl (Pandey *et al*., 2015). Human impact has led to varying degrees to a reduction in biodiversity in much of the forested area of Nepal. Conservation of such forests requires an understanding of the composition of the particular forest, the effects of past disturbances, and the present impact of neighboring utilization pattern on that forest. In order to understand the community structure of the forests, we need studies that deal with distribution of individual plant species and of various associations among species, patterns of dispersion and various indices of diversity (Longman and Jenik, 1987). The present study therefore was designed to explain variation in vegetation composition and diversity components.

The composition and ecosystem services of Himalayan forests depend on forest structure, which is believed to be changing over time (Sharma *et al*., 2017). Forest trees are the dominant structural and functional component of the forest ecosystem. Tree species diversity, stem density, and basal area are the essential attributes that describes a forest's ecosystem and measuring these attributes are fundamental in designing conservation strategies (Kunwar and Sharma, 2003). Species diversity is the most crucial descriptors, which not only captures information on species richness (number of species in a community) but the relative abundance of species in a forest (Kunwar and Sharma, 2003). It also provides information on the rarity and the commonness of a species.

1.4 Forest regeneration

Natural regeneration is an important process for the existence of species in a community under variable environmental conditions (Khumbongmayum *et al.*, 2005), it helps to predict the future health of the forest ecosystem (Good and Good, 1972; Saxena and Singh, 1984; Shankar, 2001; Pala *et al.*, 2016). The regeneration patterns and factors governing them determine the forest structure and composition (Wangda, 2003). Successful regeneration requires adequate seedlings and their survival, which is controlled by the microclimate of the site and anthropogenic stimuli. Indeed, even high starting seedling densities can't ensure successful regenerations in the zones with higher interference levels like grazing and tree felling (Rooney and Waller, 1998).

1.5 Carbon stock

Carbon stock is the quantity of carbon contained in a reservoir or system which has the capacity to accumulate or release carbon. In the context of forests it refers to the amount of carbon stored in the world's forest ecosystem, mainly in living biomass and soil, but to a lesser extent also in dead wood and litter. It is estimated that about 86% of the terrestrial above-ground carbon and 73% of the earth's soil carbon are stored in the forests (IPCC, 2000). The carbon stock in forest vegetation varies according to geographical location, plant species and age of the stand (Van Noordwijk *et al.,* 1997) Carbon sequestration is thought to be a promising means for reducing atmospheric carbon dioxide, an important greenhouse gas. The tropical forests are said to play a major role in the global carbon cycle, storing up to about 46% of the world's terrestrial carbon pool and about 11.55% of the world's soil carbon pool, acting as a carbon reservoir and functioning as a constant sink of atmospheric carbon . Deforestation combined with forest degradation has contributed about 20% of the GHG emissions which is more than the emissions by the whole transportation system (Stern, 2007).

1.6 Soil properties

Soil properties determine the composition of plant community structure and regeneration of plants (Sigdel, 2015). Soil properties depend on different environmental factors such as slope, aspect, climate, landscape, microclimate,

topography, and vegetation (Tsui, 2004). *Pinus roxburghii* is generally suitable in sandy and loamy soil, prefers well-drained soil and can grow in nutritionally poor soil. Suitable pH is mildly acid, neutral and basic (mildly alkaline) soils and can grow in very alkaline soils. *R. arboreum* prefers sandy to loamy soil and requires fairly moist and acidic soil (Srivastava, 2012), the acidic environment is created by the degradation of acidic litter of *R. arboreum* (Maithani *et al.*, 1998). Slightly acidic forest soil (pH range from 5.5 to 7.2) has excellent ability to provide balanced nutrients (Gairola *et al*., 2011).

1.7 Problem statement /justification

The studied site of Malika Community Forest was affected by human interferences, similar to the most parts of Nepal. Due to fully dependency of the people for their daily needs, the size of the lower slopes of forest may decrease in future. The study is important, since Structure and composition of the forest has not been done yet in Malika forest and the outcomes of the study will enable the forest managers to adopt best forest management system.

Malika Community Forest is mainly dominated by *Pinus roxburghii.* These species are deeply associated with the livelihood of the people from very ancient time and used it for many purposes. It is also a common source of several commercially important raw materials like resins, timber, turpentine oil etc. which contributes a remarkable portion in the annual income of the state (Singh *et al.*, 2017). Due to impact of deforestation, consumption and export, several species are in endangered state. At the same time, medicinal plants which exhibit a great importance on Ayurvedic medicines, are declining due to high intensity of human pressure. Government has not carried out any programs to rehabilitate the flora and fauna so as to sustain the forest resources. The present work is an effort to study the forests area so as to know its present condition with respect to forests diversity, regeneration status and soil characteristics. This kind of work has not been conducted in this forest. Hence, this study will contribute to understand the forests and also will assist in better management practices.

1.8 Research question

The major research questions are as follows:

- How does the community structure change at two altitudes?
- What is the species diversity along the altitudes?
- How does carbon stock differ at two different altitudinal ranges?
- How do soil properties alter at two different altitudinal ranges?

1.9 Objectives

The general objective of this research is to explore status of community composition and soil characteristics along the two different altitudes of Malika forest. Moreover, its specific objectives are: -

- To analyze the IVI and species diversity at two different altitudes.
- To determine the species diversity between altitudes.
- To determine tree carbon stock of two different altitudinal range.
- To analyze the soil properties (pH, N, P, K, soil organic carbon) at different altitude.

1.10 Limitations

This research has many significances in the present context of ecological and biodiversity study in Nepal. However, this research has following limitations:

- Study covers only the Sub-tropical and Temperate region of Malika forest area.
- The altitudinal ranges (1600-2400m) have limited the research within the relatively small altitudinal ranges.
- Sampling was not performed on very steep slopes.

CHAPTER 2
2. LITERATURE REVIEW

2.1 Species composition

Vegetation is the reflection of physiographic and climatic condition of an area. Nepal is a small country in terms of area, though it is rich in floristic composition. Being a mountainous country, altitudinal gradient is quite common feature of physiography which ultimately creates microclimatic condition that supports vegetation diversity. Floristic or inventory is the systematic enumeration and documentation of all plant species in a given geographic region and ideally provides keys, description and often illustration (Naik, 1998; Simpson, 2006). Exploration is the most important step of systematic study. In montane Nepal, altitude and aspect are the paramount importance in determining the type of forest found at particular place (Stainton, 1972).

Altitude, one of the major factors determining the climatic condition, affects directly the distribution of species of an area. Along with the increasing altitudinal gradient, the temperature and rainfall differ markedly so the species should adapt to the particular condition to sustain their life. However, majority of the species cannot adapt the major change in climatic conditions and become restricted to a limited elevation. Forests being standing stores of sequestered atmospheric carbon can serve as valuable carbon pool. It is thus, the global communities become progressively more concerned with forest ecosystem as a tool to mitigate the impacts of climate change. This study focused on the distribution pattern of forest types and their composition along altitudinal gradient.

2.2 Species richness

More heterogeneous environmental conditions may select more diverse plant species as different species may require different habitat conditions (Lee *et al*., 2016). The structure and function of forest ecosystem is determined by the plant component more than any other living component of the system (Pala *et al*., 2016). The species with high tolerance to climatic variability had followed mid-domain model predictions, and showed a nonlinear relationship with temperature, whereas tropical species richness tracked temperature and area (Pandey *et al*., 2016). The variation in quantitative

parameters, species richness as well as forest composition among all studied may be due to difference in climatic, physiographic and edaphic factors (Sharma *et al*., 2017). According to Shaheen *et al*., 2019 showed a stronger influence of tree species identity over tree diversity on soil characteristics. Vegetation communities were characterized by a high degree of species evenness, indicating that individual species exhibit uniform distribution. Fewer numbers of species in each community decreases interspecific competition, which results in a high degree of species evenness (Shaheen *et al*., 2019).

However, the previous study shows research gap in western part of Nepal. Structure and composition of the forest has not done yet in most of the western area and especially in Malika forest of Baglung district. Regarding soil analysis very little work has been conducted with relation to the soil and forest structure in the site. So, recognizing the importance of concentration of soil status and the forest structure, present study will be fulfill the research gap as it provide the basic information about the forest structure and composition of natural forests.

Species diversity is an important index in characterizing a community. It is also important in reflecting the type of community, the stage of community development and community stability (Liyun *et al*., 2006). Climatic variations influenced by the complex topography in a predominantly monsoonal area most often determine the dominant type of vegetation and the vegetation zones are partly obscured by factors of aspect, drainage, soil and human impact (Pandey *et al*., 2015). Human impact has been used to explain low regeneration of evergreen oaks and indicated the best regeneration in the least disturbed sites. Thick litter generally reduces the rates of germination and of seedling establishment (Maren *et al*., 2007). According to Ping *et al*., 2009, the forest tended to be more resilient at higher elevations. It also implied that the severity of disturbances was higher at lower elevations. The woody stem abundance and species richness of the different tree height and size classes which suggests that the regeneration was generally successful, since there were abundant young trees to replace old trees in the future (Zhang *et al*., 2014).

The vegetation can also be influenced by factors like topography and other human disturbances (Chhetri *et al*., 2017), moisture limitation, land use practices and ecological restoration such as afforestation and agricultural practices in Nepal (Baniya

et al., 2019). The forest assumes a powerful part in securing the delicate environments and keeping up different and complex biological systems. The ecological study of the forest ecosystem is very necessary. It is a habitat for many plants and animals as tree trunks and branches are usually densely covered with epiphytic plants, including ferns and orchids. Moreover, it is crucial for watershed protection and biodiversity conservation and it brings rich animal diversity (Tashi, 2004). Lopping of trees is a common practice among the mid-hill farmers for fodder. Heavy lopping results pole like the appearance of the trees with scanty leaves (Jackson, 1994). Grazing and litter collection are other disturbance factors in the Panchase forest (Maren *et al*., 2013).

2.3 Forest structure

Forest structure, composition, and diversity patterns are crucial ecological features that correlate significantly with prevailing environmental and anthropogenic components (Gairola *et al*., 2008). Stand structure and species composition are essential for forest biodiversity, and an understanding of these is the basis of sustainable forest management (Gutiérrez *et al*., 2012). Forest structure and composition also have a vital role in the global carbon budget as they act as huge C-pools (Canadell *et al.,* 2007). Comparisons in tropical forests have illustrated that mountain forests are usually shorter and less diverse than forests in the lowlands (Lieberman *et al.,* 1996). In addition to altitudinal gradient, regional climate plays a major role in influencing forest structure. It is usually inferred that forests in higher precipitation and temperature regions have taller trees and more biomass (Chave *et al.,* 2014). The shaping and configuration of forests are largely affected by changes in climate variables (Beckage *et al.,* 2008).

2.4 Regeneration

Tree regeneration can be predicted by their population structures (Khan *et al*., 1987). It helps to determine the serial stage of the community and predict the potential climax vegetation of a particular area (Gairola *et al*., 2014). The pattern of population dynamics of seedlings, saplings and adults of a plant's species can reveal the regeneration profile, which is used to determine their regeneration status (Bekele, 1994; Teketay, 1996). Good and Good, 1972 considered three major components for successful regeneration of a species which are: i) ability to germinate the seeds, ii)

ability of seedlings recruitment and saplings to survive and iii) ability of seedlings and saplings to grow. A population with sufficient number of seedlings and saplings and trees in a forest indicates successful regeneration (Khan *et al*., 1987; Dutta and Devi, 2013), while inadequate number of the species in a forest indicates poor regeneration (Tripathi and Khan, 2007). Successful regeneration provided long-term sustainability of a forest (Malik and Bhatt, 2016). Rehabilitation and ecosystem recovery also depend on regeneration capacity (Pandey and Shukla, 2001), which plays an important role in forest growth and management. Rehabilitation and ecosystem recovery also depend on regeneration capacity (Pandey and Shukla, 2001), which plays an important role in forest growth and management.

Regeneration status of tree species can be determined by using diameter at breast height (dbh) or girth at breast height (gbh) class distribution of trees (Everard, 1992). Malik and Bhat, 2016 studied on regeneration status of tree species in Western Himalaya of India and reported that the successful regeneration depends on various factors such as soil characteristics, slope, and wide variation in altitude, climatic conditions, disease, and population density of herbivorous animals. Pokhriyal *et al*., 2010 also studied on regeneration status of tree species in Garhwal Himalaya reported that the regeneration of a species is affected by fire, grazing, light, canopy density, soil moisture, soil nutrients and anthropogenic pressure.

2.5 Carbon stock

Forests play a vital role in global carbon flux and act as carbon sink by storing large quantities of carbon for a long period of time. This storage of organic matter in biomass provides a lag for complete carbon emission on account of respiration. More than 40% of the global primary production in forest ecosystem is accomplished by tropical and subtropical forests (Beer *et al.*, 2010). Forest ecosystems act as source and sink of atmospheric carbon dioxide (CO_2) and are one of the most faithful options for carbon sequestration and play a crucial role in regulating global carbon cycle. Local, regional, and national carbon inventories of source and sinks of car-bon are indispensable to assess the prospective role of various carbon sequestration pools for reducing atmospheric CO_2 accumulation, and therefore it is a pioneer step for preventing global warming. The studies also important for developing of

systems/markets for national and international carbon credit/emission trading as well as in reducing emission from deforestation and forest degradation (REDD+) programs in developing countries (Han *et al*., 2007; NEFA, 2002; Kale *et al*., 2004).

In study site, lower region of the forest known as *P. roxburghii* forest due to its dominancy along with *Rhododendron arboreum* and *Alnus nepalensis.* Above 2000m mixed type vegetation is found where *P. roxuburghii, R. arboreum, Symplocos ramosissima* are dominated. Soil properties also determine the composition and structure of plant community (Sigdel, 2015). Soil properties depend on different environmental factors such as slope, aspect, climate, landscape, microclimate, topography, and vegetation (Tsui, 2004).

