Forest Structure and Regeneration of *Quercus semecarpifolia* in Api-Nampa Conservation area, Nepal

A thesis submitted for the Partial Fulfillment of the Requirements for the

Master's Degree in Botany

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DECLARATION

I, *"Dayakrishna Joshi"*, 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 certify that the Master's thesis entitled "**Forest Structure and Regeneration of *Quercus semecarpifolia* in Api-Nampa Conservation area, Nepal"** carried out by "**Mr. Dayakrishna Joshi"** 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 partial fulfillment of M.Sc. Degree in Botany.

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This thesis work submitted by "Dayakrishna Joshi" entitled "**Forest Structure and Regeneration of *Quercus semecarpifolia* in Api-Nampa Conservation area, Nepal"** submitted to Department of Botany, Amrit Campus, Tribhuvan University by "Dayakrishna Joshi, T.U. Registration No.: 5-2-690-143-2012" has been accepted for the partial fulfillment of the requirement for Master's Degree in Botany.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
ANCA	Api-Nampa conservation area
DNPWC	Department of National Park and Wildlife Conservation
KSL	Kailash Sacred Landscape
a.s.l.	Above sea level
^{o} C	Degree Celsius
DBH	Diameter at breast height
E, W, N, S	East, west, north, south
NE	North-East
GPS	Global positioning system
m	Meter
cm	Centimetre
ha	Hectare
SPSS	Statistical Package on Social Science
sq. km	Kilometer square
%	Percentage
<	Less than
>	Greater than
Spp.	Species
IP	Important value index percent
IVI	Important value index
RF	Relative Frequency
RD	Relative Density
BA	Basal Area
SD	Standard Deviation
LOI	Loss on ignition
NA	Not available
L	Low
M	Middle
H	High

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ABSTRACT

Himalayan forest is dominated by different species of Oaks (Quercus spp.) at different altitudes. This work was carried out to study the forest structure and regeneration of *Q. semecarpifolia* along altitudinal gradient in Api-Nmpa Conservation Area. The vegetation data was collected from a total of 48 number of 20×20 m square quadrat for tree species in which plots were established at lower limit *of Q. semecarpifolia* i.e. 2489 masl to uppermost limit i.e 3636 masl. The Shrubs and tree saplings including lianas were recorded from the nested plot sized by 25 m^2 and herbs and tree seedlings from the quadrat size of 4 m^2. Importance Value Index (IVI) of tree, shrub and herb species, distribution pattern of seedlings and saplings, and soil attributes were analyzed. Regeneration was assessed by density - diameter curve. Fourty-eight soil samples were taken for laboratory analysis. A total of 188 species of woody and non-woody species belonging to 67 families were recorded. Tree species richness in the forest decreased with increasing elevation. The most frequent and dense tree species in the forest was *Q. semecarpifolia* with important value index percent of about 19% (IVI=56) and it was present in 80% of the sampling plots. IP of *Q. semecarpifolia* in the lower elevation range was 8% and in middle and upper range 17% and 41% respectively. Seedling and sapling were present in 30.2% and 75% of sample plot in the forest. The tree density of *Q. semecarpifolia* in the forest area was 235stem/ha with basal area 42.22 m^2/hectare. Seedling and sapling density of *Quercus semecarpifolia* in the forest was 4010 stem/ha and 1058 stem/ha. All the tree, sapling and seedling density and basal area of *Q. semecarpifolia* were higher in the higher elevations. The average maximum DBH of *Q. semecarpifolia* was 46.72 cm and average maximum height was 18.61 m. *Q. semecarpifolia* above 2800 m elevation showed sustainable regeneration as evident from reverse J shaped curve. However it below 2800 m elevation showed weak regeneration as evident from bell shaped curve. Altitude was the main factor for unequal distribution of species along the altitude. Soil nutrient such as nitrogen and potassium showed positive but insignificant relationship with seedlings and saplings.

Keywords: *Forest structure, Regeneration, Khasru, Brown Oak, Diversity index, Importance value index*

CHAPTER 1: INTRODUCTION

1.1. Background

Forests are dynamic ecosystems that change through time and space, and can be described by their composition, function and structure (Franklin *et al*., 1981). Community composition is the assemblage of organisms (living and non-living) that exist within the forest. It is frequently described by the presence and/or dominance of species and occasionally by relative descriptors (e.g. diversity index). Forest structure is the physical arrangement and characteristics of the forest, which is highly visible and described component (Stone & Porter, 1998). Forest stand structure is commonly based on the aggregation of individual plant measures (e.g. density, tree diameter at breast height) (Oliver and Larson, 1990).

Community structure of forest is directly regulated by species diversity, and it is the biological basis to maintain ecosystem functions (Tilman and Downing, 1994). Species richness is a simple and easily interpretable indicator of biological diversity (Peet, 1974). In the mountain ecosystem, community pattern varied according to altitude. The distribution in mountain vegetation is strongly influenced by the climatic parameters such as temperature, precipitation and winds that characteristically for mountain regions change rapidly over very short distances. Other factors such as topography, soils, postglacial succession, and, in many areas, human disturbances also affect the vegetation pattern (Krauchi *et al*., 2000).

Natural regeneration implies the process of re-growing or reproducing new individual plants in the community. It is the most important process to maintain the stable age structure of the plant species in a community, affected directly or indirectly by various climatic as well as edaphic factors (Singh and Singh, 1992). The issue of regeneration is mainly important for those forests which are under various anthropogenic pressures such as felling tree, grazing, trampling, etc (West *et al*., 1981).

The regeneration niche is defined as the range in which a species has a high chance of success in the replacement of a mature individual by new individual. The regeneration niche comprises elements of the habitat, life-form and phonological niches. The processes and events that occur during the regeneration phase of natural communities can play a key role in community composition and may affect species diversity and promote species coexistence in environments that are homogeneous at the adult plant scale (Grubb, 1977).

Quercus semecarpifolia (Family Fagaceae; local name Khasru) is a high altitude oak of the Himalayas with distribution from southwest China to Afghanistan, at elevation of 2100m to 3800m (Shrestha *et al.* 2004) and is the main forest-forming evergreen tree species at higher elevations and occurs as a climax species. Khasru is closely linked with subsistence hill agriculture, which is practiced in the mountain region of the Nepal and they also have provisioning services value due to capacity of supplying timber, wood fuel, dry season fodder and litter. In addition they maintain and protect soil fertility, watershed and local biodiversity. Unfortunately, higher rate of exploitation making them two of the overexploited trees in the Himalayan region (Shrestha 2003; Singh *et al*., 2011) and; because of the overexploitation and an inherently slow growth rate, Kharsu oak forest is failing to regenerate and shrinking in this region. (Metz 1997; Shrestha and Paudel, 1996; Singh and Singh, 1992 and Upreti *et al*., 1985).

1.2. Rationale

In the Himalayan region more than 2ºC rise in temperature has been projected because of increase in carbon dioxide concentration in the atmosphere by 1985 (Ravindranath *et al.,* 2006). The impact of this global climatic change can have a major impact on regeneration of certain viviparous species and species with short seed viability (Joshi and Tewari, 2009). The possible causes of regeneration failure include poor seed production of trees (may be limited by various factors such as resource availability, pollination failure, predation on flowers, fruits and leaves), unfavorable micro-sites and anthropogenic pressure and climatic irregularities. Annual lopping, acorn herbivory, seedling and sapling browsing, litter collection and forest fire are important factors preventing recruitment of kharsu in disturbed forests. In a nearly undisturbed forest of central Nepal (Langtang National Park), the regeneration of khasru is continuous (Vetaas, 2000) but the preliminary observation (Siluwal *et al.,* 2001) of the other forest in the same region (Shivapuri National Park, Central Nepal) revealed that the regeneration was not continuous even in the protected forest. In the western Nepal *Quercus semecarpifolia* is a tree-line forming species and it recorded upto 3500 masl in Darchula's, Chameliya valley (Elliott, 2012). Detaile study of regeneration and vegetation dynamics of the *Q. semecarpifolia* forest is not yet studied in the Western Nepal particularly in Api-Nampa conservation area. Population dynamics of trees are helpful in predicting the future contribution of constituent species in forest communities. So this research is intended to have a detail study on *Q. semecarpifolia* in this region.

1.3. Hypothesis

The null hypothesis of the study are:

1. There is a poor regeneration of *Quercus semecarpifolia* in treeline region of study area.

2. The presence and density of seedlings of the *Q. semecarpifolia* depends on microsite conditions (e.g. major soil nutrients such as N, P, K; canopy coverage, litter thickness)

1.4. Objectives of the study

The overall objective of the present study is to analyze the vegetation of Khasru forest and its regeneration pattern in Api-Nampa conservation Area. The specific objectives are follows:

1. To document the community structure of *Quercus semecarpifolia* forest.

2. To study the regeneration pattern of *Q. semecarpifolia* forest.

3. To study the sapling and seedling distribution pattern of *Q. semecarpifola* along altitudinal gradient.

1.5. Limitations

The major limitations of the study are:

1. The coverage of geographical area is limited.

2. Sampling was done only a rainy season.

3. Regeneration was only accessed by plotting density diameter curve (DBH-curve) and presence/absence of seedling and sapling in the plot.

CHAPTER 2: LITERATURE REVIEW

2.1. Vegetation types in Nepal

In Nepal, Khasru can be found in both the sub-alpine and the temperate zone forming pure stand or as a dominant species in mixed forest. It is very abundant on western Nepal but it occurs sporadically in central and eastern Nepal. The subalpine zone is restricted in the upper limit by the timberline at 4,000 m on average and in the lower limit by the absence of silver fir (*Abies spectabilis*) at an average elevation of 3,000 masl. It is characterized by frost periods that may last between four to eight months. In this life zone, *Q. semecarpifolia* is found in the Fir-Oak-Rhododendron and Fir-Hemlock-Oak Forests vegetation types, accompanying silver fir on southern aspects. It can also form pure oak stands mainly on southern aspects creating its own vegetation type called Subalpine Mountain Oak Forest.

The temperate zone is located between 2,000 to 3,000 m in elevation. It is very diverse, containing over 40 % of the vegetation types of Nepal. The precipitation distribution varies widely in this zone, ranging from semi-arid in the inner valleys and trans-Himalayan regions to humid conditions on the south of the Himalayan mountain range. On drier southern aspects in western Nepal, *Q. semecarpifolia* is associated with the west Himalayan fir (*Abies pindrow*) forming the West Himalayan Fir-Hemlock-Oak Forest. Also in western dry parts of Nepal it forms a distinctive forest with an abundance of *Rhododendron arboreum* called Mountain Oak-Rhododendron Forest. It also occurs forming pure stands in this zone forming the vegetation type Temperate Mountain Oak forest. Its distribution ends at around 2,500 m a.s.l. being replaced by *Q. lanata* and *Q. incana* (Shresta *et al.,* 2002).

Common accompanying tree species are spruce (*Picea smithiana*), Silver fir (*Abies pindrow*), east Himalayan fir (*A. spectabilis*), Himalayan yew (*Taxus baccata subsp. wallichiana*), blue pine *(Pinus wallichiana*), Himalayan hemlock (*Tsuga dumosa*), *Pyrus spp*, *Prunus padus*, *Acer caesium, Juglans regia*, *Rhododendron arboreum* and *Betula alnoides* among others. It forms the climax community and in parts of the Western Himalaya also represents the tree line (Jackson, 1994; Singh *et al*., 2011).

2.1.1. Distribution of *Quercus semecarpifolia*

In central Himalayan region distribution of Oaks (*Quercus* sp.; Family Fagaceae) is specific along an altitudinal gradient. *Q. leucotrichophora* occurs in between 1,000 to 2,500 masl and subsequent to that, *Q. lanata*, *Q. floribunda* and *Q. semecarpifolia* grows up to subalpine forests (SAFs) (Bisht *et al*., 2013). *Quercus semecarpifolia,* also called Kharsu oak is an evergreen, broadleaved, late successional tree, widespread along the Himalayan region. It extends from the wettest monsoonal slopes of the south-east Hindu Kush (Afghanistan), to the rain shadowed areas of the Inner Valleys in Bhutan (Miehe, 2015) and to south-west China (Polunin and Stainton, 1997). It commonly grows between 2,400 and 3,000 meters above sea level (masl), but depending on the amount of rainfall and humidity in the area it can also be found between 1,700 and 3,800 masl. (Jackson, 1994). Dense *Q. semecarpifolia* forests were recorded up to 3,500 masl. in Darchula's Chamilaya Valley, Nepal (Elliott, 2012).

2.1.2. Community Structure of Q. semecarpifolia

Sub-alpine forest in the Himalaya is often dominated by conifers or broad leaved deciduous species (Gairola *et al*., 2008). This forest represents a transition (ecotone) between alpine grassland and temperate forest ecosystems. With increasing altitude the dominant plant cover changes from a deciduous broad-leaved forest to coniferous forest (forming climax tree line) and to a woody shrub community and ultimately alpine meadows. Ground surface of the subalpine forests received low intensity light under the canopy since the forest had high density and crown closure which tended to decrease in the higher elevations. This led a poor ground vegetation of herbs and shrubs (Dolezal & Srutek, 2002).

Tree height decreased linearly along the altitudinal gradient. As tree becomes larger, basal cover increases, canopy cover becomes denser, and low light intensity eliminates the reproduction of shade intolerant species which thus limits the late succession diversity (Tilman, 1985).

Species diversity is an important index in characterizing a community. It is also important in reflecting the type of community, the stage of community development and community stability (Liyun *et al*., 2006). Species richness usually reduces along the vertical gradient and it is largely caused by decline in temperature (Qi-Jing, 1997).

In sub-alpine broad leaved coniferous forest, reported an increase in species richness in secondary forests during the period from 30 to 40 years but tended to decrease significantly in the old-growth coniferous forests (Jiangming *et al*., 2008).

2.1.3. Regeneration

Regeneration behavior of tree species is characterized by their population structure which depends upon the presence of adequate number of seedlings and saplings. Reverse J- shaped size class diagram is the indicative of sustainable regeneration (Vetaas, 2002).The regeneration of oaks is a multifaceted ecological process. It consists in the flowering, fruiting, and the dispersal of the seeds of mature trees, together with the germination of those seeds, seedling establishment and growth (Johnson *et al.*, 2002).Lack of sufficient regeneration is a major problem of mountain forests. Most studies on subalpine forests have reported poor seedling recruitment in under stories of undisturbed old-growth forests (Mori and Takeda, 2004).

For successful regeneration, canopy gap formation, control form of lopping and grazing and a favorable composition of herb layer species seems highly responsible (Subedi & Shakya, 1999). The dense canopy of the forest did not promote the satisfactory establishment of oak in the understory however the moderate disturbance appeared to benefit the regeneration (Thadani & Ashton, 1995). Besides browsing, growth rate and species composition of the natural regeneration are mainly determined by the light conditions (Ammer, 1996). *Quercus semecarpifolia* requires not only canopy gaps but also exposed to soil for regeneration. In the form of disturbances, gaps formed are too small to enable brown oak to establish seedlings, and in large gaps grazing/browsing does not allow regeneration to progress up to tree size (Sing *at al.*, 1997).Human impact has been used to explain low regeneration of evergreen oaks and indicated the best regeneration in the least disturbed sites. Thick litter generally reduces the rates of germination and of seedling establishment (Maren and Vetaas, 2007).

Environmental conditions play an important role in establishment and distribution of seedlings (Bonnet *et al*., 2005), regeneration of dominant trees in dry valleys is influenced even by small-scale human impacts. Under such impacts, the typical inverse J-shaped DBH class distribution observed among forest species, where frequency of individuals in larger size classes falls systematically and progressively, resulting in a non-linear relationship between frequency and size class, generally gives way to a sporadic and/or unimodal distribution (Wangda and Ohsawa, 2006). Inverse J-shaped distribution is indicative of a forest in a state of regeneration. A shift from inverse J-shape to unimodal or multiple-peaked distribution is the result of substantial changes in the state and pattern of forest regeneration, suggesting that the forest is in trouble (Ghimire *et al*., 2010).

The regeneration of oaks is a multifaceted ecological process. It consists in the flowering, fruiting, and the dispersal of the seeds of mature trees, together with the germination of those seeds, seedling establishment and growth (Johnson *et al*., 2002). In the following sections, the known information about the ecology of these oak species is going to be explained.

2.1.3.1 Reproduction, seed germination and establishment of *Q. semecarpifolia*

It is also a monoecious tree. Flowering and pollination occurs at the end of April and during May and after 8 months at the end of December and till January, the nuts ripen. Under natural conditions, the nut will remain on the soil during the dry season and germinate when the conditions are favorable, usually during the rainy or monsoon season (Troup, 1921). This dormancy allows the seed to avoid germination during unfavorable conditions (Singh, 2014). About 80 % of the fresh seeds germinate (Jackson, 1994).

