STATUS OF COMMUNITY STRUCTURE AND REGENERATION OF *QUERCUS SEMECARPIFOLIA* SM. IN FOREST OF CHANDRAGIRI HILLS, 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, Hasina Shrestha, hereby declare that the work enclosed here is entirely my own, except where states otherwise by reference or acknowledgement, and has not been published or submitted elsewhere, in whole or in part, for the requirement for any other degree or professional qualification. Any literature, data or works done by others and cited within this thesis has been given due acknowledgement and listed in the reference section.

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RECOMMENDATION

This is to recommend that the Master's thesis entitled **"Status of Community Structure and Regeneration of *Quercus semecarpifolia* Sm. in Forest of Chandragiri Hills, Central Nepal"** is carried out by Ms. Hasina Shrestha under my supervision. The entire work is based on original scientific investigations and has not been submitted for any other degree in any institutions. I therefore, recommend this thesis work to be accepted for the partial fulfilment of M.Sc. Degree in Botany.

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Hasina Shrestha

LIST OF ABBREVIATION AND ACRONYMS

°C	degree Celsius
%	Percentage
A	Abundance
ANOVA	Analysis of variance
asl	above sea level
C	Simpson's index of dominance
cm	centimeters
D	Density
DBH	Diameter at Breast Height
DPR	Department of Plant Resources
g	gram
H	Shannon- wiener index
ha	hectare
IBM	International Business Machines Corporation
IVI	Important Value Index
K	Potassium
KATH	National Herbarium and Plant Laboratories, Godawari
m	meters
mm	millimeters
N	Nitrogen
OC	organic carbon
P	Phosphorus
pH	potential of Hydrogen
pl/ha	plants per hectare
RD	Relative Density
RF	Relative Frequency
RA	Relative Abundance
SD	Standard Deviation
SPSS	Statistical Package for Social Science
SW	South West
TIA	Tribhuban International Airport
Tukey's HSD	Honestly significant difference

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ABSTRACT

Plants grow in community and community is none other than a naturally occurring, mutually sustaining and interacting assemblage of plants and animals living in the same environment and fixing, utilizing and transferring energy in some manner. To sustain the forest ecology, the role of regeneration is very crucial and good regeneration is the symbol of the healthy forest. The higher elevation of the Chandragiri Hills is mainly dominated by *Q. semecarpifolia* and this forest was heavily degraded due to over exploitation and fire in the past but now the forest of is protected and managed by the local communities under community forestry program of Nepal. At present, the forest is assumed to be re-growing but its regeneration abilities are unknown. So, this study aimed to explore the community structure and regeneration status of *Q. semecarpifolia* in four aspects of forest i.e. northern, southern, eastern and western along with effects of microsite conditions such as canopy cover, herb cover, litter thickness and soil attributes on the regeneration of *Q. semecarpifolia*. The methods used in this study were data collection by systematic random sampling, herbarium preparation and identification, soil collection, soil test and data analysis using some statistical tools like Excel 16, R version and SPSS 25. Altogether, 24 tree species and 98 herb species were recorded. *Q. semecarpifolia* was dominant tree. The northern aspect was found to be the highest tree species diversity holding aspect while southern aspect was the lowest tree species diversity holding aspect. Regeneration of all tree species and *Q. semecarpifolia* was good in all aspects of forest but regeneration of *Q. semecarpifolia* in lower elevation of study area was poor. The microsite conditions had no significant relation with regeneration i.e. seedling and sapling density of *Q. semecarpifolia* except soil phosphorus which had significant relation with sapling density. Canopy cover and litter thickness had positive correlation to both seedling and sapling density while soil nitrogen, soil potassium and organic carbon had negative correlation. Soil phosphorus and herb cover had negative correlation to seedling but positive correlation to sapling while pH had positive correlation to seedling but negative correlation to sapling. There were no significant differences of microsite conditions among the four aspects of the forest and in between the uppermost site and the lowermost site except soil potassium and soil organic carbon.

Key Words: Regeneration, *Q. semecarpifolia*, microsite conditions, canopy cover, Nepal

CHAPTER 1 : INTRODUCTION

1.1 Background

Plants grow in community, in most of the habitats members of a species grow mingled with the members of other species. The assemblages of species are called communities, which can be of any suitable size or durability and changes with change in an environment. Community is a naturally occurring, mutually sustaining, and interacting assemblage of plants and animals living in the same environment and fixing, utilizing and transferring energy in some manner (Singh *et al*., 2014). The plant community of a region is a function of time; however, altitude, slope, latitude, aspect, rainfall, and humidity play a role in the formation of plant communities and their composition (Kharkwal *et al*., 2005). Plant community may comprise different assemblage of groups like herbs, shrubs, trees, epiphytes, climbers, lianas, etc. belonging to more than one species and sharing the same habitat at a given time. They all might have different ecological roles in the community to where they belong.

Community structure is the composition of the community, including the number of species in that community and their relative numbers. Community structure and function are dependent on response of tree regeneration to site conditions, disturbances and management practices (Gray *et al*., 2005). The altitude plays a key role in determining the community structure of the forest, whereas, within one altitude the cofactors like topography, forest aspect, inclination of slope and soil type also affect the community structure (Shank and Noorie, 1950). But in most of the ecological study, forest aspects are not taken into consideration, although, community structure has some impacts of forest aspects (Sharma *et al*., 2010). Hence, the community structure and forest productivity parameters studied in mountains are overestimated in most of the ecological studies as they do not take in to consideration of forest aspects (Sharma *et al*., 2010). In Himalayas, the north-facing slopes are relatively cooler as they receive less sunlight while the south facing slopes are considered as warmer and drier due to longer insolation (longer exposure) period during the day. As a result, north aspect comprises shade loving plant species while south aspect favors sun loving plant species.

Oaks belong to family Fagaceae and according to the DPR 1997, there are eight species of oaks in Nepal. They are *Quercus floribunda* Lindl., *Q. glauca* Thunb., *Q. lamellosa* Sm., *Q. lanata* Sm., *Q. leuchotrichophora* A. Camus, *Q. mespilifolioides* A. Camus, *Q. oxyodon* Miq. and *Q. semecarpifolia* Sm. Oaks are considered as symbol of permanence, strength and courage by many people (Keator and Bazel, 1998). They are highly important for subsistence Hills

agriculture in the Himalaya region, which is widely practice in the mountainous areas of Nepal. In addition to maintaining and protecting soil fertility, watershed and local biodiversity, they also have an important provisioning service value due to their capacity of supplying fodder, leaf litter, firewood and timber. *Q. semecarpifolia*, also called brown oak and Khasru is one of the highly useful species of oak having considerable social impact, facing threat from environmental degradation and it plays vital role in water and soil conservation (Singh and Singh, 1986). It commonly grows between 2,400 and 3,000 meters above sea level (m a.s.l.), but depending on the amount of rainfall and humidity in the area it can also be found between 1,700 and 3,800 m a.s.l. (Jackson, 1994). Its forest is one of the oldest vegetation types of the Himalayan region and a climax community, especially on the southern aspect (Negi and Naithani, 1995). In Nepal, it can be found in both the sub-alpine and the temperate zone forming pure forests or being the dominant species in mixed forest.

Regeneration is a cost effective natural process by which plants re-establish themselves and this strategy help the plants to maintain their diversity and genetic identity (Hanief *et al.*, 2016). To sustain the community in a forest ecology the role of regeneration is very crucial. Without regeneration no forest can long last. Regeneration of any species is confined to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution (Grubb, 1977). Regeneration status is one of the important parameter of forest ecology which can tell us the future composition of a community. An insight to the stable natural regeneration of woody species and their population structure plays a key role in the promotion of their suitable management, utilization and conservation (Mwavu and Witkowski, 2009).

The regeneration of key species is a vital process in sustaining certain forest communities (Grubb, 1977). Forest tree species require certain environmental and micro habitat condition thereby making forest regeneration a complex and multidimensional process (Smith *et al.*, 1997). Not all seeds that reach the forest floor find suitable conditions for establishment as conditions might be highly heterogeneous at a small scale (Harper *et al.*, 1961). Even after germination, seedling mortality is high and the physical habitat surrounding seedlings contributes to the probability of long term survival (Collins and Good, 1987). Regeneration, therefore, is affected by the availability of safe sites, or microsites, suitable for the germination and establishment of seedlings (Fowler, 1988; Eriksson and Ehrlen, 1992). For regeneration, there has to be sufficient seed supply and rainfall. Subsequently, conditions are needed on the forest floor that maintain enough moisture, light and nutrients for a germinated seed to establish

(Mott and Groves, 1981). Moreover, regeneration of plants is generally controlled by various anthropogenic pressures such as felling, grazing, trampling, fire etc. (West *et al*., 1981).

Natural regeneration of *Q. semecarpifolia* is poor both in disturbed and undisturbed forests (Shrestha, 2003). Its natural regeneration is often prevented from establishing itself by a dense growth of weeds and heavy undergrowth (Troup, 1921). In this study the status of natural regeneration and population structure of *Q. semecarpifolia* has been focused along with community structure in Chandragiri Hills, Kathmandu. In spite of difficult topography of the location, this study tried to cover four directions as far as possible to explore plant community structure and regeneration.

1.2 Justification of the Study

Q. semecarpifolia is an important element of central Himalayan vegetation, which has been occurred in this region for millions of years but natural regeneration of *Q. semecarpifolia* is very poor and it is failing to regenerate under its own canopy (Shrestha, 2003). The lack of natural regeneration of this important forest flora and its frequent degradation become a serious issue in many areas of the world including Nepal (Vetaas, 2000; Shrestha, 2003). There might be several factors behind the poor natural regeneration of this species. Without knowing the actual factors related to its regeneration, it's very difficult to suggest the proper forest management strategies.

The higher elevation of the Chandragiri Hills is mainly dominated by *Q. semecarpifolia* and this forest was heavily degraded due to over exploitation and fire in the past but now the forest of entire Hills is protected and managed by the local communities under community forestry program of Nepal. At present, the forest is assumed to be re-growing but its regeneration abilities are unknown. So, it might be fruitful to know the present status of regeneration of *Q. semecarpifolia* in order to apply proper forest management strategies and to predict future composition of the forest.

Literature search shows that researches related on regeneration of *Q. semecarpifolia* on four different aspects of the forest was not done in Nepal till this date. So this study tried to find out the aspect wise regeneration of this species. Recently, Chandragiri forest is experienced many disturbances due to the human encroachment and tourism industries e.g. cable car, hotel construction, road construction, etc. A large population of plant species have been cleared for this construction purposes. So, it is assumed that all these activities have adversely affected the

Quercus forest of the Hills. Though construction work is necessary in there for development and employments as many of people are getting jobs in there, it might be threatening to the healthy regeneration of this species i.e. *Q. semecarpifolia*.

So, this study will definitely help in providing information regarding the status of natural regeneration of *Q. semecarpifolia* and community structure in Chandragiri Hills. Moreover, it will enable the forest managers to adopt best forest management strategies to induce natural regeneration.

1.3 Hypothesis

Hypotheses of this research are as follow:

- Regeneration of *Q. semecarpifolia* is affected by microsite conditions such as canopy cover, soil attributes, herb cover and litter thickness.
- Microsite conditions and regeneration are varying among the four aspects of forests i.e. in northern, southern, eastern and western.

1.4 Research Questions

- How is the community structures and natural regeneration of tree species including *Q. semecarpifolia*?
- Do the microsite conditions such as canopy cover, soil and litter thickness affect the regeneration of *Q. semecarpifolia*?
- Are there any differences in microsite conditions and regeneration of *Q. semecarpifolia* among the four aspects of the forest?

1.5 Objectives

The general objective of this research was to explore the status of community structure and natural regeneration pattern of *Q. semecarpifolia* in higher elevation of Chandragiri Hills. Moreover, its specific objectives were: -

I. To measure Importance Value Index (IVI) and species diversity of herbs and tress.
II. To analyze the microsite condition and their effects on regeneration of *Q. semecarpifolia*.
III. To compare the overall community structure and regeneration of *Q. semecarpifolia* in four different forest aspects i.e. in northern, southern, eastern and western.

1.6 Limitation

I. Due to the geographical extremeness, the end point of *Q. semecarpifolia* in the western aspect of the forest was not possible to cover.

II. In lower ends of northern aspect surface distance between the plots were taken instead of altitudinal distance as there was no enough altitudinal range.

CHAPTER 2 : LITERATURE REVIEW

2.1 *Quercus semecarpifolia*

Quercus semecarpifolia is one of the species of oak (genus *Quercus*) and commonly known as brown oak which is the main forest forming evergreen tree species from upper temperate to lower sub alpine regions of the Himalaya (Singh and Singh, 1992). It occurs in moist temperate and sub-alpine regions with heavy snowfall and moderate rainfall, and is absent from the dry regions of the inner Himalayas (Negi and Naithani, 1995). It is a gregarious species forming pure forest stands. Its forest is one of the oldest vegetation types of the Himalayan region and a climax community, especially on the southern aspect (Negi and Naithani, 1995). It is a dominant species in the Himalayas, from southwest China to Afganistan, at elevation of 2100m to 3800m asl (Shrestha, 2003). The elevation range of *Q. semecarpifolia* forests is higher than all the other evergreen oak forests in Himalaya, nevertheless its canopy is often severely disturbed by lopping (Singh *et al*., 1997). It is a late successional evergreen tree species which forms a gregarious patch in the Central Himalayan region, with one-year leaf life span and concentrated leaf drop in the spring season (Verma *et al*., 2015). Verma *et al*. (2015), recorded that *Q. semecarpifolia* produced seed crops that varied widely in quantity from year to year between 2004 to 2009 with only one good seed year in 2005.

According to the Jackson (1994), it has the largest seed among the Oak and it is generally believed that seedlings of large seeded species are better able to survive environmental hazards, including burial under soil or litter, deep shade during the cotyledon stage and drought (Westoby *et al*., 1996). Shrestha (2003), noted that the period between the pollination and the ripening of the acorn (fruit of oak) is about thirteen months. The ripening of the acorn takes place from July to August, and germination takes place immediately after the fruit falls. According to Negi and Naithani (1995), *Q. semecarpifolia* is partial vivipary in which mature seeds fall during the rainy season and are viable for very short period.

2.2 Community structure of *Q. semecarpifolia* forest

Q. semecarpifolia can be found as pure stands especially along the tops and upper slopes of ridges (Troup, 1921), but can also be found with conifer species as a component of the cool temperate forest (Norbu, 2000). Giri and Katzensteiner (2013) have done study in the mixed broadleaved community forest of the Sagarmatha National Park buffer zone area, in where they found that *Quercus semecarpifolia* and *Rhododendron arboreum* as the main dominant tree

species of forest. Some other species associated with *Q. semecarpifolia* forest are *Pieris* sp., *Myrsine* sp., *Berberis* sp. and *Daphne bholua* (Viswanath *et al*., 2002). Bakker *et al*. (2004) report that oaks are usually found surrounded by thorny shrubs. According to Troup (1921), the common associated shrubs are species of *Rosa, Rubus, Viburnum, Lonicera* and dwarf bamboo.

2.3 Regeneration of *Q. semecarpifolia*

Undisturbed old-growth forests with sustainable regeneration are found to have a reversed J shaped size class distribution (West *et al*., 1981) and a bell-shaped size class distribution has been attributed to disturbed forests where regeneration is hampered (Saxena *et al*., 1984). Poor natural regeneration of *Q. semecarpifolia* has been reported from both disturbed and undisturbed forests (Shrestha, 2003). However, regeneration is more reliable in the nearly undisturbed forest (Vetaas, 2000). Oak (*Quercus*) regeneration is affected by plant flooding tolerance, wind disturbances or forest harvests, and interactions with seed predators and herbivores (Collins and Battaglia, 2008). According to them seed dispersal, seed predation and microsite conditions on the forest floor, rather than canopy openness, were the first filters on Oak regeneration. In the article of Shrestha (2003), it is clearly mentioned that regeneration of Oak (*Quercus)* is inhibited under its own canopy cover. According to him canopy gap in mature forest stands as a requirement for reaching the sapling phase and continue growing. But Tashi (2004), reports that Oak seedlings have higher chances of survival in closed canopy.

Based on the results of Vetaas (2000), he reports that above-ground factors are more important for seedling germination and therefore, survival, than soil variables. Litter depth inhibit germination and smothering of seedlings poses a particular high hazard during the winter period (Simon *et al*., 2011). Seed germination of *Quercus* depends upon the quality and thickness of litter as well as quality of light. Thick litter decreases the rate of germination (Shrestha, 2003). According to Tripathi and Khan (1990), herbaceous cover has more adverse effects on seed germination than litter depth.

In the study of Giri and Katzensteiner (2013), which was done in Sargamatha National Park buffer zone area, the distribution of *Q. semecarpifolia* along with diameter classes showed high stem density mainly concentrated in 2-15 cm diameter class. No seedling of *Q. semecarpifolia* was recorded in the disturbed site. According to them the absence of *Q. semecarpifolia* seedlings in the disturbed forest sites could be associated with the practice of biomass removal and forest management activities. According to Bisht *et al*. (2013), *Quercus semecarpifolia*

was growing in the habitat along south-east facing aspects with moderate slopes and they found that saplings (%) of *Q. semecarpifolia* was less in the stands selected as to the seedlings percentages.