2.6 Soil properties

The role of soil in shaping plant communities in forest ecosystems has long attracted scientific interest, and many studies have pointed out the importance of edaphic properties on species distributions within the tropics. Soil type play a major role in the heterogeneity of habitats, thus contributing to physiognomic differentiation of the vegetation (Oliveira-Filho and Ratter, 2002; Guerra *et al.,* 2016). The wide variation in tropical landscapes in terms of soil age, erosion rates, topography and hydrology, among other factors, has effects on the structure and function of the ecosystems (Townsend *et al.,* 2008). Among the edaphic factors, the nutrient content in the soil may affect parameters such as tree height and basal area and thus consequently influence the structure of tropical plant communities (Becknell and Powers, 2014). According to the studies on tropical vegetation, plant species richness is positively related to soil fertility (Poulsen *et al.,* 2006; Dybzinski *et al.,* 2008).

Soils are the natural sites for all terrestrial plants, which they take up water, oxygen and nutrients from the soil through their root system. The feedback relationship between vegetation and soil has a great impact on the plant community, soil nutrient cycling, and soil and water conservation during vegetation restoration (Demenois *et al*., 2020). Insights into vegetation–soil feedback relationships are instrumental in predicting future scenarios under varying environmental conditions (Van der Putten *et al*., 2013), as well as in designing measures for vegetation restoration at different succession stages (Huang *et al*., 2018).The interactive effects of soil and vegetation

suggest that both are always co-evolving and developing, which are recognized as an important mechanism for forest succession and development (Van der Putten *et al*., 2013). The association between soil and aboveground vegetation may shift over the course of restoration (Huang *et al*., 2015). In the early stage of vegetation restoration, soil resources are the main limiting factors (Van Der Maarel and Franklin, 2013).

Research has shown that the enrichment, spatial distribution, and redistribution of soil nutrients significantly affect the growth, reproduction, distribution, succession, and net primary productivity of plants (Alday *et al.,* 2012). In particular, soil nutrients and water are the key factors in regulating vegetation development, as confirmed by the results of some fertilization experiments (Chang and Turner, 2019) and different forest succession series (Huang *et al.,* 2017). In turn, vegetation development can drive changes in the development and maintenance of soil (Huang *et al.,* 2018).

2.7 Research Gap

The study is necessary for understanding of forest structure, composition and diversity in natural forests. The vegetation zones with distinct forest structure, composition and diversity may facilitate gains for both adaptations of climate and key of forest conservation in the future. Composition, Community structure and Species richness of forest is directly regulated by species diversity, and it is the biological basis to maintain ecosystem functions. To study the different factors such as topography, soils, climate, and, human disturbances affecting the vegetation pattern.

CHAPTER 3
3. MATERIAL AND METHODS

3.1 Study area

Physiography

The study site, Malika forest is located in Malika Village Development Committee of Baglung district in Province no. 4. The area is the northern flank of Sansarkot hill is about nine km west of Baglung Bazar. The study area lies in between 28°17′30″ N and 28°19′00″N latitudes and 83°32′30″E and 83°34′00″E longitudes.

Among the two sites chosen for the study, the forests lies at an altitude ranging from 1600 to 2400m above the sea level. The study area is a part of the forest which continues to Myagdi district. Although, the area of forest is very big with disturbed vegetation, present study concentrated on two altitudinal ranges, first altitudinal range was situated from 1600 to 2000m altitudes regarded as lower site and second altitudinal range was from 2000 to 2400m regarded as upper site (Figure 3.1).

3.2 Topography

The study area is basically characterized by a mountainous topography with the elevation ranging from around 1600m to 2400m. Sansarkot peak is one of the highest peaks (2400m) in Baglung followed by other peaks like Kalikot, Rayarakot, Nagi and so on.

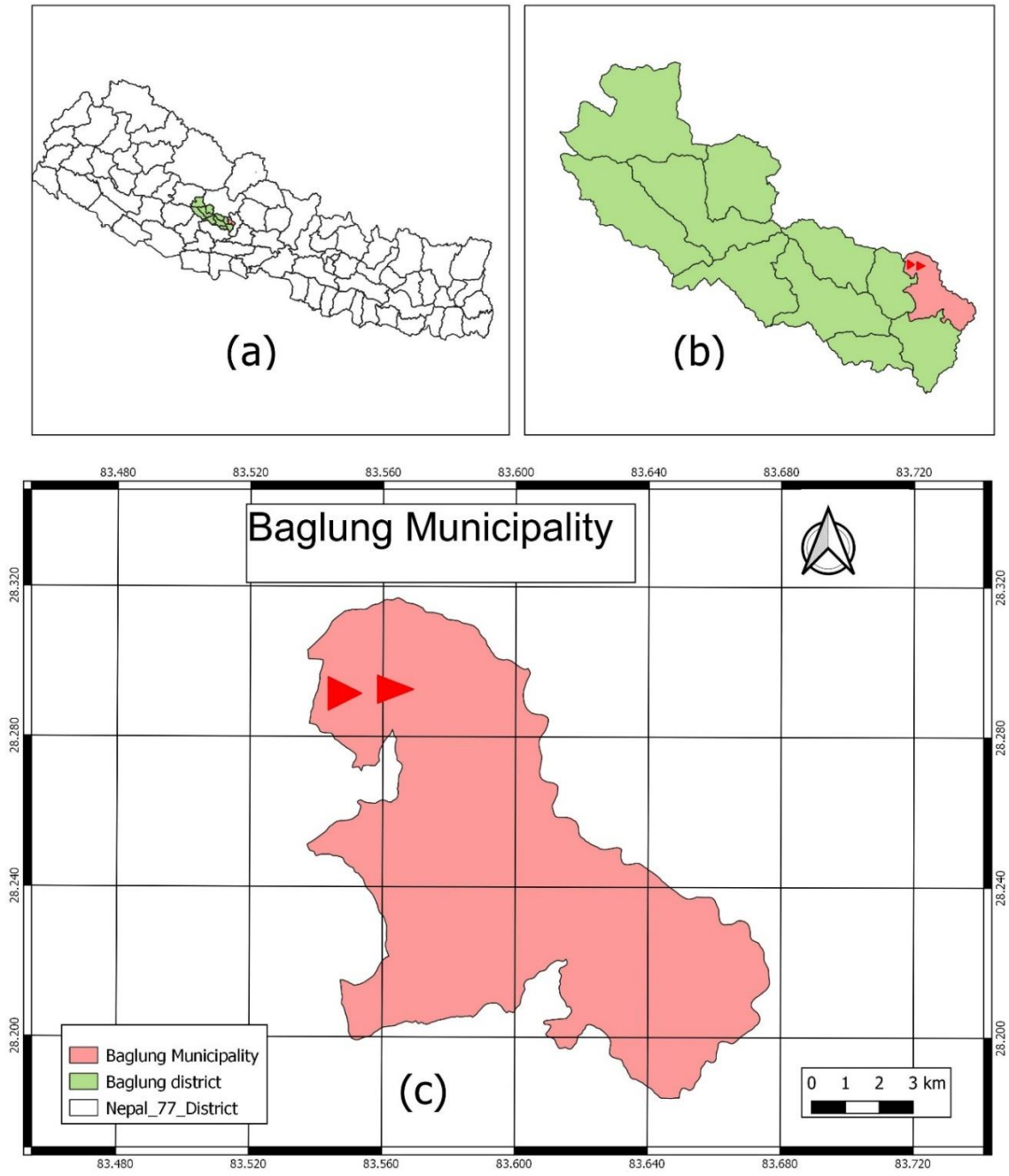


Figure 3.1: Map showing study area (a)- Nepal, (b)- Baglung district, (c)- Baglung municipality in which trangle shows study area of Malika forest

Source: Google Earth

Figure 3.2: Map showing study area

3.3 Climate

The climate of study sites has humid, subtropical climate. Their average maximum temperature 32.42°C which occur in the month of June and August where average minimum temperature is 7.52°C occur in the month of December (Figure 3.3). Rainfall ranged between 1.93 to 923.03°C mm maximum rainfalls occur in August and minimum rainfall in the month of December with 0mm. Ten years (2010-2021) of temperature record of Baglung municipality shows that there was increasing trend of temperature from January to August and decreasing in both maximum and minimum temperature.

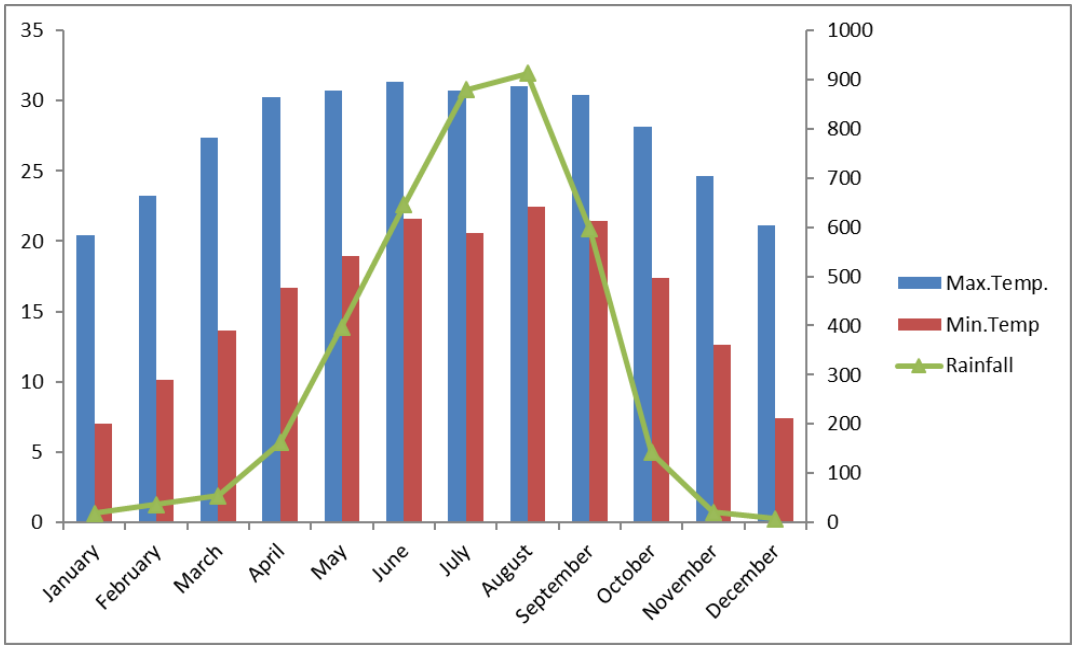


Figure 3.3. Ten years (2010-2020) mean monthly maximum and minimum temperature (℃) and Precipitation (mm) of Baglung Municipality (DHM ,2021)).

3.4 Vegetation

The study area lies in Mahabharat range having a Temperate, fairly mixed, dense, deciduous type of vegetation. The whole forest can be divided into following three categorizes.

Pinus roxburghii forest- In lower region of the forest, *Pinus roxburghii* is dominated along with *Rhododendron arboreum* and *Alnus nepalensis.* Above 2000m mixed type vegetation is found where *Pinus roxburghii*, *Rhododendron arboreum*, *Symplocos ramosissima* are dominated and shrubs *Rubus ellipticus*, *Berberis aristata* and *Gaultheria fragrantissima* are dominated and for herbs species like *Stellaria media*, *Cynodon dactylon* and some herbs (*Bergenia ciliate*, *Paris polyphylla*) with medicinal values are dominant.

3.5 Materials and methods

3.5.1 Field work

During the time of study of diversity, study area was visited three times during the study periods. The first study was carried before writing the proposal in the month of September 2020 for preliminary visit. Similarly, second visit and third visit was done in the month of Febraury 2021. At this time, primary data has been collected by carrying out vegetation sampling and soil collection. The study area was divided into two zones (i.e. Sub-tropical and Temperate region of Malika forest area). Vegetation and soil samples were conducted from each both altitudinal ranges. During fourth visit seedling, herbaceous data was collected to study the regeneration status of plant species and was done in the month of August 2022.

3.5.2 Vegetation sampling

Systematic random sampling was applied for vegetation analysis. The altitude wise collected data was divided into two altitudinal range (1600-2400m). Altogether 70 main quadrats were studied from these two altitudes. In which 70 quadrats for Tree species, Inside main quadrat 140 quadrats (70X2) for shrub species and 210 quadrats (70X3) for herb species. Circular quadrat method was used in the field of 10mX10m for tree, 5mX5m for shrubs and 1mX1m for herbs (Pandey and Bajraacharya, 2010) for 70 plots altitudinal ranges. In each quadrat, the structural attribute of woody plant species was categorized as sapling (diameter at breast height; DBH<10cm and height >20cm) and mature tree (DBH>10cm) (Deb and Sundriyal, 2008). In each quadrat tree species were recorded and their height and diameter at breast height (DBH) were measured. Diameter at breast height was measured by DBH tape and height tree species were measured with the help of clinometer. The population structure and regeneration status of trees on both altitudes was studied. The geographical location of each quadrat (longitude, latitude, and altitude) was recorded by using Global Positioning System (GPS).

3.5.3 Plant identification

Plants were identified following standard literatures (Polunin and Stainton, 1997). The identification of plant was done by knowing local name from local people and also referring to other references (Stainton, 1988; Waston *et al*., 2011).

3.6 Soil sampling

Abot 1 kg of soil samples were collected from center of each quadrat. After that the collected soil samples of nearest quadrat were mixed thoroughly to prepare final sample. At last final soil samples (16) were prepared for the laboratory analysis. Altogether 16 soil samples were used for the study of soil pH, organic matter (OM), soil texture, Nitrogen, Phosphorus and Potassium.

3.6.1 Laboratory work

Soil pH, organic matter (OM) content, soil texture and 3 macro nutrients (Nitrogen, Phosphorus and Potassium) was determined in the air-dried soil samples at the Laboratory of District Agriculture office, government of Nepal, Kanchanpur. Soil pH was measured by pH meter in a 1:1 mixture of soil and distilled water; OM content by the Walkley and Black method; total N by the micro-Kjeldahl method; available P by Olsen's modified carbonate method; and available potassium (as K_2O) by flame photometer method. All these methods are described in Gupta, 2000.

