COMMUNITY STRUCTURE AND REGENERATION OF *Abies spectabilis* D. Don IN SHAILUNG, CENTRAL NEPAL

A THESIS

Submitted for the
Partial Fulfillment of the Requirements for the
Master's Degree in Botany

BY
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FEBRUARY, 2022

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I, Aditya 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 are listed in the reference section.

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RECOMMENDATION

This is to recommend that the Master's thesis entitled **"Community Structure and Regeneration of *Abies spectabilis* D.Don in Shailung, Central Nepal"** is carried out by Aditya 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 the partial fulfillment of Master's Degree in Botany.

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APPROVAL

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ACRONYMS AND ABBREVIATIONS

ANOVA	:	Analysis of Variance
a.s.l	:	Above sea level
BA	:	Basal Area
cm	:	Centimeter
D	:	Density
DBH	:	Diameter at Breast Height
ºC	:	Degree Centigrade
F	:	Frequency
gm	:	gram
ha	:	hectare
IVI	:	Important Value Index
Kg	:	Kilogram
m	:	meter
m^2	:	Square meter
mm	:	millimeter
N	:	North
OM	:	Organic Matter
P	:	Phosphorus
K	:	Potassium
%	:	Percentage
RF	:	Relative Frequency
RD	:	Relative Density
RBA	:	Relative Basal Area
SD	:	Standard Deviation
SPSS	:	Statistical Package for Social Science

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Community structure and regeneration of *Abies spectabilis* (D.Don) was studied in *Abies spectabilis* forest located in Shailung, Dolakha. Vegetation sampling was done by circular plot (20m diameter) method and the sample plots were located by systematic random sampling method. Two sites, northern and aspect, were selected for the study. Four horizontal transects running parallel to each other of about 200m altitudinal difference were designed for each aspect. Altogether 48 plots, six in each transect were established and the aerial distance between the plot was 50m. Number of woody plant species, number of individuals of each tree species, diameter at breast height (DBH) of each individual tree, number of seedlings and saplings of tree species were recorded in each plot. Various community attributes and population characteristics were analyzed. From each horizontal transect, soil was collected by pairing of plots in each transect from a depth of 30cm and pooled together. Three soil samples of 200 g from each transect were collected and their physicochemical characteristics were analyzed.

On the basis of IVI *Tsuga dumosa* was dominant on lower elevation range on both aspects, while *Abies spectabilis,* was dominant at elevation range 2650m-2850m and 2850m-3050m, whereas, *R. arboreum* was dominant at elevation range above 3050m in northern aspect. Similarly, *A. spectabilis* and *T. dumosa* showed nearly equal dominance at elevation range 2650m-2850m, while *A. spectabilis* was dominant at elevation range 2850m-3050m and above 3050m in southern aspect.

Altogether 40 plant species (13 tree species and 27 plant species in shrub layer) were found in the study area. The tree density of both sites increased with increase in elevation up to 2850m-3050m and decreased. Similarly, the basal area of tree gradually decreased after elevation range 2650m-2850m in both aspects. Comparatively tree density was higher in northern aspect and basal area was higher in southern aspect. Soil was slightly acidic in nature. The distinct variation in soil parameters were not observed in two sites as well as along altitude. Density-diameter curve of all tree species showed sustainable regeneration. But, density-diameter curve of *A. spectabilis* in both aspects slightly deviated from reverse J shaped structure and hence did not show sustainable regeneration. Seedling density was higher than sapling density. The distribution of seedlings and saplings were not uniform.

Keywords: *Community structure*, *Regeneration*, *Abies spectabilis*, *Seedlings and Saplings.*

CHAPTER 1: INTRODUCTION

1.1. Background

Forests are described by their composition, function and structure (Franklin *et al.,* 1981). Composition is that the assemblage of organisms (living and non-living) that exist within the forest. It is frequently described by the presence and dominance of species and sometimes by relative descriptors (e.g. diversity index). Forest structure is the physical arrangement and characteristics of the forest, which is extremely visible and described component (Stone and Porter, 1998). Forest stand structure is usually supported the aggregation of individual plant measures (e.g. density, tree diameter at breast height) (Oliver and Larson, 1990).