2.4 Threats in regeneration of *Q. semecarpifolia*

The status of *Q. semecarpifolia* forests is highly threatened due to over exploitation and poor regeneration (Siluwal *et al*., 2001). *Q. semecarpifolia* seedlings are also threatened by free grazing domestic livestock, which can kill up to 75% of the seedlings if the animals stay for 3 months or more (Singh *et al*., 2011). The overharvest of *Q. semecarpifolia* through excessive lopping of the foliage, they lose their crown and start to resemble a pole. It is assumed that this stops seed production due to the need of allocating resources to produce more foliage and that it is more sensitive towards disturbance intensities than the other species (Shrestha *et al*., 2004; Rawal *et al*., 2012). According to the result of Bisht *et al*. (2011), regeneration potential of *Q. semecarpifolia* was very high in laboratory conditions, but in natural condition the results were not very satisfying.

2.5 Regeneration and canopy cover

According to Vickers and Palmer (2000), the canopy cover was found to have the largest statistical associations with the density of pine saplings. They found that the density of pine saplings of less than 1 m height was found to have a quadratic relationship with canopy cover, peaking at 20 percent cover and the densities of taller classes of pine less than 1 m were inversely associated with canopy cover. Vetaas (2000) also found most recruits under high canopy cover and high potential radiation. According to him canopy disturbance has a negative effect on the number of seedlings.

In the research work of Dupuy and Chazdon (2006), it was mentioned that creation of canopy gaps increased first year recruitment and density as well as overall mortality of seedlings whereas saplings experienced lower mortality and more prolonged gap enhanced recruitment and density than seedlings. But Kelso and Bowersox (2004) found that canopy coverage and the presence of herbaceous vegetation did not affect establishment of natural regeneration in a forest of central Pennslyvania. However, low light intensities seem to limit seed germination and seedling survival in *Q. semecarpifolia* (Maren and Vetaas, 2007). Caldeira *et al*. (2014) found that tree canopies increased seedling survival but not growth during the establishment phase, mainly by ameliorating the effects of low soil moisture and high temperatures.

According to them tree canopy indirectly facilitated survival of *Q. suber* seedlings by negatively affected the competing herb layers.

2.6 Regeneration and litter depth

Leaf litter has long been recognized for its importance in the nutrient dynamics of plant communities (Facelli and Pickett 1991; Xiong and Nilsson 1999). Studies have concentrated on the effects of leaf litter on seed germination and seedling establishment because of the potential importance of this life stage for determining future community composition (Grubb, 1977; Harper, 1977) and because of the sensitivity of this life stage to the soil micro environmental conditions (light, temperature, and moisture) on which litter can exert major impacts. Thick litter generally reduces the rates of germination and of seedling establishment (Shrestha, 2003).

Experimental studies of herbaceous and woody forest species have shown that litter quantity can strongly affect seed germination and seedling survivorship (Kostel-Hughes *et al*., 1998). Soil moisture is greater (Beatty and Sholes, 1988) and fluctuates less (Tao *et al*., 1987) under leaf litter than when bare. Larger patches of litter have greater soil organic matter and lower soil bulk density than smaller litter patches (Dighton *et al*., 2000). It also intercepts and changes the quality of light reaching soil (Vazquer-Yanes *et al*., 1990; Facelli and Pickett, 1991; Schimpf and Danz, 1999). Moreover, litter serves as physical barrier that can interfere with seeds reaching the soil, the emergence of seedlings and seed visibility to predators (Shaw, 1968; Facelli and Pickett, 1991; Myster and Pickett 1993; Vellend *et al*., 2000).

Most studies have found that smaller seeded species generally have reduced germination as litter depth increases while germination of larger seeded species is usually unaffected or increased by leaf litter (Tao e*t al*.,1987; Molofsly and Augspurger, 1992; Peterson and Facelli, 1992; Reader, 1993; Myster, 1997; Seiwa and Kikuzawa, 1996; Cintra 1997; Kostel-Hughes *et al*., 1998; Dzwonko and Gawronski, 2002). In the result of Kostel-Hughes *et al*. (2005), they found that the two smallest seeded species were better suited where there was likely to be less litter, whereas the two largest seeded oak species in their research were better suited to establish in forest with a thicker litter layer.

2.7 Regeneration and soil properties

Soil contains different nutrients such as nitrogen (N), phosphorus (P), potassium (K), organic carbon (OC), etc. and the nature of the soil is different depending on their pH ranges. These soil nutrients and nature of the soil determine the soil properties. Soil and vegetation have a complex interrelation, because they develop together over a long period of time (Sharma *et al*., 2010). The selective absorption of nutrient elements by different tree species and their capacities to return them to the soil bring about changes in soil properties (Singh *et al*., 1986). Thus, soil may have certain influences over regeneration. Soil nitrogen is supposed to be the most limiting nutrient in a majority of ecosystems (Fenn *et al*., 1998). According to Vetaas (2000), Tashi (2004) and Thakuri (2010), there was no clear relationship between recruit's density of *Q. semecarpifolia* and the soil variables but seedlings of *Q. semecarpifolia* seem to prefer total nitrogen between 2 to 3% (Vetaas, 2000). In their study soil was acidic. The effect of pH on plant growth is generally indirect, but significant (Singh *et al*., 2014). Major nutrients like nitrogen and phosphorus are most available at around pH 6-8 (Singh *et al*., 2014).

Most of the researches in regeneration of *Q. semecarpifolia* are found to be carried out in only one forest aspect. Some researches related to regeneration of *Q. semecarpifolia* are done in two localities as disturbed and undisturbed site by comparing them. But aspect wise researches in regeneration of *Q. semecarpifolia* are not found in Nepal and it is hardly found in globally. Similarly, this site was found to be less explored for the study of *Q. semecarpifolia.* Therefore, this study could be a pioneer research for the regeneration of *Q. semecarpifolia* in four different forest aspects.

CHAPTER 3 : MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location and Physiography

Chandragiri Hills lies in the Mahabharat range south west of Kathmandu valley is dominated by broad leaved mixed forests. Baniya and Shakya (1984) have identified ten forest types in the area, among them Evergreen Oak forest (2150-2400m), *Rhododendron arboreum* and *Quercus semecarpifolia* forest (2350-2450m), *Q. semecarpifolia* forest (2250-2563m) and *Q. lanata* forest (2000-2300m) at the higher elevation of the Hills. The pure stands of *Q. semecarpifolia* forests are widely distributed on South-West and South-East faces of Bhaleshwar temple.

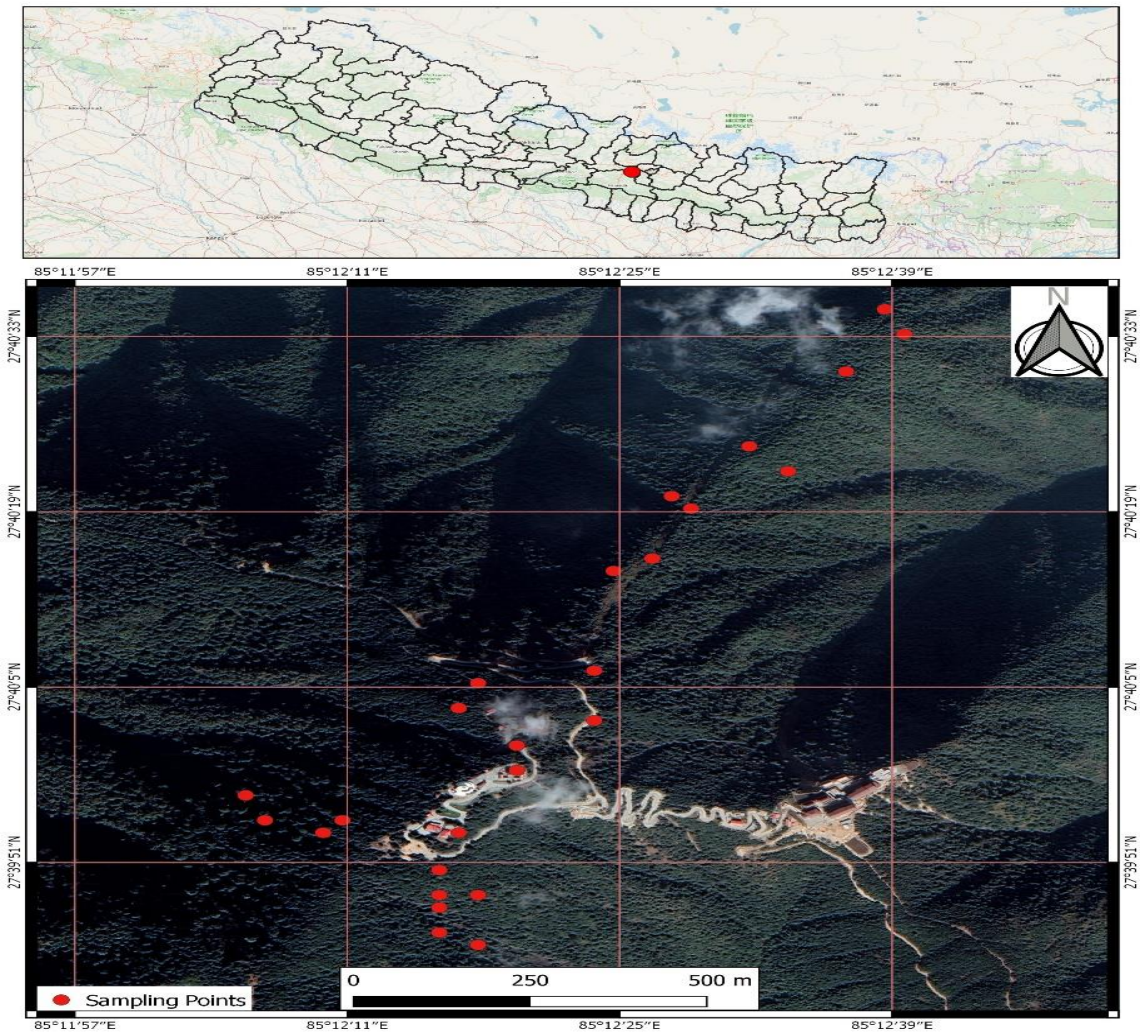

Figure 3.1: Map of the study site.

3.1.2 *Quercus semecarpifolia* Forest

The evergreen *Quercus semecarpifolia* covers the Chandragiri Hills in between 2108m and 2539m altitude. It is distributed on all four aspects of the forest i.e. Northern, Southern, Eastern and Western but it is widely distributed on south west and south east of Bhaleshwar. On the eastern and western regions of Chandragiri range the forest is less populated. Saplings are plentiful on the crest of southern region of Bhaleshwar but full grown trees are rare in the area. *Quercus semecarpifolia* occurs as pure stands on the upper altitude. On the lower altitude it mixes with *Q. lamellosa, Rhododendron arboreum, Q. leucotrichophora,* etc. Besides these tress, other shrub and thorny vegetation like *Arundinaria hookeriana, Jasminum humule, Smilax menispermoidea, Rubus hoffmeisterianus, Berberis aristata* etc. along with some herbs like *Carex daltonii, Eragrostris nigra, Geranium nepalense, Viola serpens,* etc. also occur. Some old and large tress are covered with mosses, epiphytic orchids and pteridophytes.

3.1.3 Climate of study area

Based on the data of the nearest weather station (Figure 3.2) the precipitation was highest in July (378.4 mm) and lowest in November (6.55 mm). The highest average maximum temperature was recorded in June (30.41°C) and the lowest average minimum temperature in January (19.96°C). The highest average minimum temperature was recorded in July (20.27°C) and the lowest average minimum temperature was recorded in January (2.71°C).

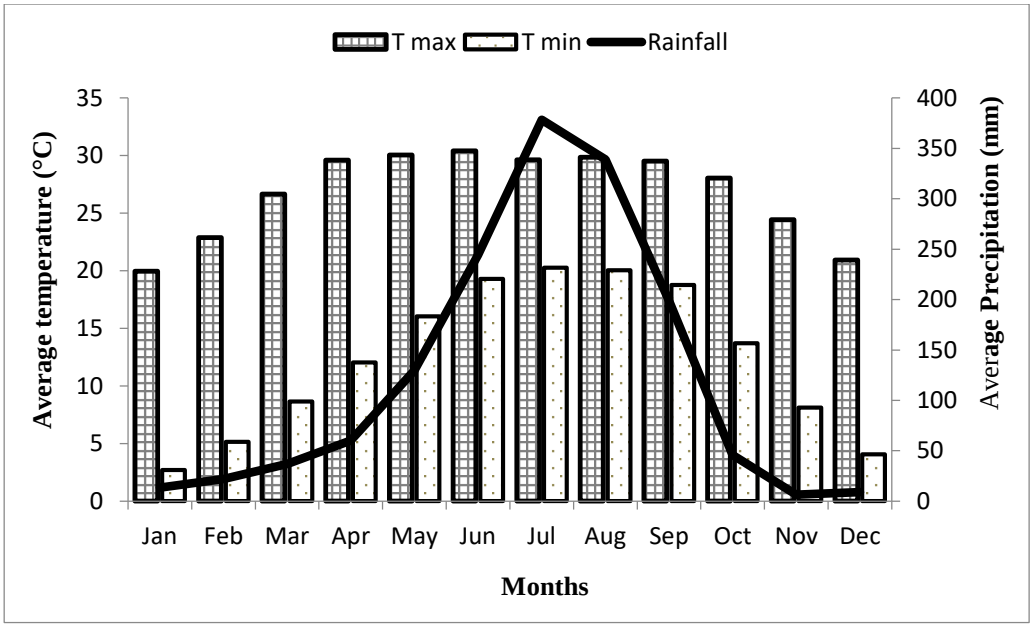

Figure 3.2: Thirty year (1988-2018) average of minimum and maximum temperature and precipitation recorded at TIA weather station, Kathmandu (Source: Department of Hydrology and Meteorology, Babarmahal, Government of Nepal).

3.2 Methods

3.2.1 Vegetation sampling

Vegetation sampling was conducted in the month of May, 2019 from May 10 to May 16. Systematic random sampling method was used as per Martin (1995) and Cunningham (2001). For this, four vertical transects in four cardinal directions from the top of the Chandragiri Hills up to the lowest occurring altitude of *Q. semecarpifolia* was made. That means vegetation sampling was done in four aspects i.e. Northern, Southern, Eastern and Western through vertical transects by making a circular plot each with 10m radius at certain interval (150 m aerial distance and 50 m altitude). All the tree species [diameter at breast height (DBH i.e. at 137 cm) ≥10 cm] which were occupied in this circular plot were noted and basically, tree numbers, measurement of DBH by using DBH tape and height of the trees by using clinometer were taken along with remarks. In total, 26 quadrats were laid 7 quadrats in northern aspect, 7 quadrats in southern aspect,7 quadrats in eastern aspect and 5 quadrats in western aspect. In each main plot, number of tree saplings (DBH≥5 cm, height ≥137 cm) were counted. Similarly, four random sub plots each with 1m radius were plotted for the sampling of tree seedlings (DBH<5 cm, height <137 cm) and herb species. Altogether, 104 sub plots were plotted.

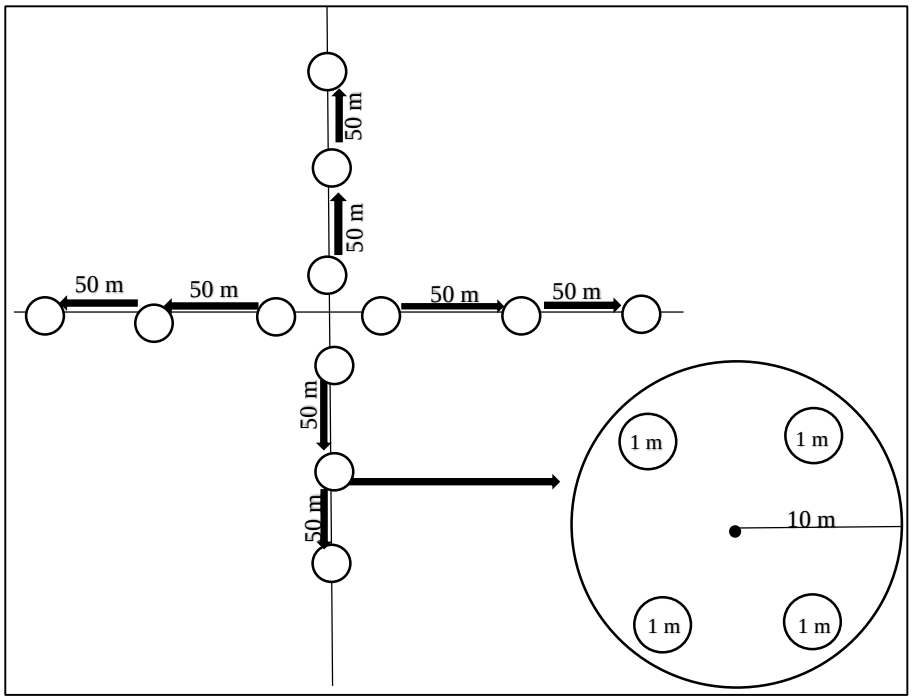

Figure 3.3: Outline of vegetation sampling.