3.7 Data presentation and analysis

3.7.1 Numerical analysis

For the data analysis and presentation of quadrat sampling of both elevations to calculate frequency, relative frequency, density, relative density, important value index, Simpson value index and Shannon wiener index, Carbon stock was calculated by using the following formulae (Zobel *et al*., 1987):

1. **Frequency (F):** Frequency is the proportion of sampling units containing the species. Where;

$$\text{Frequency (F)} = \frac{\text{Number of quadrat in which species occur}}{\text{Total quadrat studied}} \text{ x } 100$$

2. **Relative frequency (RF):** It is calculated by dividing the frequency by the sum of the frequencies of all species, multiplied by 100 (to obtain a percentage). Where;

$$\text{Relative Frequency} = \frac{\text{Frequency of individual species}}{\text{Total frequency}} \text{x } 100$$

3. **Density (D):** It is the number of individuals of a given species that occurs within a given sample unit or study area. Where;

$$\text{Density} = \frac{Total\ number\ of\ individual\ species\ in\ all\ quadrate}{\text{Total quadrate studyxarea of quadrate}}$$

4. **Relative Density (RD):** It is the density of one species as a percent of total plant density. Where;

$$\text{Relative density} = \frac{Density\ of\ individual\ species}{\text{Total density of all species}} \text{x } 100$$

5. **Basal Area (BA):** Basal area is the cross-sectional area of a tree; it was calculated from DBH and represented as m^2 ha-1 for different size classes.

$$\text{Basal area} = \frac{\pi d^2}{4}$$

Where,

D = diameter at the breast height, $\pi = 3.1416$

6. **Relative Basal Area (RBA):** Relative basal area can be obtained by comparing the basal area of occurrences of all the species present.

$$\text{Relative Basal Area (RBA, \%)} = \frac{\text{Basal area of individual species}}{Total\ basal\ area\ of\ all\ species} \text{x} 100\%$$

7. **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 an overall estimate of the importance of a species. This sum is called the importance value (IVI).

IVI =RF +RD + RBA

Where, IVI = Importance Value Index

RF = Relative Frequency

RD = Relative Density

RBA = Relative Basal Area

8. **Diversity of species:** It is a count of the numbers of individuals of each species within the quadrat. The Shannon-Wiener diversity index (H') is calculated by Shanon-Wienen index (H). Where as;

   Shanon-Wienen index (H) = - Σ Pi (Ln Pi)

   Where, Pi = Proportion of individual species

9. **Simpson's Dominance Index**

Simpson's diversity index was calculated according to Simpson, (1949) the formula is given as follows:

$$\text{Simpson's Index (D)} = \frac{\sum n(n-1)}{N(N-1)}$$

Where, N = Total number of species collected

n = Number of individuals of a species

The value of D ranges between 0 and 1, with this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give:

Simpson's index of Diversity (DI) = 1 – D

The value of this index also ranges between 0 and 1, the greater the value, the greater the sample diversity

3.7.2 Population structure of tree

Population structure of tree species was determined by arranging the diameter of tree species in diameter class interval by referring the study of Atsbha *et al.*, 2019 the

histogram was constructed by using the density of individuals of tree species (Y-axis) categorized into eight diameters classes (X-axis) i.e., 10-25 cm, 25-40 cm, 40-55 cm, 55-70 cm, 70-85 cm, 85-105 cm, 105-120 cm.

The height of trees species was presented by making height class intervals (Burju *et al.,* 2013). The densities of individuals were summed up falling in the diameter at breast height (DBH) or height classes.

Regeneration of species:

The regeneration of tree species was determined by comparing the density of seedling, sapling and of mature tree.

3.8 Carbon stock

Carbon stock is the quantity of carbon contained in a reservoir or system which has the capacity to accumulate or release carbon.

1. Basal area of all individuals of tree species which were in height were measured.

The allometric equation developed by Chava *et al.,* 2005 for the tropical forest was used to estimate the aboveground biomass of the tree layer. The allometric model for "dry forest" of Chave *et al.,* was used.

According to this model, the above ground biomass (kg) of a tree=$0.112*(\rho D^2H)^{0.916}$

Where ρ is wood density (gm^3), H is height of tree (m), D is the diameter of tree at breast height (cm). For wood density, the global database was used (Zanne *et al.,* 2009). The below ground biomass (root system of tree and shrub layer) was estimated by assuming that it constitutes 15% of the above ground biomass (MacDicken, 1997). The total dry biomass was obtained as the sum of above ground and below ground dry biomass of tree, shrubs and herbs. To estimate the carbon stock in the living biomass, the sum of dry biomass was multiplied by 0.47 (Eggleston *et al.,* 2006).

3.9 Statistical analysis

One-way ANOVA were performed to test the altitudinal ranges wise differences in distribution of different life forms (density of seedlings, saplings and adults. T- test were carried out to compare mean data of soil parameters (N,P,K,OM,pH) from two different altitudes. All data were analyzed by using excel office 2013, Statistical analysis was done by SPSS Version 25.00.

CHAPTER 4

4. RESULTS

4.1 Species Composition

A total of 96 species of plants were recorded from the study, they belonged to 50 different families. Among all 50 families, Poaceae was the largest family having 9 species followed by Fabaceae (6 species), Asteraceae (6 species). Families like Oleaceae, Urticaceae, Pteridaceae, Oxalaidaceae, Rubiceae, Primulaceae, Fagaceae etc has only one species (Figure 4.1).

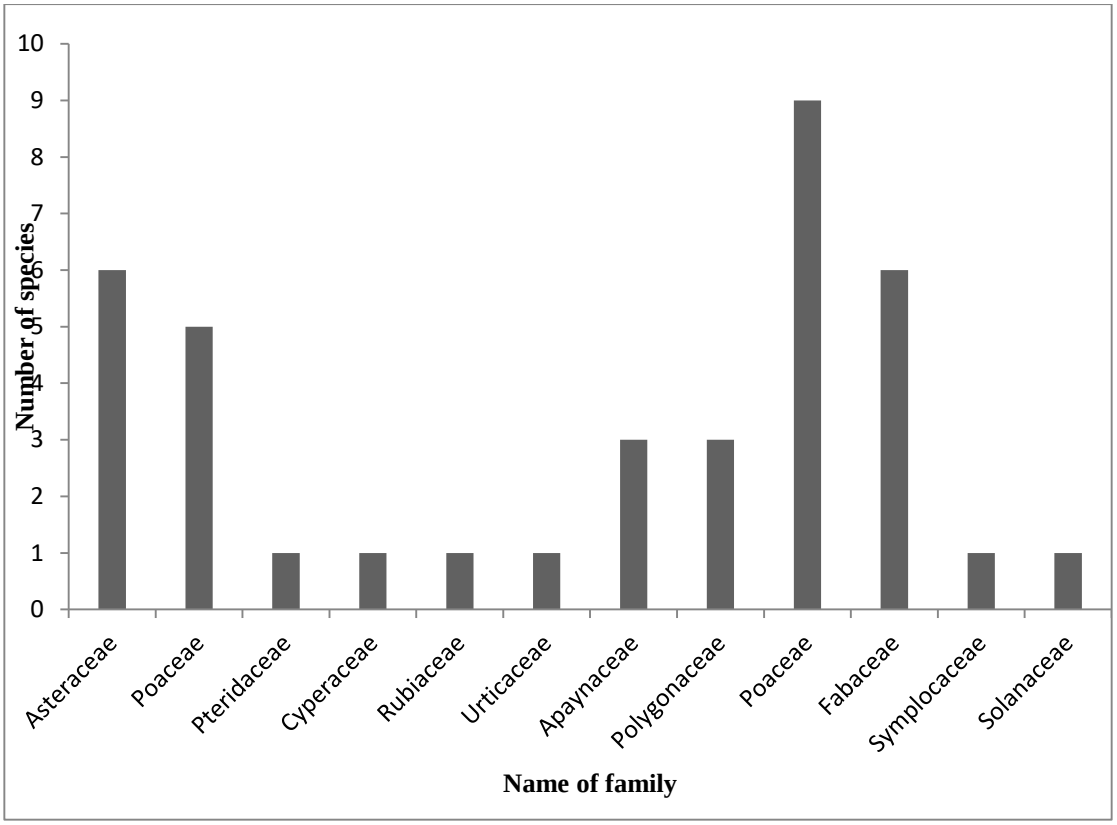
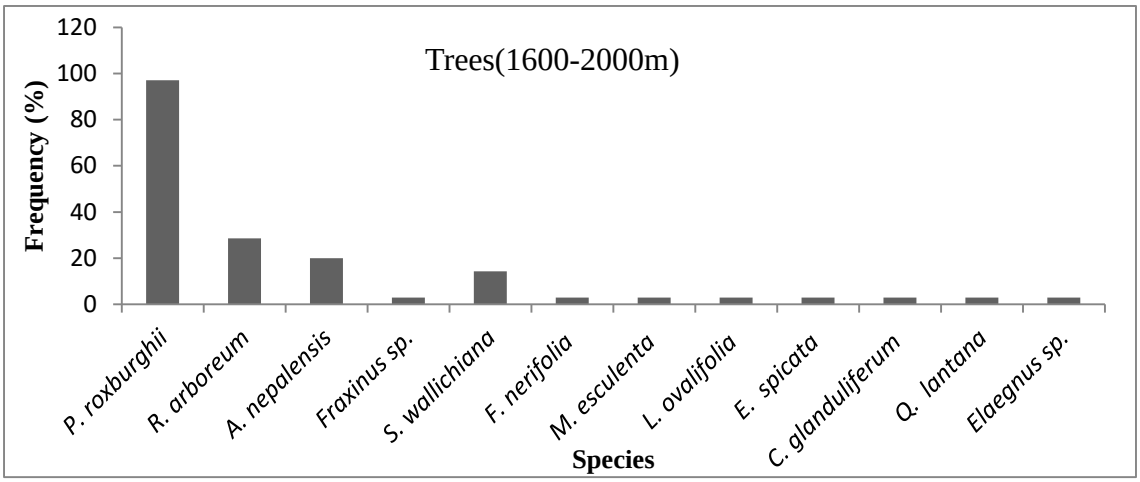
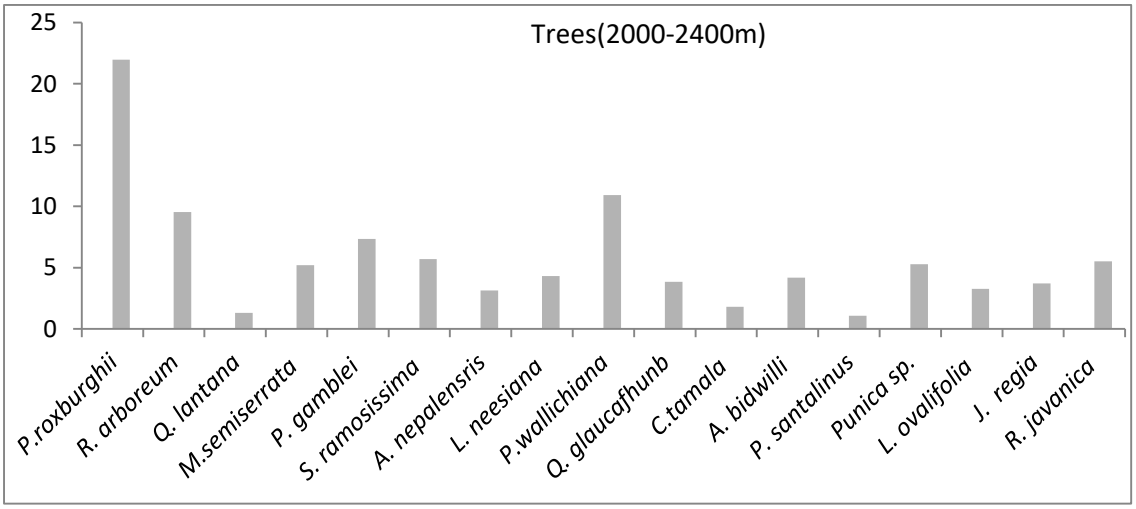


Figure 4.1: Distribution of species along with family

4.1.1 Frequency of trees, shrubs and herbs



(a)

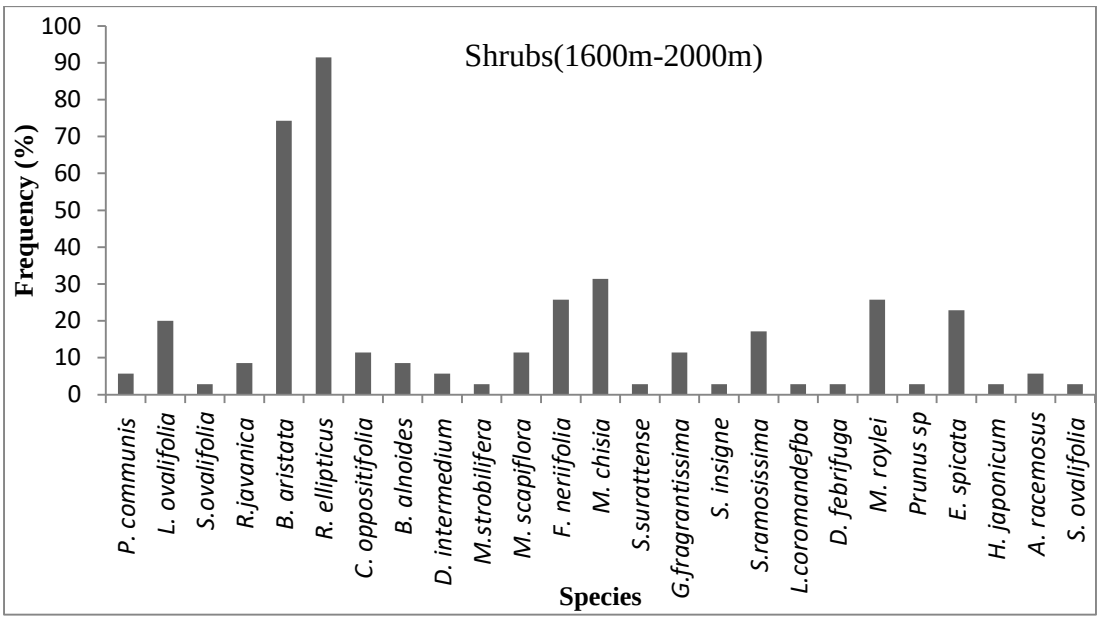


(b)

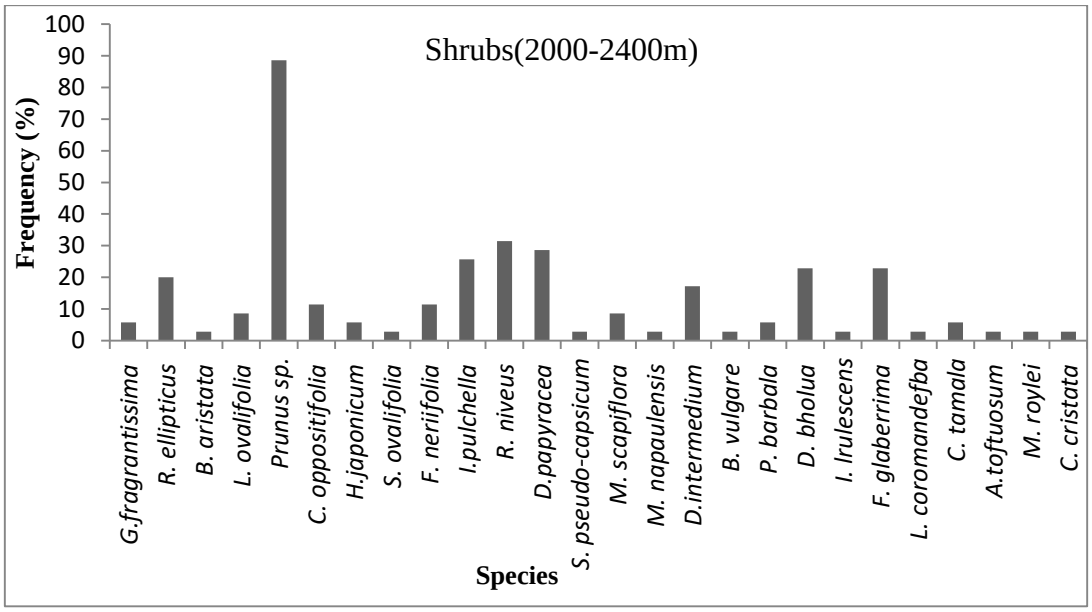
Figure 4.2 (a,b): Frequency of tree species in altitudes 1600-2000m and 2000-2400m

Among tree species the most frequently occurring species was *Pinus roxburghii* in both altitudes with frequency of 97% and 30% respectively (Figure 4.2 (a,b).