A plant community is a composition of plant species growing together during a specific location with an explicit association with each other (Singh *et al.,* 2016). Knowledge of species composition and diversity of tree species is vital to know the structure of a forest community, status of tree population, regeneration and diversity (Malik and Bhatt, 2016; Singh *et al.,* 2016; Manna and Mishra, 2017). Similarly, future sustainability of forest could even be evaluated by the assessment of forest structure and diversity (Adhikari *et al.,* 2017). The structure and vegetation diversity at any site are influenced by species distribution, abundance patterns, topography, soil, climate and geographical location of area (Sarkar and Devi, 2014; Das *et al.,* 2017; Khaine *et al.,* 2018).

Community structure is directly regulated by species diversity, and it is the biological basis to take care of ecosystem functions (Tilman and Downing, 1994; Zhang *et al.* 2004). Species diversity, seral stage, and also the community stability are the important parameters for characterizing a community (Liyun *et al.,* 2006). Species richness is a simple and simply interpretable indicator of biological diversity (Peet, 1974). Many sorts of environmental changes influence the processes which will influence the diversity (Sagar *et al.,* 2003). Diversity of any locality is influenced by altitude and climatic variables like temperature and rainfall (Sharma *et al.,* 2009). Differences in altitude and slope influence the species richness (Ellu and Obua, 2005).

Natural regeneration implies the procedure of re-growing or reproducing new individual plants within the community. It is the foremost important process to keep up the stable age structure of the plant species in an exceedingly community, affected directly or indirectly by various climatic in addition as edaphic factors (Singh and Singh, 1992). The difficulty of regeneration is essentially important for those forests which are under various anthropogenic pressures like felling tree, grazing, trampling, etc. (West *et al.*, 1981). The potential regenerative status of tree species is very important component that demonstrates the growth trend of the community, species composition and productive capacity of the forest and forest dynamics within the future (Rahman *et al.,* 2011; Awasthi *et al.,* 2015). These are the determining factors of sustainable or established forests (Subedi *et al.,* 2009; Rahman *et al.,* 2011; Awasthi *et al.,* 2015). Thus, the study of regeneration of forest trees has important implications for the conservation and management of natural forests (Tripathi and Khan, 2007; Pokhriyal *et al.,* 2010).

The regeneration niche is defined as the array in which a species contains a high chance of success within the replacement of a mature individual by new individual. The regeneration niche includes elements of the habitat, life-form and phenological niches. The processes and events that occur during the regeneration phase of natural communities can play a key role in community composition and should affect species diversity and endorse species co-occurrence in environments that are homogeneous at the adult plant scale (Grubb, 1977).

Abies, a genus under the family Pinaceace, could be a large group of softwood tree with 48 species within the world (Nagarkoti *et al.*, 2019). It is also called Himalayan silver fir (Vidakovic, 1991) while local people called 'Talispatra'. *Abies* are slow growing, tall evergreen, pyramidal tree that attains a height of 60 m. *Abies spectabilis* is, a high altitude Himalayan fir distributed in central to western Nepal, up to Afghanistan in the west, between 2400– 4400 m elevation range at temperate and alpine zones (Stainton, 1972; Ghimire *et al.*, 2008). It ranges up to the treeline, and *Betula utilis* forest flourishes at higher altitudes (Ghimire *et al.*, 2008). The plant mostly prefers moist open areas, woodland, garden, canopy zones. Three species are reported from Nepal viz. *A. spectabilis, A. densa*, and *A. pindrow* (Hara *et al.*, 1982; Press *et al.*, 2000). The common associates of the *A. spectabilis* forests are *Rhododendron, Betula, Acer and Sorbus* species (Stainton, 1972). *A. spectabilis* is one of the important timber and fuel wood tree in the temperate and sub- alpine area even up to the tree line (Nagarkoti *et al.,* 2019). Hence, high demand of the *Abies* plant for construction and fuel wood, growth pattern, regeneration, impacts like grazing, trampling, etc. are being critical alarm for sustainable use of this preferred species.

Regeneration of *A. spectabilis* forest and spatial patterns of seedling distribution in the Shailung area have not been studied yet. So this research aims to study the detail population characteristics of *A. spectabilis* in this area.