The germination is hypogenous, and the radical also descends rapidly to form a taproot. The fleshy cotyledons remain with the seedlings for some time, supplying it with nutrients (Troup, 1921). It is a light demanding species, but it can also tolerate some shade as well as frost periods. It is mainly found on dry south-facing slopes, but it reaches a greater height on wetter areas (Jackson, 1994).

2.1.3.2. Seed production and dispersal of *Q. semecarpifolia*

The seeds are also dispersed by means of zoochory (Troup, 1921). Presumably the same wildlife described for the other species dispersed them, but it is believed that smaller animals such as birds, squirrels and mice are the primary dispersers due to the smaller size of the seeds. There are 1,800 seeds per kilogram (Jackson, 1994).

2.1.3.3. Growth of *Q. semecarpifolia*

The seedling grows slowly, but at the end of the first season it can be between 5 and 12 cm in height. It can be successfully cultivated in a nursery and then transplanted, provided the roots are not excessively exposed during the process. A height growth of 50 cm in 4 years was recorded but older trees may grow faster. Direct sowing is also a successful method of artificial reproduction (Troup, 1921). It can reach 15 to 25 m in height and between 0.6 and 0.8 m in DBH (Tang, no date). Troup (1921) reported the measurement of an individual with a DBH of 1 m and a height of 21 m.

2.1.3.4. Threats to regeneration of *Q. semecarpifolia*

The seeds are prone to be attacked by insects (Jackson, 1994) as well as to suffer a severe predation pressure because of their waiting time on the ground until favorable conditions are met (Singh, 2014).There is an increasing concern about the failure to regenerate *Q. semecarpifolia*, and several ecological regeneration studies have already taken place (Vetaas, 2000; Shrestha *et al.*, 2004; Tashi, 2004; Thakuri, 2010; Bisht *et al.*, 2012; Bisht *et al.*, 2013; Shah *et al.*, 2015) which fundamentally indicate that it cannot regenerate when subjected to heavy anthropogenic pressure, mainly lopping and grazing. If we consider its economical, ecological and social importance, the state of knowledge on the regeneration of the species is still not sufficient (Maren and Vetaas, 2007). On the other hand, there is an even bigger lack of knowledge regarding the regeneration of *Q. lanata* (Wangda and Ohsawa, 2006).

Overall, *Q. semecarpifolia* and *Q. lanata* forest types are facing an imminent threat due to the even-increasing human pressure, their failure to regenerate and the climate change related alterations of climatic patterns, such as changes in the monsoon. A change in the timing of the monsoon would impact severely *Q. semecarpifolia* due to the synchronization between the monsoon and the germination of its seeds (Singh, 2014). Increasing temperature is shifting vegetation zones towards higher altitudinal areas, thereby exposing species to harsher conditions such as steeper, more erosive slopes, less fertile soils and pronounced climate fluctuations. These may pose a serious threat to their long-term survival (Shah *et al.*, 2015). Correspondingly, vegetation types from lower altitudes are encroaching into higher altitudinal areas, and could replace the original forest. The potential habitat of *Q. semecarpifolia* is predicted to shrink 40 % and 76 % with 1°C and 2°C increase in temperature, respectively (Saran *et al.*, 2010). Furthermore, rangelands are becoming more degraded and dry, increasing the dependence on *Quercus spp.* as fodder for cattle (NARMA and PSC, 2013).

CHAPTER 3: MATERIALS AND METHODS

3.1. Study area

3.1.1. Location and geomorphology

This proposed research was conducted in the Api-Nampa Conservation Area which was established in 2010 and is located in Darchula district in Sudhur Paschim Province of Nepal. It is youngest conservation area in Nepal, including Five Rural Municipalities (Byas, Apihimal, Dunhu, Naugad and Marma) of Darchula district. The Api-Nampa conservation area (ANCA) is named after the Mount Api (7132m) and Nampa (6757m) which lie within the area and includes different vegetation types. Spatially ANCA extends from 80°22’ to 81°09’ longitude and from 29°30 to 30°15’ latitude and is a part of Kailash Sacred Landscape (KSL) in the border of China, Nepal and India. Northern border extends up to the Tibet while its Southern border extends up to Lasku and Naugad khola of India. The eastern border extends up to Bajhang district and its western border extends up to Mahakali river which separates it from India. It occupies 1903 km^2 of area and the altitudes range from 539 m to 7132 m. However this study covers only altitude range from ca. 2489 m upto treeline which covers the upper belts of Apihimal Rural Municipality.

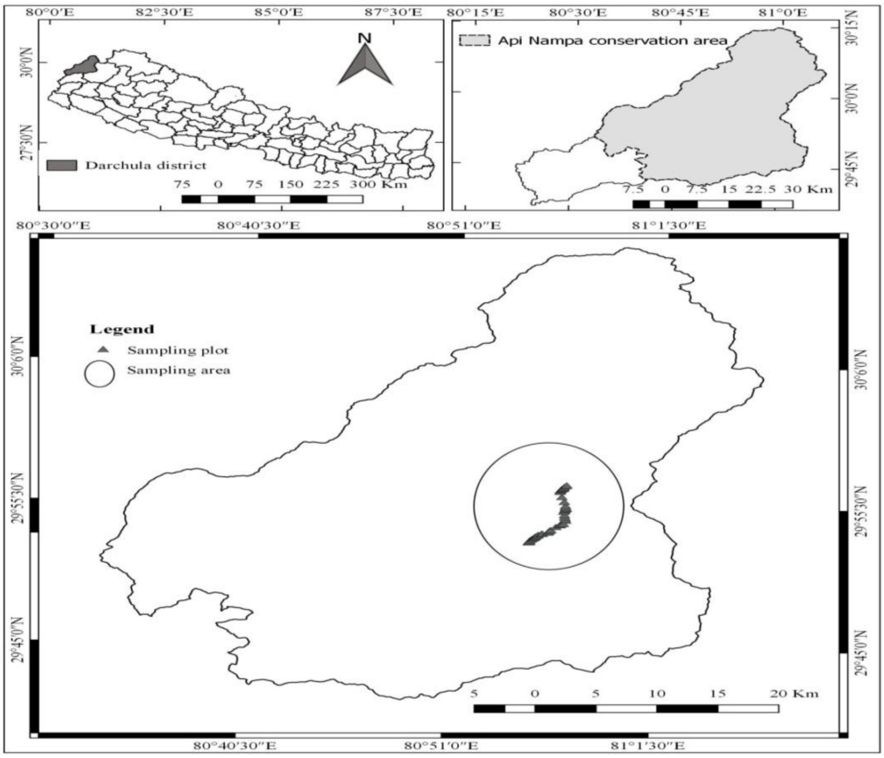
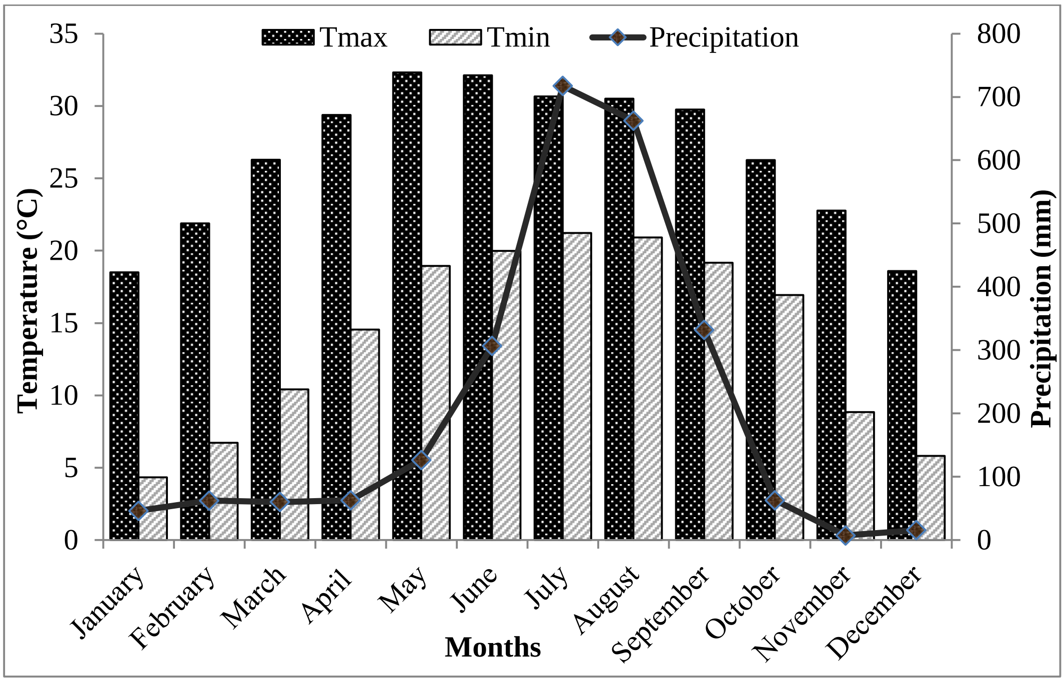


Figure 1. Map of the study site (Source: Government of Nepal, Department of Survey, 2014).

Figure 1.1 Location of plots in ANCA, Nepal (Google Maps, 2020). Asterisk represents the plots where the vegetation surveys were conducted.

3.1.2. Climate

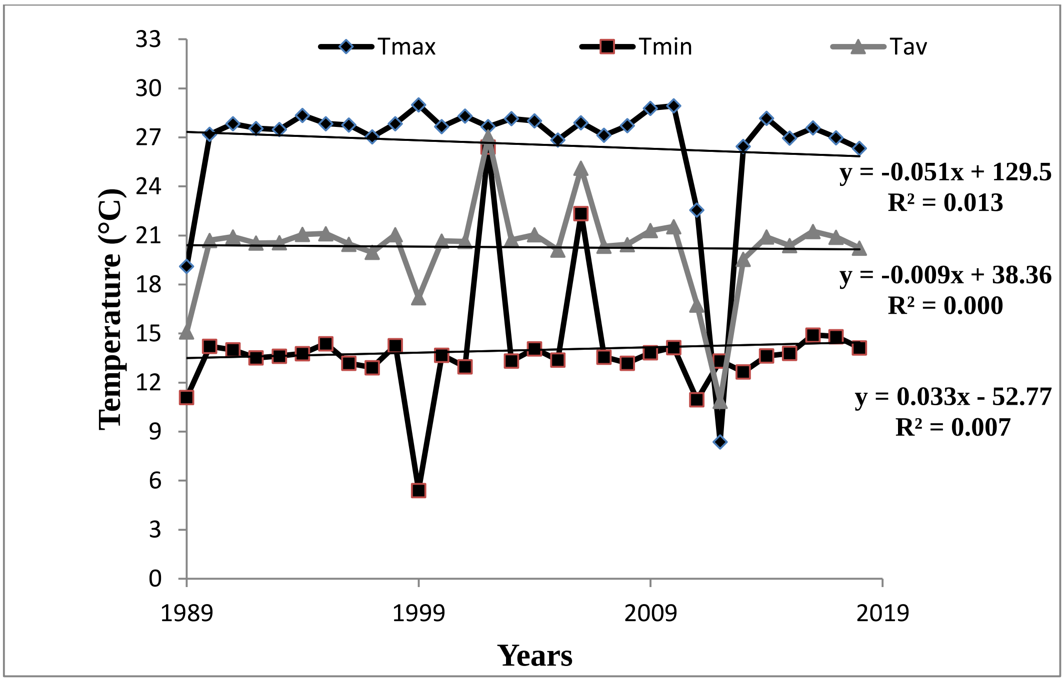
The climate of the ANCA is diverse due to variation in altitude and topography. Sub-tropical climate is more prevalent in south-eastern part and along the valleys of ANCA while temperate and alpine climate types are more dominant in the middle mountains and high Himalayas (ANCA Mgt. plan, 2010-2014). A thirty-year climatic data (1989-2018) was analyzed, which was taken from meteorological station of Drchula (1097 m) (Figure 2). Mean annual temperature was 20.28℃. The monthly maximum temperature (32.31℃), the highest, was found in May and minimum temperature (-4.33℃), the lowest, was found in January. The average annual precipitation was recorded to be 205.50 mm with highest rainfall in the month July (717.28 mm) and the least in the month November (62.89 mm). Upper range of study site covered by seasonal snow fall and Glaciers are also found in higher altitude. This snowmelt water is the main source of soil moisture for forest in this region. However rainfall and snow feed ground water are the main source of soil moisture for forest in middle and lower range. Recorded relative humidity (RH) in the station showed average annual RH of 71.34% with highest RH (80.94%) in the month of July. Details of climate data are presented in Appendix iv.



(Source: Department of Hydrology and Meteorology, Government of Nepal).

Figure 2. Thirty-year (1989-2018) average monthly maximum (Tmax) and minimum (Tmin) temperature and precipitation recorded at Darchula weather station (1097 masl), Darchula

A



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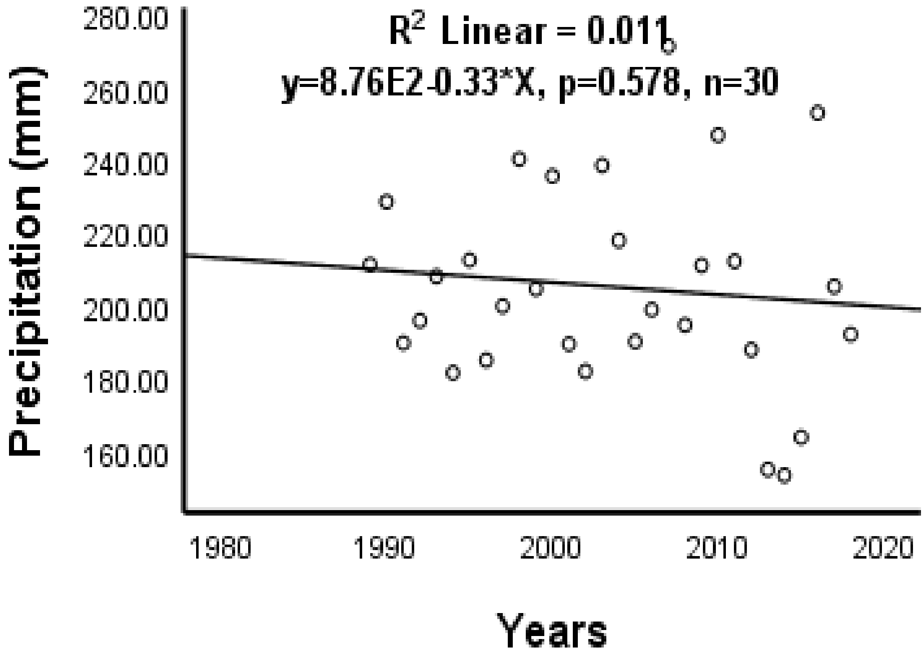

Figure 3. Regression analysis of the variation in mean annual temperature (a) and rainfall (b) with time (1989-2019) of Darchula weather station, Darchula [Tmax = Maximum temperature, Tmin = Minimum temperature and Tav = Average temperature].

3.1.3. Vegetation

ANCA covers a diverse array of biomes, ecoregions and ecosystems. Mountain peaks, high-altitude pastures, forests, glaciers, rivers, lakes, cultivated lands and settlements are the prominent features in the area. A total of 14 vegetation classes have been identified in ANCA (DNPWC, 2019). Some tropical broadleaved forests are located at elevations below 1,000 m, composed of sal *(Shorea robusta)*.Between 1,000 and 1,800 masl, subtropical broadleaved (*Shorea robusta*) and needle leaved forests (*Pinus roxburghii*) are common, while montane broadleaved and montane needle leaved forests are found up to an elevation of 3,300 masl. Oak, rhododendron and lauraceous forests comprise the montane broadleaved evergreen forests, while *Alnus glutinosa*, *Aesculus hippocastanum* are found in the montane broad leaved deciduous forests (DNPWC, 2019). The montane needle leaved forests are composed of cypress *(Cupressus torulosa)*, hemlock *(Tsuga dumosa)* and East Himalayan fir *(Abies spectabilis)*.

ANCA is home to a number of globally and nationally threatened flora and fauna. At least one globally threatened plant had been documented in ANCA i.e the critically endangered

Jatamansi *(Nardostachys grandiflora)* while the Gobre salla *(Abies spectabilis)* is near threatened (DNPWC, 2019). Three species are listed in CITES Appendix II—Panchaule (*Dactylorhiza hatagirea),* jatamansi (*Nardostachys grandiflora)* and Lauth salla (*Taxus contorta).* Ten plant species were protected under various categories by the Government of Nepal (DNPWC, 2019).