The number and the height of seedlings of *Q. semecarpifolia* were also measured. Simultaneously, the abundance and cover of different herb species found in that sub plot were estimated visually.

Forest type, physical location (latitude, longitude and altitude), topography (aspect and slope), disturbance and other environmental factors were recorded for each sampling plot. The field data sheet used for vegetation sampling has been attached in annexes (Annex 7 and Annex 8).

3.2.2 Plant collection and identification

Specimens of all unidentified herbs and tree species encountered in sampling areas were collected, 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 plants specimens after drying were mounted on herbarium sheet of 16.5" × 11" using glue and labeled in accordance to Press *et al*. (2000). The herbarium specimens were identified using references such as Polunin and Stainton (1984) and Stainton (1988) and by experts of Taxonomy. These were also compared with specimens at National Herbarium and Plant Laboratories, Godawari, Lalitpur (KATH).

3.2.3 Soil sampling

Soil samples were collected from each plot. For this soil was collected from four corners and center of each plot at a depth of 10-15 cm by using trowel. Then, these sub samples were mixed thoroughly to get single sample. The collected soil samples were air dried after removing stones, plant debris and other objects or particles. After that the soil samples were sieved at mess size 0.5mm and 500 g of fine sample was kept in air tight polythene bag for laboratory analysis. There were altogether 26 soil samples.

3.2.4 Canopy cover, herb cover and litter thickness

Canopy cover was measured at four corners of main plot by visual estimation and average value was taken. Similarly, herb cover was also estimated visually. The litter thickness was measured by ruler to the nearest centimeters in each sub plots and average value was taken.

3.2.5 Soil analysis

Collected soil samples were analyzed and tested in the laboratory of Agricultural Technology Centre (ATC), Jwagal, Lalitpur. For each soil sample pH, organic carbon, nitrogen, phosphorous and potassium was estimated by following procedure described by Gupta (2000) and Zobel *et al*. (1987).

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 was determined electronically on a EI digital pH meter 111, using a glass electrode with a saturated potassium chloride (KCl)-calomel reference electrode. A 1:2.5 soil water ratio was used.

Total Nitrogen (%)

For this analysis, the Kjeldahl method was used.

Reagents:

- Digestion Mixture: 10 gm of grinded copper sulphate with 200 gm of sodium sulphate.
- Concentrated Sulphuric acid

- Sodium Hydroxide (40%)
- Mixed Indicator: 0.5 gm Bromo cresol green and 0.1 gm methyl red dissolved in 100 ml of 95% ethanol
- Boric acid (4%)
- 0.1N HCl
- Phenolphthalin Indicator

Method:

2 gm soil was taken in a 50 ml kjeldhal Digestion flask. 2 gm catalyst digestion mixture and 10 ml concentrated sulphuric acid were added. The solution was then swirled and gradually heated by increasing heat for several minutes till the sample turned turquoise. The solution was then allowed to cool for few minutes. Then distilled water was gradually added to the solution with swirling and made up to the volume. The solution was then transferred to a 100 ml volumetric flask, leaving the sand in the digestion flask and made up to the volume

20 ml aliquot with 20 ml of 40% NaOH was added to the distilling flask and distilled, collecting the liberated gas in 50 ml of 4% boric acid solution containing few drops of mixed indicator. The final solution was then titrated with 0.01N HCl. A blank was run without soil.

Calculation:

Soil N (%) = $\frac{14 \times \mathrm{N} \times (\mathrm{S}-\mathrm{B}) \times 100}{M}$

Where,

N = Normality of HCl

S = Volume of HCl consumed with sample (mL)

B = Volume of HCl consumed with blank (mL)

M = Mass of soil taken (mg)

Available Phosphorus (%)

It was determined by Olsen's Bicarbonate Method.

Reagents:

- Sodium bicarbonate ($NaHCO_3$) 0.5 M extracting solution
- Darco-G-60 or equivalent grade phosphorus free charcoal
- Ammonium molybdate solution
- Ascorbic acid solution
- Antimony potassium tartrate solution
- Sulphuric acid 2.5 M
- Using the above reagents, prepration of the Murphy-Riley color developing solution; In a 500 mL volumetric flask, 250 mL of 2.5 M H_2SO_4 was added, followed by 75 mL of ammonium molybdate solution, 50 mL of ascorbic acid solution, and 25 mL of antimony potassium tartrate solution. Then 100 mL of distilled water was added and mixed on a magnetic stirrer.
- P- nitrophenol indicator
- Preparation of Standard Stock P solution: Exactly 0.439 g A.R. grade potassium dihydrogen orthophosphate (KH_2PO_4) was dissolved in 500 mL distilled water after drying in oven at 60^0 C for 1 hour and cooling in desiccator. 25 mL of 7 N H_2SO_4 was added to the solution and the volume was made 1 Liter with distilled water. This gave a 100 ppm stock solution of P (100 μg P L^{-1}) from this 5 mL solution was taken in a 100 mL volumetric flask and made up to the volume. This gave 5 ppm P solution (5 μg P L^{-1}).

Preparation of standard curve:

In order to prepare standard curve of P, 1, 2, 3, 4, and 5 mL of 5 ppm P solution were taken in 50 ml volumetric flasks. To these 5 mL of the extracting solution ($NaHCO_3$) was added. Then 10 ml of distilled water and one drop of p-nitrophenol indicator were added. Then 2.5 M H_2SO_4 was added drop wise until the solution became clear. At the point where indicator's yellow color disappeared, the correct pH (5.0) for the color development had been attained. If the end-point exceeded through addition of excessive acid, the pH could be brought back up again by adding NaOH.

To each flask 8 mL of the Murphy-Riley solution was added and the volume was made 50 mL with distilled water and mixed. Then these standards had P concentration 0.1, 0.2, 0.3, 0.4, and

0.5 µg P mL^{-1}. A blank was prepared with $NaHCO_3$ solution, distilled water and Murphy-Riley reagent. After waiting for 15 minutes, the intensity of the blue color was read on spectrophotometer at 730 nm. Absorbance values (readings) for the standards having 0, 0.1, 0.2, 0.3, 0.4 and 0.5 µg P mL^{-1} were used to construct a standard curve between absorbance values and the concentration of P in standards.

Method:

- 2.5 g sample of air dried soil (ground to less than 2 mm) was taken in a 125 mL Erlenmeyer flask.
- A little of phosphorus free Darco-G-60 or activated charcoal was added.
- To each flask 50 mL of $NaHCO_3$ solution at 25^0 C was added.
- Then shaken for 30 min on a reciprocating shaker at 120 strokes per minute.
- Similarly, a blank without soil was also run.
- The extract was filtered using Whatman No. 40 filter paper. If the filtrate was cloudy, it was re filtered as necessity.
- 10 mL aliquot of the extract was taken in a 50 mL volumetric flask, and 10 mL of distilled water and one drop of p-nitrophenol indicator were added. Then content was acidified to pH by adding 2.5 M H_2SO_4 drop by drop till the color disappeared.
- 8 mL of the Murphy-Riley solution was added and made the volume up to 50 mL with distilled water. After waiting for 15 minutes, the intensity of blue color was read on spectrophotometer at 730 nm (as in case of standard).

Calculation:

ppm Phosphorous = R × 20/2

Phosphorous (%) = ppm in the solution * 0.0001

Where,

R = Phosphorous of soil extract in ppm from the standard curve.

20 = Volume of extraction solution taken.

2 = Wt. of soil taken.

Available Phosphorous (%) = ppm in the solution * 0.0001

Available Potassium (%)

It was determined by Flame Photometer method (Gupta, 2000).

Equipment and Reagents

- Flame photometer
- Centrifuge or shaker
- Erlenmeyer flask
- Neutral normal ammonium acetate solution
- Standard KCl solution

Method:

2.0 g of air dried soil was taken in a 125 ml conical flask and 20 ml of 1N ammonium acetate at pH 7 was added. The solution was shaken in a mechanical shaker for 5 minutes and then filtered through Whatman No 42 filter paper. A standard curve was drawn from the flame photometer readings of 0, 5, 10, 15, 20 and 25 ppm K standard solutions and potassium content in the soil was calculated by comparing the Flame photometer reading of soil solution with the standard curve.

Calculations:

ppm Potassium = R × 20/2

Potassium (%) = ppm in the solution * 0.0001

Where,

R = Potassium of soil extract in ppm from the standard curve.

20 = Volume of extraction solution taken.

2 = Wt. of soil taken.

Organic carbon (%)

Soil Organic Carbon was determined by Walkley and Black rapid titration method (Walkley and Black, 1934).

Reagents:

- Standard 1N potassium dichromate
- 0.5N ferrous ammonium sulphate
- Diphenylamine indicator
- Concentrated sulphuric acid
- Sodium fluoride

Method:

1.0 g of soil was taken in a 500 mL conical flask and 10 mL of 1N $K_2Cr_2O_7$ was added and swirled gently. Then 20 mL of H_2SO_4 was added and swirled gently again. The flask was allowed to stand for 30 minutes and then 200 mL of distilled water was added. 0.5 g sodium fluoride and few drops of diphenylamine indicator were added. The contents were titrated with 0.5 N ferrous ammonium sulphate solutions till the color changed from blue-violet to green. Simultaneously, a blank was run without soil.

Calculations:

Carbon (%) = $(1 - \frac{S}{B})\ (\frac{3.951}{W})$

Where,

B = Volume of ferrous ammonium sulphate used up for blank titration (mL)

S = Volume of ferrous ammonium sulphate used up for sample titration (mL)

W = Weight of soil sample taken (gm).

3.2.6 Data analysis

Community Structures

After getting field data, density, frequency, abundance and the importance value index (IVI) of trees and herbs were calculated following Zobel *et al*. (1987). The density of seedlings and saplings of *Q. semecarpifolia* was also calculated. The calculated importance value index (IVI) of trees were presented in bar graph by keeping IVI on Y- axis and name of trees on X- axis. The formulae which were used for the calculation of these attributes are given below:

$$\text{Density of plants per hectare (D)} = \frac{\text{Total individuals in all plots}}{\text{Total plot} * \text{size of plot}} \text{x} 10{,}000$$

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

$$\text{Frequency (F)} = \frac{\text{Number of quadrat in which species occured}}{\text{Total no.of quadrat studied}} \text{ x } 100\%$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of individual species}}{\text{Total frequency of all species}} \text{ x } 100\%$$

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

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

Importance value index (IVI) = RD+ RF+RA

Species Diversity is the combination of species richness and species evenness. Species richness is the number of species per sampling unit and species evenness is the distribution of individuals among the species. Evenness is the maximum when all the species have same or nearly equal number of individuals. Species diversity can be expressed in single index number. Among the several indices most commonly used two indices are Simpson's index (Simpson, 1949) and Shannon-Wiener's index (Shannon and Weaver, 1949). Simpson's index (C) reflects the dominance because it is more sensitive to the most abundant species than the rare species. Following relations were used to calculate Simpson's and Shannon-Weiner indices following Barbour *et al*. (1999).

Simpson's index of dominance (C) = $\Sigma \left(\frac{\text{No.of individual species}}{\text{Total no.of all species}}\right)^2$

Simpson's index of diversity = 1-C

Shannon-Wiener diversity index (H) = $- \Sigma P_i(L_n P_i)$ Where, P_i = Proportion of individual species

$H_{max} = L_n$ (Total no. of Species)

Regeneration

As our main objective of this research was to assess the regeneration pattern of *Q. semecarpifolia*, so regeneration pattern was obtained by plotting the density-diameter curve (d-d curve) separately for each aspects of the forest. For developing the d-d curves, total individuals of all sampling plots of one aspect at one time were counted, and placed in DBH classes (5-10 cm, 10-20 cm, 20-30 cm, 30-40 cm, …...,). Density - diameter (d-d) curve was obtained by plotting diameter class (cm) on x-axis and density (Pl/ha) on y-axis. Seedling, sapling and tree percentage of *Q. semecarpifolia* were obtained along with bar gram.

3.2.7 Statistical analysis

The calculation of density, frequency, abundance, the importance value index (IVI), species diversity, bar grams were performed in Excel 2016. One-way ANOVA was used to compare means of different attributes of four different aspects by using IBM SPSS version 25. Similarly, mean values of different attributes of top of the study area and bottom of the study area were compared by student's t-test using IBM SPSS version 25. Spearman's correlation coefficients were determined among the different attributes by using R version. Linear regression model was obtained for those which had significant values as well as for those which were correlated by more than 40 %. That was done through IBM SPSS version 25.

CHAPTER 4 : RESULTS

4.1 Community structure

Altogether 24 tree species were found in the study area. Among them the most dominant tree species was *Quercus semecarpifolia* Sm. (IVI 119.33) followed by *Q. lamellosa* Sm. (IVI 25.63), *Rhododendron arboreum* Sm. (IVI 24.81), *Q. leucotrichophora* A. Camus. (IVI 19.83), whereas the least dominant species were *Prunus cerasoides* D. Don., *Schima wallichii* (DC.) Korth., *Litsea lancifolia* Roxb. Ex Wall., *Actinodaphne sikkimensis* Meisn., *Viburnum erubescen*s Wall. ex DC. and one unidentified species with same IVI value 2.87 (Table 4.1). In all the aspects *Q. semecarpifolia* Sm. was the most dominant tree species. Southern aspect contained the highest IVI (190.16) of *Q. semecarpifolia* Sm., whereas, northern aspect had lowest IVI (84.00). In northern aspect altogether 14 tree species were found, whereas, in southern, eastern and western aspect of forest total 8, 13, and 7 tree species were found respectively (Table 4.1).

In case of herbs, altogether, 98 species were recorded. Among them 41, 45, 49 and 37 species were recorded in northern aspect (Annex 1), southern aspect (Annex 2), eastern aspect (Annex 3), and western aspect (Annex 4) respectively. *Arundinaria hookeriana* Munro. was the most dominant species in northern and eastern aspect (Annex 1 and 3). Whereas, *Capillipedium assimile* (Steudel) A. Camus and *Eurya acuminata DC.* were the most dominant herb species in southern aspect (Annex 2) and western aspect (Annex 4) respectively.

Table 4.1: Importance value index (IVI) of tree species in the study area.

S.N	Name of tree	IVI	IVI in different aspects			
			Northern	Southern	Eastern	Western
1	*Quercus semecarpifolia* Sm.	119.33	84.00	190.16	124.37	152.18
2	*Quercus lamellosa* Sm.	25.63	31.80	0.00	51.54	0.00
3	*Rhododendron arboreum* Sm.	24.81	20.93	36.34	26.09	33.62
4	*Quercus leucotrichophora* A. Camus.	19.83	54.36	0.00	0.00	23.29
5	*Castanopsis tribuloides* (Sm.) A. DC.	11.22	22.66	0.00	17.06	0.00
6	*Quercus lanata* Sm.	11.17	0.00	12.78	0.00	44.19
7	*Ilex dipyrena* Wall.	9.78	0.00	22.59	0.00	0.00
8	*Litsea elongata* (Nees) Hook. f.	8.05	0.00	0.00	15.43	0.00
9	*Saurauia nepaulensis* DC.	6.96	7.01	9.52	12.53	0.00
10	*Myrica esculenta* Buch-Ham ex D. Don.	6.89	15.46	0.00	6.74	0.00
11	*Eurya ceracifolia* (D. Don.) Kobuski.	6.33	14.37	0.00	0.00	0.00
12	*Flemingia strobilifera var. bracteata* (Roxb.) Baker	5.17	10.69	0.00	6.74	0.00
13	*Quercus lineata* Blume.	5.17	0.00	9.52	9.64	0.00
14	*Myrsine semiserrata* Wall.	5.17	7.01	0.00	0.00	17.75
15	*Eurya acuminata* DC.	4.60	0.00	0.00	9.64	0.00
16	*Schefflera impressa* (C.B. Clarke) Harms.	4.21	7.01	0.00	6.74	0.00
17	*Wendlandia coriaceae* (Wall) DC.	4.21	10.69	0.00	0.00	0.00
18	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	4.21	0.00	9.52	0.00	12.21
19	*Prunus cerasoides* D. Don.	2.87	0.00	0.00	6.74	0.00
20	*Schima wallichii* (DC.) Korth.	2.87	0.00	0.00	6.74	0.00
21	*Litsea lancifolia* Roxb. Ex Wall. Sensu Hook. f.	2.87	7.01	0.00	0.00	0.00
22	Unknown	2.87	7.01	0.00	0.00	0.00
23	*Actinodaphne sikkimensis* Meisn.	2.87	0.00	9.52	0.00	0.00
24	*Viburnum erubescens* Wall. ex DC.	2.87	0.00	0.00	0.00	16.76

4.2 Species diversity

Simpson's index dominance (C), Simpson's index of diversity (1-C), Shannon Weiner diversity index (H) and evenness (H/ H_{max}) were determined (Table 4.2 and Table 4.3). The northern aspect had highest tree diversity (1-C=0.7579 & H=1.8097) whereas southern aspect had the lowest tree diversity (1-C=0.2387 & H=0.5719) (Table 4.2).

Table 4.2: Diversity indices of tree species in the study area.