1.2. Justification of the study

Forests are the most important natural resources of Nepal, however due to unsustainable use of forests these are being degraded gradually. Deforestation and forest fire are the main problems for the degradation of forest. Increasing human population of Nepal ultimately lead to increase in demand of forest resources. Therefore, an investigation of how the utilization of forest influences biodiversity is importance in planning a sustainable forestry in Nepal.

A. spectabilis forests in specific are relatively less studied forest ecosystem. A few regeneration studies had been undertaken in mixed *A. spectabilis* forests, but mature *A. spectabilis* forest has been relatively less studied. This present study is pertaining to community structure and regeneration status of mature *A. spectabilis* forest in Shailung, Dolakha, would be important to understand the impact of conservation to plant diversity and vegetation dynamics in the study area. It would be helpful to know the effect of altitude and other environmental factors in vegetation composition and regeneration of forest at temperate and sub-alpine region.

1.3. Research Questions

1. What is the effect of altitude on community structure of *Abies spectabilis* forest in the study area?
2. How is the regeneration status of the *A. Spectabilis* forest in the study area?
3. What is the distribution pattern of seedlings and saplings at different altitude of both sites?

1.4. Objectives

The general objective of the study is to analyze vegetation structure of *Abies* forest. The specific objectives were:

1. To analyze the community structure of *Abies spectabilis* forest.
2. To determine the sapling and seedling distribution in *A. spectabilis* forest.
3. To analyze the regeneration pattern of *A. spectabilis* forest.

1.5. Limitations

1. Herbs were not included in this research.
2. Regeneration of only *Abies spectabilis* was studied.
3. Only 24 samples of soil were taken for laboratory analysis.
4. Sampling was done only at an elevation range 2450m to above 3050m in both northern and southern aspects.

CHAPTER 2: LITERATURE REVIEW

2.1. Community structure

Community structure is essentially the composition of a community, including the number of species in that community and their relative numbers. Community structure is greatly influenced by various environmental factors like (slope, aspect and soil factor) (Stainton, 1972). Community structure is determined by both climatic and topographical features (Khadka, 2004). Plant community of a region is a function of time; however, altitude, slope, latitude, aspect, rainfall, and humidity play vital role in formation of plant communities and their composition (Kharkwal *et al.*, 2005).

In cool temperate zone of Eastern Nepal, Oshawa *et al.*, (1973) reported the decreasing tendency of tree height and basal area with increasing altitude. Similarly, the decreasing pattern of ecological parameters such as density, basal area, IVI, alpha and beta diversity with increase in altitude was reported in Annapurna Conservation Area (Nepal, 2001).

In sub-alpine coniferous forest, the number of woody species becomes less towards higher altitudes while due to lower crown intensity herb layer was richer (Liu Qi-jing, 1997). In northern slope of Changbai Mountain, reported linear decrease in richness and diversity with increase in altitude in different successional layers of trees or shrubs and herbs (Zhanging *et al.*, 2002). Similarly, in Satpura National Park, India, Khatri *et al.*, (2004) identified three foremost communities, at three altitudes. The density was decreased with increasing altitude also diversity index was higher on lower elevation.

In Nagarjun hill, maximum species diversity was reported at lower altitude (Yadav and Shah, 1998). Similarly, the decrease in diversity of trees with rise in altitude was reported which was because of topographic features, soil and climate in Shivpuri hill (Sharma, 2000). He also reported inverse relation of Soil nutrient, organic matter, pH of soil with altitude. In Central Western Ghats, the high elevation evergreen forests were richer and diverse as compared to medium elevation evergreen forests (Santhosha, 2005). Forests in eastern aspects were more diverse than western aspect.

In the Himalayas of the Mid-Nepal between an elevation range1650m-3300m, 16 tree species from 16 genera and 11 families were reported. The dominant species reported in the study area were *Acer recurve, Picea smithiana, Prunus sp, Aesculus indica* and *Betula utilis D. Don.* (Kunwar and Sharma, 2004). Similarly, 192 plant species belonging to 55 families and 136 genera were reported at elevation range (2700m-4200m) in Pooh valley of Kinnaur district (Verma and Kapoor, 2010).