3.2. Study species

Oak (*Quercus*), a genus under the family Fagaceae, is a large group of hardwood trees with about 600 species. Oaks are found in the northern temperate zone, subtropical and tropical Asia, and the Andes of South America. Oaks dominate many forest landscapes and are intimately linked with a large number of other organisms, ranging from fungi to ferns, birds to bears, and wasps to ants. Human beings have always had a strong connection with oak. Throughout history the oak has been a symbol of permanence, strength, and courage (Keator and Bazel, 1998).

Himalayan oaks are evergreen, mostly gregarious, medium- to large-sized tree, distributed at elevations of 800 to3800 masl throughout the Himalayan region. There are more than35 species reported from this region (Negi and Naithani, 1995), most of which are abundant in temperate forest. Eight species occur in Nepal (DPR, 1997): *Q. floribunda*, *Q. glauca*, *Q. lamellosa*, *Q. lanata*, *Q. leuchotrichophora*, *Q. mespilifolioides*, *Q. oxyodon* and *Q. semecarpifolia*.

Quercus semecarpifolia, commonly known as brown oak (locally known as Kharsu Oak), is the main forest-forming evergreen tree species from upper temperate to subalpine regions (2,500–3,300 m). The epithet *semecarpifolia* was given by James Edward Smith when he described the species in 1814 and refers to the resemblance of the leaves of this species to those of *Semecarpus anacardium*, an Indian plant known as “marking nut” by Europeans (Troup, 1921). It is found throughout the Himalaya from Bhutan westwards into Afghanistan, on the Myanmar-Manipur frontier, Thailand, and into China. On the southern slopes of the main Himalayan range this species often forms the limit of tree growth (Lacasia, 2014).

Quercus semecarpifolia is a medium to large sized evergreen tree up to 3.5 m in girth and 30 m high. The bark is silvery-grey to blackish, rough, with shallow cracks, exfoliating in irregular woody scales. Its leaves are 5-10 cm long × 2.5-8 cm wide, nearly sessile, oblong-ovate, entire, spinous toothed and obtuse. The upper surface is glabrous; the lower surface is brown and tomentose with lateral nerves bifurcating in 6-12 pairs. The leaf base is cordate (heart-shaped), and petioles are up to 5 mm long. Male catkins are 5-12 cm long, softly pubescent. Female flowers arranged in few-flowered short spikes. Acorns, borne singly, are dark brown, globose, and smooth. Cupule scales are thin and imbricate, and cover only the base of the nut (Troup, 1921).

As is the case with most oaks, it commonly reproduces through its seeds. However, the seeds are frequently damaged by insects and also eaten by birds and wild animals, including bears, squirrels, rats, and monkeys. Poor seed crops and high rates of consumption by animals have significantly impacted on the ability of oaks of this species to regenerate naturally (Upreti *et al*., 1985).

The seed germination of all the Western Himalayan oaks is hypogeal (occuring below ground), the radical emerging from the apex of the nut and the plumule extricating itself by the elongation of the cotyledonary petioles (Singh and Singh, 1987). In the case of *Q. semecarpifolia* this elongation is of an abnormal character with the petioles remaining united in the form of a tube, which serves as a protection to the minute plumule, while the elongation of the united petiole enables the young plant to reach the soil surface as soon as possible. A short period of seed viability combined with vivipary (germination while still attached to the parent plant) and the intolerance of its seedlings to shade are the characteristic features of this oak. The seed maturation and germination of this oak is synchronized with the commencement of monsoon rainfall (Singh and Singh, 1987).

A rise in temperature and water stress may advance seed maturation, which might result in the breakdown of the synchrony between the commencement of monsoon rains and seed germination. Moreover, the seedling is a light demander and fails to establish itself under conditions of shade (Singh and Singh, 1987).

3.3. Methods

3.3.1. Vegetation sampling

The vegetation data was collected from total of 48 square plots for tree species in which every square quadrate of 20*20 m was established at lower limit *of Quercus semecarpifolia* i.e. 2489 m to uppermost limit i.e 3336 m. The vertical distance between the quadrats ranges from 40m to 100m, depending upon slope and topography. The rocky places and very steep slopes were avoided from sampling which resulted to unequal length of plots. For the analysis, again altitude wise collected data was divided into three broad altitudinal rages i.e lower (2489-2829 m), middle (2829-3317 m) and upper (3317-3636 m). The Shrubs and tree saplings including lianas were recorded from the plot of $25m^2$, i.e, single quadrat in the middle of main plot; herbs and tree seedlings were record from two quadrats of $4m^2$ each in the opposite corner of the main plot. Thus, altogether, 48 quadrats for shrubs and tree saplings, and 96 quadrats for herbs and tree seedlings were laid for the study. In each sample plot, the woody plant species (trees, shrubs, and lianas) was recorded along with the following structural attributes. Individuals of each species was grouped into seedling (height <20 cm), sapling (DBH<10 cm and height >20 cm) and mature tree (DBH>10 cm) as per Deb and Sundriyal (2008). Every woody and non woody plant species within each quadrat was recorded and coded with vernacular or scientific name as much as possible and their cover abundance (ground cover) percentage was estimated.

3.3.2. Soil

Litter thickness was measured by a Scale. For a detailed analysis, soil samples were collected from the each quadrat in each elevation. In each sampling quadrat 4 soil samples (10 cm depth) collected each from 4 corners and single samples from the center were mixed and sieved to form a single soil sample; 48 such complete samples was collected, air dried, and stored in plastic bags for laboratory analysis.

3.4. Laboratory works

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

3.5. Data management and analysis

3.5.1. Numerical Analysis

3.5.1.1. Community Structure

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

Frequency (F)

Frequency is the proportion of sampling units containing the species.

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

Relative frequency (RF)

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

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

Density (D)

Density is the number of individuals per unit area.

$$\text{Density (stem/ha)} = \frac{\text{Total number of individuals of a species in all plots} \times 10000}{\text{Total number of plot studied} \times \text{Size of the plot (m}^2\text{)}}$$

Relative density (RD)

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

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

Basal Area (BA)

Basal area is one of the characters which determine dominance. Basal area cover indicates the amount of ground occupied by the stems. The circumference data of tree at 1.3 3m above the average level at the base of tree is used for calculating basal area which is given by: Basal area = $\pi d^2/4$

Where,

d = DBH (diameter at the breast height)

$\pi = 3.1416$

$$\text{Basal area of a species (m}^2\text{/ha)} = \frac{\text{Total basal area of a species} \times 10000}{\text{Size of the plot (m}^2\text{)}}$$

Relative Basal Area (RBA)

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

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

Importance Value Index (IVI)

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

$IVIi = RFi + RDi + RBAi$

Where,

IVIi = Importance Value Index of species i

RFi = Relative Frequency of species i

RDi = Relative Density of species i

RBAi = Relative Basal Area of species i

Species Diversity Index (H')

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

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

Where,

H' = Species Diversity Index

P_i = proportion of the species

$P_i = n_i / N$

N = total importance value of plants

n_i = importance value of each species

Simpson's Dominance Index

Simpson's diversity index given by Simpson (1949) is an accepted and often used calculation of plant diversity within a habitat. Within a sample area all plants of all species are counted. The diversity is then calculated using the following equation:

$$D = \Sigma (n_i/N)^2$$

Where,

D = Simpson's Dominance Index

N = total importance value of plants

n_i = importance value of each species

Population structure and regeneration

Population structure of *Quercus semecarpifolia* was analyzed by clustered column graph for different three elevation ranges. The column graph was prepared on the basis of total density of individuals. Regeneration potential of *Q. semecarpifolia* was evaluated based on the density of seedling and juvenile. In addition, density-diameter (d-d) curve was also developed for adults to assess regeneration patterns and population structure of adults (Singh and Singh, 1992). Height class distribution of *Quercus semecarpifolia* was grouped in four meter interval. Differences in average basal diameter and average height of *Q. semecarpifolia* in different elevation ranges were analyzed by drawing column graph and tabulated form.

3.5.2. Statistical analysis

For each environmental variable and community attribute, mean values were calculated. Coefficient of variation (CV) was calculated as the standard deviation expressed as the percentage of mean. Variation among community attributes, abundance of recruits (density of saplings and seedlings) and the environmental variables were analyzed by correlation. For some of the variables, regression was performed and regression diagrams were shown. One way ANOVA were performed to check the differences in distribution of different life forms and height and diameter variations of *Q. semecarpifolia* in different elevations. Statistical Package for Social Sciences (SPSS, version 16), R-Studio and Microsoft excel was used for all statistical analyses.

CHAPTER 4: RESULTS

4.1 Vegetation composition and diversity

A total of 188 species of woody and non woody species belonging to 103 genera and 67 famililies were recorded. Analysis of the habit of species recorded form the study site revealed that the largest percentage of herb species followed by tree, shrub, grass and climber (Figure 4). Among 69 woody species 19% (35) species of tree belonging to 19 families and 18% (34) species of shrub belonging to 17 families were recorded. The most dominant family of the tree and shrub species in the study area were Rosaceae which are represented by 2 genera (5 species) of tree and 7 genera (11 species) of shrub. Similarly, a total of 59% (102) species of herb including grass belonging to 27 families and 4% (8) species of climber belonging to 8 families were reported (Appendix i). The family Asteraceae was most dominant having 14 species of herbs were belonging to 8 genera and all eight families for climbers bearing only single species in each.

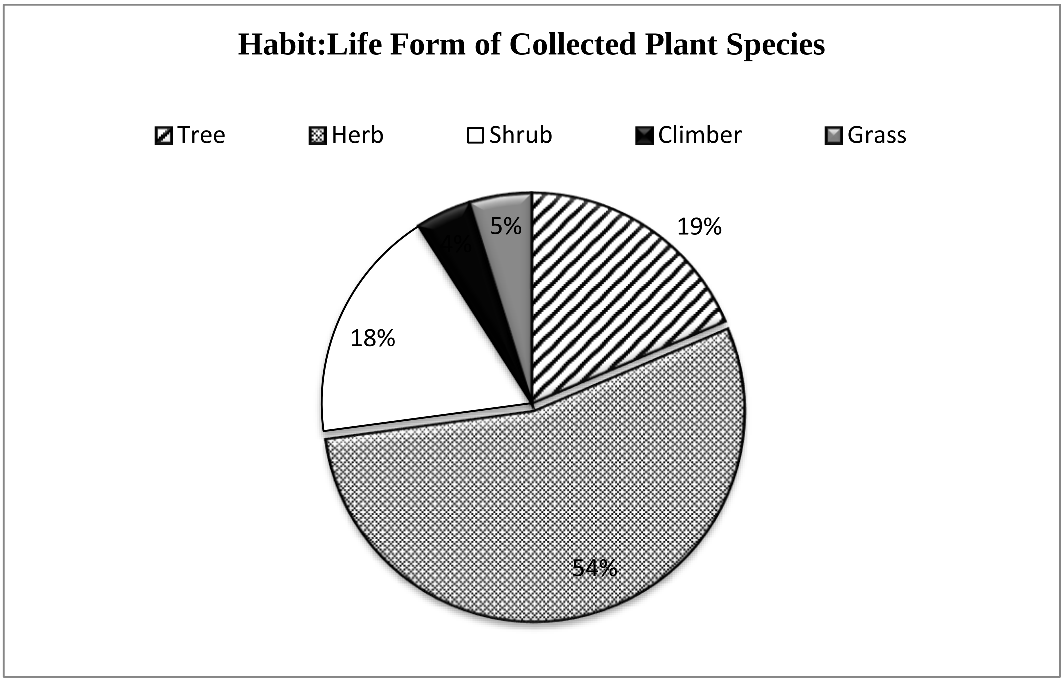

Figure 4. The growth form of collected Plant species.

Ranunculaceae is represented by 7 species (13.16%) and Ericaceae, Polygonaceae and Urticaceae are represented by 6 species (11.28%) each of the total floristic composition.

Similarly, Sapindaceae is represented by 5 species (9.4%) and Actinidaceae, Araceae, Bracecaceae and Caryophyllaceae are represented by 4 species (7.5%) each of the total floristic composition. The remaining eight families namely Apiaceae, Asparagaceae, Balsaminaceae, Betulaceae, Boraginaceae, Cyperaceae, Gentianaceae, Liliaceae are represented by 3 species (5.64%) each and Amaranthaceae, Fagaceae, Primulaceae are represented by 2 species (3.76%) each. Theother 28 families are represented by only onespecies (Appendix i).

With regard to genera number contributing to total floristic composition, Rosaceae is the most dominant with contributing 9 genera (9.27%) to the total and followed by Asteraceae with contributing 8 genera (8.24%). Ranunculaceae, Polygonaceae and Bracaceae contributed 4 genera each (4.12%each). Poaceae and Urticaceae have contrinuted 5 and 6 genera (5.15% and 6.18%) respectively. Similarly Cyperaceae and Ericaceae contributed by 3 genera each (3.09% each) to the total floristic composition. The remaining families of the study area comprises of 1 and or 2 genera (Appendix i). The growth forms of collected plant species with number and relative percentage of families are given in Table 1.

Table 1. Growth form of collected plant species with number and relative percentage of family and species.

Habit	**No. of families**	**No. of species**	**Species percentage**	**Most dominant family**
Trees	19	35	19	Rosaceae
Shrubs	17	34	18	Rosaceae
Herbs	27	102	59	Asteraceae
Climbers	8	8	4	

Vegetation in Shrub and herb layer

Shrub layer was mainly dominated by *Sorbus foliolosa, Rhododendron lepidotum, Rosa siricea* and *Prunus braccteopadus* with some other shrub species (Appendix ii). In lower altitude shrub layer was dominated by *Debregeasia salicifolia, Rubus calycinus, Dutzia compacta, Bouhmeria penduliflora* and *Prinsepia utilis* with some other frequently occurred shrub species. Dominant species contributed to shrub layer formation were mainly *Sorbus foliolosa, Rhodendron lepidotum, Prunus bracteopadus, Aconogonum molle* and *Rosa macrophylla* at middle altitudinal range whereas it was dominated by *Rhododendron anthopogon, Aconogonum molle, Rosa macrophylla, Sorbus foliolosa* and *Salix lindleyana* at upper range. Some seleected associated Shrub and tree species were presented in the appendices ii, iii. Total shrub density in the forest ranged from 175 stem/ha (min) to 1175 stem/ha (max) (Appendix ii). Herbaceous layer in the forest during the study period constituted the species of *Anaphilis, Potentilla, Rumex, Thalictrum, Stellaria, Arisaema, Aster,* etc. (Appendix i)

Simpson's Index of dominance (D) for tree was 0.86 and Shannon- Wiener Index (H') of Species diversity was 2.71 in the forest while Simpson's Index of Dominance (D) for shrub was 0.95 and Shannon- Wiener Index (H') of species diversity was 3.28 for shrubs. Similarly, Simpson's index of dominance (D) for herbs was 0.98 and Shannon- Wiener Index (H') of species diversity for herbs was 4.19 (Table 2).

Table 2. Diversity indices as per growth forms.

Growth forms	**Simpson's index**	**Simpson's index of Diversity**	**Shannon-Weiner index of diversity**	**Evenness**
Tree	0.132	0.867	2.71	0.771
Shrubs	0.042	0.957	3.28	0.955
Creeping	0.172	0.827	1.88	0.859
Herbs	0.019	0.980	4.18	0.538

4.2. Community structure

The forest was mixed forest of *Quercus semecarpifolia, Abies spectabilis, Prunus nepaulensis* and *Betula utilis* with some other tree species. Tree species richness in the forest was decreased with increasing elevations (33 tree species present in the lower altitude range, 18 tree species were present in the middle altitude range and only 12 tree species present in the uppermost altitude range) (Appendix i).

The most frequent and dense tree species was *Quercus semecarpifolia* with important value index of about 19% (IVI=56) in the forest. *Q. semecarpifolia* was present in 80% of the total sampling plots. Seedling and juvenile were present in 30.2% and 75% of sample plots in forest respectively. The frequency percentage of adult, juvenile and seedling were 81.25%, 62.25%, and 6.25% at lower elevation range however there are 50%, 56.25% and 6.25% at middle range and 81.25% each for adult and juvenile and 13.24% for seedlings at upper elevation respectively (Figure 5).