Forest / Diversity indices	Whole study area	Northern aspect	Southern aspect	Eastern aspect	Western aspect
Simpson's index dominance (C)	0.4787	0.2421	0.7613	0.4435	0.5386
Simpson's index of diversity (1-C)	0.5212	0.7579	0.2387	0.5565	0.4614
Shannon Weiner diversity index (H)	1.3852	1.8097	0.5719	1.2804	1.003
H_{max}	3.1780	2.6391	2.0794	2.5649	1.9459
Evenness (H/ H_{max})	0.4358	0.6857	0.2750	0.4992	0.5154

In contrast, southern aspect had the highest herb diversity (1-C=0.9276 & H=3.1435) and northern aspect had the lowest herb diversity (1-C=0.8536 & H=2.6794) (Table 4.3).

Table 4.3: Diversity indices of herbs.

Forest aspect / Diversity indices	Northern	Southern	Eastern	Western
Simpson's index of dominance (C)	0.1464	0.0724	0.0959	0.0852
Simpson's index of diversity (1-C)	0.8536	0.9276	0.9040	0.9148
Shannon Weiner diversity index(H)	2.6794	3.1435	2.9739	2.8751
H_{max}	3.7377	3.8067	3.8918	3.6109
Evenness (H/ H_{max})	0.7169	0.8258	0.7641	0.7962

4.3 Population Structure and Regeneration

4.3.1 Percentage of seedlings, saplings and trees and Density diameter curves in study area

The overall population ratio of different growth form of the forest was 53.67 % seedlings, 31.05 % saplings and 15.28 % trees in case of all tree species, whereas the population ratio of different growth form of *Q. semecarpifolia* was 27.41 % seedlings, 47.60 % saplings and 24.99 % trees (Figure 4.1).

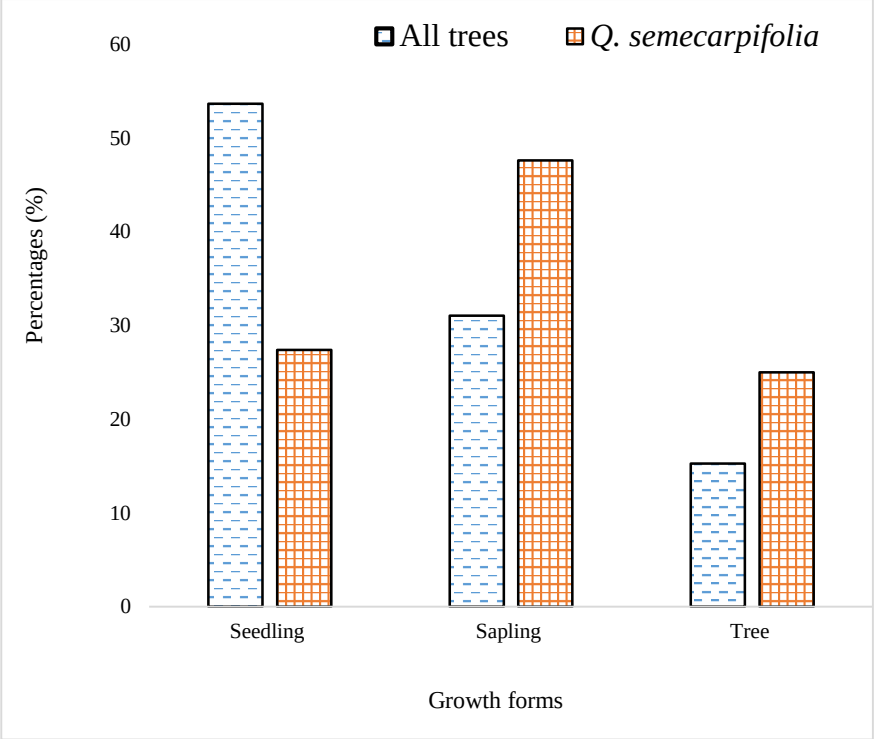

Figure 4.1: Percentage of seedlings, saplings and trees of study area.

The density diameter curves of all tree species as well as *Q. semecarpifolia* alone were inverse J- shaped (Figure 4.2).

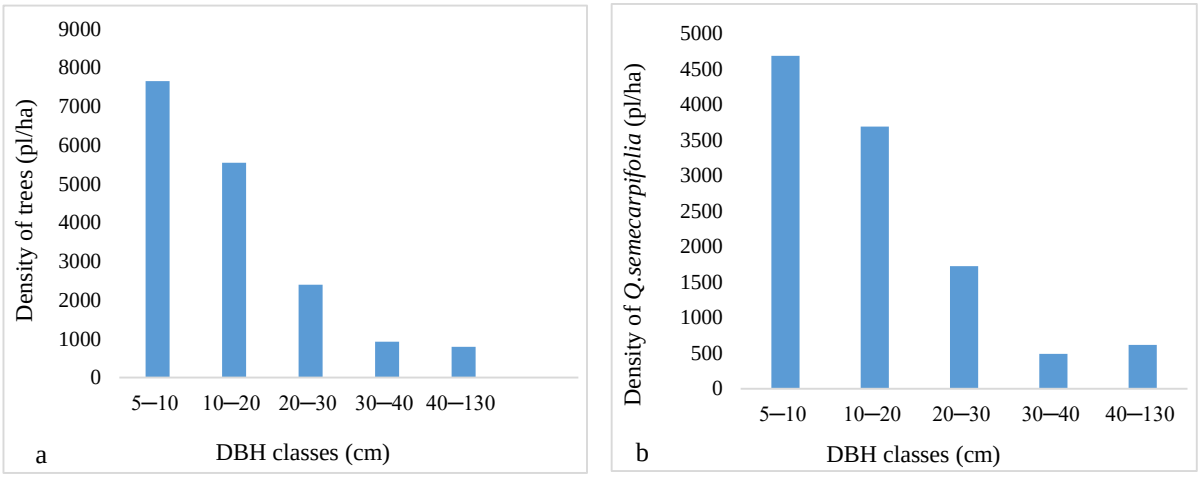

Figure 4.2: Density diameter curves in study area of a) all trees b) *Q. semecarpifolia*.

4.3.2 Percentage of seedlings, saplings and trees in four aspects of forest

In northern aspect of forest, the population of all tree species consists of 72.27% seedlings, 17.46% saplings and 10.27% mature trees (Figure 4.3a), whereas the population of *Q.*

semecarpifolia consists of 38.81% seedlings, 35.92% saplings and 25.27% trees (Figure 4.3b). In Southern aspect of forest, there were 37.28% seedlings, 46.75% saplings and 15.97% mature trees in case of all tree species (Figure 4.3a), whereas the population structure of *Q. semecarpifolia* alone includes 20.99% seedlings, 56.30% saplings and 22.71% mature trees (Figure 4.3b). In eastern aspect of forest, population structure of all tree species includes 55.49% seedlings 24.11% saplings and 20.40% trees (Figure 4.3a), whereas population structure of *Q. semecarpifolia* alone consists of 29.80% seedlings, 40.26% saplings and 29.93% mature trees (Figure 4.3b). In western aspect of forest, population of all tree species includes 33.60% seedlings, 47.85% saplings and 18.55% mature trees (Figure 4.3a), whereas population of *Q. semecarpifolia* alone consists of 29.98% seedlings, 47.48% saplings and 22.54% mature trees (Figure 4.3b).

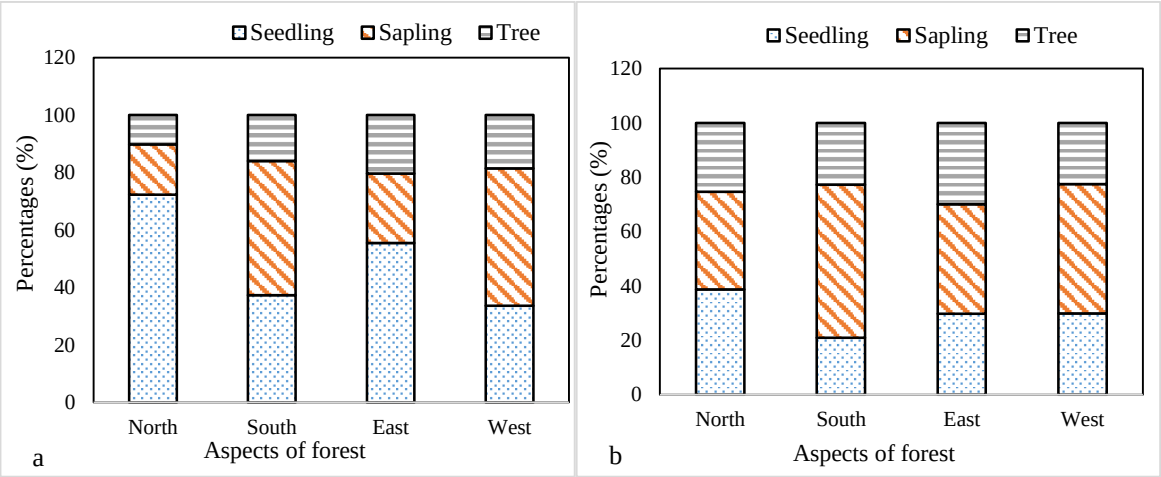

Figure 4.3: Percentage of seedlings, saplings and trees in four different aspects of forest a) all trees b) *Q. semecarpifolia*.

4.3.3 Density diameter curves in northern aspect of forest

Density diameter class curve of all tree species and *Q. semecarpofolia* alone were inverse J-shaped (Figure 4.4). There were greater numbers of individual in lower diameter classes. The diagram indicated the ongoing regeneration pattern of trees including *Q. semecarpifolia.*

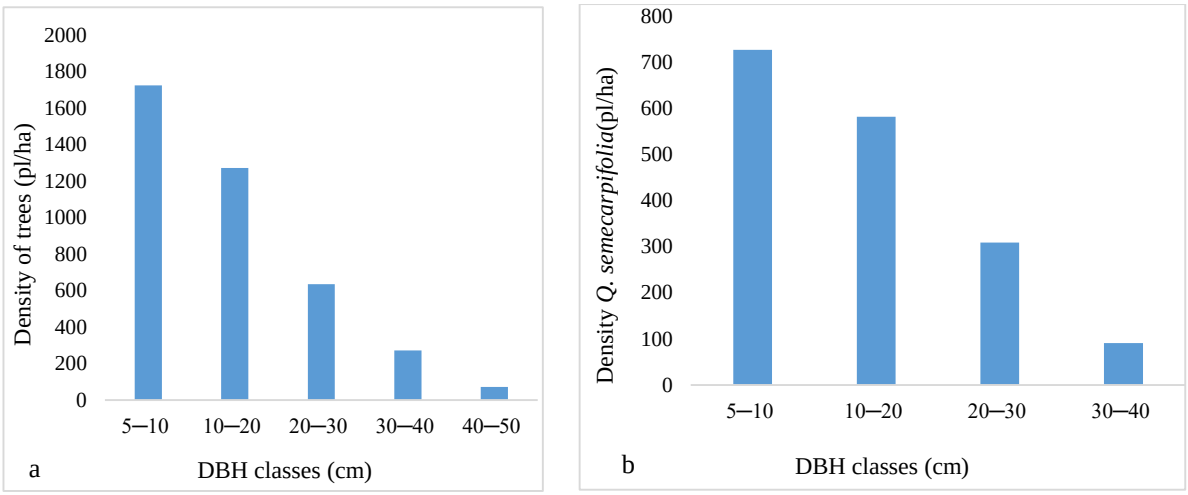

Figure 4.4: Density diameter curves in northern aspect of forest a) all trees b) *Q. semecarpifolia.*

4.3.4 Density diameter curves in southern aspect of forest

Density diameter curve of all tree species as well as *Q. semecarpifolia* showed that there were greater numbers of individuals in lower diameter classes and both the curves were inverse J-shaped (Figure 4.5). The individual of *Q. semecarpifolia* upto 120cm DBH were recorded on this aspect.

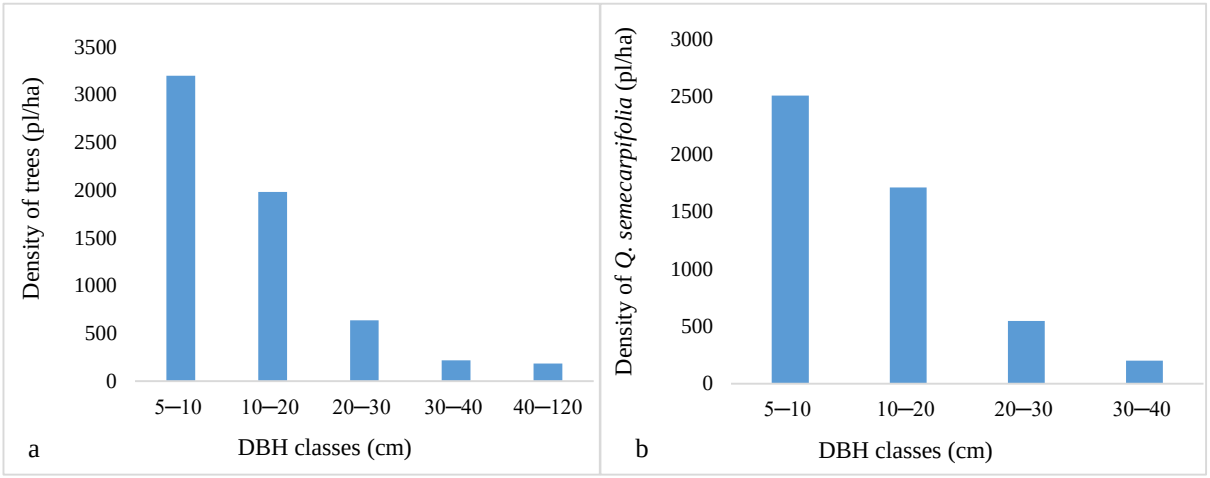

Figure 4.5: Density diameter curves in southern aspect of forest a) all trees b) *Q. semecarpifolia*.

4.3.5 Density diameter curves in eastern aspect of forest

Here, density diameter curves of all tree species as well as *Q. semecarpifolia* were inverse J-shaped (Figure 4.6). Both of the curves possessed greater numbers of individuals in lower classes.

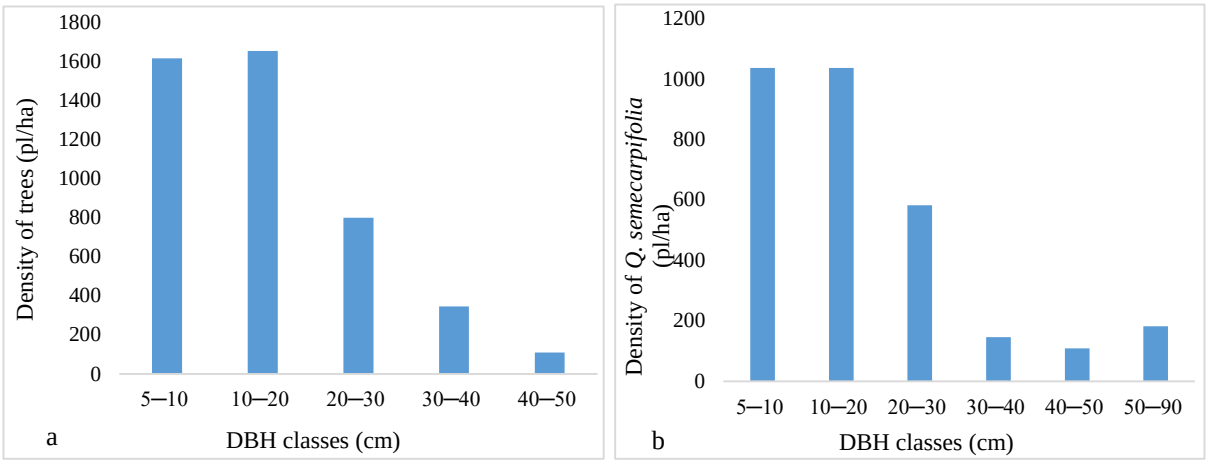

Figure 4.6: Tree density of different diameter classes in eastern aspect of forest a) all trees b) *Q. semecarpifolia.*

4.3.6 Density of different diameter curves in western aspect of forest

The density diameter curves for all tree species as well as *Q. semecarpifolia* alone were almost inverse J- shaped (Figure 4.7). As like in the other aspects of forest, greater number of individuals were in lower DBH classes. The largest size of *Q. semecarpifolia* was found to be DBH of 130 cm, which was the largest one among aspects of forest.