In a trans-Himlayan dry valley, Shrestha *et al.,* (2007) analyzed distribution and community structure of treeline birch (*B. utilis*) forest of Central Nepal. They found highest IVI for *B. utilis* D. Don (161.41) followed by *A. spectabilis* (85.59) and *P. wallichiana* (52.88) between elevation range of 3500m-3900m. The highest IVI value for *B. utilis* D. Don (286.87) was recorded between an altitude of 3900m-4200m asl, great increase in the basal cover of *B. utilis* D. Don was observed from altitude of 3500m to 4100m. In a forest of Kumaun region of India at 3000 – 3200 m altitude, 3 tree species shared dominance with nearly equal IVI *A. pindrow* (49.32), *B. utilis* D. Don (48.32) and *Acer caesium* (45.54) respectively (Gairola *et al.,* 2008). In *Juniperus indica* forest in southern Manang valley, only 3 species of trees in a sub-alpine forest on southern slope of the Manang valley were found. Only *J. indica* was found at highest altitude on southern slope in these forests (Ghimire *et al.,* 2008). In Langtang National Park Tiwari (2010) reported that 11 species at tree stage in *A. spectabilis* dominated forest, only 3 species reached to canopy layer and remaining 8 species confined only to sub canopy layer. It was found that the highest IVI value for *A. spectabilis* (84%) followed by *R. campanulatum* (4.87%) and *B. utilis* (4.75%).

In coniferous forest of sub-alpine region there is characteristic decline in total tree density and total basal cover with increase in altitude (Gairola *et al.,* 2008). Adhikari *et al.,* (1991) also found that total tree density and basal area vary from 320 trees/ha to 1600 trees/ha and 44m$^{2/}$ha to 98m^2/ha respectively in Kumaun Himalaya. Pande (2001) observed that density and total basal area ranged in between 885 tree/ha to 1111 tree/ha and 56.42m^2/ha to 126m^2/ha respectively in Garhwal Himalayan forest. In a pure *Betula utilis* forest of Manang the basal cover was 2.3% (Shrestha *et al*., 2007). In this forest, the basal cover generally increased from 3500 to 4100 m. The total basal cover of *Juniperus indica* forest was 0.17% in mixed *Juniperus* forest (Ghimire *et al.,* 2008). Total tree density in mixed forest of *Pinus wallichiana* and *Abies spectabilis* (3500 - 3800 m) ranged from 675 to 960 stem/ha (Ghimire and Lekhak, 2007). Similarly, in Kumaun Himalaya forest Hussain *et al.,* (2008) found highest tree density for *Quercus floribunda* (181 trees/ha)-*Rhododendron arboreum* group (175 trees/ha) and the lowest for *A. pindrow* (151 trees/ha)–*B. utilis* group (85 trees/ha). Kharkwal (2010) reported total density of tree, shrub and herb species ranged from 10-28.6 indiv/100m², 1.8-21.7 indiv/25 m², and 28.1-103.7 indiv/m² respectively in Kumaun Himalaya. Total tree density of *A. spectabilis* forest in Sagarmatha National Park was 267.11 stem/ha (Nagarkoti *et al.,* 2019). In weatern Himalaya, India, Maletha *et al.,* (2021) reported total tree density of *B. utilis* forest ranged from 1133 individual/ha to 2137 individual/ha.

2.2. Regeneration

Regeneration generally means the renewal of forest by natural or artificial means. The regeneration status is carried out to study the regeneration of a particular area in terms of recruits, seedlings, saplings etc. A small sample of ages of seedlings and saplings combined with their densities is adequate for determining the regeneration status of each species (Veblen, 1986). The 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, 2000). Environmental factors influence the regeneration of plants, eg. drought, water logging, high or low temperature, could also affect the age structure of plants (Block and Treter, 2001).

In mixed *B. utilis* forest of Manang, Acharya (2004) reported that the seedling density of *A. spectabilis* to be 3923 stem/ha and sapling density to be 117 stem/ha. In subalpine forest of upper Manang, the density diameter curve of tree population of *A. spectabilis* showed reverse J- shaped (Ghimire and Lekhak, 2007). They found that the distribution of seedling and sapling was more or less uniform. In trans-Himalayan dry valley of Manang, size class diagram of *B. utilis* resembled a reverse J- shaped structure in both mixed and pure forest. The regeneration was found higher in mixed *B. utilis* forest. Spatially heterogenous distribution of seedling and sapling was observed and seemed to depend on canopy cover. It was found that the parial opening of canopy may induce seedling establishment and hence continuous regeneration of *B. utilis* (Shrestha *et al.,* 2007). Similarly, in Baima Snow Mountain, the diameter class structure of *A. georgei* population showed a reverse J- shape (Qiaoying *et al.,* 2008).