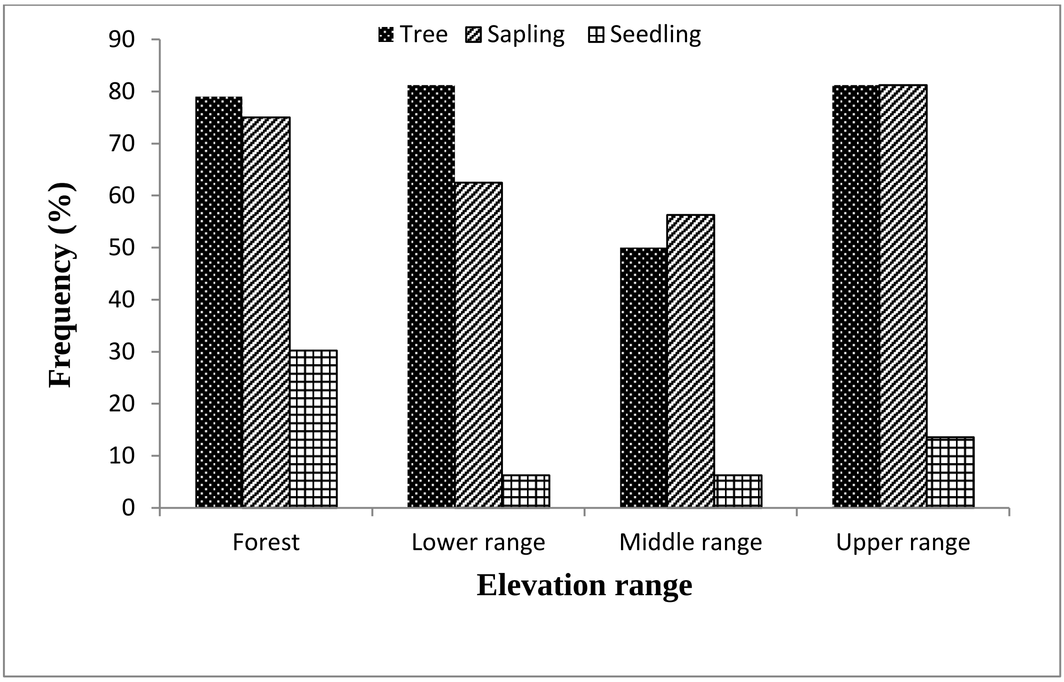

Figure 5. Elevation wise frequency of *Quercus semecarpifolia* based on life stages.

Important value index percent of *Quercus semecarpifolia* was quite lower (about 8%) in the lower altitudinal range with compared to mid (about 17%) and upper altitudinal range (about 41%) (Table 3). Important value index percent for *Betula utilis* was accounted by 8% and 16% at middle and upper elevation however it was accounted by 8% and 10% for *Rhododendron arboreum* at lower and middle elevational ranges respectively.

Table 3. Important value index percent and average tree density of selected species at three different elevation ranges.

Tree species	Lower elevation (2489-2829)m		Middle elevation (2830-3317)m		Upper elevation (3318-3636)m	
	Density/ha	**IP%**	**Density/ha**	**IP%**	**Density/ ha**	**IP%**
Quercus semecarpifolia	92.19	8(IVI=24)	146	17(IVI=51)	467	41(IVI=123)
Betula utilis	absent	absent	43.75	8(IVI=24)	126.56	16(IVI=48)
Rhodendron arboreum	81.25	8(IVI=24)	60.94	10	Absent	absent

Quercus semecarpifolia formed treeline vegetation frequently mixed with *Betula utilis, Rhododendron arboreum* and some *Juniperus* species on dry, mostly southern aspect interrupted by landslides, and rocky cliffs at some places. Total tree density of *Quercus semecarpifolia* in the forest was 235 stem/ha with maximum density in an individual plot by 850 stem/ha (Table 4). Seedling and sapling density in the forest were 4010 stem/ha and 1058 pl/ha with maximum density in an particular individual plot by 23750 stem/ha and 4000 stem/ha respectively. This indicates that tree density is lower than the seedling and sapling density of *Quercus semecarpifolia* in the forest.

Table 4. Density of seedling, sapling and tree of *Quercus semecarpifolia* in the Forest.

Plant size	Stem density/ ha	Maximum stem density/ ha in an individual plot
Seedling	4010	23750
Sapling	1058	4000
Tree	235	850

Basal area is used to describe average amount of an area occupied by tree stems. Total basal area of the *Quercus semecarpifolia* in the forest was 42.221 m^2/ha which is 25% coverage in the ground. From the elevation wise analysis of basal area of Khasru tree, it was 24.438 m2/ha (15% area occupied) in lower elevation, 35.743 m2/ha (21% area occupied) in middle elevation and 66.483 m2/ha (39% area occupied) in upper elevation. Total basal area of khasru stems increases with increase in elevation. The basal area is lower and the density of stem is higher in total and elevation wise (Figure 6, Table 3 and 4).

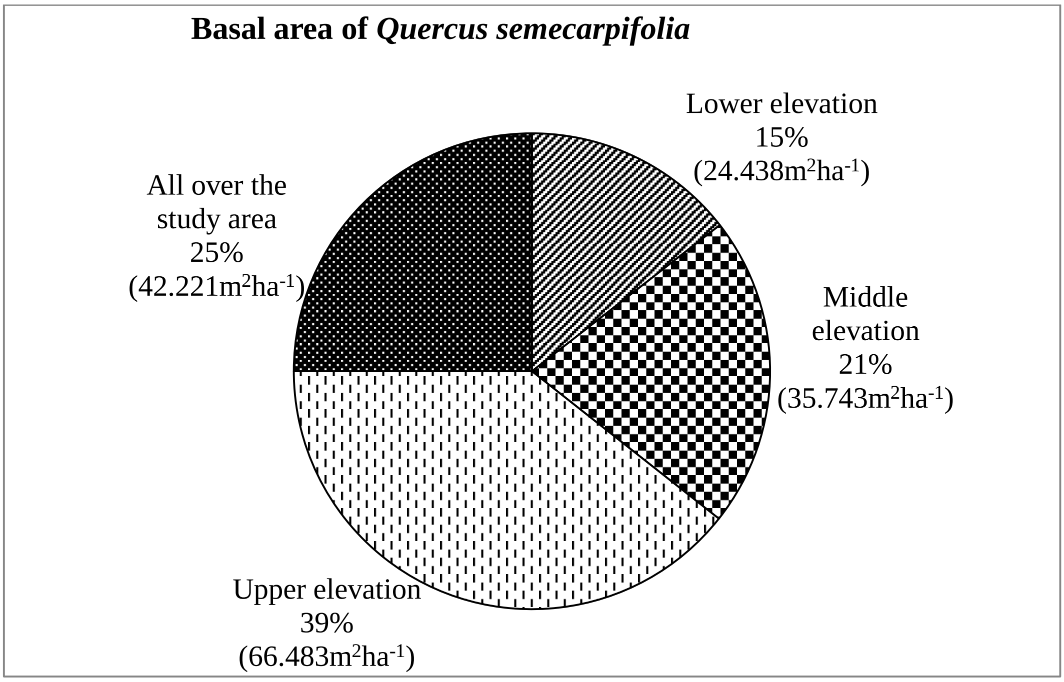

Figure 6. The Basal cover of *Quercus semecarpifolia.*

One way ANOVA and Post-Hoc was performed to check the differences in different life stages of *Quercus semecarpifolia* at different altitude ranges. In upper altitudinal range all tree, sapling and seedling density was higher than in middle and lower range (Table 5).

Table 5. ANOVA table showing variation in density of different life stages of *Quercus semecarpifolia* at different elevation ranges.

Altitude (m)	Tree density(Stem/ha)	Sapling density (Stem/ha)	Seedling density (Stem/ha)
Lower range	92.1875^{a}	550^{b}	1406.25^{c}
Middle range	167.1875^{a}	750^{b}	6250^{c}
Upper range	446.875^{a}	1875^{b}	7500^{c}
F	21.112	13.124	3.724
P*	0.000	0.000	0.032

P values are based on one way ANOVA and Post-Hoc test. The mean values sharing the different alphabet in a row in superscript are significantly different.

ANOVA analysis showed no significant differences in seedling density between middle and uppermost altitudinal range however, there was significant difference at $p<0.01$ and $p>0.01$significant levels in tree and sapling density. Similarly, ANOVA showed significant differences ($p<0.01$ and $p<0.01$) in tree and sapling density between lowermost and uppermost altitudinal range.

4.2.1 Comparison of DBH in different altitude

Results of one way analysis of ANOVA to compare DBH of *Quercus semecarpifolia* at different altitude is given in Table 6. P value for comparison of DBH is 0.002 which is smaller than 5% level of significance. This indicates that there is significant difference between DBH of *Quercus* at different altitudes. From the result of ANOVA DBH of *Quercus* measured within the altitude between 2689-2889m was significantly different from the DBH measured within the altitude between 3489-3689m. Similarly, diameter of *Quercus* measured in the altitude from2800to 3000 m was significantly different from the diameter of that plant measured in the habitat above 3200 m elevations.

Table 6. Comparing DBH at different altitudes (ANOVA Analysis).

Source	Degree of freedom	Sum of squares	Mean square	F value	Significance (P value)
Between altitude	5	12623.43	2524.686	3.78	0.002
Within altitude	497	332728.18	669.48		
Total	502	345351.608			

The DBH of *Quercus* is lowest at altitude between 3489-3689 m and is highest at 2889-3089 m. The DBH of *Quercus* increased from 2489 m to 3089 m altitude and after that it decreases. The trend is also clear from figure 7.

Table 7. Mean and standard deviation of DBH (cm) of *Quercus semecarpifolia* in different altitude.

S.N	Altitude (m)	Mean DBH (cm)/SD
1	2489-2689	38.94 ± 23.24
2	2689-2889	43.95 ± 36.15
3	2889-3089	46.72 ± 28.93
4	3089-3289	34.97 ± 26.09
5	3289-3489	31.08 ± 25.64
6	3489-3689	31.07 ± 22.64

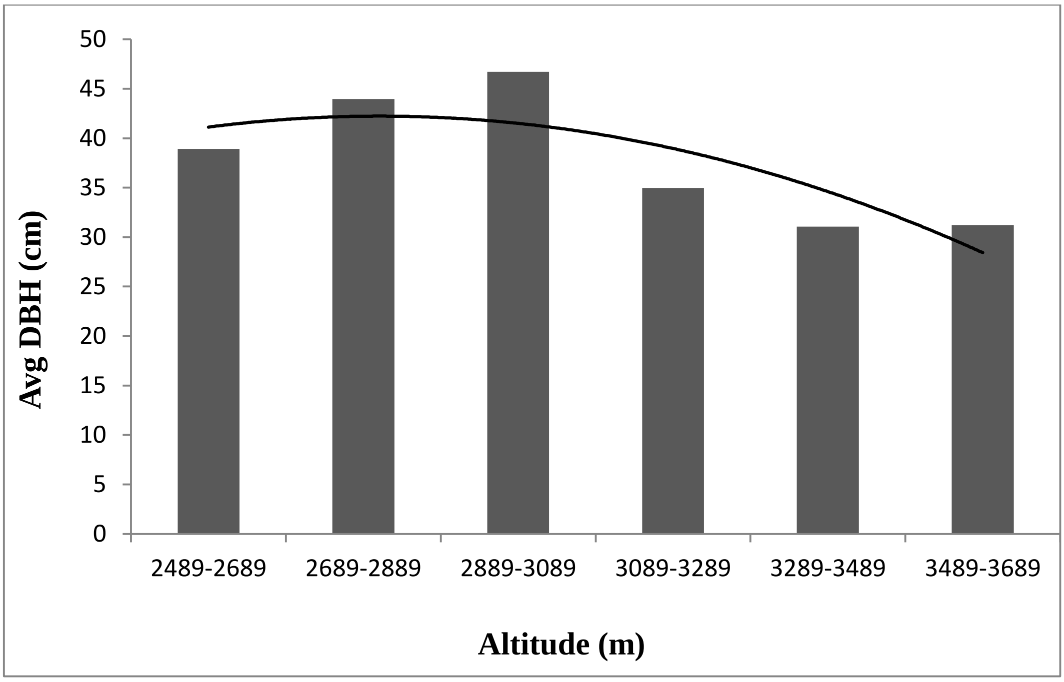

Figure 7. Average DBH of *Quercus semecarpifolia* along altitudinal gradient.

4.2.2 Comparison of Height in Different Altitude

Results of one way analysis of ANOVA to compare height of *Quercus semecarpifolia* at different altitude is given in Table 8. P value for comparison of height is 0.00 which is less than 5 percent level of significance. This implies that there is significant difference between heights of *Quercus semecarpifolia* in different altitudes. The result ANOVA, height of *Quercus semecarpifolia* measured in the habitat between 2489 m. to 2689 m. was significantly different than the height of that plant measured in the habitat between 3089 m. to 3289 m. Similarly, Khasru tree height in the habitat above 3089 m upto 3489 m. was significantly different from the tree height of that plant measured above 3489 m.

Table 8. Comparing height of *Quercus semecarpifolia* at different altitudes (ANOVA analysis).

Source	Degree of freedom	Sum of squares	Mean square	F	Significance (P value)
Between altitude	5	4382.7	876.5	21.081	0.00
Within altitude	434	18045.7	41.5		
Total	439	22428.4			

From Table 9, it can be seen that the height of tree is lowest at altitude between 2489 and 2689 m and highest between 3089 and 3289 m. The trees were found to be smaller in both the lowest and highest altitude. The height of trees has increased from the lowermost occurrence of *Quercus semecarpifolia* to the elevation around 3300 m and then the height of trees gets continuously decreased upto the uppermost limit. The trend is also clear from figure 8.

Table 9. Mean and standard deviation of height (m) of *Quercus semecarpifolia* in different altitude.

S.N	Altitude (m)	Mean height (m)/ SD
1	2489-2689	13.88 ± 3.04
2	2689-2889	17.19 ± 6.88
3	2889-3089	17.77 ± 5.46
4	3089-3289	18.61 ± 6.21
5	3289-3489	12.80 ± 5.99
6	3489-3689	10.12 ± 7.18

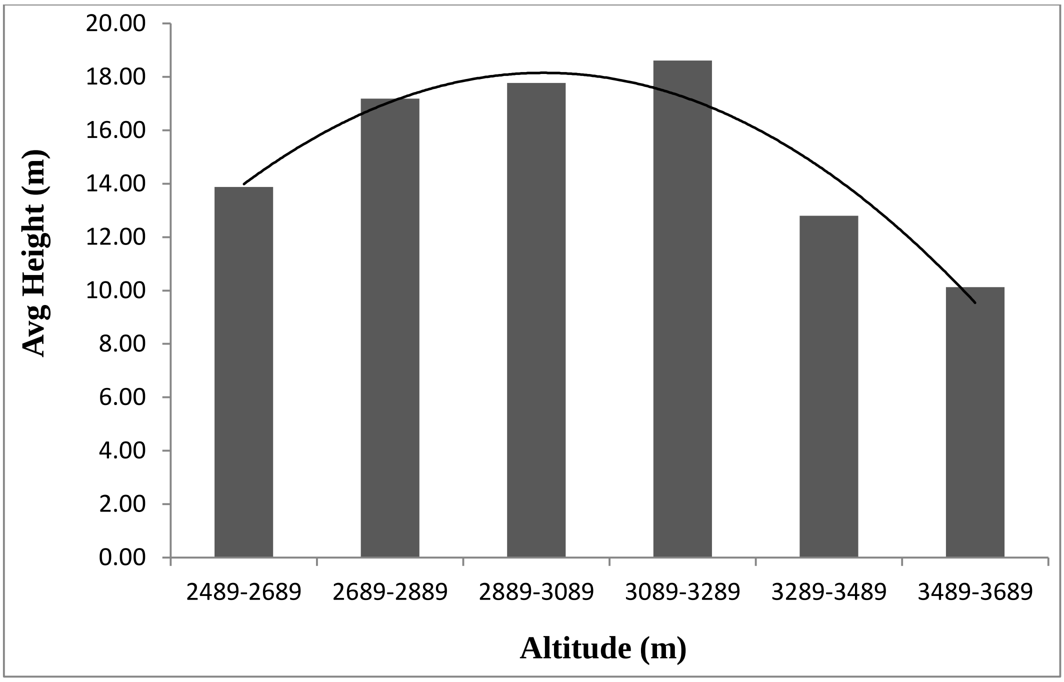

Figure 8. Average height of *Quercus semecarpifolia* along the altitudinal gradient.

4.3. Regeneration and size-class distribution

4.3.1 DBH-class distribution

The regeneration pattern resembled a typical reverse J shape with some deviation along the altitudinal gradient, except smallest DBH class (<10 cm). The density of tree species has decreased with increasing diameter. The density of tree was maximum in 10-20 cm class and followed by <10 cm DBH class in all elevations (Figure 9). The largest DBH class size (>90 c) individuals were fewest except at lower elevation.