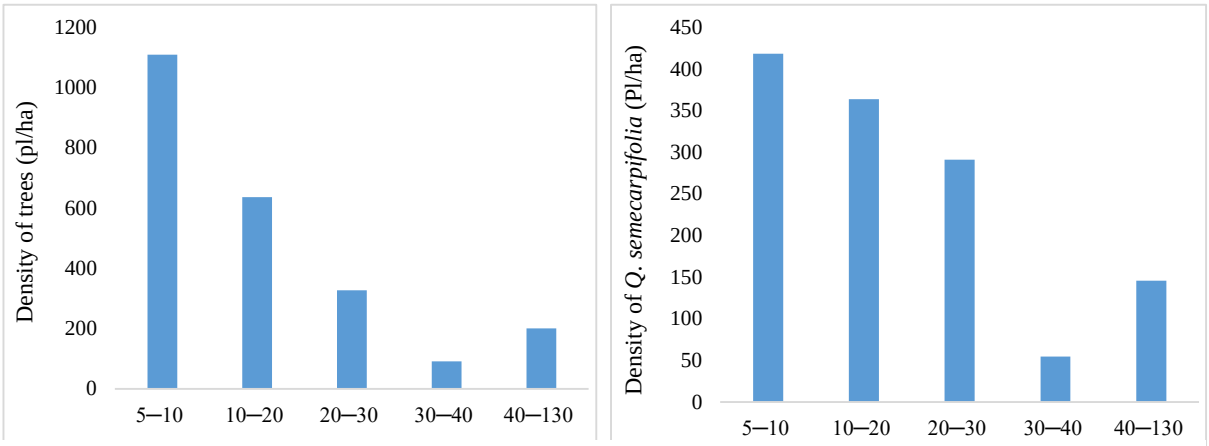

Figure 4.7: Tree density of different diameter classes in western aspect of forest a) all trees b) *Q. semecarpifolia.*

4.3.7 Percentage of seedlings, saplings and trees at uppermost and lowermost site

At the uppermost site of the study area, the percentages of seedlings, saplings and mature trees of all tree species were 24.27 %, 59.13 % and 16.60 % respectively. But at the lowermost site of study area there were 69.68 % seedlings, 13.87 % saplings and 16.45 % mature trees. Similarly, at the uppermost site of the study area, the population structure of *Q. semecarpifolia* consists of 23.98 % seedlings, 58.01 % saplings and 18.02 % mature trees, whereas at the lowermost site of the study area, the percentage of seedlings, saplings and mature trees were 13.97 %, 29.05 % and 56.98 % respectively (Figure 4.8).

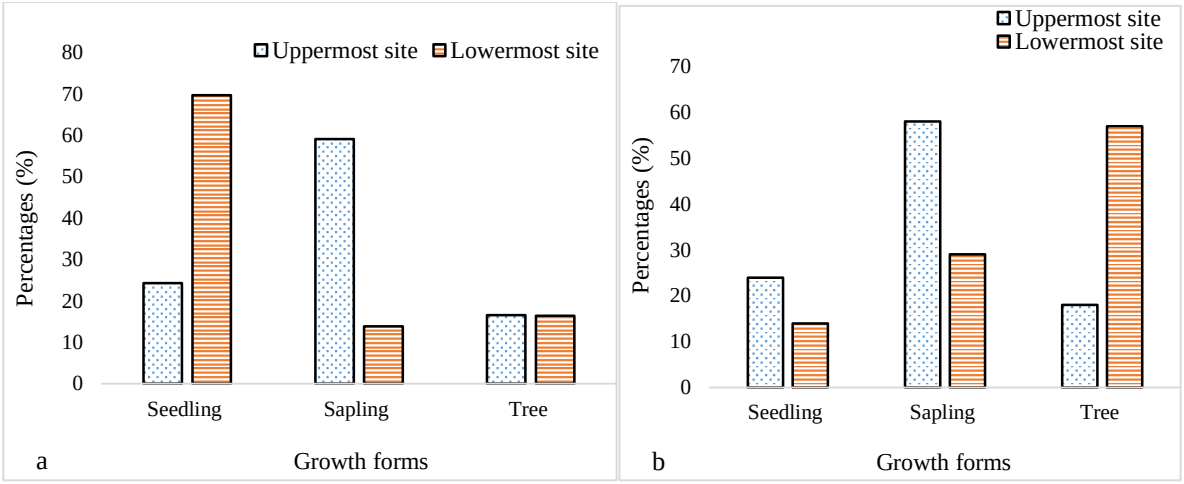

Figure 4.8: Percentage of seedlings, saplings and trees at lowermost and uppermost site a) all trees b) *Q. semecarpifolia*.

4.3.8 Density diameter curves in uppermost and lowermost sites

The density diameter curve of all tree species at uppermost site of the study area was inverse J- shaped but at the lowermost site of the study area the curve was deviated from J- shaped (Figure 4.9).

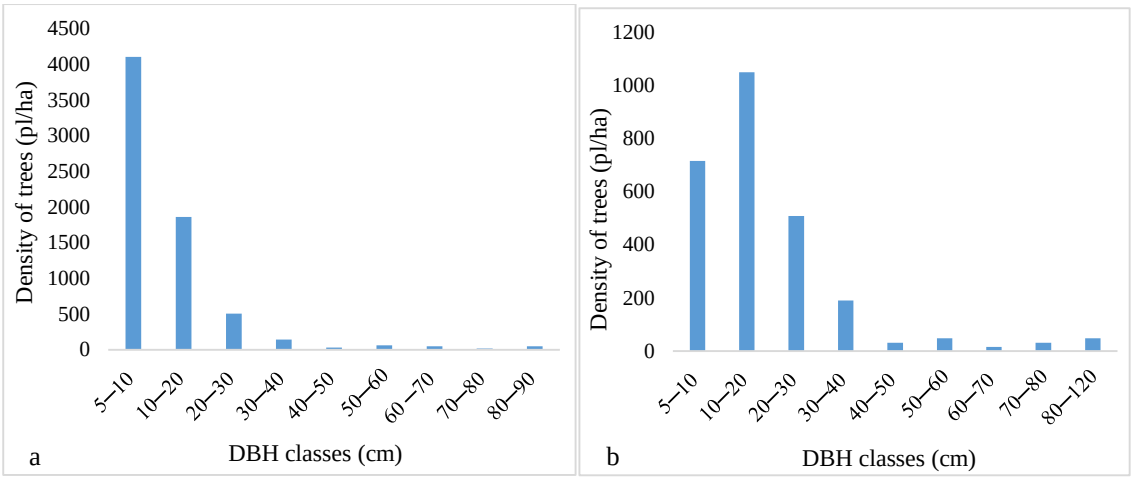

Figure 4.9: Density diameter curves of all trees a) at uppermost site b) at lowermost site.

In case of *Q. semecarpifolia*, the d-d curve of uppermost site of the study area was quite similar to inverse J- shaped but the curve of the lowermost site of the study area was deviated from the J- shape (Figure 4.10).

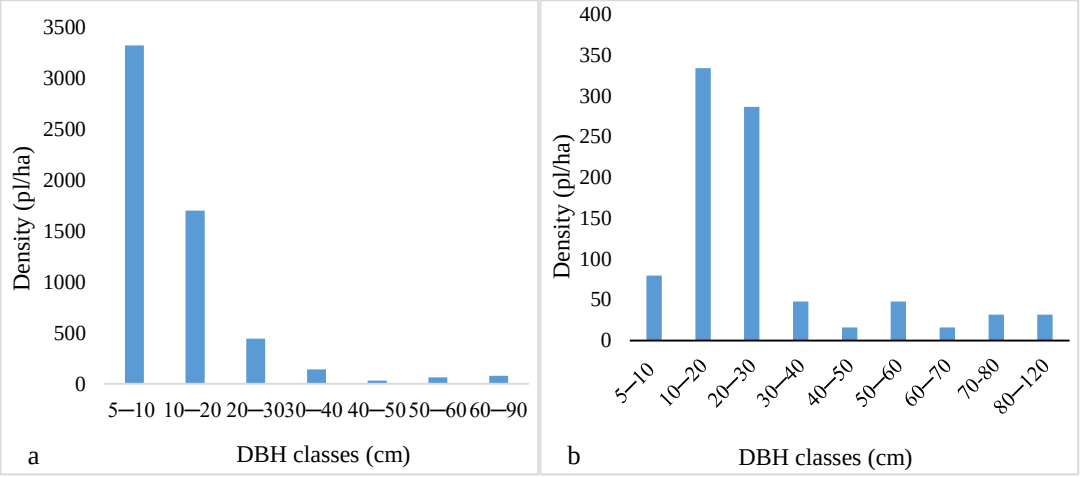

Figure 4.10: Density diameter curves of *Q. semecarpifolia* a) at uppermost site b) at lowermost site.

4.4 Microsite conditions

4.4.1 Mean values (±SD) comparison in four aspects of study area of recruits' density and other attributes by one-way ANOVA.

One-way ANOVA analysis showed no significant differences between group means of soil nitrogen ($p = 0.143$), soil phosphorus ($p = 0.809$), soil pH ($p = 0.639$), canopy cover ($p = 0.284$), herb cover ($p = 0.150$), litter thickness ($p = 0.291$), seedling density ($p = 0.936$) and sapling

density (p = 0.336) among the four different aspects of the forest as p values were greater than 0.05 at 5 % level of significance (Table 4.4). But there were significant differences between group means of soil potassium (p = 0.036) and soil organic carbon (p = 0.026) among the four different aspects of the forest as p values were less than 0.05 at 5 % level of significance (Table 4.4). A Tuckey HSD post hoc test revealed that those significant differences between the group means of soil organic carbon and soil potassium were occurred in between eastern and western aspects.

Table 4.4: Mean values (±SD) comparison of soil and other attributes in four aspects of forest by one way ANOVA.

Attributes	Mean value (±SD)				P value
	Northern	Southern	Eastern	Western	
Soil Nitrogen (%)	1.13±0.53	0.96±0.25	0.81±0.17	1.22±0.12	0.143
Soil Phosphorus (%)	0.00019±0.000028	0.0002±0.000068	0.0002±0.000025	0.00017±0.00004	0.809
Soil Potassium (%)	0.000022±0.000054	0.000032±0.00012	0.000021*±0.000012	0.000028**±0.000143	0.036*
Soil Organic carbon (%)	11.53±2.93	11.17±2.86	9.33*±2.12	14.19**±1.48	0.026*
Soil PH	4.43±0.68	4.76±0.68	4.51±0.31	4.75±0.52	0.639
Canopy cover(%)	50.71±12.05	52.14±17.76	39.29±4.5	50±15.81	0.284
Herb cover (%)	6.55±1.37	4.79±2.38	6.78±2.7	8.03±2.86	0.150
Litter thickness(cm)	4.9±1.21	4.96±2.95	7.06±2.86	5.06±1.87	0.291
Seedling density (per ha)	1590.94±2053.9	2386.41±2793.6	2045.49±3401.57	1927.48±2517.23	0.936
Sapling density (per ha)	363.64±736.15	1599.99±1973.39	695.46±1104.57	835.84±1311.3	0.336

*significant at p<0.05

4.4.2 Mean values (±SD) comparison in uppermost site and lowermost site of study area of recruits' density and other attributes by Student's t-test.

The mean values of different attributes at uppermost site and lowermost site of study area were compared by Student's t-test (Table 4.5). There were no significant differences between group means of soil nitrogen (p = 0.249), soil phosphorus (p = 0.346), soil organic carbon (p = 0.244), soil pH (p = 0.321), canopy cover (p = 0.123), herb cover (p = 0.167) and litter thickness (p = 0.883) (Table 4.5) as p values were greater than 0.05 at 5% level of significance. But there were significant differences between group means of soil potassium (p = 0.009), seedling density (p = 0.038) and sapling density (p = 0.008) as p values were less than 0.05 at 5% level of significance.

Table 4.5: Mean values (±SD) comparison in uppermost site and lowermost site of study area of soil and other attributes by Student's t-test.

Attributes	Mean value (±SD)		T value	P value
	Uppermost site	Lowermost site		
Soil Nitrogen (%)	0.89±0.32	1.01±0.24	-0.846	0.249
Soil Phosphorus (%)	0.0019±0.000013	0.0002±0.000034	-0.146	0.346
Soil Potassium (%)	0.000019±0.00008	0.000036±0.00002	-2.082	0.009*
Soil Organic carbon (%)	10.4±3.76	11.7±2.95	-1.046	0.244
Soil PH	4.58±0.51	4.88±0.62	-0.774	0.321
Canopy cover(%)	52.5±15.12	41.25±9.91	1.76	0.123
Herb cover (%)	7.72±2.28	6.28±2.28	0.412	0.167
Litter thickness(cm)	6.19±2.08	5.6±3.4	1.259	0.883
Seedling density (per ha)	3679.05±2687.07	198.87±368.23	3.629	0.038*
Sapling density (per ha)	1901.14±1908.85	147.16±134.92	2.592	0.008*

*significant at p<0.05

4.5 Effects and relations of microsite conditions on *Q. semecarpifolia* regeneration

The correlation matrices for recruit's density (seedling and sapling density) of *Q. semecarpifolia* and other attributes of microsite conditions showed several sets of significant and insignificant relationships (Table 4.6). The seedling density was positively correlated with canopy cover (r = 0.315), soil pH (r = 0.032) and litter thickness (r = 0.013), whereas it was

negatively correlated with soil nitrogen (r = -0.094), soil phosphorus (r = -0.243), soil potassium (r = -0.165), soil organic carbon (r = -0.207) and herb cover (r = -0.047). Similarly, sapling density was positively correlated with canopy cover (r = 0.378), soil phosphorus (r = 0.453), herb cover (r = 0.022) and litter thickness (r = 0.051), whereas it was negatively correlated with soil nitrogen (r = -0.265), soil potassium (r = -0.362), soil organic carbon (r = -0.260) and soil pH (r = -0.069). Among them, soil phosphorus had a significant correlation ($p<0.05$) with sapling density.

Table 4.6: Correlation coefficient between various attributes.

Attributes	Seedling density	Sapling density	Canopy cover	N	P	K	OC	pH	Herb cover
Seedling density									
Sapling density	0.052								
Canopy cover	0.315	0.378							
N	-0.094	-0.265	-0.112						
P	-0.243	0.453*	0.342	-0.363					
K	-0.165	-0.362	-0.133	0.204	-0.157				
OC	-0.207	-0.260	-0.292	0.825	-0.345	0.379			
pH	0.032	-0.069	-0.150	0.019	-0.003	0.557*	0.121		
Herb cover	-0.047	0.022	-0.225	0.058	0.072	-0.007	0.150	0.026	
Litter thickness	0.013	0.051	-0.020	-0.361	0.011	-0.431*	-0.473*	-0.176	-0.40

*significant at $p<0.05$

Note: N= soil nitrogen, P= soil phosphorus, K= soil potassium and OC= soil organic carbon.

Here, soil nitrogen was increased with soil organic carbon significantly (R^2= 0.681, p= 0.00) as shown in Figure 4.11.

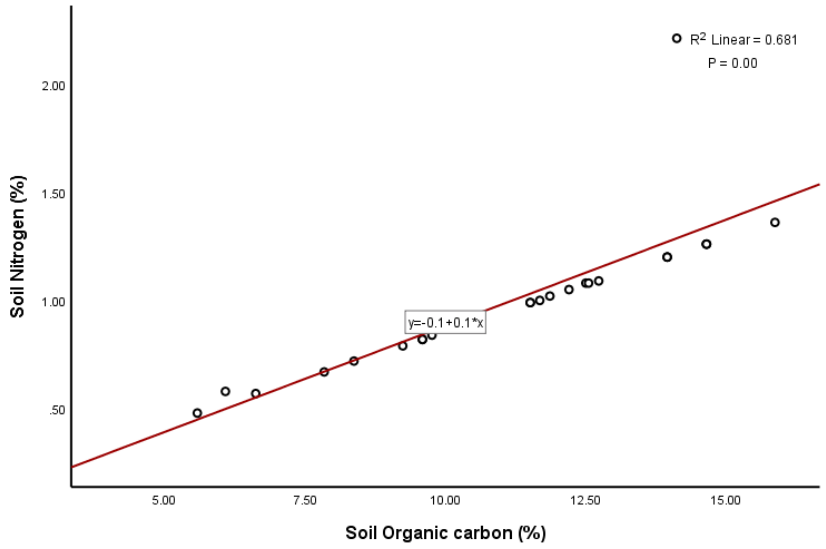

Figure 4.11: Relationship between soil organic carbon and soil nitrogen.

Here, sapling density was significantly increased with soil phosphorous (R^2= 0.205, p= 0.020) as shown in Figure 4.12.

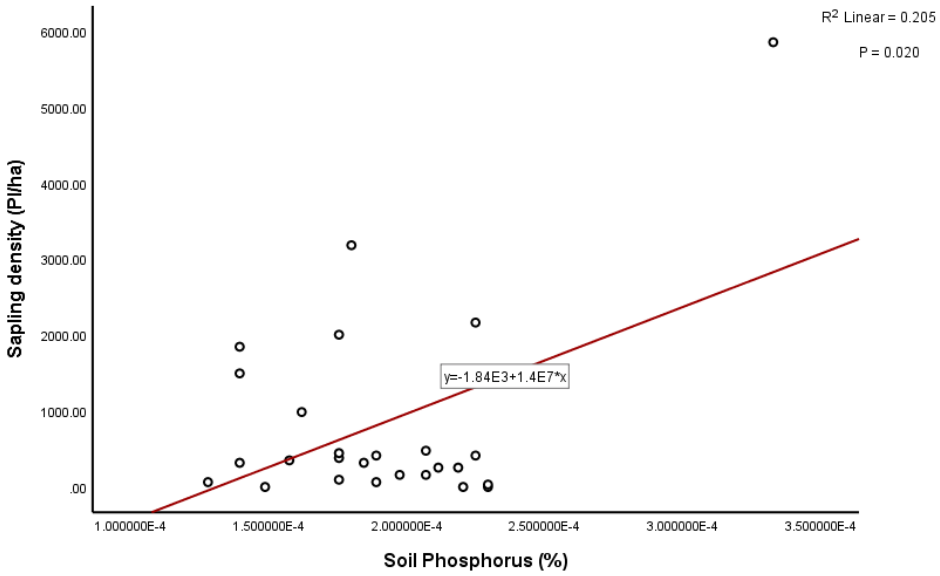

Figure 4.12: Relationship between soil phosphorus and sapling density of *Q. semecarpifolia*.