In northwest Himalaya in India, the recruitment of *Taxus buccata* was higher at higher elevation due to least anthropogenic activities. But reduced at lower altitude due to the overharvesting and other anthropogenic pressure which were higher at lower elevation leading to poor regeneration (Lanker *et al.,* 2010). Malik *et al.,* (2012) revealed that the *P. gerardiana* has maximum established regeneration of the (291.66 plant/ha) in semiarid zone on western aspect in Himachal Pradesh. Overall the mean natural regeneration status of the species was very poor (15%).

In treeline ecotone of Langtang National Park, the density diameter curve of *B. utilis* was found to be bimodal and bell shaped. Average sapling density of *B. utilis* was found to be 37 stem/ha while seedling density was found to be 20 stem/ha (Gaire *et al.*, 2010). 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 sustainable changes in the state and pattern of forest regeneration suggesting that the forest is in trouble (Ghimire *et al.*, 2010). It was also found that development of seedlings and saplings was also low. In *B. utilis* forest in Kashmir India, the regeneration in both the forest division was poor and decreased further with increasing altitude but did not show any definite trend along the altitudinal gradient. Density diameter curve for *B. utilis* was not continuous and displayed reverse J- shaped structure depicting unsustainable regeneration success along the altitude (Mir *et al.*, 2017). In Sagarmatha National Park, the density diameter curve for *A. spectabilis* was slightly deviated from the typical reverse J- shape, which indicates a discontinuous regeneration pattern (Nagarkoti *et al.*, 2019). In Nanda Devi Biosphere Reserve India, the density diameter curve of *B. utilis* forest resembled a reverse J-shape which exhibits good regeneration with higher number of individuals in seedlings and saplings stage followed by sharp decline in tree class. It was recorded that seedling density of *B. utilis* to be 1783 seedlings/ha and 1306 seedlings/ha in north and south aspects respectively. Similarly, sapling density of *B. utilis* to be 1033 saplings/ha and 1475 saplings/ha in north and south aspects respectively (Maletha *et al.*, 2021).

Most of the studies related to *A. spectabilis* are found to be focused on high altitude sub-alpine and alpine forests in various parts of Nepal. But, present study site ranged from temperate to sub-alpine region. The studies related to regeneration of *A. spectabilis* in temperate to sub-alpine region are very few in literatures. Thus, this study will help to fulfill this gap. Similarly, the site was found to be less explored. Therefore, this study could be a pioneer research for this site.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study Area

3.1.1. Geomorphology

The study area was located in Shailung rural municipality, Dolakha in central Nepal. The district covers an area of 2191 km² and expands between 27.77 84º N, 86.17 52º E. The altitude of district ranges from 762-7183 m asl and climatic zone vary from upper subtropical to Nival. Dolkha district has total 78,111 ha forest area which constitutes 36% of district area (DFO Dolakha, 2009/10).

The study was carried out in *Abies spectabilis* forest of shailung located between 27.64 79º N, 85.93 20º E in an elevation ranging from 2450m to above 3050m on northern and southern facing slope. The study area mainly includes temperate and subalpine type of vegetation with dominance of *A. spectabilis*, *Tsuga dumosa*, and *Rhododendron* species. Logging of *A. spectabilis* and *Rhododendron* species were found. Trees were felled down mainly for timber and fire wood. Local people preferred *A. spectabilis* for timber and *Rhododendron* species for fire wood.