Frequency of shrubs



(a)

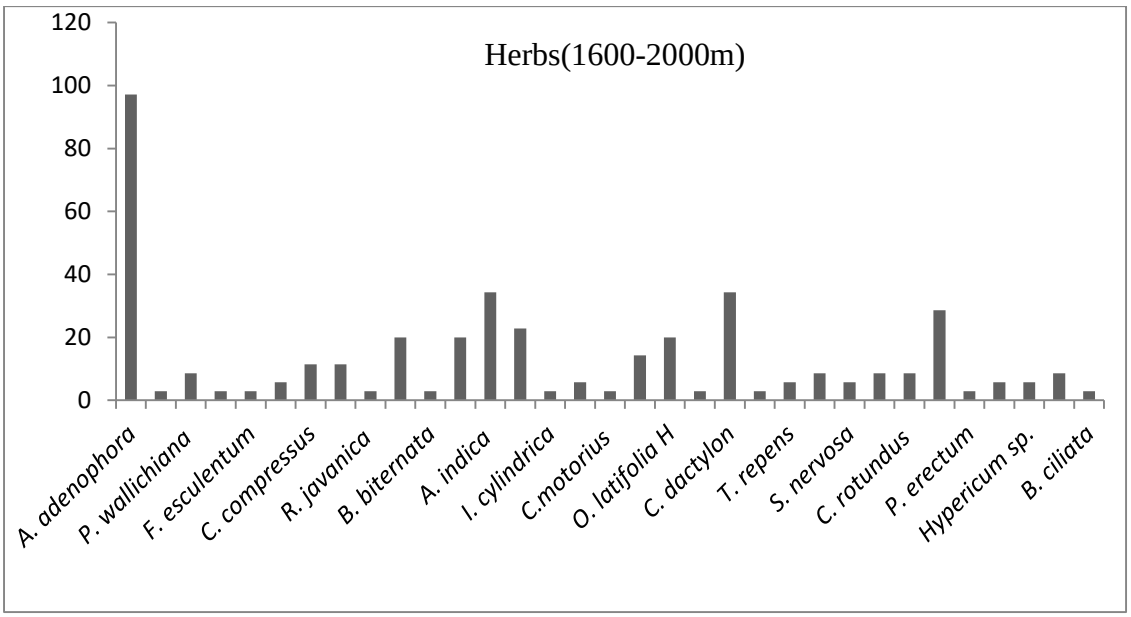


(b)

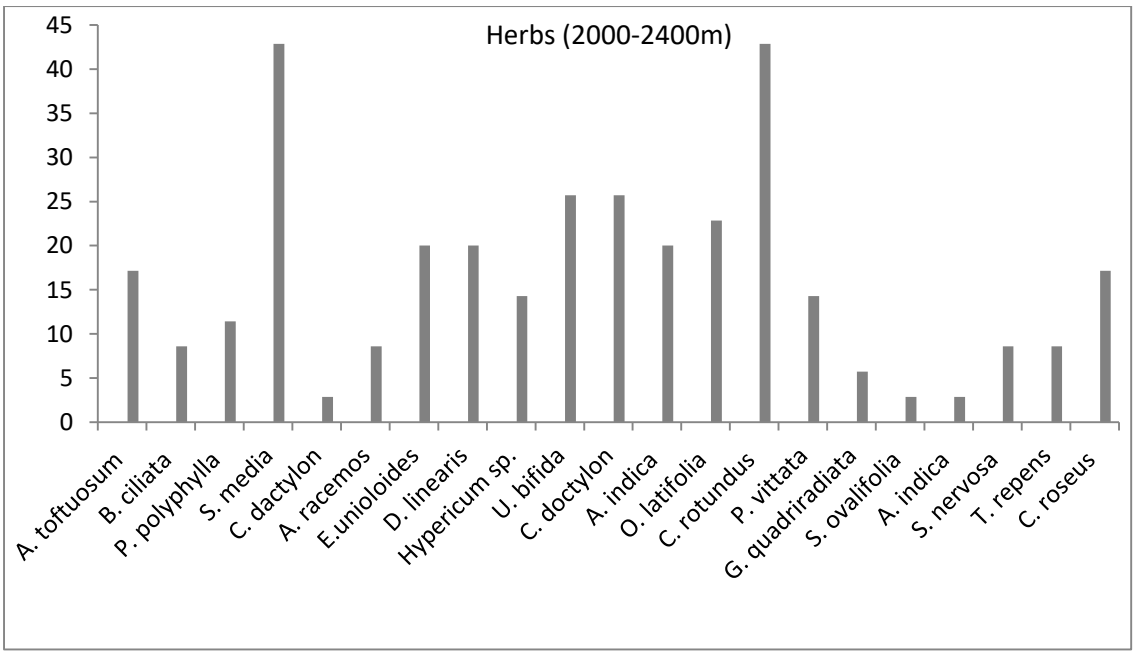
Figure 4.3 (a,b): Frequency of shrubs species in altitude 1600-2000m and 2000-2400m

The highest frequencies were of *Rubus ellipticus* and *Berberis aristata* in lower altitude and higher *Prunus* sp. in upper altitude (Figure 4.3 (a,b).

Frequency of herbs



(a)



(b)

Figure 4.4 (a,b): Frequency of herbs species in altitude 1600-2000m and 2000-2400m

The highest frequency was of *Adenophora (*97%) *Artemisia indica* and *Cynodon dactylon* which was 34% in lower altitudinal range whereas *Arisaema* (57%) *Stellaria media* and *Cyperus rotundus* has highest frequency (42%) in upper altitude (Figure 4.4 a,b).

4.1.2 Density

In altitudinal range of 1600m-2000m the highest density in herbs species was *of Ageratina adenophora* which was 57% and lowest was of *Murdannia scapiflora* which was 2.8% whereas the highest density was of *Stellaria media* and *Oxalis latifolia* (Annex5)

For shrub species highest density was of *Maesa chisia* in altitude of 1600-2000m and *Mahonia napaulensis* in 2000-2400m (Annex 6) whereas for tree species highest density was of *Pinus roxburhgii* in both altitudinal ranges (Annex 7).

4.1.3 Species richness

The species richness of vegetation of two altitudes was calculated as shown in table below.

Table 4.1. Species richness between two altitudes

	Species richness		
	1600-2000m	2000-2400m	P-value(Between altitudes)
Trees	12	18	0.12
Shrubs	25	29	0.47
Herbs	36	29	0.68

The species richness of two altitudes was calculated. For shrubs and trees species higher species richness was found in higher altitude i.e 2000-24000m whereas for herbs higher species richness was in lower altitude 1600-2000m. From above table (Table 4.1), no significance different was found in distribution of vegetation among two altitude. Tree species richness was lowest from low altitudes compared to high (Figure 4.5). Regarding herbs, species richness was highest from low altitudes.

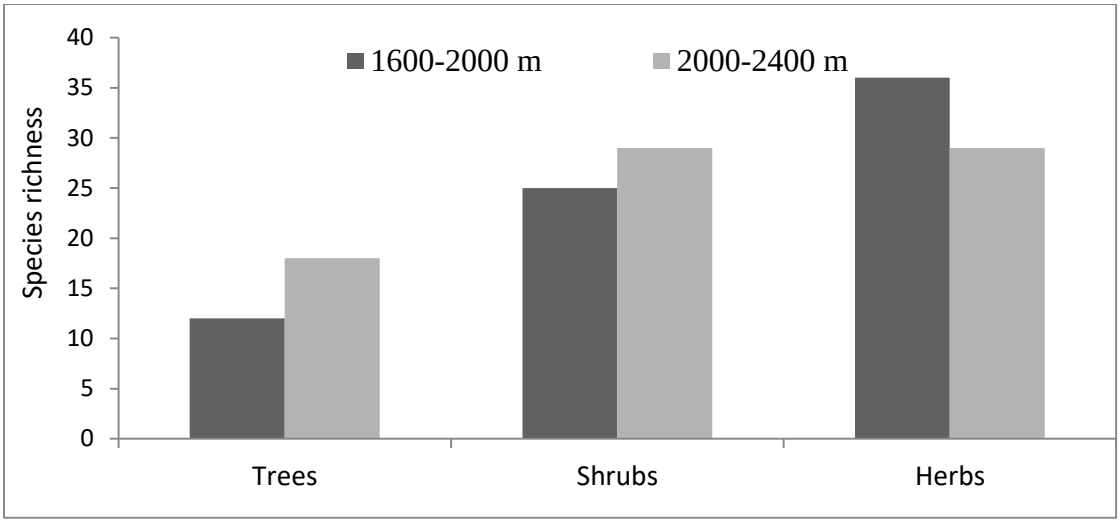


Figure 4.5. Species richness between two altitudes

4.1.4 Diversity Index

1 Simpson's Index (D)

The highest diversity was observed in herbs species in both altitudes while lowest species diversity was of tree species, since there was decrease in trees with increasing altitudes (Table 4.2).

Table 4.2. Table showing Simpsons'n Diversity Index

Species type	**Simpson's Index (D)**		**Simpsons diversity index(1-D)**	
	Altitude			
	1600-2000 m	2000-2400 m	1600-2000m	2000-2400 m
Herbs	0.4	0.3	0.6	0.7
Shrubs	0.24	0.16	0.76	0.84
Trees	0.19	0.11	0.81	0.89

2. Shannon-Wiener Diversity Index

The highest Shannon-Wiener Diversity Index d was found among herbs species i.e H=2.97 in low altitude whereas highest diversity in shrubs species in upper altitude of 2000-2400m i.e, H=2.66.The higher the value of *H*, the higher the diversity of species in a particular community. (Table 4.3).

Table 4.3. Table showing Shannon-Wiener Diversity Index

Species type	**Shannon–Wiener diversity index**	
	Altitudinal range	
	1600-2000m	2000-2400m
Herbs	2.97	1.99
Shrubs	2.45	2.66
Trees	0.60	2.53

3. Important Value Index

IVI is used as a measurement of the ecological importance of species. It shows the complete picture of ecological importance of the species in a community. Community structure study is made by studying frequency, density, abundance and basal cover of species.

In studied area the highest IVI for herbs species was of *Sterellia media* and *Ageratina adenophora* and *Dicranopteris linearis* (Annex 2 and 3), for shrubs species highest IVI was of *Lyonia ovalifolia* and *Prunus* sp. For tree species highest IVI was for *Pinus roxburghii* (Figure 4.6 a,b) in both altitudes. In upper altitudes, *P. roxburghii* was mixed with *P. wallichiana* (Figure 4.6b).