Here, soil pH was significantly increased with soil potassium percentage (R^2= 0.311, p= 0.003) as shown in Figure 4.13.

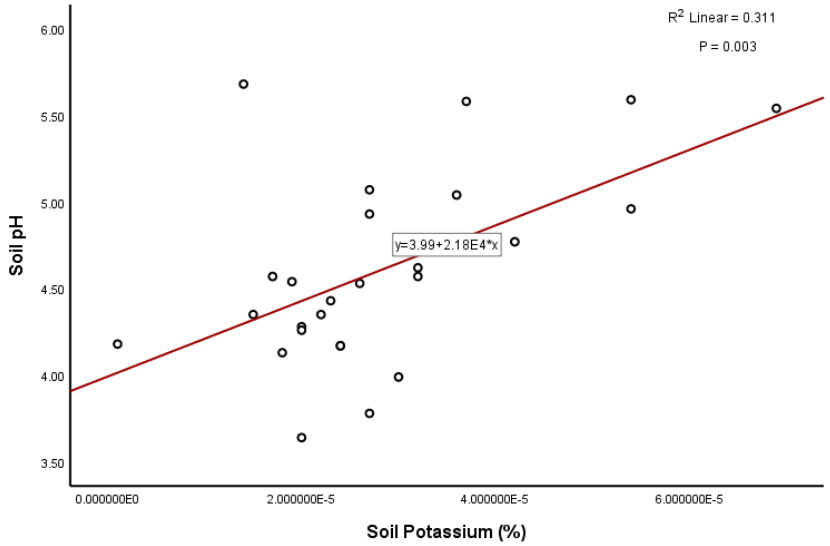

Figure 4.13: Relationship between soil potassium and soil pH.

Here, soil potassium was significantly decreased with litter thickness (R^2= 0.186, p= 0.028) as shown in Figure 4.14.

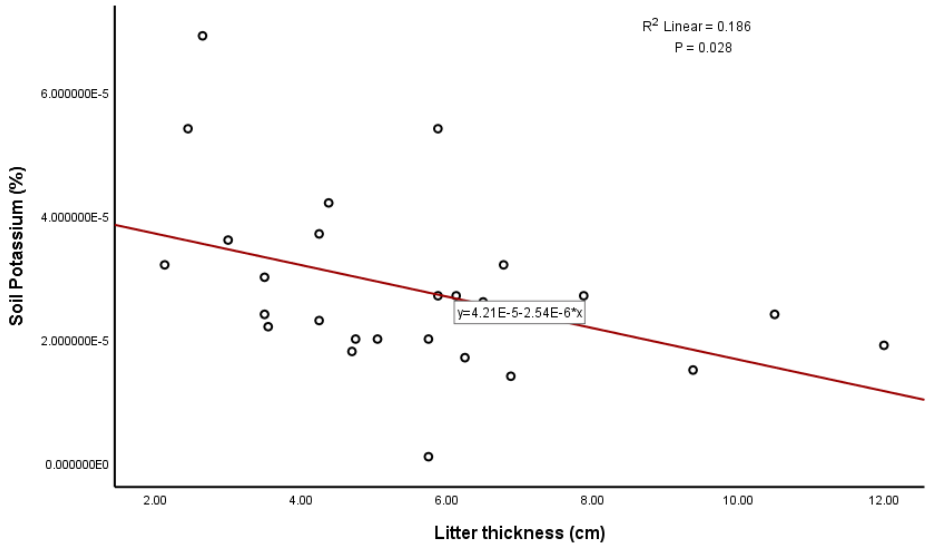

Figure 4.14: Relationship between litter thickness and soil potassium.

Here, soil organic carbon was significantly decreased with litter thickness (R^2= 0.224, p= 0.015) as shown in Figure 4.15.

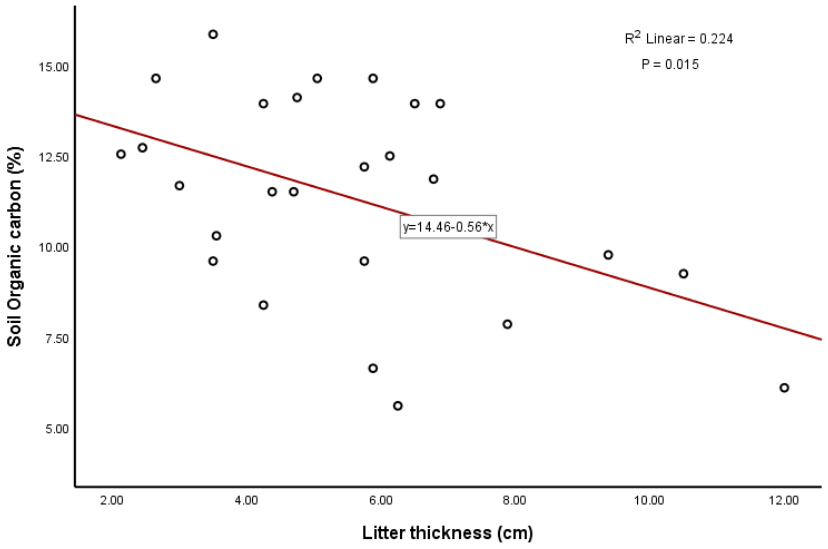

Figure 4.15: Relationship between litter thickness and soil organic carbon.

Here, herb cover was significantly decreased with litter thickness (R^2= 0.020, p= 0.495) as shown in Figure 4.16.

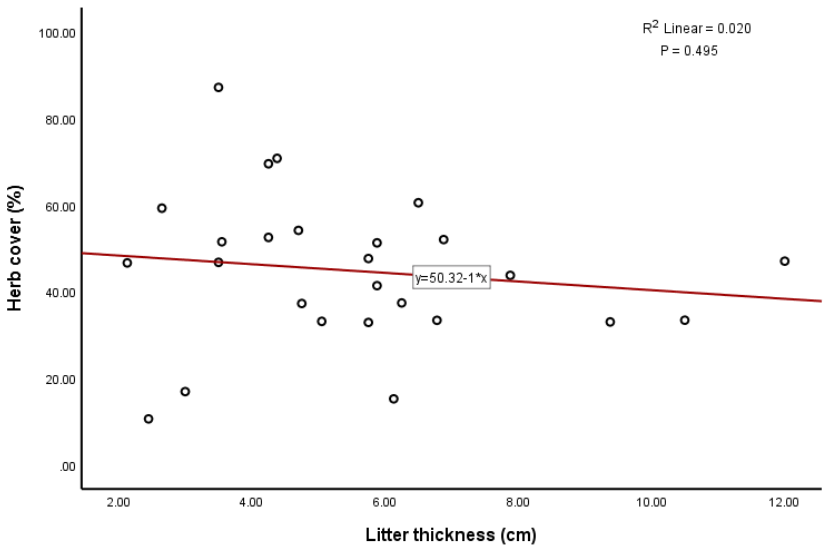

Figure 4.16: Relationship between litter thickness and herb cover.

CHAPTER 5 : DISCUSSION

5.1 Community Structure

Tree canopy was mainly formed by *Q. semecarpifolia* in all aspects of forest accompanied by some other subordinate species like *Q. lamellosa* Sm., *Rhododendron arboreum* Sm., *Q. leucotrichophora* A. Camus. as previously reported (Singh and Rawat, 2012). *Q. semecarpifolia* was the most dominant tree species with highest IVI in all aspects of forest. This is similar to the findings of Thakuri (2010), in where *Q. semecarpifolia* was the most dominant tree species in same altitudinal range and ecological habitats as present study. The dominance of *Q. semecarpifolia* might be due to the availability of suitable habitat for only this species and other species have existed only in very small patches. Southern aspect contained the highest IVI of *Q. semecarpifolia* Sm. compared to the other aspects. This might be due to less number of tree species in the southern aspect of forest, and relatively low representation of associated species in the community.

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 and Rawat, 2012). The diversity of trees is fundamental to total forest biodiversity (Huang *et al*., 2003). In the present study, among the four aspects of forest, Simpson's index for tree was higher in southern aspect of forest (0.76) and lower in northern aspect of forest (0.24). This might be due to the higher concentration of single dominant tree species i.e. *Quercus semecarpifolia* in southern aspect of forest. Also, in the study of Baduni and Sharma (1997), Simpson index was strongly affected by the importance value index of the first three relatively important species in a community. But, in case of herb species, Simpson's index was higher in northern aspect (0.15) and lower in southern aspect (0.07).

Simpson's index of diversity and Shannon Weiner index are inversely related to Simpson index (dominance) of species (Zobel *et al*., 1976). The higher values of Shannon-Wiener diversity index and Simpson's diversity index on northern aspect and higher values of Simpson index on southern aspect have been reported in this study. This result is similar with the result of Sharma *et al*. (2010), in his study he also found that the higher values of Shannon-Wiener diversity index and Simpson's diversity index on northern aspect and higher values of Simpson index on southern aspect. This might be due to prevalence of drier conditions on southern

aspects than the northern aspects and also due to the highest species richness and evenness in northern aspect and lowest species richness and evenness in southern aspect.

Result of present study indicates that herb diversity is just opposite to the tree diversity as Simpson's index of diversity and Shannon Weiner index for herbs were higher on southern aspect. Somehow, results of present study imply that higher the tree diversity lower would be the herb diversity and vice versa. This might be due to the fact that the diversity of tree layer can influences the diversity of 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 with 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 (Hicks, 1980; Ingerpuu *et al*., 2003; Mölder *et al*., 2008) and some found no effect (Ewald, 2002; Borchsenius *et al*., 2004; Houle, 2007).

5.3 Population structure and Regeneration

Successful regeneration of any species depends on the population of seedling, sapling and adult (Ghimire and Lekhak, 2007). The population structure of *Q. semecarpifolia* showed that there was greater occurrence of saplings (67.6%). This result is different from the results of Metz (1997), and Shrestha *et al*. (2004), because Metz (1997) only recorded large old trees and seedlings but no saplings at all while Shrestha *et al*. (2004) recorded greater occurrences of seedlings than the saplings. But result of present study shows greater occurrences of saplings than the seedlings which might be due to the process of transformation of previous seedlings into present saplings by time because some previous studies indicate that *Q. semecarpifolia* forest elsewhere in central Nepal has well representation of seedlings (Metz, 1997; Vetaas, 2000; Shrestha *et al*., 2004). Another reason might be the fact that this study site was free from grazing by domestic animals so that there were no restrictions for seedlings to become saplings and hence sapling density of *Q. semecarpifolia* became higher. Comparing the population structure of *Q. semecarpifolia* in four different aspect of the forest, results showed that greater portion belongs to seedling phase in northern aspect and it is similar to the result of Metz (1997), Bisht *et al*. (2013) and Shrestha *et al*. (2004). Population structure of *Q. semecarpifolia* in remaining three aspects of forest holds greater portion in sapling phase.

The population structure of *Q. semecarpifolia* showed that in the uppermost site (above 2400 m), greater portion belongs to sapling phase followed by seedling while in the lowermost site (Below 2300 m), greater portion belongs to the mature trees followed by sapling. This might be due to the very low density and poor regeneration of *Q. semecarpifolia* at lowermost site. But this finding doesn't agree with the findings of Shrestha *et al*. (2004), because he recorded saplings only below 2300 m of elevation in Shivapuri. According to him, at that elevation the number of associated species was high and *Q. semecarpifolia* tree was smaller (av. dbh 29cm) with few larger trees (dbh up to 99cm). So, *Q. semecarpifolia* forest at lower limit of distribution in Shivapuri was not mature and had few saplings.

Undisturbed old-growth forests with sustainable regeneration are found to have an inverse J-shaped size class distribution (West *et al*., 1981) and a bell-shaped size class distribution has been attributed to disturbed forests where regeneration is hampered (Saxena *et al*., 1984). Results show that regeneration curves of forest and *Q. semecarpifolia* in overall study area as well as in four different aspects were inverse J-shaped which indicate good regeneration pattern and a healthy stand (Wangda and Ohsawa, 2006). This result doesn't match with the result of Shrestha *et al*. (2004), because in his study the regeneration curve was bell-shaped indicating the lack of sustainable regeneration. The good regeneration in present study might be due to the presence of favorable environmental condition and no disturbed by cattle grazing and litter collection as litter collection can damage the seedling and sapling (Shrestha and Poudel, 1996). According to the regeneration curves, maximum portion belongs to the lower classes and there is lack of thick trees which might be due to past logging of bigger individuals and the consequent opening of the canopy so that facilitating sudden growth of smaller ones. Also, there was lack of individual in some higher diameter classes and this might either be due to the lack of regeneration in some years in past or due to logging of the trees.

The regeneration curves of forest as well as *Q. semecarpifolia* of uppermost site were inverse J shaped while the regeneration curves of them at lowermost site were quite deviated from the J shape. So, it seems that the uppermost site must have better regeneration than the lowermost site. It might be due to the fact that the altitudinal range of uppermost site falls under the mid-range of *Q. semecarpifolia* and the altitudinal range of lowermost site falls under the starting range of *Q. semecarpifolia* below which no *Q. semecarpifolia* tree can be easily found as *Q. semecarpifolia* is a dominant species in the Himalayas, at elevation of 2100m to 3800m asl (Shrestha, 2003).

5.4 Variation of microsite conditions and recruit's density

Soil was acidic in all aspects of forest. Statistically, there was no variation in soil pH on the different aspects of the forest. This result is similar to the research of Sharma *et al*. (2010) which was conducted in Garhwal Himalaya altitudinal range at 1500 m to 3100 m. In his research he also did not find any statistical variation in soil pH on different slope and soil was found to be acidic (pH ranges from 4.2 to 6.7). The acidic nature of soil in present study might be due to the high rainfall (Figure 3.2) which is sufficient to remove basic cations out of the surface horizons of the soils. However, soil pH was slightly greater in lowermost site than uppermost site. This might be due to removal of basic cations by rain from the uppermost site to the lowermost site.

Statistically, there were not significant variations on soil nitrogen and soil phosphorus on different aspects of forest. It might be due to occurrence of almost similar dominating species in all aspects of forest. Because similar dominating species might have tendency of similar absorption and return back of nutrients that bring about changes in soil properties (Singh *et al*., 1986). However, soil potassium and soil organic carbon were significantly different in between eastern and western aspect of the forest. But in results of Sharma *et al*. (2010), there was no significant variation of organic carbon and soil NPK in *Q. semecarpifolia* forest, on different slope aspects. Soil nitrogen, soil potassium and soil organic carbon were found to be higher in lowermost site than the uppermost site. This might be due to leaching of those soil nutrients from the upper site to the lower site.

Since the study area was not easily accessible for the purpose of litter collection there was accumulation of thick litter. High litter accumulation and soil organic matter decrease soil pH (Biswas and Mukherjee, 1994). This might be one of the reason behind acidic soil in the study area. Though, there was no statistical variation in litter thickness on different aspect of the forest, the litter thickness was quite more in eastern aspect of the forest (Table 4.4). This might be due to comparatively less slope inclination in eastern aspect of forest than other aspects of forest, so that, comparatively greater amount of litter could be accumulated there.

However, there was no significant variation of canopy cover in different aspects of the forest. But eastern aspect contained comparatively lower canopy cover (Table 4.4) and this could be one of the reason behind greatest litter thickness in this aspect as canopy cover and litter thickness had negative correlation (Table 4.6). Whereas, canopy cover was greater in uppermost site than the lowermost site, however, there was no variation of canopy cover

significantly. This might be due to higher tree density at uppermost site than the lowermost site. Herb cover also did not possess significant variation, however, it was lowest in southern aspect and highest in western aspect (Table 4.4). It might be due to lack of high coverage holding herb species in southern aspect unlike other aspects of the forest.

Both seedling density and sapling density of *Q. semecarpifolia* was higher in southern aspect of forest and lower in northern aspect of forest. It might be due to sufficient light radiation in southern aspect of forest which remains longer period during the day so that it remains warmer and drier. In contrast, the northern aspect is relatively cooler as it receives less sunlight because it lacks longer insolation (longer exposure) period during the day. Vetaas (2000), also found that most recruits were found under high potential radiation. According to some researches, *Q. semecarpifolia* was a typical tree that grows on south facing slopes (Dobremer, 1976; Singh & Singh, 1987). Seedling density and sapling density of *Q. semecarpifolia* were significantly different in between uppermost site and lowermost site. Uppermost site had higher seedling density and sapling density of *Q. semecarpifolia* than the lowermost site. This might be due to presence of higher density of *Q. semecarpifolia* trees at uppermost site than lowermost site, so that good regeneration could occur at uppermost site.