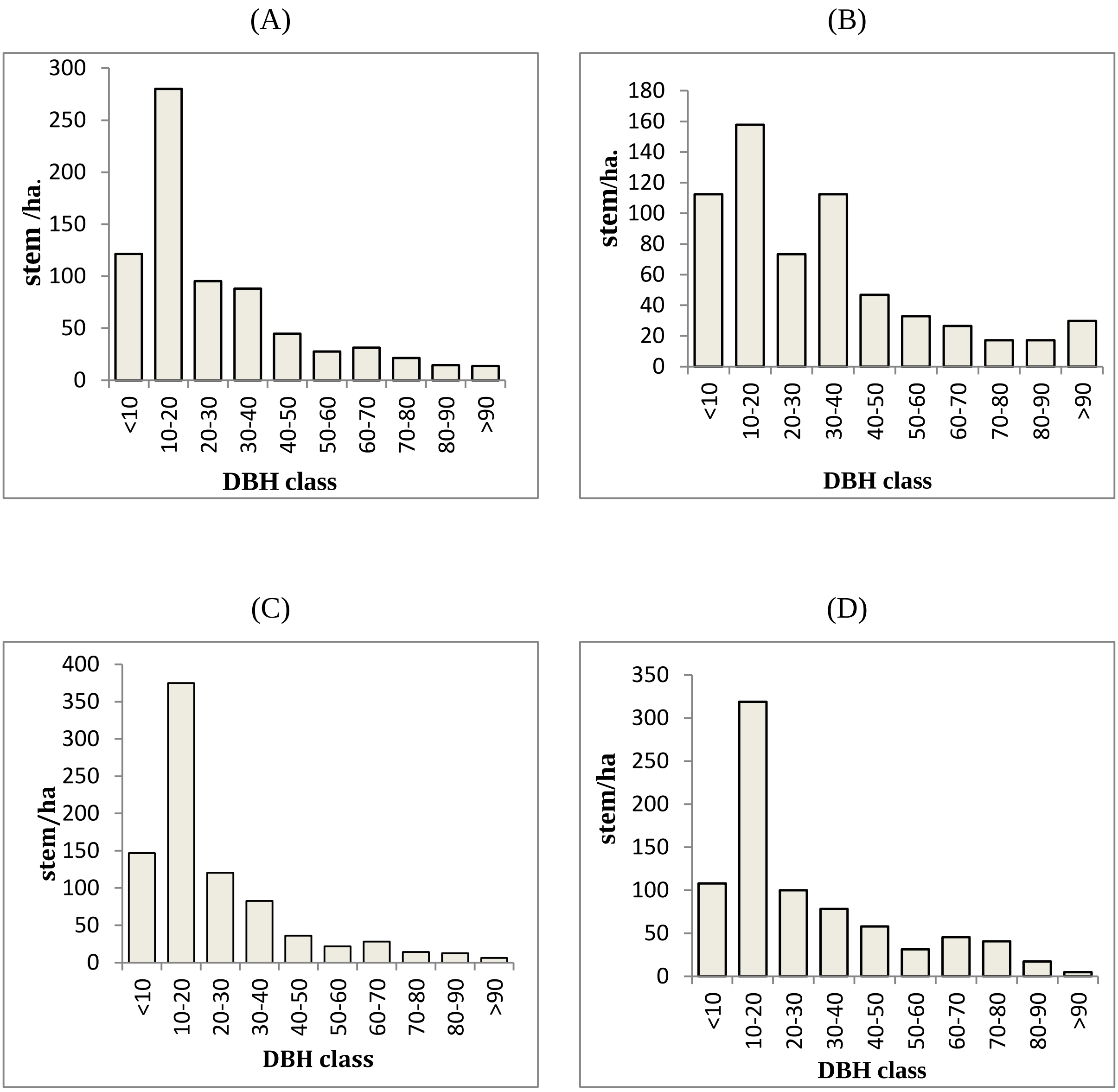

Figure 9. DBH size class distributions of all tree species in (a= all over the forest, b=at lower range, c=middle range, d=upper range).

The size class diagram of *Quercus semecarpifolia* showed variations in regeneration along altitudinal gradient. In overall forest (Figure 10a) and lower elevation range (Figure 10b), d-d curve was a typical bell shaped as maximum density in medium size class was found (size class 10cm to 50cm). In the middle elevation (Figure 10c) and upper elevation (Figure 10d), d-d curve showed typical reverse J shaped with little deviation as stem density decreased with increasing DBH except DHB class less than 10cm. Very few individuals of *Quercus* (n= 50)were more than 90 cm DBH and almost absent in lower elevation.

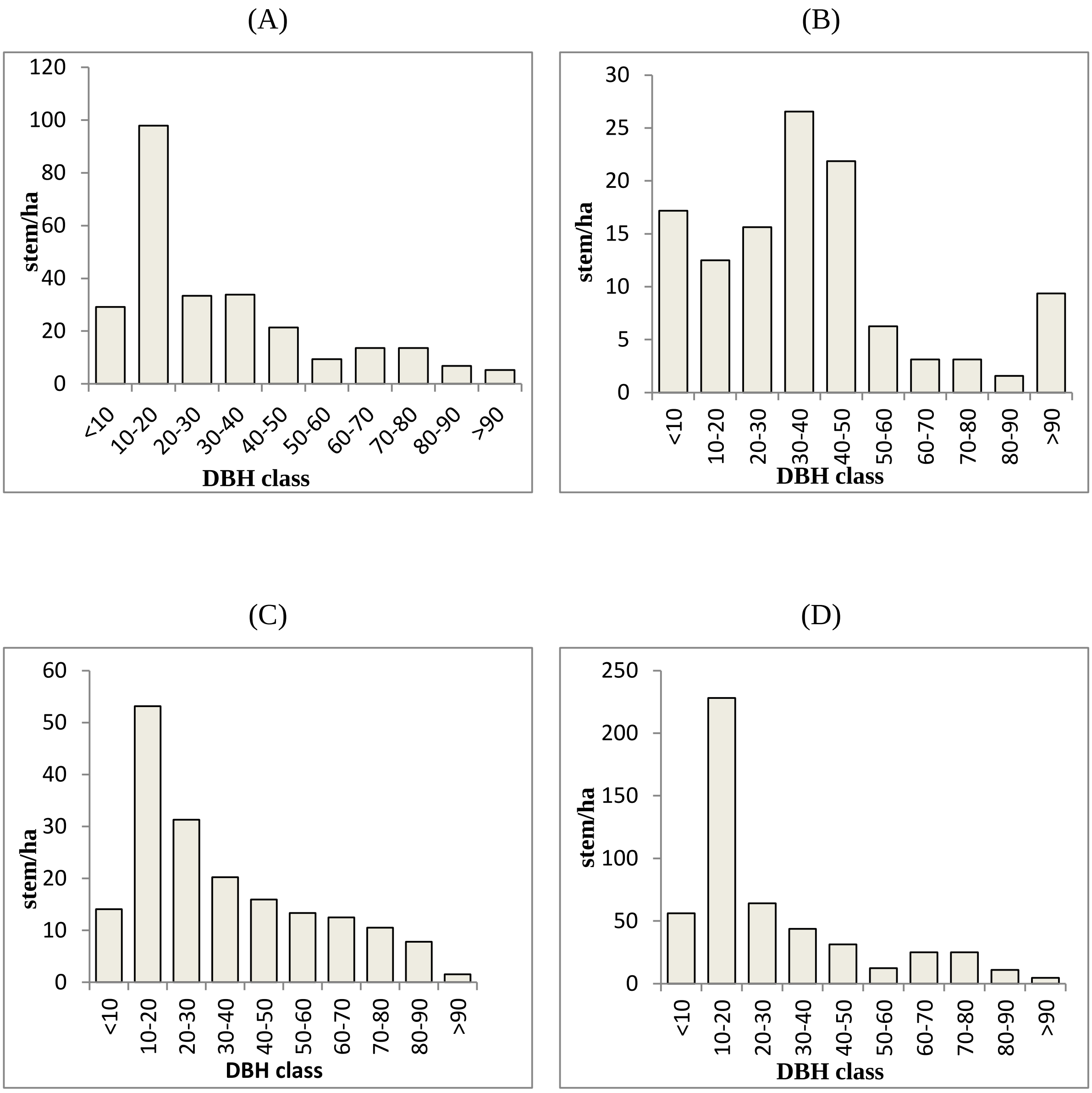

Figure 10. DBH size class distribution of *Quercus semecarpifolia* in the study site; (a) in overall forest, (b) at lower range, (c) middle range, (d) upper range).

4.3.2 Height class distribution

The bar graph of height of *Quercus semecarpifolia* showed that the trees with smaller height are denser in uppermost elevations in comparison to the lowermost and middle elevations. The density of trees within the tree height between 2 to 6 m was maximum (ca. 180 stem/ha) in uppermost elevation range with comparison to middle and lowermost elevations, where the tree density was maximum within the tree height between 10 to 14 m (Figure 11).Taller trees of >20 m height were completely absent in uppermost elevation range.

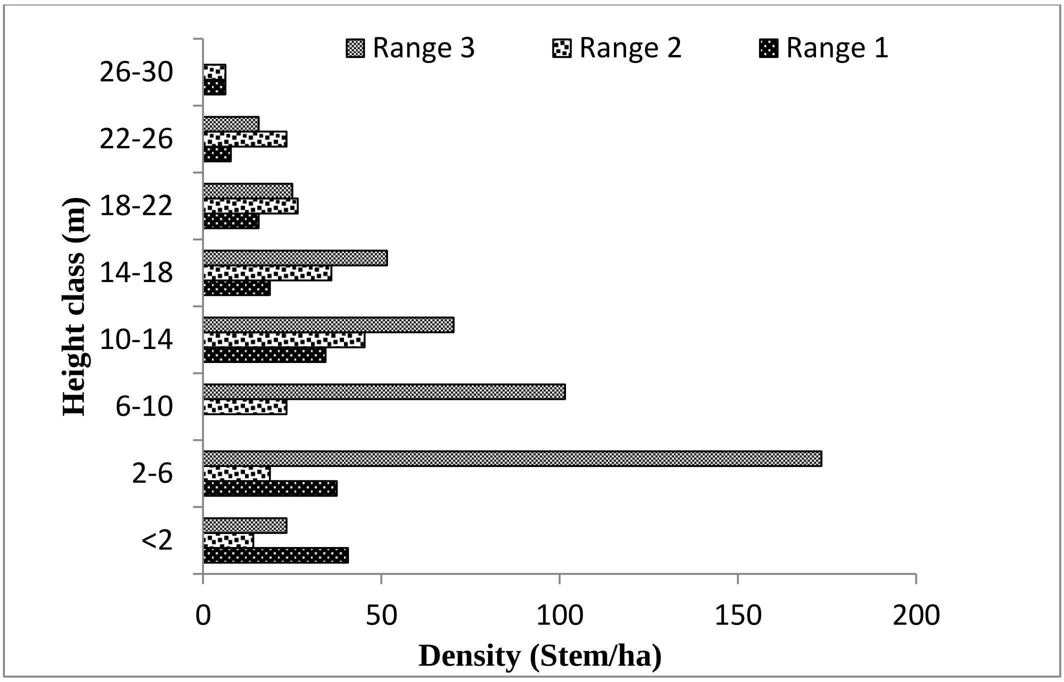

Figure 11. Density of *Quercus semecarpifolia* with different height (m) in different altitudinal range. Range 1, 2 and 3 represents lower elevational range, middle elevational range and upper elevational range.

4.4 Regeneration and environmental factors

Forest soil was found to be acidic in the study site (pH 5.0-5.9) (Figure 12) and soil pH value has increased with increasing elevation however the values were insignificantly different. All the parameters (like seedling density sapling density, canopy coverage, organic matter contained, N, P) were insignificantly negatively correlated with pH except altitude and phosphorus, which was insignificantly positively correlated (Table 10). The seedling and sapling density increased with increasing elevation (r^2=0.358, $p<0.01$ and r^2=0.368, $p<0.01$ respectively) (Figure 12, Table 10). The total organic matter contained in the soil ranged from 0.64% to 6.64%, available nitrogen from 0.03 to 0.33%, available phosphorus from 8.30 to 218 kg/ha and available potassium from 31.2 to 412.8 kg/ha. All of these values were higher at the higher elevations but the relation between them and elevation were not significant (Figure 12, Table 10). The available nitrogen with the organic matter contained and the available potassium with the available phosphorus were positively correlated (r=0.999, $p<0.01$ and r=0.463, $p<0.01$) however available phosphorus and available potassium with the canopy cover were negatively correlated r=-0.277, $p<0.05$ and r=-0.078, p=0.01) (Table 10).

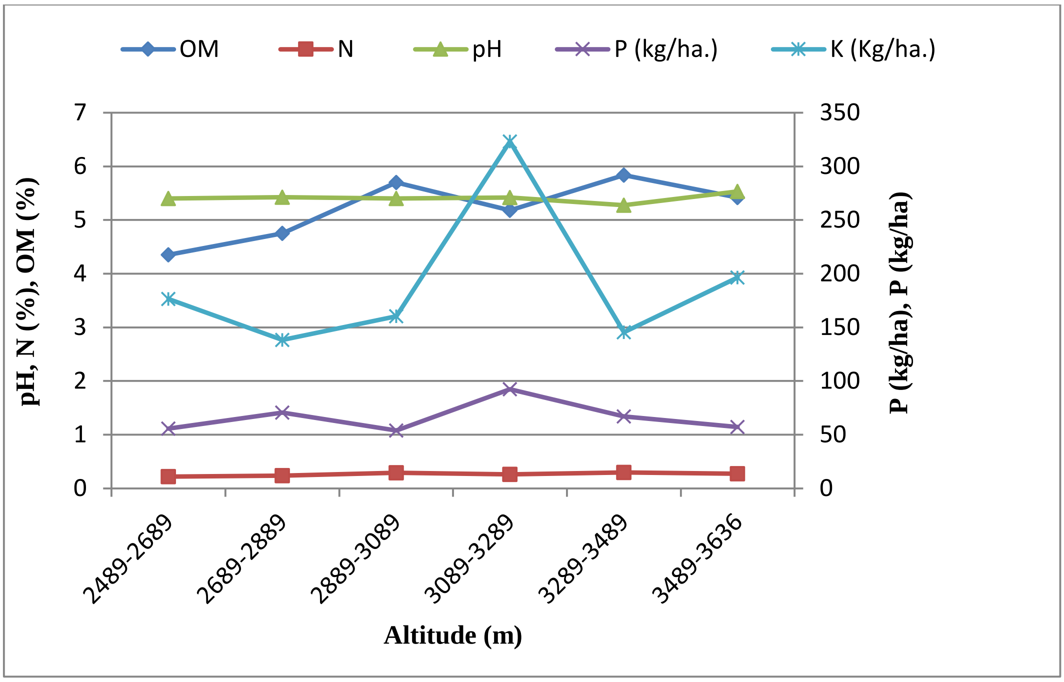

Figure 12. Soil pH, available nitrogen (%), organic matter (%)), available phosphorus (kg/ha), and available potassium (kg/ha) of soil samples collected from different elevations.

Table 10. Correlation of seedling and sapling density with microsite variables

	SEL	**SAL**	**ALT**	**CC**	**OM**	**N**	**P**	**K**
SAL	0.508**							
ALT	0.599**	0.607**						
CC	0.254	0.131	-0.082					
OM	0.249	0.133	0.262	0.097				
N	0.254	0.143	0.266	0.089	0.99**			
P	-0.069	-0.094	0.010	-0.277*	-0.229	-0.231		
K	0.027	-0.026	0.058	-0.426**	-0.201	-0.208	0.463**	
pH	-0.023	-0.067	0.039	-0.078	-0.189	-0.188	0.047	-0.025

**correlation is significant at the 0.01 level.

*correlation is significant at the 0.05 level.

SEL=Seedling, SAL=Sapling, ALT=Altitude, CC=Canopy coverage, OM=Organic matter, N=Nitrogen, P=Phosphorus, K=Potassium.

The linear regression graph of the sapling, seedling density and elevation shows the significant relationship. Figure 13a and 13c shows that 37%and 36% variations in the sapling density are explained by the increase in elevation respectively (R^2=0.368 and R^2= 0.358), where 01 unit increase in elevation the sapling, seedling density is increased by 1.57 and 8.05 unit respectively (y= -3.74E3+1.57*X, $P<0.05$ and y= 2.06E4+8.05*X, $P<0.05$). Similarly, seedling and sapling density also shows the significant linear relationship (Figure 13d). 26% variation in seedling density is explained by increase in the sapling density in the forest (R^2=0.258, $P<0.05$).However, sapling density and nitrogen percentage shows the linear relationship but insignificant (Figure 13b). Only 2.1% variation in sapling density is explained by increase in Nitrogen percentage (R^2=0.021). From all these regression analysis it can be concluded that elevation gradient is the main factor which strongly affected the seedling and sapling density in the forest.