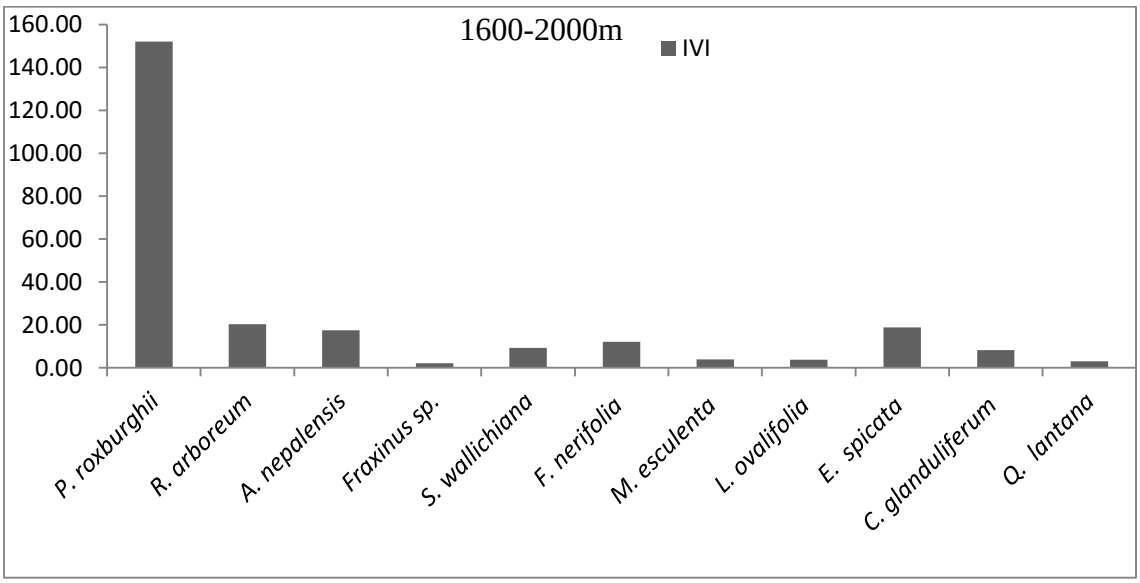


Figure 4.6 (a). IVI of tree species in altitude 1600-2000m

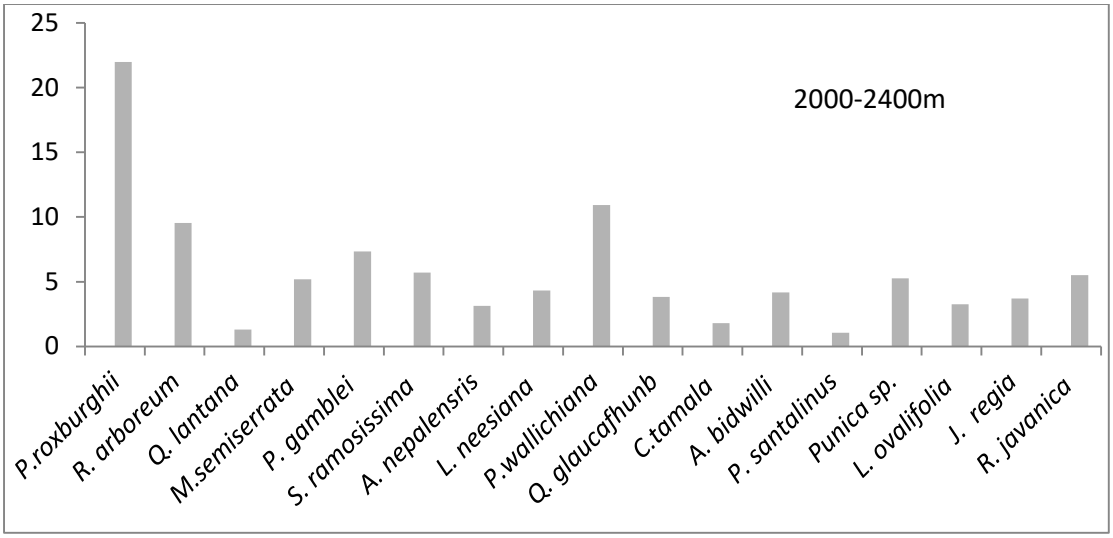


Figure 4.6 (b). IVI of tree species in altitude 2000-2400m

4.2 Density/ DBH class in both altitudinal ranges

Population structure of major species occurred in both altitudinal ranges (Figure 4.7) was observed and DBH-density was observed. At lower altitude the individuals have high DBH. The density of tree was found maximum in the DBH class 10-25 cm followed by 25-40 cm. The highest DBH was found of *Alnus nepalensis* in lower altitude(1600-2000m) (Figure 4.7).

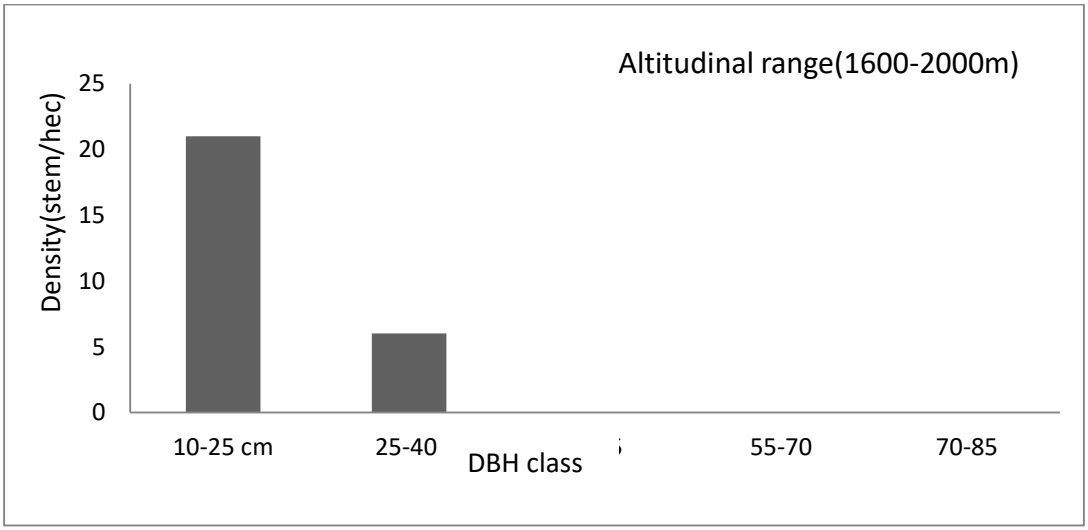


Figure 4.7 (a). DBH size class distribution of species occurred in lower altitude

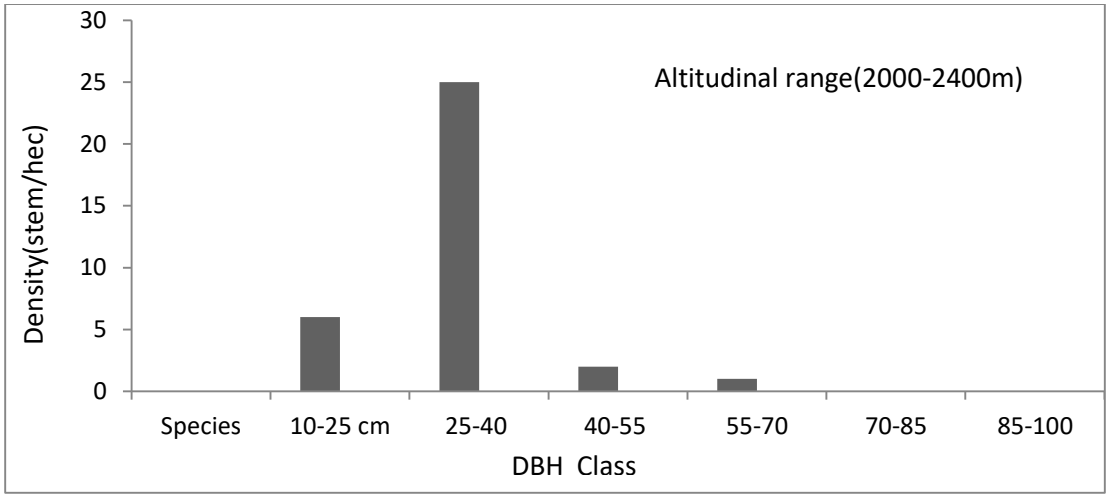


Figure 4.7 (b). DBH size class distribution of species occurred in upper altitude

4.3 Basal area

The basal area of a stand of trees is the sum of the cross-sectional surface areas of each live tree, measured at DBH. Basal area is a measure of tree density. The highest basal area was recorded for *Alnus nepalensis* (Figure 4.8 a) at lower altitude whereas *Rhododendron arboreum* (Figure 4.8 b) scored highest basal area in upper altitude.

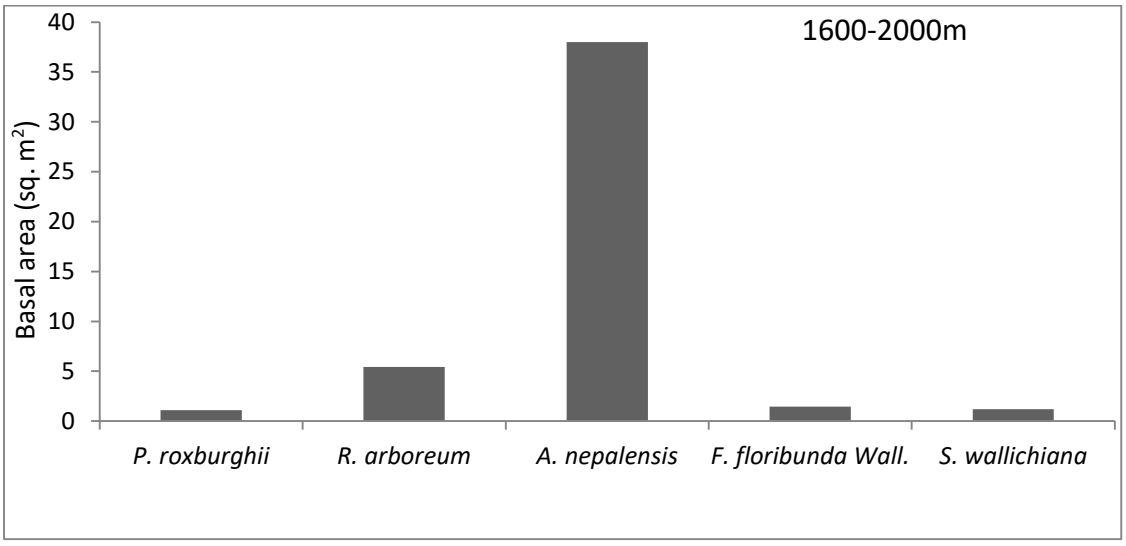


Figure 4.8 (a). Basal area of dominant tree species occurred in lower altitude.

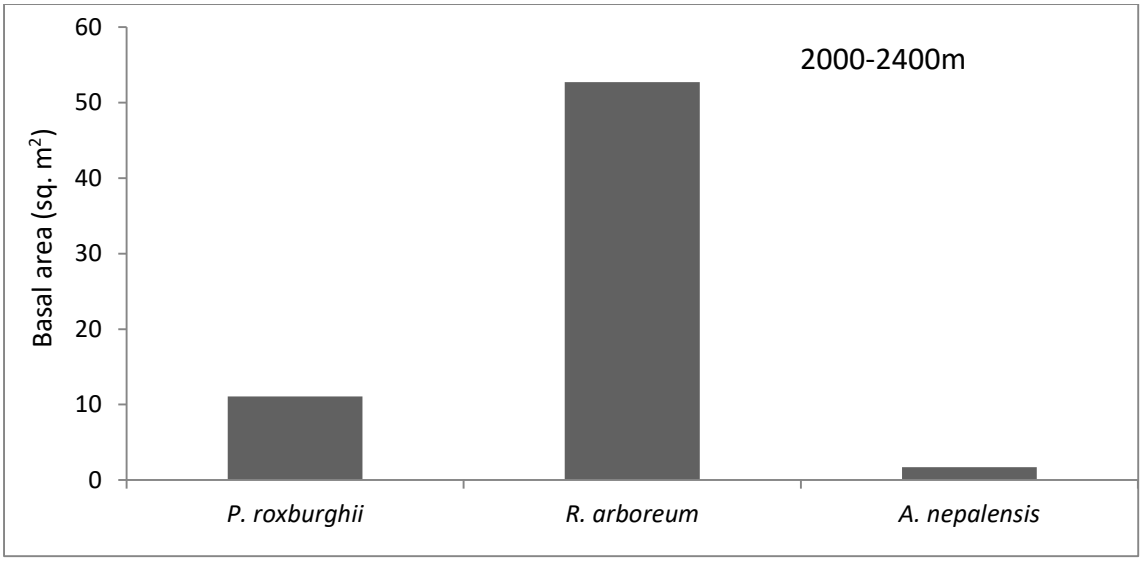
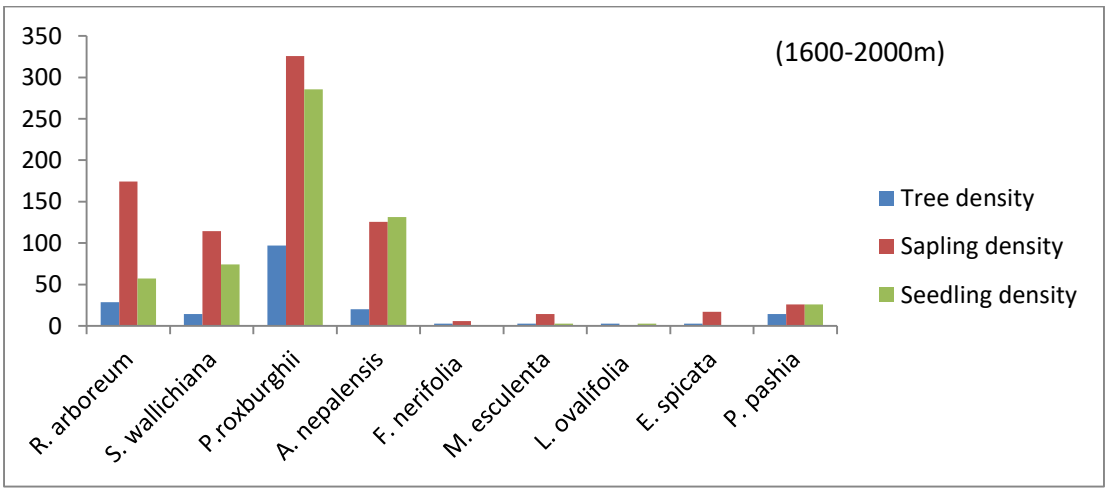


Figure 4.8(b). Basal area of dominant tree species occurred in upper altitude

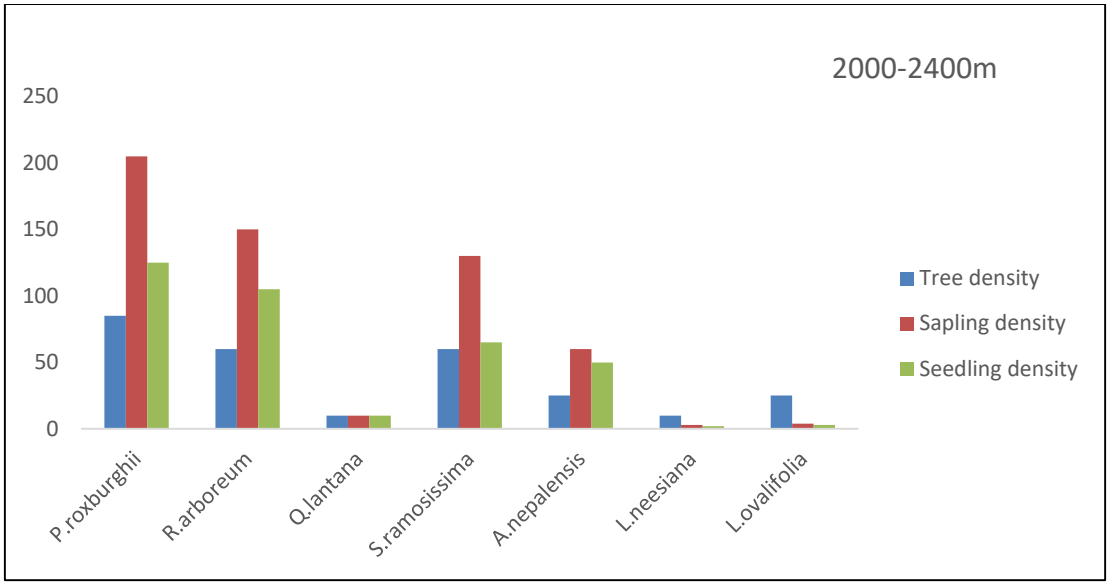
4.4 Regeneration Pattern

4.4.1 Regeneration Patterns of Tree Species

The regeneration pattern of tree species in different altitudinal ranges within the forest was shown in Figure 4.9a,b. The highest numbers of well-regenerating tree species were recorded in lower (1600–2000m) and, the number was lowest in upper altitudinal range (2000-2400m). In both altitudinal ranges, *P. roxburghii* showed the highest regeneration as compared to other associated species (*R. arboreum*, *A. nepalensis*, and *L. ovalifolia*).