5.5 Relationship of recruits' density with microsite conditions

5.5.1 Soil Attributes

Soil pH was weakly correlated to both seedling density and sapling density. But seedling density had positive correlation and sapling density had negative correlation. Vetaas (2000) and Tashi (2004) reported that *Q. semecarpifolia* seedlings seems to prefer a soil pH of around 6. Soil was also acidic in the study of Thakuri (2010) which was conducted on *Q. semecarpifolia* forest in Shivapuri National Park and Simbhanjyang.

Seedling density was negatively correlated to soil nitrogen, soil phosphorus, and soil potassium. Sapling density was negatively correlated to soil nitrogen and soil potassium but positively correlated to soil phosphorus. Linear regression model (Figure 4.12) also shows the significant increments of sapling density with the increments of soil phosphorus. In research of Vetaas (2000), there were no significant relationships between saplings and the soil variables except for a weak response to total nitrogen. Soil nitrogen is supposed to be the most limiting nutrient in a majority of ecosystems (Fenn *et al*., 1998). But other himalayan studies have suggested that high levels of nitrogen facilitate regeneration (Saxena *et al*., 1984; Singh &

Singh 1987; Singh *et al*., 1990). In case of soil organic carbon, both seedling density and sapling density had negative correlation.

5.5.2 Canopy cover, herb cover and litter thickness

Results show both seedling density and sapling density had positive correlation with canopy cover. Vetaas (2000) also found that most recruits were under the high canopy cover and high potential radiation. According to him canopy disturbance has a negative effect on the number of seedlings. But Lei *et al*. (2002) concluded that the rate of successful recruitment of seedlings of particular species may be hindered by closed canopy created by its parent population. Herb cover had negative correlation to seedling density whereas, positive correlation to sapling density. Some researchers found that herb cover had an adverse effect on seedling emergence, survival and growth (Tripathi & Khan, 1990; Dzwonko & Gawronski, 2002). Thick litter generally reduces the rates of germination and of seedling establishment (Shrestha, 2003). But there was positive correlation with seedling and sapling density in the present study. This result is quite similar with the result of Tripathi & Khan (1990) and Dzwonko & Gawronski (2002), because in their results there was also positive correlation between the numbers of seedling density and litter cover. But this result does not agree with the results Tashi (2004) as he found that the litter depth did not seem to have any significant effect on the presence or the survival of the *Q. semecarpifolia* seedling. Similarly, in the study of Thakuri (2010), there was no relation between litter and seedling density. The positive correlation of seedling and sapling density with litter thickness might be due to the virtue of litter that protect recruits from external factors and moreover, litter have greater soil organic matter and lower soil bulk density that helps better survival of the recruits. As *Q. semecarpifolia* has comparatively larger seed it prefers greater litter depth because most studies have found that smaller seeded species generally have reduced germination as litter depth increases while germination of larger seeded species is usually unaffected or increased by leaf litter. In the result of Hughes *et al*. (2005), smallest seeded species were better suited where there was likely to be less litter, whereas the largest seeded oak species in their research were better suited to establish in forest with a thicker litter layer.

CHAPTER 6 : CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Q. semecarpifolia was the most dominant tree species in all four aspects of the forest accompanied by some other subordinate species like *Q. lamellosa* Sm., *Rhododendron arboreum* Sm., *Q. leucotrichophora* A. Camus etc. There were 24 tree species and 98 herb species in overall study area. Among the four aspects of the forest, northern aspect had more species richness and more species diversity than other three forest aspects in terms of trees. But in terms of herbs southern aspect had more species diversity.

According to regeneration curves and population structures, regeneration status of overall study area was good. However, there was lack of individual in some size classes. Though there was good regeneration in overall study area including all four aspects of the forest, the regeneration status of the lowermost site was not quite convincing as compare to the uppermost site.

There were no significant differences in microsite conditions and regeneration among the four aspects of forest except soil potassium and soil organic carbon. Similarly, there were no significant differences in microsite conditions between the uppermost site and lowermost site except soil potassium. Except soil phosphorus microsite conditions did not show any significant relations with regeneration of *Quercus semecarpifolia* (seedling density and sapling density). Hence, both the hypotheses were rejected in this study.

6.2 Recommendations

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

1. Management interventions should be applied for thinning high density of *Q. semecarpifolia* saplings at uppermost site of southern aspect.
2. Impose strict restriction for extreme lopping practices as canopy cover was found to be positively correlated to seedling and sapling density.

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ANNEXES

Annex 1: Density (D), Relative Density (RD), Frequency (F), Relative Frequency (RF), Abundance(A), Relative Abundance and Importance Value Index (IVI) of herb species in northern aspect.

S. N	Name of Species	D	RD	F	RF	A	RA	IVI
1	*Arundinaria hookeriana* Munro.	34349.41	34.99	82.14	11.73	13.13	9.39	56.11
2	*Aconitum ferox* Wall. ex Seringe.	8189.26	8.34	46.43	6.63	5.54	3.96	18.93
3	*Carex daltonii* Boott.	6369.43	6.49	53.57	7.65	3.73	2.67	16.81
4	*Smilax menispermoidea* A. DC.	3525.93	3.59	75.00	10.71	1.48	1.06	15.36
5	*Capillipedium assimile* (Steudel) A. Camus.	5118.29	5.21	21.43	3.06	7.50	5.36	13.64
6	*Pogonatherum incans*	5004.55	5.10	32.14	4.59	4.89	3.49	13.18
7	*Eragrostris nigra* Nees ex Steud.	3184.71	3.24	10.71	1.53	9.33	6.67	11.45
8	*Ageratina adenophora* (Spreng.) R.M. King & H. Rob.	3867.15	3.94	32.14	4.59	3.78	2.70	11.23
9	*Heracleum nepalense* D. Don.	2161.06	2.20	7.14	1.02	9.50	6.79	10.01
10	*Selaginella sp.*	1137.40	1.16	3.57	0.51	10.00	7.15	8.82
11	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	2388.54	2.43	32.14	4.59	2.33	1.67	8.69
12	*Lindenbergia grandiflora* (Buch-Ham.) Benth.	2274.80	2.32	10.71	1.53	6.67	4.77	8.61
13	*Polystichum aculeatum* (L.) Schott.	2047.32	2.09	32.14	4.59	2.00	1.43	8.11
14	*Gaultheria fragrantissima* Wall.	1933.58	1.97	10.71	1.53	5.67	4.05	7.55
15	*Thalictrum rotundifolium* DC.	1933.58	1.97	25.00	3.57	2.43	1.74	7.28
16	*Eurya acuminata DC.*	1478.62	1.51	32.14	4.59	1.44	1.03	7.13
17	*Rubus hoffmeisterianus* Kunth. Ex Bouch.	1819.84	1.85	21.43	3.06	2.67	1.91	6.82
18	*Polygonatum verticillatum* (L.) All.	1251.14	1.27	7.14	1.02	5.50	3.93	6.23
19	*Rubia manjith* Roxb. Ex Fleming.	1251.14	1.27	25.00	3.57	1.57	1.12	5.97
20	*Quercus semecarpifolia* Sm.	1364.88	1.39	21.43	3.06	2.00	1.43	5.88
21	*Thelypteris cana* (Baker) Ching.	1478.62	1.51	14.29	2.04	3.25	2.32	5.87
22	*Rhododendron arboreum* Sm.	1023.66	1.04	21.43	3.06	1.50	1.07	5.18
23	*Piptanthus nepalensis* (Hook.) D.Don.	796.18	0.81	7.14	1.02	3.50	2.50	4.33
24	*Geranium nepalense* Sweet.	682.44	0.70	7.14	1.02	3.00	2.14	3.86
25	*Rabdosia lophanthoides* (Buch-Ham. Ex D. Don.) Hara.	454.96	0.46	3.57	0.51	4.00	2.86	3.83

26	*Quercus lamellos* Sm.	568.70	0.58	7.14	1.02	2.50	1.79	3.39
27	*Miscanthus nepalensis* (Trin.) Hackel.	341.22	0.35	3.57	0.51	3.00	2.14	3.00
28	*Galium acutum* Edgew.	227.48	0.23	3.57	0.51	2.00	1.43	2.17
29	*Quercus leucotrichophora* A. Camus.	227.48	0.23	3.57	0.51	2.00	1.43	2.17
30	*Hemarthria compressa* (Linn.f) R. Br.	227.48	0.23	3.57	0.51	2.00	1.43	2.17
31	*Lepisorus mehrae* Fraser-Jenk.	227.48	0.23	3.57	0.51	2.00	1.43	2.17
32	*Berberis aristata* DC.	227.48	0.23	7.14	1.02	1.00	0.71	1.97
33	*Nephrolepis cordifolia* (L.) Presl.	113.74	0.12	3.57	0.51	1.00	0.71	1.34
34	*Niola sp.*	113.74	0.12	3.57	0.51	1.00	0.71	1.34
35	*Mucuna pruriens* (L.) DC.	113.74	0.12	3.57	0.51	1.00	0.71	1.34
36	*Sarcospora sp.*	113.74	0.12	3.57	0.51	1.00	0.71	1.34
37	*Hedera nepalensis* K. Koch.	113.74	0.12	3.57	0.51	1.00	0.71	1.34
38	*Tetrastigma serrulatum* (Roxb.) Planch.	113.74	0.12	3.57	0.51	1.00	0.71	1.34
39	*Diplopterygium giganteum* (Wall. ex Hook.) Nakai.	113.74	0.12	3.57	0.51	1.00	0.71	1.34
40	*Jasminum humile* L.	113.74	0.12	3.57	0.51	1.00	0.71	1.34
41	*Adiantum capillus-veneris* Linn.	113.74	0.12	3.57	0.51	1.00	0.71	1.34
	Total	98157.42	100.0	700.0	100.0	139.9	100.0	300.0

Annex 2: Density (D), Relative Density (RD), Frequency (F), Relative Frequency (RF), Abundance(A), Relative Abundance and Important Value Index (IVI) of herb species in southern aspect.

S.N	**Name of Species**	**D**	**RD**	**F**	**RF**	**A**	**RA**	**IVI**
1	*Capillipedium assimile* (Steudel) A. Camus.	14103.73	19.56	50.00	7.69	8.86	6.16	33.41
2	*Ageratina adenophora* (Spreng.) R.M. King & H. Rob.	9326.66	12.93	60.71	9.34	4.82	3.35	25.63
3	*Drymaria diandra* Blume.	3070.97	4.26	60.71	9.34	1.59	1.10	14.70
4	*Polygonatum verticillatum* (L.) All.	3639.67	5.05	14.29	2.20	8.00	5.56	12.81
5	*Bergenia ciliata* (Haw.) Sternb.	3753.41	5.21	21.43	3.30	5.50	3.82	12.33
6	*Rhododendron arboreum* Sm.	2388.54	3.31	7.14	1.10	10.50	7.30	11.71
7	*Eragrostris nigra* Nees ex Steud.	2616.01	3.63	21.43	3.30	3.83	2.67	9.59
8	Unknown	2616.01	3.63	17.86	2.75	4.60	3.20	9.57
9	*Viburnum erubescens* Wall. ex DC.	1819.84	2.52	7.14	1.10	8.00	5.56	9.18
10	*Viola serpens* Wall.	2161.06	3.00	28.57	4.40	2.38	1.65	9.04
11	*Gerbera maxima* (D. Don.) Beauverd.	2274.80	3.15	21.43	3.30	3.33	2.32	8.77

12	*Arundinaria hookeriana Munro.*	2161.06	3.00	21.43	3.30	3.17	2.20	8.50
13	*Polystichum aculeatum* (L.) Schott.	1933.58	2.68	25.00	3.85	2.43	1.69	8.22
14	*Mucuna pruriens* (L.) DC.	1933.58	2.68	21.43	3.30	2.83	1.97	7.95
15	*Quercus lanata* Sm.	1933.58	2.68	21.43	3.30	2.83	1.97	7.95
16	*Berberis aristata* DC.	1478.62	2.05	7.14	1.10	6.50	4.52	7.67
17	*Justicia procumbens* L.	909.92	1.26	3.57	0.55	8.00	5.56	7.37
18	*Quercus semecarpifolia* Sm.	1251.14	1.74	25.00	3.85	1.57	1.09	6.67
19	*Potentilla indica* (Andreuss.) Th. Wolf.	1364.88	1.89	21.43	3.30	2.00	1.39	6.58
20	*Fimbristylis aestivalis* (Retz.) Vahl.	1023.66	1.42	7.14	1.10	4.50	3.13	5.65
21	*Ainslaca latifolia* (D. Don) Sch.Bip.	1023.66	1.42	10.71	1.65	3.00	2.09	5.15
22	*Schefflera impressa* (C.B. Clarke) Harms.	568.70	0.79	3.57	0.55	5.00	3.48	4.81
23	*Jasminum humile* L.	796.18	1.10	10.71	1.65	2.33	1.62	4.37
24	*Rubus hoffmeisterianus* Kunth. Ex Bouch.	682.44	0.95	14.29	2.20	1.50	1.04	4.19
25	*Thelypteris cana* (Baker) Ching.	682.44	0.95	7.14	1.10	3.00	2.09	4.13
26	*Hedera nepalensis* K. Koch.	568.70	0.79	14.29	2.20	1.25	0.87	3.86
27	*Mazus japonicus* (Thunb.) O. Kuntze.	568.70	0.79	7.14	1.10	2.50	1.74	3.63
28	*Anemone rivularis* Buch-Ham. Ex DC.	568.70	0.79	10.71	1.65	1.67	1.16	3.60
29	*Stellaria monosperma* Buch-Ham. Ex D. Don.	454.96	0.63	10.71	1.65	1.33	0.93	3.21
30	*Symplocos sumuntia* Buch-Ham. Ex D. Don.	454.96	0.63	7.14	1.10	2.00	1.39	3.12
31	*Clematis connata* DC.	454.96	0.63	7.14	1.10	2.00	1.39	3.12
32	*Lindenbergia grandiflora* (Buch-Ham.) Benth.	454.96	0.63	7.14	1.10	2.00	1.39	3.12
33	Unknown	341.22	0.47	3.57	0.55	3.00	2.09	3.11
34	*Rubus paniculatus* J.E. Sm.	341.22	0.47	3.57	0.55	3.00	2.09	3.11
35	*Eurya acuminata DC.*	341.22	0.47	10.71	1.65	1.00	0.70	2.82
36	*Pogonantherum sp.*	341.22	0.47	10.71	1.65	1.00	0.70	2.82
37	*Anaphilis adnata* Wall. ex DC.	341.22	0.47	10.71	1.65	1.00	0.70	2.82
38	*Smilax menispermoidea* A. DC.	227.48	0.32	3.57	0.55	2.00	1.39	2.26
39	*Boehmeria ternifolia* D. Don.	227.48	0.32	3.57	0.55	2.00	1.39	2.26
40	*Diospyros malabarica* (Desr.) Kostel.	113.74	0.16	3.57	0.55	1.00	0.70	1.40
41	*Urtica dioca* L.	113.74	0.16	3.57	0.55	1.00	0.70	1.40
42	*Thalictrum rotundifolium* DC.	113.74	0.16	3.57	0.55	1.00	0.70	1.40
43	*Rubia manjith* Roxb. Ex Fleming.	113.74	0.16	3.57	0.55	1.00	0.70	1.40

44	*Theropogon pallidus* (Wall. ex Kunth) Maxim.	113.74	0.16	3.57	0.55	1.00	0.70	1.40
45	*Cyathea dealbata* (G. Forst.) Sw.	113.74	0.16	3.57	0.55	1.00	0.70	1.40
46	*Bidens pilosa* L.	113.74	0.16	3.57	0.55	1.00	0.70	1.40
47	*Vitex negundo* L.	113.74	0.16	3.57	0.55	1.00	0.70	1.40
	Total	72111.01	100	650	100	143.83	100	300

Annex 3: Density (D), Relative Density (RD), Frequency (F), Relative Frequency (RF), Abundance(A), Relative Abundance and Important Value Index (IVI) of herb species in eastern aspect.