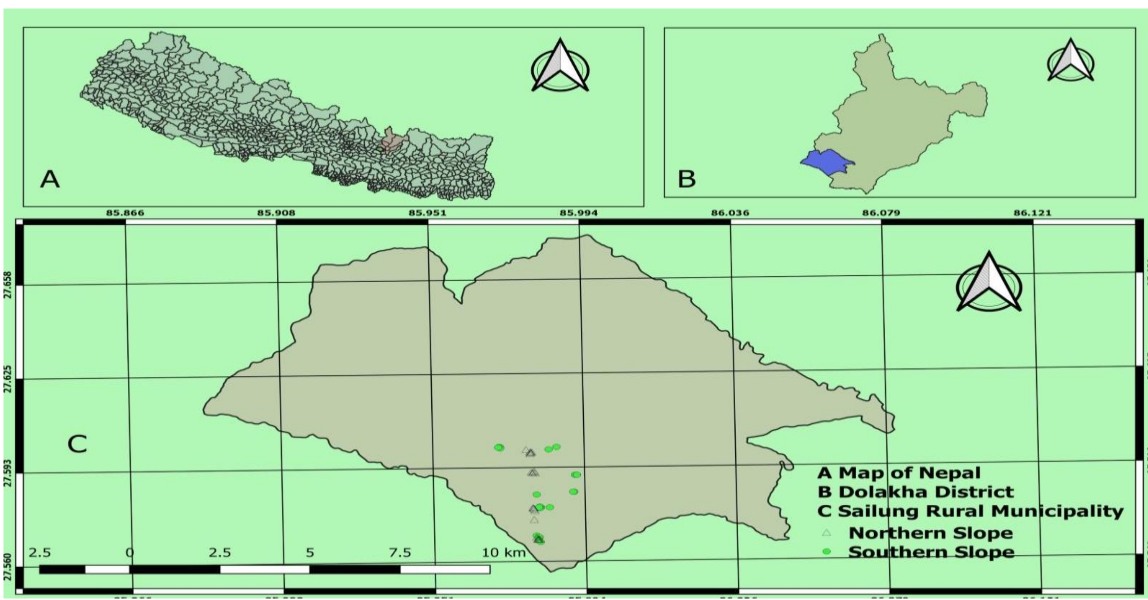

Figure 3.1. Location map showing the study Area.

3.1.2. Climate

Climatic data of nearest weather station (Charikot) from 2009-2020 showed that average annual rainfall was 1286.9mm with the highest monthly rainfall in July (369.9 mm) and lowest in November (7mm) respectively. Climatic data showed that monthly average maximum and minimum temperature was 16℃ and -7℃ in the months of June and January respectively.

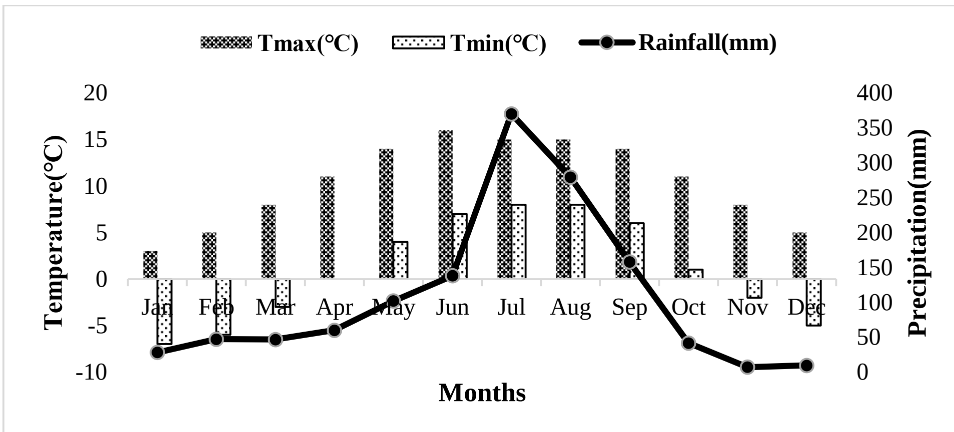

Figure 3.2. Average monthly maximum (Tmax) and minimum (Tmin) temperature and precipitation recorded at charikot weather station between 2009 and 2020. (Source: Department of Hydrology and Meteorology, Kathmandu).

3.2. Methods

3.2.1. Field sampling

Vegetation sampling was done by circular plot (20m diameter) method and the sample plots were located by systematic random sampling. Two sites site – A (northern aspect) and site – B (southern aspect), were selected for the study. Four horizontal transects running parallel to each other of about 200m altitudinal difference were designed for each aspect. Altogether 48 plots, six in each transect were established and the aerial distance between the plot was 50m. In each plot DBH (at 137cm) of each tree species was measured.