(a)



(b)

Figure 4.9 (a,b). Distribution of trees, saplings, and seedlings along the two different altitudinal ranges

The differences in different life stages (tree, sapling, and seedling) of trees at different altitudinal ranges were checked by performing one - way ANOVA test. The density of all trees (185.71 stem ha^{-1}), saplings (802.85 $stemha^{-1}$) and seedlings (580 stem ha^{-1}) in lower altitude while, the density of trees was 285.71 stem ha^{-1} saplings and seedlings had 557.14 stem $ha^{-1}$and 368.57 stem ha^{-1} respectively. The density of life stages was found to be lower at lower altitudes (Table 4.4).

Table 4.4. One-way ANOVA table showing variation in density of different life stages of *R. arboreum* between altitudes

Altitude(m)	**Tree density((stemha^{-1})**	**Seedling density (stemha^{-1})**	**Sapling density (stemha^{-1})**
1600-2000	185.71	580	802.85
2000-2400	285.71	368.57	557.14
F	0.89	3.40	1.81
P(F<=f)	0.43	0.07	0.24

One-way ANOVA analysis showed insignificant differences in sapling density between altitudes (*P = 0.24*) and for seedlings density (*P = 0.07*) and for trees density (*P = 0.43*) between altitudes.

4.5 Soil Analysis

Soil analysis was done in lab. Texture of sampled soil was recorded Table 4.5, 4.6 in both gradient and then further nutrient content was analyzed Table 4.7 and 4.8.

Table 4.5. Soil Texture of altitude 1600 -2000m

In most of sampled soil, the highest content was of sand. Moisture was low since sandy soil is low in moisture content.

S.No.		Sand	Silt	Clay	Moisture
1	**Clay**	45.44	20.88	31.07	16
2	Clay	37.59	20.03	23.55	16.5
3	Clay	41.48	15.43	12.97	10
4	Clay Loam	28.14	43.89	26.7	12
5	Clay Loam	23.45	46.81	12.11	15
6	Sandy Clay	56.27	18.95	11.75	13
7	Clay Loam	49.72	24.1	12.45	13.8
8	Sandy Clay Loam	61.71	26.16	9.13	13.7

Table 4.6. Soil Texture of altitude 2000 -2400m

S.No		Sand	Silt	Clay	Moisture
1	Clay Loam	31.12	40.64	26.57	16
2	Clay	35.51	16.25	16.05	21
3	Sandy Clay	66.25	19.85	9.96	23
4	Clay	35.38	25.94	16.5	6.1
5	Clay Loam	33.65	37.83	26.36	11
6	Sandy Clay	50.62	10.91	18.24	7
7	Silty Clay	10	45	45	11.5
8	Silty Clay	15	48	37	15.6

As the texture of a soil determines soil characteristics that affect plant growth such as water-holding capacity, permeability, and soil workability. Soil texture affects how well nutrients and water are retained in the soil; thus, clayey and organic soils hold nutrients and water much better than sandy soils, in which water drains and carries

nutrients along with it. When nutrients leach into the soil, they are not available for plants to use.

Table 4.7. Nutrients Content in sample soil of altitude 1600-2000m

Sample	N %	P kg/h	K kg/h	OM	PH
1	1.855	61.988	217.728	18.56	7.6
2	1.481	72.246	266.656	15.81	6.4
3	1.702	51.416	212.896	18.023	6.4
4	1.669	63.426	337.088	16.71	6.3
5	1.321	62.071	352.672	13.4	6.2
6	1.891	73.735	261.28	18.928	5.8
7	1.871	61.123	358.592	18.727	5
8	1.725	62.457	310.208	18.258	5.8

There was low nitrogen content in all sampled area where as Potassium was highest per hectare i.e, in sample no 8. The soil was slightly acidic. Organic matter content was lowest in soil sample no.3.In soil, without enough nitrogen, plant growth is affected negatively. Soils under evergreen trees had higher % OM than those under deciduous trees.

All sampled soil were acidic in nature. Nitrogen content was highest in sample no 6 whereas p and k content was highest in sample no. 1. Organic matter content was in similar range from 18-19.

Table 4.8. Nutrients Content in sample soil of altitude 2000-2400m

Sample	N %	P kg/h	K kg/h	OM	PH
1	1.818	62.256	382.784	19.196	5.3
2	1.795	61.942	294.08	18.961	5.5
3	1.877	53.781	304.832	18.794	5.4
4	1.888	51.988	223.648	18.894	5.4
5	1.899	51.854	309.664	19.129	5.4
6	1.931	51.607	382.24	19.363	5.6
7	1.805	52.277	294.08	18.09	5.2
8	1.821	52.359	290.304	19.296	5.9

4.6 Comparison of soil factors between two altitude

The nutrient content of soil of two elevation 1600-2000m and 2000-2400mwas calculated and in order to compare the nutrient availability in soil significance test was done. The test value of significance was performed by assuming equal variance.

The mean of all plots from both altitudes was compared. P value less than 0.05 shows that there was significant different in mean values i.e, there was effect of altitude in soil variable content.

The mean of all plots from both altitude was compared .P value less than 0.05 shows that there is significant different in mean values i.e, there was effect of altitude in soil variable content. All soil factors shows significant differences.

4.7 Carbon stock

For dry wood density, the global database was used (Zanne *et al.,* 2009) was used. A total of 70 sampling plots were studied. All the species have different AGB and BGB associated with different concentration of carbon stock capacity.

Table 4.9. Carbon stock of plot 1600-2000m

S.N.	Scientific Name	AGB(kg)	BGB(kg)	Total Carbon (kg)	carbon stock(ton/ha)
1	*Pinus roxburghii*	2138.454	909.9806	3048.43501	3.04843501
2	*Rhododendron arboreum*	80.58432	34.2912	114.87552	0.11487552
3	*Alnus nepalensis*	137.0144	58.304	195.3184	0.1953184
4	*Fraxinus sp*	6.25664	2.6624	8.91904	0.00891904
5	*Schima wallichiana*	96.01536	40.8576	136.87296	0.13687296
6	*Ficus nerifolia*	4.512	1.92	6.432	0.006432
7	*Myrica esculenta*	3.12832	1.3312	4.45952	0.00445952
8	*Lyonia ovalifolia*	3.12832	1.3312	4.45952	0.00445952
9	*Engelhardia spicata*	8.4224	3.584	12.0064	0.0120064
10	*Cinnamomum glanduliferum*	3.3088	1.408	4.7168	0.0047168
11	*Quercus lantana*	91.98464	39.1424	131.12704	0.13112704
12	*Elaegnus sp*	13.8368	5.888	19.7248	0.0197248

Table 4.10. Carbon stock of plot 2000-2400m

S.N.	Scientific name	AGB (kg)	BGB (kg)	Total Carbon(kg)	Carbon(ton/ha)
1	*Pinus roxburghii*	2802.106	560.4212	3362.527392	3.362527392
2	*Rhododendron arboreum*	783.6532	156.7306	940.3838208	0.940383821
3	*Quercus lantana*	31.8848	6.37696	38.26176	0.03826176
4	*Persea gamblei*	20.9056	4.18112	25.08672	0.02508672
5	*Symplocos ramosissima*	17.4464	3.48928	20.93568	0.02093568
6	*Alnus nepalensrs*	611.9174	122.3835	734.300928	0.734300928
7	*Lindera neesiana*	125.5539	25.11078	150.664704	0.150664704
8	*Pinus wallichiana*	101.0086	20.20173	121.210368	0.121210368
9	*Quercus glauca*	1001.814	200.3629	1202.17728	1.20217728
10	*Cinnamomum tamala*	382.7981	76.55962	459.357696	0.459357696
11	*Araucaria bidwilli*	58.8064	11.76128	70.56768	0.07056768
12	*Pterocarpus santalinus*	7.18912	1.437824	8.626944	0.008626944
13	*Punica sp*	41.99168	8.398336	50.390016	0.050390016
14	*Lyonia ovalifolia*	138.0672	27.61344	165.68064	0.16568064
15	*Juglans regia*	222.4115	44.4823	266.893824	0.266893824
16	*Rhus javanica*	105.1898	21.03795	126.227712	0.126227712
17	*Betula alnoides*	202.8896	40.57792	243.46752	0.24346752
18	*Ficus nerifolia*	196.8134	39.36269	236.176128	0.236176128

The highest carbon stock (3.04 and 3.36 **ton/hec**) was found in *Pinus roxburghii* in both altitudes simultaneously. (Table 4.10, 4.11). The potential of forest to store carbon depends on the forest type, age of the forest, size of trees, and forest management.

CHAPTER 5
5. DISCUSSION

5.1 Species composition

In this study, lower altitude have dominant species like *Artemisia indica* and *Cynodon dactylon* with associate like *Stellaria media*, Similarly in shrubs like *Rubus ellipticus Berberis aristata* and *Prunus* sp were prominently found, Similarly in upper altitude *Stellaria media* was dominant species in herbs while *Prunus* sp. was dominant species in shrubs.

In the present study variations in plant species diversity between altitudes have been observed. Plant species richness declines from the lower to higher altitudes in Malika Community Forest Annex (1,2,3). It was observed that forest of lower altitude had higher diversity values than at higher altitude which was consistent with previous studies (Sharma e*t al.,* 2009, Yang *et al.,* 2014, Zhang *et al*., 2016).

5.2 Species richness

In the present study, altitudinal richness patterns for various growth forms differed. Specifically, tree species richness was higher in lower elevation than in higher elevation (Annex3). Trees are often absent at higher elevation due to several constraints, such as the environment, a regional lack of capable species, or a multitude of disturbances (Korner, 2012). Thus, trees are usually common at lower altitude, although tree species richness can also be affected by anthropogenic disturbances is supported by work done by (Acharya *et al.*, 2011) in eastern Himalayas, in Baekdudaegan Mountains (Lee *et al*., 2013) and Ethiopia (Berhanu *et al*., 2016).

Although species richness was higher in shrubs than in trees, the elevational richness pattern of shrub species was similar to that of trees (Annex 2). This could be attributed to the open canopy cover and biotic homogenization (Mori *et al.,* 1983; Zhang *et al.,* 2016). Higher shrub than tree species richness may also be due to selective cutting of trees for various purposes, including construction, timber, and firewood, together with local climatic variation.

Altitudinal trends in species richness are generally thought to mimic latitudinal trends in species richness, and the same factors are often used to explain this altitudinal pattern (MacArthur, 1972; Brown and Lomolino, 1998; Givnish, 1999). Several studies have found a decreasing trend in species richness with altitude (Yoda, 1967; Alexander and Hilliard, 1969; Patterson *et al*., 1998; Vazquez and Givnish, 1998; Odland and Birks, 1999). The species richness in Himalaya's increases from low altitude then reaches saturation at middle altitude and decline further up and forming a unimodal pattern (Baniya *et al.,* 2010; Bhattarai *et al.,* 2014). In this study statistically the tree species richness significantly varied among the three altitudinal ranges were observed. The highest species richness was recorded in upper altitudinal range. This result indicates greater diversity, and which leads to a higher community stability according to the study of MacArthur, 1955.

5.3 Species diversity

Diversity Index is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species. In this study highest diversity was observed in herbaceous species than shrubs and trees (Table 4.1). Importance Value is a measure of how dominant a species is in a given forest area. Previous research has suggested that elevational patterns of plant diversity may be influenced by climate, biotic processes, environmental heterogeneity, and evolutionary history (Mccain *et al.*, 2010). In the present study, the elevational richness pattern of herb plant species was different (Annex 1) than other growth forms. The pattern of the herbaceous plant species richness could be attributed to inter-specific competition, which may be the main driver of plant community assembly at the middle elevations (Zhang *et al*., 2016). Zhang and Shao, (2015) observed altitude and slope position as the most important factors affecting species diversity and reported that the value of Shannon-Wiener index ranged from 1.129 to 2.114, Similarly, (Paudyal, 2015) also reported Shannon-Weiner Index values 1.676 in the subtropical forest of Central Nepal. The variation in diversity between the three different altitudinal ranges might be due to physiographic, climatic, and edaphic factors (Rosbakh *et al*., 2014). The lower diversity was found to be in upper altitudinal range this may be because of human disturbances as they cause the soil and water erosion and make the site poor in terms of resources (Lodhiyal, 2013).

5.4 Forest structure

The IVI value of tree species represents the dominance of species in a mixed forest, and it gives a clear picture of the social structure or ecological significance of species in a community. It is also useful to form an association of dominant species (Parthasarathy and Karthikeyan, 1997; Abunie and Dalle, 2018. In studied area the highest IVI for herbs species was of *Sterellia media* and *Ageratina adenophora* and *Dicranopteris linearis* for shrubs species highest IVI was of *Lyonia ovalifolia* and *Prunus* sp. For tree species highest IVI was for *Pinus roxburghii* in 2000-2400m. The abundance and dominance of these species in the forest was considered as the establishment sign of early succession (Ghanbari and sefidi, 2020). Poudel, 2003 reported similar associated species with *R. arboreum* in Kaski district.