S.N	**Name of Species**	**D**	**RD**	**F**	**RF**	**A**	**RA**	**IVI**
1	*Arundinaria hookeriana* Munro.	24340.31	22.31	75.00	9.95	10.19	5.34	37.61
2	*Geranium nepalense* Sweet.	18312.10	16.79	75.00	9.95	7.67	4.02	30.76
3	*Viola serpens* Wall.	9554.14	8.76	35.71	4.74	8.40	4.40	17.90
4	*Wikstroemia canescens* Meissner.	3980.89	3.65	7.14	0.95	17.50	9.18	13.77
5	*Smilax menispermoidea* A. DC.	3753.41	3.44	60.71	8.06	1.94	1.02	12.52
6	*Strobilanthus nutans* (Nees) T. Anders.	5004.55	4.59	14.29	1.90	11.00	5.77	12.25
7	*Rubia manjith* Roxb. Ex Fleming.	3753.41	3.44	53.57	7.11	2.20	1.15	11.70
8	*Lepisorus mehrae* Fraser-Jenk.	1364.88	1.25	3.57	0.47	12.00	6.29	8.02
9	*Jasminum humile* L.	1364.88	1.25	3.57	0.47	12.00	6.29	8.02
10	*Rubus hoffmeisterianus* Kunth. Ex Bouch.	2957.23	2.71	21.43	2.84	4.33	2.27	7.83
11	*Aconitum ferox* Wall. ex Seringe.	2843.49	2.61	25.00	3.32	3.57	1.87	7.80
12	*Curculigo orchioides* Gaertn.	2274.80	2.09	32.14	4.27	2.22	1.17	7.52
13	*Wendlandia coriacea* (Wall) DC.	2616.01	2.40	17.86	2.37	4.60	2.41	7.18
14	*Polystichum aculeatum* (L.) Schott.	2047.32	1.88	25.00	3.32	2.57	1.35	6.54
15	*Lindenbergia grandiflora* (Buch-Ham.) Benth.	2161.06	1.98	17.86	2.37	3.80	1.99	6.34
16	*Eurya acuminata* DC.	1706.10	1.56	28.57	3.79	1.88	0.98	6.34
17	*Anaphilis busua* (Buch-Ham ex D. Don.) DC.	1706.10	1.56	14.29	1.90	3.75	1.97	5.43
18	*Anaphilis adnata* Wall. ex DC.	1478.62	1.36	10.71	1.42	4.33	2.27	5.05
19	*Rubus paniculatus* J.E. Sm.	1478.62	1.36	10.71	1.42	4.33	2.27	5.05
20	*Rhododendron arboreum* Sm.	796.18	0.73	3.57	0.47	7.00	3.67	4.87
21	*Hemarthria compressa* (Linn.f) R. Br.	1364.88	1.25	10.71	1.42	4.00	2.10	4.77
22	*Berberis aristata* DC.	1023.66	0.94	21.43	2.84	1.50	0.79	4.57
23	*Capillipedium assimile* (Steudel) A. Camus.	1137.40	1.04	17.86	2.37	2.00	1.05	4.46

24	*Thelypteris cana* (Baker) Ching.	1023.66	0.94	7.14	0.95	4.50	2.36	4.25
25	*Carex daltonii* Boott.	1023.66	0.94	7.14	0.95	4.50	2.36	4.25
26	*Nephrolepis cordifolia* (L.) Presl.	1137.40	1.04	10.71	1.42	3.33	1.75	4.21
27	*Ageratina adenophora* (Spreng.) R.M. King & H. Rob.	1023.66	0.94	14.29	1.90	2.25	1.18	4.01
28	*Eragrostris nigra* Nees ex Steud.	909.92	0.83	7.14	0.95	4.00	2.10	3.88
29	*Quercus semecarpifolia* Sm.	682.44	0.63	14.29	1.90	1.50	0.79	3.31
30	*Pogonatherum incans*	682.44	0.63	10.71	1.42	2.00	1.05	3.10
31	*Gaultheria fragrantissima* Wall.	454.96	0.42	3.57	0.47	4.00	2.10	2.99
32	*Hedera nepalensis* K. Koch.	454.96	0.42	3.57	0.47	4.00	2.10	2.99
33	*Lyonia ovalifolia* (Wall.) Drude.	568.70	0.52	7.14	0.95	2.50	1.31	2.78
34	*Stellaria monosperma* Buch-Ham. Ex D. Don.	454.96	0.42	10.71	1.42	1.33	0.70	2.54
35	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	454.96	0.42	7.14	0.95	2.00	1.05	2.41
36	*Thalictrum rotundifolium* DC.	454.96	0.42	7.14	0.95	2.00	1.05	2.41
37	*Theropogon pallidus* (Wall. ex Kunth) Maxim.	341.22	0.31	3.57	0.47	3.00	1.57	2.36
38	*Schefflera impressa* (C.B. Clarke) Harms.	341.22	0.31	7.14	0.95	1.50	0.79	2.05
39	*Adiantum capillus-veneris* Linn.	341.22	0.31	7.14	0.95	1.50	0.79	2.05
40	*Anaphalis margaritacea* (L.) Benth.	227.48	0.21	3.57	0.47	2.00	1.05	1.73
41	*Cyathea dealbata* (G. Forst.) Sw.	227.48	0.21	3.57	0.47	2.00	1.05	1.73
42	*Tetrastigma serrulatum* (Roxb.) Planch.	227.48	0.21	3.57	0.47	2.00	1.05	1.73
43	*Fimbristylis aestivalis* (Retz.) Vahl.	227.48	0.21	3.57	0.47	2.00	1.05	1.73
44	*Flemingia strobilifera* (L.) W. T. Aiton.	227.48	0.21	7.14	0.95	1.00	0.52	1.68
45	*Indigofera bracteata* Baker.	113.74	0.10	3.57	0.47	1.00	0.52	1.10
46	*Castanopsis tribuloides* (Sm.) A. DC.	113.74	0.10	3.57	0.47	1.00	0.52	1.10
47	*Pteris cretica* L.	113.74	0.10	3.57	0.47	1.00	0.52	1.10
48	*Anemone rivularis* Buch-Ham. Ex DC.	113.74	0.10	3.57	0.47	1.00	0.52	1.10
49	Unknown	113.74	0.10	3.57	0.47	1.00	0.52	1.10
	Total	109076.43	100	753.57	100	190.71	100	300

Annex 4: Density (D), Relative Density (RD), Frequency (F), Relative Frequency (RF), Abundance(A), Relative Abundance and Importance Value Index (IVI) of herb species in western aspect.

S.N	**Name of Species**	**D**	**RD**	**F**	**RF**	**A**	**RA**	**IVI**
1	*Eurya acuminata DC.*	21178.34	16.00	20.00	2.74	33.25	18.60	37.35

2	*Capillipedium assimile* (Steudel) A. Camus.	21178.34	15.76	80.00	10.96	8.19	4.58	31.30
3	*Elatostema sessile* J.R.Forst.	21178.34	13.48	50.00	6.85	11.20	6.27	26.59
4	*Quercus semecarpifolia* Sm.	21178.34	7.22	50.00	6.85	6.00	3.36	17.43
5	*Thelypteris cana* (Baker) Ching.	21178.34	3.97	50.00	6.85	3.30	1.85	12.67
6	*Arundinaria hookeriana* Munro.	21178.34	4.69	25.00	3.42	7.80	4.36	12.48
7	*Polystichium discretum* (D. Don) J. Sm.	21178.34	3.73	50.00	6.85	3.10	1.73	12.31
8	*Daphne bholua* Buch-Ham. Ex D. Don.	21178.34	4.33	25.00	3.42	7.20	4.03	11.79
9	Unknown	21178.34	3.49	30.00	4.11	4.83	2.70	10.30
10	*Stellaria monosperma* Buch-Ham. Ex D. Don.	21178.34	2.89	25.00	3.42	4.80	2.69	9.00
11	*Smilax menispermoidea* A. DC.	21178.34	2.17	35.00	4.79	2.57	1.44	8.40
12	*Galium acutum* Edgew.	21178.34	1.20	5.00	0.68	10.00	5.60	7.48
13	*Rubus hoffmeisterianus* Kunth. Ex Bouch.	21178.34	2.05	15.00	2.05	5.67	3.17	7.27
14	*Fimbristylis aestivalis* (Retz.) Vahl.	21178.34	1.32	35.00	4.79	1.57	0.88	7.00
15	*Thalictrum rotundifolium* DC.	21178.34	1.93	15.00	2.05	5.33	2.98	6.96
16	*Viburnum erubescens* Wall. ex DC.	21178.34	1.93	20.00	2.74	4.00	2.24	6.90
17	*Rabdosia lophanthoides* (Buch-Ham. Ex D. Don.) Hara.	21178.34	1.56	15.00	2.05	4.33	2.42	6.04
18	*Lindera pulcherrima* (Nees) Benth. ex Hook. f.	21178.34	1.44	20.00	2.74	3.00	1.68	5.86
19	*Rubia manjith* Roxb. Ex Fleming.	21178.34	1.32	10.00	1.37	5.50	3.08	5.77
20	*Piptanthus nepalensis* (Hook.) D.Don.	21178.34	1.32	10.00	1.37	5.50	3.08	5.77
21	*Brachiaria villosa (*Lam.) A.Camus.	21178.34	0.84	5.00	0.68	7.00	3.92	5.44
22	*Geranium nepalense* Sweet.	21178.34	1.08	20.00	2.74	2.25	1.26	5.08
23	*Asplenium amoenum* Mett.	21178.34	0.72	5.00	0.68	6.00	3.36	4.76
24	*Mucuna pruriens* (L.) DC.	21178.34	0.96	10.00	1.37	4.00	2.24	4.57
25	Unknown	21178.34	0.96	15.00	2.05	2.67	1.49	4.51
26	*Eragrostris nigra* Nees ex Steud.	21178.34	0.72	20.00	2.74	1.50	0.84	4.30
27	*Arisaema speciosum* (Wall.) Marlo. Ex Schott.	21178.34	0.60	15.00	2.05	1.67	0.93	3.59
28	*Strobilanthus nutans* (Nees) T. Anders.	21178.34	0.60	10.00	1.37	2.50	1.40	3.37
29	*Viola serpens* Wall.	21178.34	0.36	5.00	0.68	3.00	1.68	2.72
30	*Quercus lamellosa* Sm.	21178.34	0.36	5.00	0.68	3.00	1.68	2.72
31	*Pogonantherum sp.*	21178.34	0.24	5.00	0.68	2.00	1.12	2.04
32	*Theropogon pallidus* (Wall. ex Kunth) Maxim.	21178.34	0.12	5.00	0.68	1.00	0.56	1.36

33	*Hedera nepalensis* K. Koch.	21178.34	0.12	5.00	0.68	1.00	0.56	1.36
34	*Polystichium obliquum* (D.Don) T.Moore.	21178.34	0.12	5.00	0.68	1.00	0.56	1.36
35	*Lepisorus scolopendrium* (Buch.-Ham. ex D. Don) Mehra & Bir.	21178.34	0.12	5.00	0.68	1.00	0.56	1.36
36	*Heracleum nepalense* D. Don.	21178.34	0.12	5.00	0.68	1.00	0.56	1.36
37	*Berberis aristata* DC.	21178.34	0.12	5.00	0.68	1.00	0.56	1.36
	Total	132325	100	730	100	178.73	100	300

Annex 5: Altitude (m), Density of seedling (/ha), Density of sapling (/ha), Herb cover (%), Canopy cover (%) and Litter thickness (cm) of different plots of four different aspects of forest.

Aspect	**Plot No.**	**Altitude (m)**	**Density of seedling(/ha)**	**Density of sapling (/ha)**	**Herb cover (%)**	**Canopy cover (%)**	**Litter thickness(cm)**
Northern	1	2481	3181.88	2004.55	52.00	40	6.875
	2	2452	4772.81	381.82	41.38	65	5.875
	3	2302	3181.88	0.00	37.25	60	4.75
	4	2193	0.00	63.64	33.13	35	5.05
	5	2142	0.00	0.00	46.75	55	3.5
	6	2132	0.00	0.00	54.13	60	4.7
	7	2108	0.00	95.45	51.50	40	3.55
Southern	1	2539	1590.94	5854.55	37.38	80	6.25
	2	2498	3181.88	986.36	33.40	55	10.5
	3	2460	3181.88	1845.45	15.25	50	6.125
	4	2445	7954.69	445.45	16.93	70	3
	5	2428	0.00	1495.45	46.63	40	2.125
	6	2380	0.00	159.09	10.63	40	2.45
	7	2281	795.47	413.64	52.50	30	4.25
Eastern	1	2514	2386.41	3181.82	47.63	40	5.75
	2	2449	9545.63	318.18	69.50	40	4.25
	3	2402	795.47	350.00	43.75	45	7.88
	4	2268	795.47	477.27	70.75	30	4.38
	5	2187	0.00	254.55	32.88	40	5.75
	6	2108	795.47	254.55	47.03	40	12.00
	7	2121	0.00	31.82	33.00	40	9.38
Western	1	2510	795.47	2163.64	87.13	60	3.50
	2	2491	3977.35	318.18	60.50	40	6.50

	3	2454	3181.88	413.64	33.38	70	6.78
	4	2405	0.00	63.64	51.25	30	5.88
	5	2355	0.00	159.09	59.25	50	2.65

Annex 6: Values of Soil Nitrogen %, Soil Phosphorus % , Soil Potassium %, Soil Organic Carbon, Soil pH and GPS points of different plots of four different aspects of forest.

Aspect	Plot No.	Nitrogen(%)	Phosphorus(%)	Potassium(%)	Organic Carbon(%)	pH
Northern	1	1.20	0.000175	0.000014	13.95	5.68
	2	0.57	0.000175	0.000027	6.62	4.93
	3	2.21	0.000149	0.00002	14.12	4.28
	4	1.26	0.000189	0.00002	14.65	3.64
	5	0.82	0.00022	0.00003	9.59	3.99
	6	0.99	0.000229	0.000018	11.51	4.13
	7	0.88	0.000175	0.000022	10.29	4.35
Southern	1	0.48	0.000333	0.000017	5.58	4.57
	2	0.79	0.000162	0.000024	9.24	4.17
	3	1.08	0.000139	0.000027	12.5	3.78
	4	1	0.000175	0.000036	11.68	5.04
	5	1.08	0.000139	0.000032	12.55	4.62
	6	1.09	0.000207	0.000054	12.73	5.59
	7	1.2	0.000225	0.000037	13.95	5.58
Eastern	1	0.82	0.00018	0.000001	9.59	4.18
	2	0.72	0.000184	0.000023	8.37	4.43
	3	0.67	0.000157	0.000027	7.84	5.07
	4	0.99	0.000207	0.000042	11.51	4.77
	5	1.05	0.000219	0.00002	12.2	4.26
	6	0.58	0.000211	0.000019	6.08	4.54
	7	0.84	0.000229	0.000015	9.76	4.35
Western	1	1.36	0.000225	0.000024	15.87	4.17
	2	1.2	0.000139	0.000026	13.95	4.53
	3	1.02	0.000189	0.000032	11.86	4.57
	4	1.26	0.000128	0.000054	14.65	4.96
	5	1.26	0.000197	0.000069	14.65	5.54

Annex 7: Data sheet for tree and saplings.

Aspect: ……. Date: ……

Longitude: …… Plot no.: ……

Latitude: ……. Canopy cover (%): ……

Altitude: ……. Sub plot: ……

for tree

S.N	Name of Species	Number	DBH	Height	Remarks

for saplings

S.N	Name of Species	Number	Remarks

Annex 8: Data sheet for Herbs and seedlings.

Aspect: ……. Date: ……

Longitude: …… Plot no.: ……

Latitude: ……. Sub plot: ……

Altitude: ……. Litter thickness (cm): ……

S.N	Name of Plant species	Number	Coverage	Remarks

PHOTO PLATES

PHOTO PLATE I

Photo 1: Seedling of unhealthy *Quercus semecarpifolia*.

Photo 2: Seedling of healthy *Quercus semecarpifolia*.

Photo 3: Litter on the forest floor.

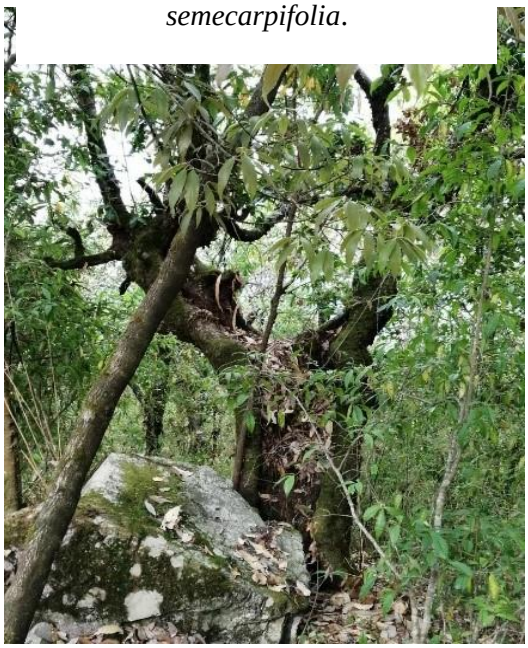

Photo 4: Old dying tree of *Quercus semecarpifolia*.

PHOTO PLATE II

Photo 5: An overview of eastern aspect of forest.

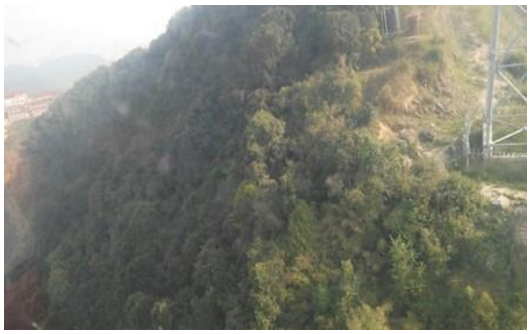

Photo 6: An overview of northern aspect of forest.

Photo 7: An overview of western aspect of forest.

Photo 8: An overview of southern aspect of forest.

PHOTO PLATE III

Photo 9: Cut down tree of *Quercus semecarpifolia.*

Photo 10: Mother tree of *Quercus semecarpifolia*.

Photo 11: Bushes of *Arundinaria hookeriana.*

Photo 12: Measuring DBH of tree.

PHOTO PLATE IV

Photo 13: Sampling of herbs.

Photo 14: Mounting the herbarium specimens on the herbarium sheet.

Photo 15: Arranging the herbarium specimens.

Photo 161: Identifying of the herbarium specimens by experts in KATH.