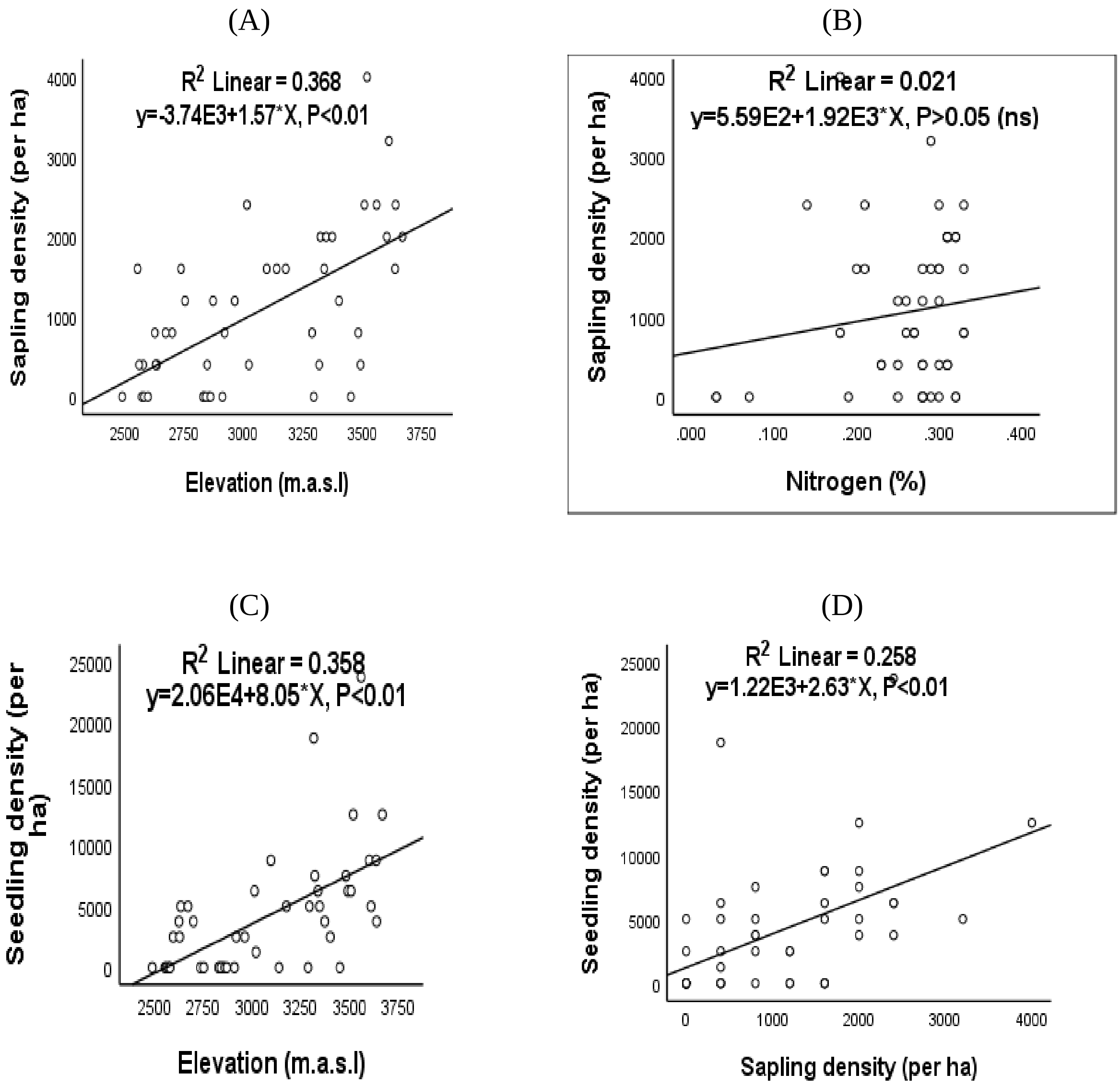

Figure 13. Relation of sapling density with altitude (a) and nitrogen (b); seedling density with altitude (c) and sapling (d). The fitted lines are based on linear regression.

CHAPTER 5: DISCUSSION

5.1. Vegetation composition and diversity

Variations in temperature, elevation, aspects, geology and soils all combine to create a multitude of habitats for a wide variety of flowering plants, trees, ferns, mosses and lichens in ANCA. At least 535 species of angiosperm, 12 species of gymnosperm and 69 species of Pteridophyte have been documented from ANCA by DNPWC (2019). Similarly, Singh (2014) documented 428 species of vascular plants belonging to 112 families and 323 genera from the Shivapuri National Park. However, this study found much lower number. These differences might be due to the study design and study area i.e, current study did not cover the whole ANCA. In this present study Compositae and Rosaceae are the largest families having highest number of genera and species. This finding is also similar to findings of Singh (2014) in Shivapuri National Park and findings of DNPWC (2019) in ANCA.

Information on species composition and diversity patterns is fundamental for conservation of natural areas; these patterns have been frequently focused in ecological studies. The knowledge of the floristic composition of a plant community is a prerequisite to understand the overall structure and function of any ecosystem. Quantitative analysis of diversity and regeneration status of tree species recorded in this study may provide baseline information for formulating conservation and management strategies for ANCA forest. The values of diversity indices reported in this study are best fitted within those reported earlier from different parts of the Himalayas.

The tree diversity index analyzed for most of the low elevation Central Himalayan forest is (0.33 - 2.95) by Saxena and Singh (1982). Tripathi *et al.* (1991) have reported tree diversity values between 2.69 and 3.82from low to high elevation. Giri *et al.* (2008) have reported tree diversity between 0.88 and 2.11. Monk (1967) and Risser and Rice (1971) obtained between 2 and 3 as the highest values for diversity index of temperate forest. The variation in diversity might be due to the presence in tree species such as Oak dominated forest had higher diversity in compared to Pine dominated forest (Sing *et al.*, 2014). In present study Simpson's Index of Dominance (C) for tree (0.16) was found to higher than species diversity (2.71) in the forest. Jiangming *et al*. (2008) found Shannon-Wiener Index (H') of species diversity to be 3.48 in subalpine broadleaved forest of western Sichuan (China). In mixed *Larix chinensis* forest of China, Liyun *et al*. (2006) found Shannon-Wiener Index (H') of species diversity to be 4.75.

Comparing with these values in the forest had similar value of Shannon – Wiener Index (H') of species diversity. There was low concentration of dominance to single species (i.e. high evenness) which was indicated by lower value of Simpson's index than of Shannon-Wiener index. This showed that the dominance in the present study forest was not concentrated to any single species. Singh *et al.* (2016) found that the high evenness of tree species layer and low concentration of dominance to the single species in the Grawhal Himalaya which is similar to the present study.

5.2. Community Structure

The forest was composed of mixed type; Altogether 35 tree species with *Quercus semecarpifolia* were recorded and their combined density was 724 stem/ha. The upper canopy was mainly formed by *Q. semecarpifolia*, *Ilex dipyrena, Saurauia nepaulensis*, *Betula alnoids* in lower elevation (annex diversity) and *Q. semecarpifolia, Betula utilis* and some species of Rhododendron formed upper canopy in higher elevations. The other species formed a sub canopy and lower canopy. The *Q. semecarpifolia* alone had a tree density of 235 stem/ha and basal area 42.221 m^2/ha. Present value closely agree with reports from Shivapuri National Park (217 stem/ha) by Siluwal et al. (2001) and 203 stem/ha by Shrestha et al. (2017). Kharsu density in Langtang National Park was 400 ha^{-1} (Vetaas, 2000) and in Kumaun it was 872 ha^{-1} (Singh and Singh, 1992). Basal area (48.4m^2 ha^{-1}) in Kumaun forest is similar to the present value (42.221 m^2/ha). Seedling density of *Q. semecarpifolia* in the forest was 4010 pl/ha, which is very close to the seedling density reported by Shresth *et al.* (2017) in Shivapuri Hill, Central Nepal. Khasru forest elsewhere in Central Nepal also had well representation of seedling (Vetaas, 2000; Metz, 1997) but in some forest of Kumaun Himalaya (India) seedlings were extremely poorly represent (Singh and Singh, 1992). In present study maximum seedling density (23750) was found at 3558 m elevation in the barren land with trampling and Cow dung, and had thin litter with open canopy (20%). This clearly indicates that grazing was not a limit to seedling growth, as reported by Metz (1997) in disturbed stand.

Comparatively sapling density was lower than the seedling density (4010 stem/ha>1058 stem/ha) in the study area. Sapling was present in about 75% of the total sampling plot in the total study area and at lower most elevation range seedling density was fewest. Shresth *et al.* (2004) reported too low sapling density (62 stem/ha) and they were present only 10% of total sampling plot in Shivapuri Hill. Density of seedlings should be greater than the density of saplings for a normal demographic development (West *et al.*, 1981) but in present study, differences between seedling and sapling density is far more. This implies that weak demographic development.

Lower altitude and moderate slopes constitute suitable habitat condition for many tree species (Gairola *et al.*, 2011), comparatively this number of associated species was high and density of *Quercus semecarpifolia* was low at lower elevation in present study. However, *Q. semecarpifolia* preferred higher altitude and comparatively as a result in steeper slopes which may be due to its competition with other tree species at lower elevation. So, that the density of *Q. semecarpifolia* is higher in higher altitude. Results are similar with Lacasia (2014) who reported that the *Q. semecarpifolia* forest showed regeneration in steep slopes in Gaurishankar Conservation area and it reached up to 3500 m elevation in Darchula Chamilaya Valley, Nepal (Eliott, 2012). In present study, *Q. semecarpifolia* reached upto 3636 m elevation and contributed in treeline formation.

However, Sapling density was less than that of seedling density at higher elevations. So the problem of regeneration is that khasru seedling did not survive beyond sapling stage under its own canopy. Primary reason behind weak representation of sapling might be due to the human disturbances such as cutting down and looping of small sized trees (saplings) for fuel wood, making temporary residential house during the NTFP collection and Shepherd.

In present study, basal area of *Q. semecarpifolia*is is relatively higher in the higher elevation. It was because old growth forest of *Q. semecarpifolia* were present in the higher altitude. Gairola *et al.* (2011) reported that relatively high basal area of *Abies pindrow* in the old growth forest in Grawhal Himalaya, India. Generally *Quercus* forest has many anthropogenic disturbances like looping, stem cutting, grazing, fuel wood collection, etc are prevalent in the Himalayan region (Troup, 1921; Vetaas, 2000; Shresth, 2003; Tashi, 2004). However in present study, disturbances (looping and cutting of pole sized tree) only in lower elevation and forest in higher elevations less prevalent from disturbances. Morever, forest in higher elevation seems to be reached its upper limit of productivity. These could be the possible reason for high basal area value in this region.

5.2.1. Comparison of DBH and Height in Different Altitude

Diameter and height has also been used as a basis for distinguishing developmental stages in natural forests. These factors determine the forest stand structure which is also known to change with elevation (Kruspan, 2009). Most of the studies show that height and diameter of trees decreases with elevation. But in present study both the trees height and diameter are smaller in both the lowest and highest altitude. Presence of smaller sized trees at 3289 m elevation is due to the higher number of associated tree species and is a immature forest in this elevation. The decrease in height and diameter of trees above 3289 m elevation might be due to climatic factors. The limiting climatic conditions in the higher elevations like the physical effects of wind, snow, site factors, physiological effects, and nutrient limitations may have strong controlling effects in limiting height and diameter in higher altitudes (Stevens & Fox, 1991).

5.3. Regeneration and size-class distribution

5.3.1. DBH class distribution

The regeneration pattern (including all tree species) resembled a typical reverse J shape with some deviation along the altitudinal gradient (Figure 9a to 9d) which is the indication of regeneration (Vetaas, 2002). However, regeneration pattern resembled reverse J shape only above 2800 m elevation for *Q. semecarpifolia*. (Figure 10c and 10d). Below 2800 m elevation the d-d curve appeared bell shape (Figure 10a and 10b), a characteristics of non regenerating forest (Shresth *et al.*, 2004). So, only above 2800 m elevation *Q. semecarpifolia* shows the regeneration and might be the suitable habitat in this elevation. Size class diagram of *Q. semecarpifolia* resembled bell shape with higher density of medium sized trees in the *Quercus* forest in Shivapuri hill (Shresth *et al*., 2004) which is similar to size diagram for *Q. semecarpifolia* below 2800 m elevation in present study. The regeneration of *Quercus semecarpifolia* also finds to be weak in old growth forest of Bhutan (Tashi, 2004).

In present study, regeneration potential of overall forest (mixed prospective) was higher than that of *Quercus semecarpifolia* alone in the forest. Sujakhu (2015) find that the regeneration potential of tree species is higher in the mixed forest than the *Betula* forest in Manaslu Conservation area. An open canopy caused by mild disturbance to the forest allows the growth of seedlings and saplings, which ensures sustainable regeneration. However, in a mature forest with closed canopy, seedling establishment is constrained by lower light intensity on the ground surface. The fact is that tree species are well-represented at the adult stage but not as seedlings indicates a high light requirement (Borman & Likens, 1979). Removal of canopy trees increased light intensity to the forest floor and reduced litter accumulation, which is suitable for seed germination and seedling establishment of species. (Carlton & Bazzaz, 1998).

Population structure of khasru from seedling to mature tree revealed that the regeneration was hampered even if the trees were producing abundant number of viable seeds, as evident from seedling density in the present study site. The major problem appeared to be the survival of large seedling and sapling responsible for the poor regeneration of Khasru at lower elevation in the study area. A wide range of biotic and abiotic factors have been proposed by Vetaas (2000) to be responsible for large scales of death of seedling, sapling and recruit, and thus the poor regeneration of khasru. Vetaas (2000) suggested that fire prevents recruit from reaching the canopy phase and some external factors (e.g. radiation) rather than soil may be responsible for lower representation of sapling. However, in present study no any fire signs had been appeared. Metz (1997) hypothesized that khasru cannot regenerate under its own canopy and needs severe disturbance for successful regeneration. In present study, maximum number of seedlings has been found in the plot which have open canopy with less herbaceous species. Negi and Naithani (1995) reported that the dense growth of herbs (e.g. *Pteracanthus alatus* and *P. urticifolius* inhibited the survival of seedling and sapling. Similarly adverse effect of herbaceous cover on seedling emergence, survival and growth was reported by Tripathi and Khan (1990) in *Quercus dealbata* and *Q. griffithii*. In disturbed forest lopping reduced seed production, and litter collection damaged the seedling and sapling (Shrestha and Poudel, 1996).

5.3.2. Height class distribution

Height of *Quercus semecarpifolia* were of smaller height in upper elevations with compare to the lower and middle elevations. The density of tree within the tree height between 2 to 6 m was maximum (ca. 180 stem/ha) in upper elevation range with compare to middle and lower elevations. Tree height more than 20 m tall were completely absent in uppermost elevation range. Lacasia (2014) reported the results of the height class diagrams, that regeneration is continuous in the least degraded forest and almost completely absent in the disturbed forest, which may lead to the displacement of this species by other tree species in the future. It also shows that canopy disturbances create a very dense herbaceous and shrub layer, which may outcompete *Q. semecarpifolia* seedlings and saplings.

5.4. Soil

Soil of the forest in the study site was acidic (pH 5.0-5.9) and soil pH had increasing pattern with increasing elevation. Shrestha *et al*. (2007) reported that soil of mixed *Betula utilis- Abies spectabilis* forest was slightly acidic with pH 5-7; similar to the present study where the *Q. semecarpifolia* was found mixed with some conifer trees such as *Tsuga dumodsa* and *Abies* *spectabilis*. The acidic nature of the soil is due to the conifer foliage that contain acid substances and after decomposition of leaves it makes soil slightly acidic or neutral (Zhang and Zhao, 2007). The pH range of 5.5 to 6.5 may provide most satisfactory plant nutrient and is most suitable for most plants (Brady and Well, 1984). The edaphic condition (soil moisture, OM, N, P and K) of forest soils was higher at high elevations which appear to be favorable for the establishment of early successional deciduous broadleaved species.

The seedling density is positively correlated with the nutrients such as nitrogen (N) and Phosphorus (P). The values of these nutrients were also higher at higher elevations and might be important in facilitating the regeneration process. Results found similar with other Himalayan studies suggesting that high levels of LOI and nitrogen facilitate regeneration (Saxena *et al*., 1984; Singh *et al*., 1990; Singh and Singh, 1987). Seedling relationship with canopy is also positive but showed weak relationship (not significant). Seedlings under modrrate canopy had high performance and increased canopy seems to facilitate a very dense herbaceous ground layer and a dense thicket of shrubs in very open sites (Vetaas, 1997). Competition with the sub-canopy shrubs and herbaceous vegetation may play an important role as suggested by several other studies (Lorimer *et al*., 1994, Negi and Naithani, 1995, Crow, 1988).