5.5 Density and DBH

The basal area of all dominant species, i.e., *R. arboreum*, *P. roxburghii S. wallichi* was found to be the highest in DBH class (10-25cm) in lower altitude while highest value of basal area in DBH class (25-40 cm) in upper altitude. The highest DBH was found of *Alnus nepalaensis* in lower altitude. This result also indicates that species with the highest basal area do not necessarily have the highest density, indicating size difference between species (Shibru and Balcha, 2004; Dereje, 2007). This might be due to the effect of disturbances on the density of individuals in DBH classes (Vetaas, 2002). Similar result was observed by Neelo *et al*., 2013 in dry woodlands adjacent to Molapo Farms in Northern Botswana, according to them pole-sized and mature individuals may have been cut by the local people for various purposes.

5.6 Regeneration status

The highest number of well-regenerating species was recorded in lower altitudinal range (1600-2000m). This variation in regeneration might be due to a significant difference in associated species density, which was higher in low and middle altitudinal ranges but lower in upper altitudinal range. The density of seedlings and saplings of *P. roxburghii* was found to be higher in lower and upper altitudinal range. This might be due to availability of enough light through open canopy and nutrient availability (Sharma, 2016; Paul *et al*., 2019). Similar result was reported by

Pokhriyal *et al*., 2010 in Garhwal Himalaya, India, they reported the forest having good canopy cover may have affected the survival of seedlings under good canopy. In upper altitudinal range density of sapling was lower than seedlings and adults. Current results could be impacts on developing stages of saplings before reaching the canopy level. Shrestha, 2003 also reported similar results for *Quercus semecarpifolia* in the Himalayan region of Nepal. *R. arboreum* had the highest total seedling density (285 stem ha^{-1}) and sapling density (325 stem $ha^{-1)}$ in lower altitudinal range. The high density of seedlings were reported in upper altitudinal range, which might be because of maximum seed-bearing trees in this altitudinal range, which was encouraging the regeneration and producing more seedlings and saplings (Chauhan *et al*., 2017).

5.7 Soil properties

Soil nutrients are considered as one of the main factors limiting tropical forest structure, primary productivity, and other biological processes such as plant root allocation, growth, and litter production (Wright *et al*., 2011; Zhang *et al*., 2015). The differences in the soils from the 16 studied samples , in terms of texture and chemical composition, demonstrated the influence of environmental heterogeneity on the land scape (Table 4.5, 4.6., 4.7 and 4.8). These edaphic variations are commonly found in ecotonal areas (Arruda *et al.,* 2013; Veloso *et al.,* 2014) and may be the result of biotic processes that create edaphic gradients, instead of being single-handedly determined by the pre-existing edaphic conditions (Silva *et al.,* 2013).

Soil OM was greater, but pH was lower in sampled area of Kalika Community Forest (Table 4.9) and similar trends were also observed by Sparrius and Kooijman, 2013 in inland dunes. This might be due to the density of *R. arboreum* also increased with increasing altitude and the acidic environment was created by the degradation of acidic litter of *R. arboreum.* Degradation process is faster due to higher rainfall and natural dense forests in higher altitude. Soil phosphorus is an important nutrient regulating plant growth and development in forest ecosystems (Chen *et al.,* 2000). Moreover, forest productivity at the late recovery stages has been found to be limited by Phosphorus (Cuevas and Medina, 1988).

Plant community attributes, such as plant biomass, vegetation cover, and species composition, can be impacted by variation in soil nutrients (Perroni-Ventura *et al.,*

2006). Especially, in the early stages of reforestation, tree communities and the rate of forest recovery can be limited by a lack of soil nutrients, especially nitrogen (Carate *et al.*, 2018).

5.8 Tree Carbon stock

The potential of using the basal area as predictor of aboveground carbon in trees as determined by allometric equations. The amount of carbon stored in a forest stand depends on its age, tree species, the location of forests on a landscape and management practices imposed. However, much attention has also to be paid to the human development activities such as cultivation of crop, collection of fire woods, cutting down of trees for charcoal and timber which involves clearing of forest's trees which reduces the amount of carbon in a particular forest stand. Different studies indicate that forests store different amounts of carbon in defined pools including aboveground biomass carbon (AGB), below ground biomass carbon (BGB), leaf litter, dead woody and soil organic matter carbon (SOC). It is clearly known that the changes in forestland affect the carbon stock of a particular forest and hence the annual carbon storage and average carbon density (Rowell, 1994). The carbon stocks in each plot varied with tree species. This variation is possibly attributed to the differences in tree ages and canopy size.

The carbon stocks in each plot varied with tree species. This variation is possibly attributed to the differences in tree ages and canopy size. The carbon contents in t/ha was the highest in *Pinus roxburghii* in both elevation i.e. 0.313 ton/hec in elevation 1500-2000m and 0.61ton/hec in elevation 2000-2400m and. *Quercus glaucahunb* i.e 0.152 kg/hec.in elevation of 2000-2400m (Table 4.9 and 4.10*).* The aboveground carbon stocks vary widely depending on the extent of the tree cover and associated characteristics as reported by Grace *et al.,* 1995. The differences in tree carbon between plant communities may also results from the sizes and age of tree species that constituted in these communities. Normally, forest types with larger trees accumulated more biomass, hence higher carbon stock contents. It is anticipated that the biomass and thus the carbon stock of natural forests increase over time (Baker *et al*., 2004). Large trees also store approximately 600 times more carbon than small trees. A relatively low value of the carbon stock can be attributed to the regenerating stage of the forests**.**

The results of the aboveground carbon storage in natural ecosystems were mainly explained by functional diversity incorporating wood density, maximum diameter, and maximum height traits in natural habitat and carbon stocks Zhang *et al.*, 2012.

CHAPTER 6

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

- Forest was dominated by *Pinus roxburghii* in both altitudes. Higher number of species was associated in higher altitudes compared to lower. In the present study, the tree and shrub species richness increased from lower to higher altitudes.
- Tree species diversity decreased from the lower to higher altitudes
- *P. roxburghii, Lyonia ovalifolia* and *Stellaria media* had highest IVI in both altitudes,
- *P. roxburghii* had the highest frequency and density in both altitudes.
- High density of trees with DBH class 10-25cm was recorded at lower altitude and maximum density with DBH class 35-40cm was recorded at higher altitude.
- The density of seedling and saplings of *P. roxburghii* were highest in both altitudes. However, higher number was reported from lower altitude.
- The soil of the low altitude forest was found to be acidic to neutral. It was more acidic in high altitude forest.
- In most of sampled soil, the highest content was of sand. In NPK test, potassium was highest among the sampled soil.
- Tree carbon stock of *P. roxburghii* was highest in lower altitude compared to higher altitude.

6.2 Recommendation

- The regeneration status of seedling and sapling of *P. roxburghii* was lower in higher altitude. Rayarakot and sansarakot area are situated in higher altitude site. These areas are famous for local pilgrimage. Therefore less no of seedling and sapling in high altitudes was mainly due to human encroachment. Hence the local government need to pay attention to the management of these forests and restrict the unnecessary movement of pilgrims in the forest area.

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ANNEXES

Annex I: List of species

S. N	Common Name	Botanical Name	Family	Habit
1.	Aakamaro	*Ageratina adenophora*	Asteraceae	H
2.	Abhijalo	*Drymeria diandra* Blume	Caryophyllaceae	H
3.	Ainselu	*Rubus ellipticus* Smith	Rosaceae	S
4.	Angeri	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	S
5.	Angeri	*Lyonia ovalifolia* (Wall.) Drude	Ericaceae	T
6.	Bajh	*Quercus lantana*	Fagaceae	T
7.	Bakhre lahara	*Ichnocarpus lrulescens* (L) R. Br.	Apocynaceae	S
8.	Banko	*Arisaema toftuosum* (Wall.) Schot	Araceae	S
9.	Bansi bans	*Bambusa vulgare* Schrad	Poaceae	S
10.	Banso	*Eragrostis unioloides*		H
11.	Baruwa	*Daphne papyracea* Wall. ex Steud.	Thymelaceaceae	S
12.	Basak	*Dichroa febrifuga* Lour.	Hydrageaceae	S
13.	Bhakimlo	*Rhus javanica* L.	Anacardiaceae	H, T
14.	Bhalayo	*Rubus javanica* L.	Anacardiaceae	S, T
15.	Bilauni	*Maesa chisia* Buch.-Ham. ex D. Don	Primulaceae	S
16.	Buki	*Anaphalis busua* (Buch.-Ham. ex Don) DC.	Asteraceae	H
17.	Chari amilo	*Oxalis latifolia* Humb.	Oxalidaceae	H
18.	Chilauni	*Schima wallichiana* (DC) Korth.	Theaceae	T
19.	Chunetro ghas	*Maghania strobilifera* (L.) Jaume St. Hil. ex. Jack	Fabaceae	S
20.	Cutro	*Berberis aristata* DC	Berberidaceae	S
21.	Dabdabe	*Symplocos ramosissima* Wall ex. G. Don	Symplocaeae	S, T
22.	Dansinki	*Codariocalyx motorius* (Houtt.) H. Ohashi	Fabaceae	H
23.	Darim	*Punica*		T
24.	Dhursul	*CoIebrookea oppositifolia* Sm	Lamiaceae	S
25.	Dubo	*Cynodon dactylon*	Poaceae	H
26.	Dudhelahari	*Marsdenia roylei* Wight.	Apocynaceae	S
27.	Dudilo	*Ficus neriifolia* Sm	Moraceae	S, T
28.	Fern	*Dicranopteris linearis*	Gleicheniaceae	H
29.	Galinsuga	*Galinsoga quadriradiata*	Asteraceae	H
30.	Gandhe jhar	*Artemisia indica* Wrlld.	Asteraceae	H
31.	Ganye jhar	*Borreria articularis* (L.f.) F.N.Will.	Rubiaceae	H
32.	Guyali	*Elaegnus*	Elaegnaceae	T
33.	Hande	*Dicranopteris linearis* (Burm.) Underw.	Gleicheniaceae	H

	unyu			
34.	Janai ghas	*Paspalum distichum* L.	Poaceae	H
35.	Jhyangkada	*Lannea coromandefba* (Houtt.) Men.	Anacardiaceae	S
36.	Kade	*Araucaria bidwilli* Hook		T
37.	Kafal	*Myrica esculenta* Buch.-Ham. ex D. Don	Myricaceae	T
38.	Kali kath	*Myrsine semiserrata* W all.		T
39.	Kane jhar	*Cyanotis cristata* (L.) D. Don	Commelinaceae	S
40.	Kanike ghas	*Hypericum japonicum* f hunb. ex Murray	Hypericaceae	S
41.	Kans	*Saccharum spontaneum* L.	Poaceae	H
42.	Kanthakari	*Solanum surattense* Burm.f.	Solanaceae	S
43.	Kathe kaulo	*Persea gamblei* [(ing ex Hook. f.) Kosterm		T
44.	kharso ghas	*Lecanthus peduncularis* (Royle) Wedd.	Urticaceae	H
45.	Khirro	*Sapium insigne* (Royle) Benth. ex Hook.f.	Euphorbiaceae	S
46.	Khursani jhar	*Solanum pseudocapsicum* L.	Solanaceae	S
47.	Kukur daino	*Smilax ovalifolia* Roxb.	Smilaceae	S
48.	Kurilo	*Asparagus racemosus* Willd	Aspargaceae	S
49.	Kuro	*Bidens biternata* (Lour.) Men. & Sherfi	Asteraceae	H
50.	Lakuri	*Fraxinus floribunda* Wall	Oleaceae	T
51.	Laligurans	*Rhododendron arboreum* Smith	Ericaceae	T
52.	Lekali sallo	*Pinus roxburghii* Sargent	Pinaceae	T
53.	Lekali sallo	*Pinus roxburghii*		T
54.	Lokta	*Daphne bholua* Buch.- Ham. ex D. Don	Thymelaceaceae	S
55.	Mail	*Prunus* sp	Rosaceae	S, T
56.	Makuri	*Asparagus racemosus* Willd.	Aspargaceae	S
57.	Mandre cutro	*Mahonia napaulensis* DC	Berberidaceae	S
58.	Mauwa	*Engelhardia spicata* Lsch. Ex. Bl	Juglandaceae	T, S
59.	Mithe phaphar	*Fagopyrum esculentum* Moench -	Polygonaceae	H
60.	Mothe jhar	*Cyperus compressus* L.	Cyperaceae	H
61.	motho	*Cyperus rotundus* L.	Cyperaceae	H
62.	Muse kharuki	*Capillipedium assimile* (Steud.) A. Camus	Poaceae	H
63.	Nagebeli	*Lycopodium clavatum*	Lycopodiaceae	H
64.	Naspati	*Pyrus communis* L.	Rosaceae	S
65.	Nigalo	*Drepanostachyum intermedium* (Munro) Keng f.	Poaceae	S
66.	Okhar	*Juglans regia* L.		T
67.	Paite	*Murdannia scapiflora* (Roxb.) Royle	Commelinaceae	S, H

68.	Paiyu	*Betula alnoides* Buch-Ham.ex D.Don	Betulaceae	S, T
69.	Pakhan bed	*Bergenia ciliata* (Haw.) Stemb.	Sexifragaceae	H
70.	Pakhuri	*Ficus glaberrima* Blume	Moraceae	S
71.	Patpate	*Gaultheria fragrantissima* Wall.	Ericaceae	S
72.	Phalat	*Quercus glauca* fhunb.		T
73.	Phul sisso	*Dalbergia sissoo* Roxb.ex DC.	Fabaceae	S
74.	Phurse ghas	*Indigofera pulchella* Roxb.	Fabaceae	S
75.	Pirri	*Persicaia barbala* (L.) Hara	Polygonaceae	S
76.	Polygonum	*Polygonum erectum*	Polygonaceae	H
77.	Pyauli	*Trifolium repens* L.	Fabaceae	H
78.	Raktachandan	*Pterocarpus santalinus* L. f .		T
79.	Raktanyaule jhar	*Persicaia capitata* (Buch.-Ham.) H. Gross	Polygonaceae	H
80.	Rato ainselu	*Rubus niveus* Thunb.	Rosaceae	S
81.	Rhumus	Catharanthus roseus (L.) G.Don	Apocynaceae	H
82.	Saltimur	*Lindera neesiana* (Wall ex . Nees) Kurz.		T
83.	sarpako makai	*Arisaema toftuosum* (Wall.) Schott	Araceae	H
84.	Satuwa	*Paris polyphylla* Smith	Melanthiaceae	H
85.	Sim ghas	*Urlicularia bifida* L.	Poaceae	H
86.	Sinkauli	*Cinnamomum glanduliferum* (Wall.) Meisn.	Lauraceae	T
87.	Siru	*Impereta cylindrica*	Poaceae	H
88.	Stellaria	*Stellaria media*	Caryophyllaceae	H
89.	Tej pat	*Cinnamomum tamala*(Buch.- Ham.) Ness & Eberm.	Lauraceae	S, T
90.	Tin khutte sottar	*Pteris wallichiana* Agardh	Pteridaceae	H
91.	Tite	*Swertia nervosa* (G.Don) C.B. Clarke	Gentianaceae	H
92.	Titepati	*Artemisia indica* Wlld.	Asteraceae	H
93.	Utis	*Alnus nepalensis* D.Don	Betulaceae	T
94.	Vanmara	*Ageratina adenophora* Spreng.	Asteraceae	H

Annex II: Importance Value Index

		Importance value index		
		Herbs		
S. N	Altitude (1600-2000)m	IVI value	Altitude (2000-2400)m	IVI value
1	*Ageratina adenophorum* Spreng.	7.73357077	*Arisaema toftuosum* (Wall.) Schott	38.4243554
2	*Dicranopteris linearis* (Burm.) Underw.	5.84643791	*Bergenia ciliata* (Haw.) Sternb.	39.8779274
3	*Pteris wallichiana* Agardh	4.71616757	*Paris polyphylla* Smith	10.0431087
4	*Paspalum distichum* L.	20.8448212	*Artimisia vulgaris*	6.04413648
5	*Fagopyrum esculentum* Moench -	16.5733445	*Stellaria media*	3.72201339
6	*Saccharum spontaneum* L.	7.40147479	*Cynodon dactylon*	7.97594168
7	*Cyperus compressus* L.	15.5496007	*Anaphalis busua*	7.69147385
8	*Persicaia capitata* (Buch.-Ham.) H. Gross	6.62736777	*Asparagus racemos*	5.5952716
9	*Ageratina adenophora*	14.0083604	*Eragrostis unioloides*	6.73400975
10	*Rhus javanica* L.	12.7888674	*Dicranopteris linearis*	4.80300173
11	*Capillipedium assimile* (Steud.) A. Camus	9.97358354	*Hypericum perforatum* L.	13.0099228
12	*Bidens biternata* (Lour.) Men. & Sherfi	15.7893279	*Urlicularia bifida* L.	8.67225361
13	*Reinwardtia indica* Dumorl	3.71951847	*Cynodon doctylon*	8.81343291
14	*Artemisia indica* Wlld.	14.3507729	*Artemisia indica* Wrlld.	12.5638595
15	*Anaphatis busua* (Buch.-Ham. ex Don) DC.	7.83973612	*Oxalis latifolia* Humb.	9.06788821
16	*Impereta cylindrica*	15.323414	*Cyperus rotundus* L.	4.35116004
17	*Murdannia scapiflora* (Roxb.) Royle	20.560197	*Pteris vittata*	2.8483965
18	*Codariocalyx motorius* (Houtt.) H. Ohashi	6.59647759	*Galinsoga quadriradiata*	3.41601934
19	*Catharanthus roseus* (L.) G.Don	2.97630163	*Smilax ovalifolia* Roxb	5.09370916
20	*Oxalis latifolia* Humb.	2.993441	*Artemisia indica* Wlld.	7.80434705
21	*Galinsoga quadriradiata*	2.25022416	*Lecanthus peduncularis* (Royle) Wedd.	4.80300173
22	*Cynodon dactylon*	5.51423679	*Swertia nervosa* (G.Don) C.B. Clarke	18.1961519
23	*Borreria articularis* (L.f.) F.N.Will.	6.04516867	*Impereta cylindrica*	2.20634192
24	*Trifolium Repens*	3.7777594	*Trifolium Repens*	6.91211189
25	*Lecanthus peduncularis* (Royle) Wedd.	6.75406103	*Catharanthus roseus* (L.) G.Don	4.21015671
26		9.01449658	*Bidens biternata* (Lour.) Men. & Sherfi	4.26683621
27	*Swertia nervosa* (G.Don) C.B. Clarke	10.7511249	*Centella asiatica*	4.04949464
28	*Arisaema toftuosum* (Wall.)	23.2832172	*Persicaia capitata* (Buch.-	7.53700792

	Schott		Ham.) H. Gross	
29	*Cyperus rotundus* L.	12.6108155	*Eupatonum adenophorum* Spreng.	4.94702089
30	*Stellaria media*	7.84651322		
31	*Polygonum erectum*			
32	*Drymeria cordata*			
33	*Hypericum*			
34	*Lycopodium clavatum*			
35	*Bergenia ciliata* (Haw.) Stemb.			

Important Value Index			
Shrubs	**IVI value**		**IVI value**
	1600-2000		2000-2400m
Lyonia ovalifolia (Wall.) Drude	11.4198041	*Gaultheria fragrantissima* Wall.	24.9824602
Smilax ovalifolia Roxb.	18.3073498	*Rhubus ellipticus* Smith	28.0061419
Rhus javanica L.	3.62087784	*Berberis aristata* DC	16.3153684
Berbeis aristata DC	12.3433853	*Lyonia ovalifolia* (Wall.) Drude	10.0635446
Rubus ellipticus Smith	37.0719359	*Prunus* sp.	53.2864808
CoIebrookea oppositifolia Sm	51.7166125	*CoIebrookea oppositifolia* Sm	68.0515616
Betula alnoides Buch-Ham.ex D.Don	10.0621539	*Dalbergia sissoo* Roxb.ex DC.	12.6699
Drepanostachyum intermedium (Munro) Keng f.	11.1163914	*Hypericum japonicum* f hunb. ex Murray	8.85485993
Maghania strobilifera (L.) Jaume St. Hil. ex. Jack	2.95250159	*Smilax ovalifolia* Roxb.	6.66485179
Murdannia scapiflora (Roxb.) Royle	2.76407191	*Ficus neriifolia* Sm	20.6876715
Ficus neriifolia Sm	6.87823918	*Indigofera pulchella* Roxb.	13.5486829
Dalbergia sissoo Roxb.ex DC.	10.5176843	*Rubus niveus* Thunb.	22.4789558
Maesa chisia Buch.-Ham. ex D. Don	10.3957709	*Daphne papyracea* Wall. ex Steud.	33.6486445
Solanum surattense Burm.f.	20.6373526	*Solanum pseudocapsicum* L.	21.3094104
Gaultheria fragrantissima Wall.	3.37756884	*Murdannia scapiflora* (Roxb.) Royle	4.89119092
Pyrus communis L.	7.71937184	*Mahonia napaulensis* DC	10.9639389
Sapium insigne (Royle) Benth. ex Hook.f.	2.02892048	*Drepanostachyum intermedium* (Munro) Keng f.	16.0085108
Symplocos ramosissima Wall ex. G. Don	12.2742796	*Bambusa vulgare* Schrad	14.3055108
Lannea coromandefba (Houtt.) Men.	5.21805964	*Persicaia barbala* (L.) Hara	5.50633894
Dichroa febrifuga Lour.	8.65050781	*Daphne bholua* Buch.- Ham. ex D. Don	9.58501389
Marsdenia roylei Wight.	14.4106283	*Ichnocarpus lrulescens*(L) R. Br.	23.5418771
Prunus sp	4.96952621	*Ficus glaberrima* Blume	4.16655324

Hypericum japonicum f hunb. ex Murray	11.677903	*Lannea coromandeba* (Houtt.) Men.	19.7616779
Asparagus racemosus Willd	2.02892048	*Cinnamomum tamala*(Buch.-Ham.) Ness & Eberm.	10.0529658
	6.49093097	*Arisaema toftuosum* (Wall.) Schot	9.73915909
	3.12903541	*Marsdenia roylei* Wight.	5.15482578
	3.25591434	*Cyanotis cristata* (L.) D. Don	4.95745783
	4.96430178	*Asparagus racemosus* Willd.	2.43754791

IVI	**IVI value**		**IVI value**
Tree species	**1600-2000**		**2000-2400**
P. roxburghii	152.18428	Pinus roxburghii	60.4040187
R. arboreum	20.3394784	*P.roxburghii*	26.2020753
A. nepalensis	17.5484125	*R. arboreum*	3.60349711
Fraxinus sp.	2.12698539	*Q. lantana*	14.2872628
S. wallichiana	9.24639518	*M.semiserrata*	20.1590912
F. nerifolia	12.1288848	*P. gamblei*	15.6894391
M. esculenta	3.91567434	*S. ramosissima*	8.61310087
L. ovalifolia	3.69593726	*A. nepalensris*	11.8860636
E. spicata	18.7931521	*L. neesiana*	30.0431473
C. glanduliferum	8.2126894	*P.wallichiana*	10.5490211
Q. lantana	3.0745006	*Q. glaucafhunb*	4.94719597
Elaegnus spp.		*C.tamala*	11.5015507
		A. bidwilli	2.93173401
		P. santalinus	14.4825979
		Punica sp.	8.9883428
		L. ovalifolia	10.2086228
		J. regia	15.1529447
		R. javanica	6.30225323

Annex III: Regeneration status of lower elevation

Name of Species	Tree density(m2)	Sapling density	Seedling density
R. arboreum	28.571	174.286	57.143
S. wallichiana	14.286	114.286	74.286
P.roxburghii	97.143	325.714	285.714
A. nepalensis	20.000	125.714	131.429
F. nerifolia	2.857	5.714	
M. esculenta	2.857	14.286	2.857
L. ovalifolia	2.857		2.857
E. spicata	2.857	17.143	
P. pashia	14.286	25.714	25.714

Annex IV: Regeneration status of upper elevation

Scientific name	Tree Density	Seedling Density	Sapling Density
Pinus roxburghii	85.71429	125.7143	205.7143
Rhododendron arboretum	62.85714	108.5714	151.4286
Quercus lantana	8.571429	8.571429	8.571429
Symplocos ramosissima Wall ex. G. Don	71.42857	74.28571	122.8571
Alnus nepalensrs D. Don	22.85714	42.85714	54.28571
Lindera neesiana (Wall ex . Nees) Kurz.	8.571429	2.857143	5.714286
Lyonia ovalifolia (Wall.) Drude	25.71429	5.714286	8.571429

Annex V: Density of shrubs

S.N	Plant species	Density(m2)
1	*Pyrus communis* L.	22.85714
2	*Lyonia ovalifolia* (Wall.) Drude	811.4286
3	*Smilax ovalifolia* Roxb.	45.71429
4	*Rhus javanica* L.	45.71429
5	*Berberis aristata* DC	1360
6	*Rubus ellipticus* Smith	2582.857
7	*CoIebrookea oppositifolia* Sm	228.5714
8	*Betula alnoides* Buch-Ham.ex D.Don	45.71429
9	*Drepanostachyum intermedium* (Munro) Keng f.	34.28571
10	*Maghania strobilifera* (L.) Jaume St. Hil. ex. Jack	22.85714
11	*Murdannia scapiflora* (Roxb.) Royle	160
12	*Ficus neriifolia* Sm	240
14	*Maesa chisia* Buch.-Ham. ex D. Don	1062.857
15	*Solanum surattense* Burm.f.	22.85714
16	*Gaultheria fragrantissima* Wall.	354.2857
17	*Sapium insigne* (Royle) Benth. ex Hook.f.	11.42857
18	*Symplocos ramosissima* Wall ex. G. Don	308.5714
19	*Lannea coromandefba* (Houtt.) Men.	22.85714
20	*Dichroa febrifuga* Lour.	57.14286
22	*Marsdenia roylei* Wight.	605.7143
23	*Prunus* sp	57.14286
24	*Engelhardia spicata* Lsch. ex Bl.	240
25	*Hypericum japonicum* f hunb. ex Murray	11.42857
26	*Asparagus racemosus* Willd	251.4286
28	*Smilax ovalifolia* Roxb.	11.42857

Annex VI: Density of herbs

Plant species	Density(m2)
Ageratina adenophora	57.21
Dicranopteris linearis (Burm.) Underw.	194.00
Pteris wallichiana Agardh	11.67
Paspalum distichum L.	10.00
Fagopyrum esculentum Moench -	6.00
Saccharum spontaneumL.	15.00
Cyperus compressusL.	15.25
Persicaia capitata (Buch.-Ham.) H. Gross	10.25
Rhus javanica L.	3.00
Capillipedium assimile (Steud.) A. Camus	25.29
Bidens biternata (Lour.) Men. & Sherfi	18.00
Reinwardtia indica Dumorl	10.71
Artemisia indica Wlld.	20.58
Anaphatis busua (Buch.-Ham. ex Don) DC.	17.63
Impereta cylindrica	5.00
Murdannia scapiflora (Roxb.) Royle	2.00
Codariocalyx motorius (Houtt.) H. Ohashi	2.00
Catharanthus roseus (L.) G.Don	3.80
Oxalis latifolia Humb.	9.57
Galinsoga quadriradiata	3.00
Cynodon dactylon	27.33
Borreria articularis (L.f.) F.N.Will.	2.00
Trifolium Repens	9.00
Lecanthus peduncularis (Royle) Wedd.	8.33
Swertia nervosa (G.Don) C.B. Clarke	6.50
Arisaema toftuosum (Wall.) Schott	18.00
Cyperus rotundus L.	5.67
Stellaria media	8.10
Polygonum erectum	5.00
Drymeria cordata	2.50
Hypericum	11.00
Lycopodium clavatum	4.33
Bergenia ciliata (Haw.) Stemb.	6.00

PHOTO PLATES

Photo 1: Upper altitiude

Photo 2: Upper altitude

Photo 3 and 4: Lower altitude

Photo 5: Data collection

Photo 5 and 6 : Drying soil sample

Photo 7: Measuring diameter of tree