CHAPTER 6: CONCLUSIONS AND RECOMMENDATION

6.1. Conclusion

The forest in the study area was mixed forest in all three elevation ranges. The woody species richness was lower than the herb species richness in all elevation ranges. The dominant tree species in the lower elevation were *Quercus semecarpifolia, Abies spectabilis, Rhododendron arboreum, Tsuga dumosa* and *Acer capadocicum* and in the middle elevation*Quercus semecarpifolia, Acer pectinatum, Rhododendron barbatum, Rhodendron arboretum, Betula utilis* were dominant. Similarly, in the uppermost elevation range mainly *Quercus semecarpifolia, Betula utilis, Prunus nepaulensis, Tsuga dumosa, Juniperus squamata* were dominant tree species. This implies that the *Quercus semecarpifolia* is dominant species in all the elevations forming a dominating forest. Woody species richness decreased with increased elevation whereas species diversity of the forest was relatively low, which might be due to the anthropogenic factors such as cattle grazing, fire wood collection and logging.

Density-diameter curve for all tree species in the forest was continuous and show slightly deviated typical reverse J – shaped structure and hence show sustainable regeneration in all the elevation ranges. However, density diameter curve for *Quercus semecarpifolia* was not similar for all the elevations as it was discontinuous in the lower elevation range and for the overall forest; and slightly deviated typical J- shaped in the middle and uppermost elevation ranges. This suggests that the middle and uppermost elevation range i.e above 2800 m elevation the *Quercus semecarpifolia* show sustainable regeneration. The sequence of tree young and juvenile of *Q. semecarpifolia* were as seedlings>saplings>trees and hence shows regeneration in all the elevation ranges. Both the seedling and sapling density were higher in the higher elevations in compared to lower elevation range. Height and DBH of *Q. semecarpifolia* were maximum in the 2800 m elevation and decreased both in higher and lower elevations. The basal area was maximum in the uppermost elevation even the DBH decreased is due to the density of younger *Quercus* tree were greater in the upper elevations. Absence of tree with high girth class (> 90 cm) indicates disturbances in the forest.

Microsite conditions such as organic matter content and nitrogen showed positive correlation with the saplings of *Q. semecarpifolia* and in addition potassium showed positive correlation with the seedlings but none of their values were significant. This indicates that soil nutrient plays important role in the seedling and sapling growth and organic matter adds the soil where it supports the rooting in the soil. Beside that both the seedling and sapling showed positive correlation with the tree canopy but not significant. The moderate canopy is batter for growth of seedlings as light facilitations. The dense canopy restricts the light requirement to the ground level which inhibits seedling growth and high canopy openness promotes higher herbaceous species and thus increases the competition to the seedlings.

6.2. Recommendation

The natural regeneration of *Quercus semecarpifolia* is still very perplexing. Following recommendation have been suggested on the basis of the results of present study:

1. More experimental works are needed to further supplement the result of present study.

2. Seasonal grazing by cattle and human beings as a NTFP collector are main causes of forest destruction. Thus it should be controlled.

3. The relationship between canopy coverage and seedling recruitment density in the forest was positive. So that there should be maintenance of moderate canopy cover. That's why extreme lopping should not be done.

4. The DBH and height class distribution of trees in the forest in lower altitude range (which is near to the human settlement) shows that the failure of regeneration of *Quercus semecarpifolia* is a real problem. If management patterns are not adapted, the forest will becomes dominated by other less useful species for the local communities. Therefore strong management practices need to be applied for the conservation of the *Quercus* forest of the region.

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APPENDICES

Appendix I. Checklist of Herb, Shrub and Tree Species Found in the Studied Forest.

Rangee	Family	Scientific namee of species	Nepali name	Habit	Elevation in ANCA
1	Asparagaceae	*Asparagus racemosus* Wilid.	Kurilo	Shrub	2400
1	Cannabaceae	*Cannabis sativa* L.	Bhango, Ganja	Shrub	2300
1	Brassicaceae	*Sarcococca saligna* (D. Don) Mull. Arg.	Telparo	Shrub	2400
1	Hyperaceae	*Hypericum urallum* Buch. Hum. ex D. Don	Ratomirado	Shrub	2400
1	Primulaceae	*Myrsine africana* L.	Chadiyello	Shrub	2400
1	Rosaceae	*Rubus foliolosus* D. Don	Kalo ainselu	Shrub	2400
1	Urticaceae	*Bouhmeria penduliflora* Wedd. ex D. G. Long		Shrub	2400
1	Urticaceae	*Debregeasia salicifolia* (D. Don) Rendle	Tusare	Shrub	2400
1	Rosaceae	*Rosa brunonii* Lindl.		Shrub	2500
1	Buxaceae	*Buxus wallichiana* Bail.	Papro	Shrub	2600
1	Polygonaceae	*Rumex hastatus* D. Don	Raktabhuj	Shrub	2600
1	Rosaceae	*Rubus calycinus* Wall. ex D. Don		Shrub	2300-2700
1	Rosaceae	*Prinsepia utilis* Royle	Dhatelo	Shrub	2400-2600
1	Rosaceae	*Prinsepia utilis* Royle		Shrub	2400-2600
2	Sexifragaceae	*Bergenia bola*		Shrub	3300
2	Rosaceae	*Rosa macrophylla* Lindl.		Shrub	2800-3200
3	Ericaceae	*Rhododendron anthopogon* D. Don	Chimle	Shrub	3500
3	Salicaceae	*Salix lindleyana* Wall. ex Anderson		Shrub	3600
3	Thymelaceae	*Dephne retusa* Hemsl.		Shrub	3300-3700
4	Caprifoliaceae	*Leycesteria formosa* Wall.		Shrub	2400-3200
4	Hydrangeaceae	*Deutzia compacta* Craib	Bhyatkude, Kankunyu	Shrub	2400-3300

4	Fabaceae	*Desmodium elegans* DC.	Bhattyau	Shrub	2700-3000
4	Ericaceae	*Rhododendron campanulatum* D. Don	Ratakapa	Shrub	3000-3600
4	Berberidaceae	*Berberis kumaonensis* C.K. Schneid		Shrub	3000-3700
4	Rosaceae	*Potentilla fruticosa* L.		Shrub	3100-3500
4	Rosaceae	*Prunus bracteopadus* Koehne		Shrub	
5	Brassicaceae	*Sarcococca hookeriana* Baill.	Telparo	Shrub	2400-3500
5	Ericaceae	*Rhododendron lepidotum* Wall. ex G. Don	Sunpati	Shrub	2400-3600
5	Polygonaceae	*Aconogonum molle* (D. Don) H. Hara	Thotne	Shrub	2400-3700
5	Rosaceae	*Sorbus foliolosa* (Wall.) Spach		Sub-shrub	2400-3700
5	Rosaceae	*Artemisia gmelinii* Weber ex Stechm	Pati	Shrub	2500-3900
5	Rosaceae	*Rosa Siricea* Lindl.	Khuyasi	Habit	2600-3700
1	Aquifoliaceae	*Ilex dipyrena* Wall		Tree	2400
1	Betulaceae	*Betula alnoids* Buch. Ham. ex D. Don	Saud, Kalo bhojpatra	Tree	2500
1	Actinidaceae	*Saurauia napalensis* DC.	Gogin, Fokse	Tree	2600
1	Anacardiaceae	*Texicodendron wallichii* (Hool. f.)	Bhakimlo	Tree	2400-2800
1	Betulaceae	*Alnus nepalensis* D. Don	Uttis	Tree	2400
1	Coriariaceae	*Coriaria nepalensis* Wall.		Tree	2400
1	Juglandaceae	*Juglans regia* L.	Okhar	Tree	2400-2700
1	Meliaceae	*Toona sinensis* (juss.) M. Roem		Tree	2400
1	Pentaphylaceae	*Eurya acuminata* DC.	Bhatras	Tree	2400
1	Rosaceae	*Prunus cerasoides* D. Don	Paiyu	Tree	2400
1	Rutaceae	*Xenthoxylum armatum* DC.	Timur	Tree	2500
1	Sapindaceae	*Acer capadocicum* Gled.	Tililo	Tree	2400-2800
1	Sapindaceae	*Acer sterculiaceum* Wall		Tree	2400-2600
1	Sapindaceae	*Acer sterculiaceum* Wall.		Tree	2600
1	Sapindaceae	*Aesculus indica* (Wall. Ex Cambess) Hook.	Pangar	Tree	2600

1	Ulmaceae	*Ulmus wallichiana*	Chamde	Tree	2400-2700
1	Cannabaceae	*Celtis australis* L.	Khadko	Tree	2400
1	Cupressaceae	*Juniperus Squamata* Buch. Ham. ex D. Don	Dhupi	Tree	2400
4	Ericaceae	*Lyonia ovalifolia* (wall.) Drude		Tree	2400-3300
4	Ericaceae	*Rhodendron arboreum* Sm.		Tree	2400-3300
4	Ericaceae	*Rhododendron barbatum* Wall. ex G. don		Tree	2800-3200
4	Lauraceae	*Neolitsea pallens* D. Don		Tree	2400-2900
4	Rosaceae	*Sorbus lanata*(D.Don) Schauer		Tree	3000-3700
4	Sapindaceae	*Acer pectinatum* Wall. Ex G.Nicholson		Tree	2700-3200
4	Elaeagnaceae	*Hippophae salicifolia* D. Don	Sankhadhara	Tree	2500-2900
5	Betulaceae	*Betula utilis* D. Don	Bhuj	Tree	2800-3700
5	Celasytaceae	*Euonymus porphyreus* Loes.	Dandan	Tree	2700-3400
5	Fagaceae	*Quercus semecarpifolia*	Thulo Banjh, Timsu	Tree	2300-3700
5	Rosaceae	*Prunus cornuta* (Wall. ex Royle) Steud.	Lek Arato	Tree	2400-3500
5	Rosaceae	*Prunus nepaulensis* (Ser.) Steud	Arya, Airo	Tree	2500-3700
5	Rosaceae	*Prunus persica* (L.) Batsch		Tree	2400-3600
5	Rosaceae	*Sorbus vestitata* (Wall ex G. Don) Lodd.		Tree	2400-3700
5	Pinaceae	*Tsuga dumosa* (D. Don) Eichler	Thingre salla	Tree	2400-3600
5	Pinaceae	*Abies spectabilis* (D.Don) Spach	Gobre salla	Tree	2400-3800
5	Cupressaceae	*Juniperus indica* Bertol.	Dhupi	Tree	2400-4500
1	Acanthaceae	*Barlaria cristata* L.		Herb	2400
1	Acanthaceae	*Strobilanthes tomentosa* (Nees) J.R.I Wood		Herb	2600
1	Acanthaceae	*Strobilanthes urticifolia* Wall. ex Kuntze		Herb	2400-2600

1	Amaranthaceae	*Achyranthes bidenata* Blume		Herb	2400
1	Araceae	*Arisaema flavum*	Kalo banko	Herb	2230-2280
1	Asteraceae	*Galinsoga quadriradiata* Ruiz and Pav.		Herb	2300
1	Balsaminaceae	*Impatiens bicornuta* Wall.		Herb	2400-2800
1	Caryophyllaceae	*Stellaria media* (L.) Vill.		Herb	2600
1	Cyperaceae	*Carex myosurus* Nees		Herb	2400
1	Cyperaceae	*Eriophorum comosum* (Wall.) Nees		Herb	2700
1	Fabaceae	*Trifolium repens* L.	Tinpate	Herb	2600
1	Gentianaceae	*Gentiana capitata Buch*. Ham. ex D. Don		Herb	2400-3700
1	Gentianaceae	*Swertia angustifolia Buch*. Ham. Ex D. Don	Tite, Chiraito	Herb	2600
1	Poaceae	*Drepanostachyum falcatum* (Nees) Keng f.	Nigalo	Herb	2400-2700
1	Poaceae	*Imperata cylindrica* (L.) P. Beauv	Siru	Herb	2400
1	Polygonaceae	*Persicaria capitata* (Buch. Ham. ex D. Don) H. Gross	Ratnaulo	Herb	2400
1	Ranunculaceae	*Thalictrum foliolosum* DC.		Herb	2400-2700
1	Rosaceae	*Potentilla nepalensis* Hook.		Herb	2400
1	Solanaceae	*Nicandra physalodes* (L.) Gaertn.	Ishmagoli	Herb	2600
1	Urticaceae	*Pilea umbrosa* Wall. ex Blume		Herb	2400-2800
1	Cyperaceae	*Carex myosurus* Nees		Herb	2400
1	Cyperaceae	*Eriophorum comosum* (Wall.) Nees		Herb	2700
1	Poaceae	*Drepanostachyum falcatum* (Nees) Keng f.	Nigalo	Herb	2400-2700
1	Poaceae	*Imperata cylindrica* (L.) P. Beauv	Siru	Herb	2400
2	Amaranthaceae	*Achyranthes aspera* L.	Bipya kuro	Herb	2900
2	Rosaceae	*Potentilla arbuscula* (D. Don)Prodr. Fl.		Herb	3300

3	Asteraceae	*Anaphalis xylorhiza* Sch. Bip. Ex Hook. f.		Herb	3400-3900
3	Caprifoliaceae	*Nardostachys jatamansi* (D. Don) DC	Balchan	Herb	3200-3700
3	Liliaceae	*Lilium nanum* Klotzsch		Herb	3700
3	Polygonaceae	*Aconogonon rumicifolium* (royle ex Bab.) H. Hara	Bhuj	Herb	3300-3700
3	Rosaceae	*Potentilla eriocarpa* Wall. ex Lehm		Herb	3600
3	Rosaceae	*Potentilla eriocarpa* Wall. ex Lehm.		Herb	3600
4	Adaxaceae	*Vivernum continifolium* D. Don		Herb	2200-2900
4	Araceae	*Arisaema concinnum* Schoot	Banko	Herb	2200-2900
4	Araceae	*Arisaema tortuosum*	Gau banko	Herb	2700-2900
4	Asparagaceae	*Polygonatum cirrhifolium* (Wall.) Royle	Khiraulo	Herb	2300-3000
4	Asparagaceae	*Polygonatum hookari* Baker		Herb	2900-3700
4	Asteraceae	*Anaphalis triplinervis* (Sims) C.B. Clarke	Phosrosan	Herb	2400-3000
4	Asteraceae	*Artimecia dubia* Wall. Ex Besser	Titepati	Herb	2400-3200
4	Asteraceae	*Aster sikkimensis* Hook. f.		Herb	2400-3100
4	Asteraceae	*Cirsium falconeri* (Hook. F.) Petr.		Herb	3000-3700
4	Brassicaceae	*Rorippa amphibia* (L.) Besser ?		Herb	
4	Caryophyllaceae	*Stellaria monosperma* Buch. Ham. ex		Herb	2400-3400
4	Cyperaceae	*Kobresia nepalensis* (Nees) Kuk.		Herb	2900-3700
4	Gentianaceae	*Gentiana stipitata* Edgew.		Herb	3000-3700
4	Geraniaceae	*Geranium nepalense* Sweet		Herb	2400-3200
4	Poaceae	*Cynodon Dactylon* (L.) Peris.	Dubi, Dubo	Herb	2400-3000
4	Rosaceae	*Galium asperifolium* Wall.		Herb	2400-3000
4	Rosaceae	*Galium elegens* Wall.		Herb	2400-3000
4	Rosaceae	*Potentilla arbuscula* D. Don (New)		Herb	

4	Rosaceae	*Potentilla argyrophylla* Wall. ex Lehm.		Herb	3200-3900
4	Rosaceae	*Potentilla sundersiana* Royle		Herb	3100-3700
4	Urticaceae	*Girardinia diversifolia* (Link) Friis	Allo, Chalne Sisno	Herb	2600-3000
4	Urticaceae	*Lecanthus peduncularis* (Wall. ex Royle) Wedd	Kholejhar	Herb	2400-3200
4	Gentianaceae	*Swertia ciliata* (D. Don ex G. Don) B.L. Burtt		Herb	2800-3700
4	Gentianaceae	*Swertia paniculata* (new)		Herb	
4	Poaceae	*Impetiens repens* (new)		Herb	
4	Zingiberaceae	*Roscoea alpina* Royle		Herb	
4	Cyperaceae	*Kobresia nepalensis* (Nees) Kuk.		Herb	2900-3700
4	Poaceae	*Cynodon Dactylon* (L.) Peris.	Dubi, Dubo	Herb	2400-3000
4	Poaceae	*Impetiens repens* (new)		Herb	
5	Apiaceae	*Heraclem nepalense* D. Don	Chatere	Herb	2400-3700
5	Apiaceae	*Heracleum candicans* Wall. ex DC.		Herb	2200-3700
5	Apiaceae	*Heracleum wallichii* DC.	Chetare	Herb	2700-3700
5	Araceae	*Arisaema jacquemonti* Blume	Chari banko	Herb	2700-4300
5	Asparagaceae	*Polygonatum verticillatum* (L.) All.		Herb	2800-3400
5	Asteraceae	*Anaphalis contorta* (D. Don) Hook. F.		Herb	1700-4700
5	Asteraceae	*Anaphalis margaritacea* (L.) Benth. & Hook. F	Pasan	Herb	2400-3600
5	Asteraceae	*Anaphalis royleana* DC.		Herb	1200-4200
5	Asteraceae	*Aster falconeri* (C.B. Clarke)		Herb	2700-3700
5	Asteraceae	*Dubyaea hispida* (D. Don) DC.		Herb	2700-3700
5	Asteraceae	*Saussurea fastuosa* (Decne.) Sch. Dip.		Herb	2700-3700
5	Asteraceae	*Senecio cappa* Buch. Ham. ex D. don)		Herb	2400-3700

5	Asteraceae	*Senecio raphanifoliums* Wall. ex DC.		Herb	2300-3700
5	Balsaminaceae	*Impatiens sulcata* Wall.	Banvingiro	Herb	2400-3700
5	Balsaminaceae	*Impatiens urticifolia* Wall.		Herb	2700-3800
5	Boraginaceae	*Cynoglossum ambile* Stapf & J.R. Drumm.		Herb	2400-3600
5	Boraginaceae	*Cynoglossum glochidiatum* Wall. ex Blenth	Tejraj	Herb	2500-3700
5	Boraginaceae	*Cynoglossum zeylanicum* (Vahl. ex Hornem.)Thunb. ex lehm.	Musekuro	Herb	2400-4100
5	Brassicaceae	*Cardamine flexuosa* With.		Herb	2700-3700
5	Caryophyllaceae	*Drymaria cordata* (L.) Wild. ex Schult	Oxalo	Herb	2400-3700
5	Caryophyllaceae	*Stellaria patens* D. Don		Herb	2400-4000
5	Liliaceae	*Fritillaria cirrhosa* D. Don	Padhya	Herb	2400-3700
5	Liliaceae	*Lilium nepalense* D. Don		Herb	2400-3700
5	Orchidaceae	*Dactylorhiza hatagirea* (D. Don) Soo	Hattijara, Panchaule	Herb	2400-3700
5	Poaceae	*Digeteria cruciata* (Nees ex Steud.) A. Cumus		Herb	2400-3500
5	Poaceae	*Phelum alpinum* L.		Herb	2500-3700
5	Polygonaceae	*Rumex acetosa* L.		Herb	2400-3600
5	Polygonaceae	*Rumex nepalensis* Spreng	Halhale	Herb	2400-3700
5	Primulaceae	*Primula edgeworrthi* Pax		Herb	2400-3700
5	Ranunculaceae	*Aconitum spicatum* (Bruhl.) Stapf	Bishjara	Herb	2400-4200
5	Ranunculaceae	*Anemone demissa* Hook. f. & Thomson		Herb	2700-3700
5	Ranunculaceae	*Anemone Polyanthes* D. Don	Abhijalo	Herb	2400-4400
5	Ranunculaceae	*Rannunculus brotherusii* Freyn		Herb	3000-3700
5	Ranunculaceae	*Thalictrum alpinum* L.		Herb	2800-3700
5	Ranunculaceae	*Thalictrum cultratum* Wall.		Herb	2400-4200

5	Rosaceae	*Fragaria nubicola* (Hook. f.) Lindl. ex Lacaita	Kappu	Herb	2400-3700
5	Rosaceae	*Potentilla cuneata* Wall. ex Lehm.		Herb	2400-4900
5	Rosaceae	*Potentilla lineata* Trevir.		Herb	2400-4800
5	Urticaceae	*Urtica diota* L.	Sisnu	Herb	2400-4500
5	Violaceae	*Viola biflora* L.	Chiphulya	Herb	2400-3700
5	Poaceae	*Digeteria cruciata* (Nees ex Steud.) A. Cumus		Herb	2400-3500
5	Poaceae	*Phelum alpinum* L.		Herb	2500-3700

Range 1=find only in range 1, Range 2=find only on range 2, Range 3=found only range 3, Range 4=find in any two range, Range 5=find in all over the range

Appendix II. Important Value Index of Some Selected Shrub Species in the Forest.

Name of Shrub species	**D (per ha)**	**RD (%)**	**F (%)**	**RF (%)**	**A**	**R.A (%)**	**IVI**
Sorbus foliolosa (Wall.) Spach	1200	15.56	68.75	16.67	4.36	8.96	41.19
Rhododendron lepidotum Wall. ex G. Don	1083.3	14.05	56.25	13.64	4.81	9.88	37.57
Rosa Siricea Lindl.	891.7	11.57	58.33	14.14	3.82	7.84	33.55
Prunus bracteopadus Koehne	841.7	10.92	43.75	10.61	4.81	9.87	31.39
Deutzia compacta Craib	833.3	10.81	43.75	10.61	4.76	9.77	31.19
Rosa macrophylla Lindl.	816.7	10.59	47.92	11.62	4.26	8.75	30.95
Rubus calycinus Wall. ex D. Don	633.3	8.21	29.17	7.07	5.43	11.14	26.43
Debregeasia salicifolia (D. Don) Rendle	575.0	7.46	27.08	6.57	5.31	10.89	24.92
Desmodium elegans DC.	383.3	4.97	16.67	4.04	5.75	11.80	20.81
Rhododendron anthopogon D. Don	450.0	5.84	20.83	5.05	5.40	11.08	21.97
Total	7708.3	100.0	412.5	100	48.7	100	300.0

Appendix III. Important Value Indix of tree Species in different elevations in the forest (A=Lower elevation, B=middle elevation, C=higher elevation).

(A)

Name of Tree Species	d/ha	RD (%)	F (%)	RF (%)	A	RA (%)	IVI	IP (%)
Quercus semecarpifolia	92.2	11.7	81.3	6.4	4.5	5.7	23.9	8.0
Abies spectabilis	84.4	10.7	56.3	4.5	6.0	7.6	22.8	7.6
Rhodendron arboreum	81.3	10.3	56.3	4.5	5.8	7.3	22.1	7.4
Tsuga dumosa	64.1	8.1	37.5	3.0	6.8	8.6	19.8	6.6
Acer capadocicum	48.4	6.2	62.5	5.0	3.1	3.9	15.0	5.0
Ilex dipyrena	32.8	4.2	43.8	3.5	3.0	3.8	11.4	3.8
Hippophae salicifolia	17.2	2.2	12.5	1.0	5.5	7.0	10.1	3.4
Prunus cerasoides	25.0	3.2	50.0	4.0	2.0	2.5	9.7	3.2
Prunus persica	21.9	2.8	56.3	4.5	1.6	2.0	9.2	3.1
Acer sterculiaceum	21.9	2.8	56.3	4.5	1.6	2.0	9.2	3.1
Neolitsea pallens	20.3	2.6	50.0	4.0	1.6	2.1	8.6	2.9
Saurauia napalensis	18.8	2.4	56.3	4.5	1.3	1.7	8.5	2.8
Betula alnoids	18.8	2.4	43.8	3.5	1.7	2.2	8.0	2.7
Acer pectinatum	15.6	2.0	18.8	1.5	3.3	4.2	7.7	2.6
Alnus nepalensis	15.6	2.0	43.8	3.5	1.4	1.8	7.3	2.4
Prunus cornuta	15.6	2.0	43.8	3.5	1.4	1.8	7.3	2.4
Texicodendron wallichii	14.1	1.8	18.8	1.5	3.0	3.8	7.1	2.4
Prunus nepaulensis	15.6	2.0	37.5	3.0	1.7	2.1	7.1	2.4
Sorbus lanata	15.6	2.0	37.5	3.0	1.7	2.1	7.1	2.4
Xenthoxylum armatum	15.6	2.0	37.5	3.0	1.7	2.1	7.1	2.4
Ulmus wallichiana	14.1	1.8	43.8	3.5	1.3	1.6	6.9	2.3

Sorbus vestitata	14.1	1.8	37.5	3.0	1.5	1.9	6.7	2.2
Toona sinensis	12.5	1.6	31.3	2.5	1.6	2.0	6.1	2.0
Celtis australis	12.5	1.6	31.3	2.5	1.6	2.0	6.1	2.0
Betula utilis	9.4	1.2	12.5	1.0	3.0	3.8	6.0	2.0
Juglans regia	10.9	1.4	37.5	3.0	1.2	1.5	5.8	1.9
Eurya acuminata	10.9	1.4	37.5	3.0	1.2	1.5	5.8	1.9
Aesculus indica	10.9	1.4	25.0	2.0	1.8	2.2	5.6	1.9
Juniperus indica	9.4	1.2	25.0	2.0	1.5	1.9	5.1	1.7
Euonymus porphyreus	9.4	1.2	25.0	2.0	1.5	1.9	5.1	1.7
Coriaria nepalensis	7.8	1.0	25.0	2.0	1.3	1.6	4.6	1.5
Rhododendron barbatum	6.3	0.8	12.5	1.0	2.0	2.5	4.3	1.4
Lyonia ovalifolia	4.7	0.6	18.8	1.5	1.0	1.3	3.3	1.1
Total		**100.0**		**100.0**		**100.0**	**300.0**	**100.0**

(B)

Name of Tree Species	**d/ha**	**RD (%)**	**F (%)**	**RF (%)**	**A**	**RA (%)**	**IVI**	**IP (%)**
Quercus semecarpifolia	137.5	23.8	56.3	9.0	9.8	17.8	50.7	16.9
Acer pectinatum	75.0	13.0	62.5	10.0	4.8	8.8	31.8	10.6
Rhodendron arboreum Sm.	60.9	10.6	56.3	9.0	4.3	7.9	27.5	9.2
Rhododendron barbatum	54.7	9.5	43.8	7.0	5.0	9.1	25.6	8.5
Betula utilis	43.8	7.6	50.0	8.0	3.5	6.4	22.0	7.3
Tsuga dumosa	43.8	7.6	43.8	7.0	4.0	7.3	21.9	7.3
Prunus nepaulensis	32.8	5.7	43.8	7.0	3.0	5.5	18.2	6.1

Prunus cornuta	32.8	5.7	37.5	6.0	3.5	6.4	18.1	6.0
Abies spectabilis	20.3	3.5	37.5	6.0	2.2	4.0	13.5	4.5
Sorbus lanata	17.2	3.0	43.8	7.0	1.6	2.9	12.8	4.3
Prunus persica	15.6	2.7	31.3	5.0	2.0	3.7	11.4	3.8
Juniperus indica	10.9	1.9	31.3	5.0	1.4	2.6	9.5	3.2
Lyonia ovalifolia	10.9	1.9	31.3	5.0	1.4	2.6	9.5	3.2
Acer sterculiaceum	4.7	0.8	6.3	1.0	3.0	5.5	7.3	2.4
Euonymus porphyreus	6.3	1.1	18.8	3.0	1.3	2.4	6.5	2.2
Hippophae salicifolia	4.7	0.8	18.8	3.0	1.0	1.8	5.6	1.9
Prunus cerasoides	3.1	0.5	6.3	1.0	2.0	3.7	5.2	1.7
Juniperus Squamata	1.6	0.3	6.3	1.0	1.0	1.8	3.1	1.0
Total		**100.0**		**100.0**		**100.0**	**300.0**	**100.0**

(C)

Name of Tree species	**d/ha**	**RD (%)**	**F (%)**	**RF (%)**	**A**	**RA (%)**	**IVI**	**IP (%)**
Quercus semecarpifolia	454.7	59.6	93.8	15.8	19.4	46.5	121.9	40.6
Betula utilis	126.6	16.6	87.5	14.7	5.8	13.9	45.2	15.1
Prunus nepaulensis Steud	32.8	4.3	62.5	10.5	2.1	5.0	19.9	6.6
Tsuga dumosa	34.4	4.5	37.5	6.3	3.7	8.8	19.6	6.5
Juniperus Squamata	25.0	3.3	68.8	11.6	1.5	3.5	18.3	6.1
Prunus cornuta	25.0	3.3	56.3	9.5	1.8	4.3	17.0	5.7

Juniperus indica	21.9	2.9	56.3	9.5	1.6	3.7	16.1	5.4
Prunus persica	15.6	2.0	43.8	7.4	1.4	3.4	12.8	4.3
Euonymus porphyreus	12.5	1.6	37.5	6.3	1.3	3.2	11.2	3.7
Sorbus lanata	9.4	1.2	31.3	5.3	1.2	2.9	9.4	3.1
Lyonia ovalifolia	3.1	0.4	12.5	2.1	1.0	2.4	4.9	1.6
Rhodendron arboreum	1.6	0.2	6.3	1.1	1.0	2.4	3.7	1.2
Total	**762.5**	**100.0**	**593.8**	**100.0**	**41.7**	**100.0**	**300.0**	**100.0**

Appendix IV. Geographical position of quadrat with Aspect, Slope, Litter depth, canopy coverage and Disturbance level (L= low, M = medium, H= high)

Plots	**Latitude**	**Longitude (N)**	**Altitude (m)**	**Slope**	**Aspect**	**Litter depth (cm)**	**Canopy cover (%)**	**Disturbance Level**
1	80.91624	29.87979	2489		278W	1	60	M
2	80.91735	29.88002	2577	41	270W	1.5	50	M
3	80.91737	29.88098	2553	38	255W	NA	65	
4	80.91746	29.88189		28	227SW	2	35	M
5	80.91878	29.88327	2571		NA	NA		NA
6	80.91878	29.88327	2571		NA			NA
7	80.92004	29.88449	2597	25	NA	1	55	L
8	80.92115	29.88553	2626	42	290W	2.5	45	L
9	80.92169	29.88623	2635	38	331N	2	70	L
10	8092239	29.88715	2629	39	306NW	2	55	L
11	80.92379	29.88822	2671	54	288W	1.5	60	M

12	80.92444	29.88909	2699	19	308NW	1	30	M
13	80.92723	29.89039	2736	17	277W	2	70	L
14	80.92799	29.89068	2753	18	304NW	1.5		L
15	80.93255	29.89221	2831	14	275M	0.5	30	L
16	80.93338	29.89305	2846	20	317NW	2	40	L
17	80.93387	29.89448	2829		NA			L
18	80.93511	29.89524	2853	12	284W			L
19	80.93511	29.89524	2853	12	284W			M
20	80.93920	29.89921	2871	15	304NW	1.5		M
21	80.93920	29.89921	2871	15	304NW	1.5		M
22	80.94232	29.90138	2910	41	300NW	1		L
23	80.94348	29.90227	2919	30	325NW	0.5		L
24	80.94554	29.9032	2962	18	315NW	0.5	10	L
25	80.94726	29.90706	3013	40	240SW	1	15	L
26	80.94690	29.90929	3021	38	238SW	1.5	15	L
27	80.94635	29.91142	3096	35	255W	2	12	L
28	80.94613	29.91406	3138	41	269W	2.5	60	L
29	80.94604	29.91967	3176	57	269W	1.5	70	L
30	80.94553	29.91817	3287	27	298W	0.5	60	L
31	80.94600	29.92028	3294	36	280W	1	45	M
32	80.94659	29.92108	3317	7	252W	1.5	70	L
33	80.94754	29.92197	3338	15	218S	1.5	60	M
34	80.94655	29.92313	3322	12	295W	2.5	65	L

35	80.94670	29.92533	3346	9	251W	2.5	60	NA
36	80.94548	29.93037	3372	12	190S	1.5	50	M
37	80.94321	29.93637	3400	8	182S	0.5	20	M
38	80.94321	29.93637	3400	8	182S	0.5	20	M
39	80.94166	29.94275	3481	11	174S	3	20	M
40	80.94151	29.94402	3491	35	133SE	2.5	55	M
41	80.94209	29.94489	3507	20	167S	1.5	50	M
42	80.94263	29.94597	3518	18	120SW	2	65	M
43	80.94358	29.94622	3558	23	130SE	2	70	M
44	80.94406	29.94659	3667	33	147SE	1.5	50	M
45	80.94445	29.94772	3601	29	111E	0.5	40	M
46	80.94483	29.94862	3610	26	157SE	1.5	25	M
47	80.9463	29.94992	3638	10	90E	0.5	15	H
48	80.94693	29.95085	3636	39	149SE	0.5	20	M

Appendix V. Selected Photo Plates.

A

B

C

D

E

F

A=Landscape of the study site, B & C= Example of disturbances, D=Flowering twig of *Quercus semecarpifolia*,*E*= *Quercus semecarpifolia* twig with young acorn, F=Natural eed

germination of *Quercus semecarpifolia*.