Individuals of tree species were grouped into three growth life stages: trees (DBH>10 cm), saplings (DBH<10 cm, height > 30 cm) and seedling (height < 30 cm) (Sundryal and Sharma, 1996). All shrub species present in the plot were also recorded. Due to variation in growth form some species were included both in tree and shrub layer. If the individual plants had profuse branching from the basal region, they were included in shrub layer. If the individual plant has no branching below breast height (137 cm from the base) and DBH exceed 10 cm, they were included in tree layer. Seedlings and saplings present inside the quadrat were counted within each quadrat. In each sampling plot, the number of trees, sapling, and seedlings were counted for each tree species. Diameter at breast height and height of trees was measured. All the trees of *A. spectabilis* were divided into different size classes of 10 cm and the size class diagram was developed to analyze regeneration pattern.

Soil from each transect was collected for measuring the pH, organic matter (OM), Nitrogen (N), Phosphorus (P), and Potassium (K). From each horizontal transect, soil was collected by pairing of plots in each transect from a depth of 30cm and pooled together. Three soil samples of 200 g from each transect were collected. The soil samples were air dried in shade and packed in air tight plastic bags until laboratory analysis.

Specimens of all the tree and shrub species from the plots were collected for identification. Most of the plant specimens were identified in the field with the help of standard reference (Stainton and Polunin, 1987; Stainton, 1988) and remaining specimens were identified in Department of Botany, Amrit Campus, Kathmandu with the help of experts. Herbarium of an unidentified plant species were submitted to the Department of Botany, Amrit Campus, Kathmandu.

3.3. Laboratory Analysis of Soil

Soil pH, organic matter (OM) content, and 3 macro nutrients (Nitrogen N, Phosphorus P, and Potassium K) were determined in the air-dried soil samples (n = 24) at Department of Agriculture, Regional Soil Testing Laboratory, Kanchanpur, Nepal. 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).

3.4. Community Structure

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

Frequency is the proportion of sampling units containing the species.

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

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

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

Density is the number of individuals per unit area.

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

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

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

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. which is given by: Basal area = $\pi d^2/4$

Where, d = DBH (diameter at the breast height) $\pi = 3.1416$

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

Relative Basal Area

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

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

Importance Value Index (IVI)

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

$IVI_i = RF_i + RD_i + RBA_i$

Where,

IVI_i = Importance Value Index of species i

RF_i = Relative Frequency of species i

RD_i = Relative Density of species i

RBA_i = 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:

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

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:

$D = \sum (ni/N)\ 2$

Where,

D = Simpson’s Dominance Index

N = total importance value of plants

ni = importance value of each species

3.5. Statistical Analysis

For each environmental variables and community attributes mean value was calculated. Variation among community attributes, abundances of recruits (density of seedlings and saplings) and the environmental variables were analyzed by correlation. Shapiro-Wilk test was done for testing normality of data and it was found that the data were normal. Parametric test ANOVA was performed for comparison of height and DBH of *A. spectabilis* at different altitudes. Similarly, Tukey's post hoc test was also done after ANOVA to compare height amd DBH at different altitudes. Statistical Package of Social Sciences (SPSS, version 25) and Microsoft excel was used for all statistical analysis.

CHAPTER 4: RESULTS

4.1. Community structure

While observing species composition *Tsuga dumosa* was dominant on lower elevation range on both aspects, while *Abies spectabilis, Rhododendron campanulatum, R. arboreum* were dominant in other three elevation range in both northern and southern aspects. *R. barbatum, symplocus sp* etc. were associated species of *Abies*. In case of shrubs *Berberis sp, Daphne bholua, Sarcoccoca sp* were dominant in both aspects. Altogether 13 tree species and 27 species were recorded in shrub layer in both north and south aspects. However, *A. spectabilis, T. dumosa* reached to canopy layer. Remaining species were confined only to sub-canopy layer.

The IVI of the tree species showed that mainly *A. spectabilis, T. dumosa, R. arboreum, R. campanulatum,* and *R. barbatum* are dominant over other species.

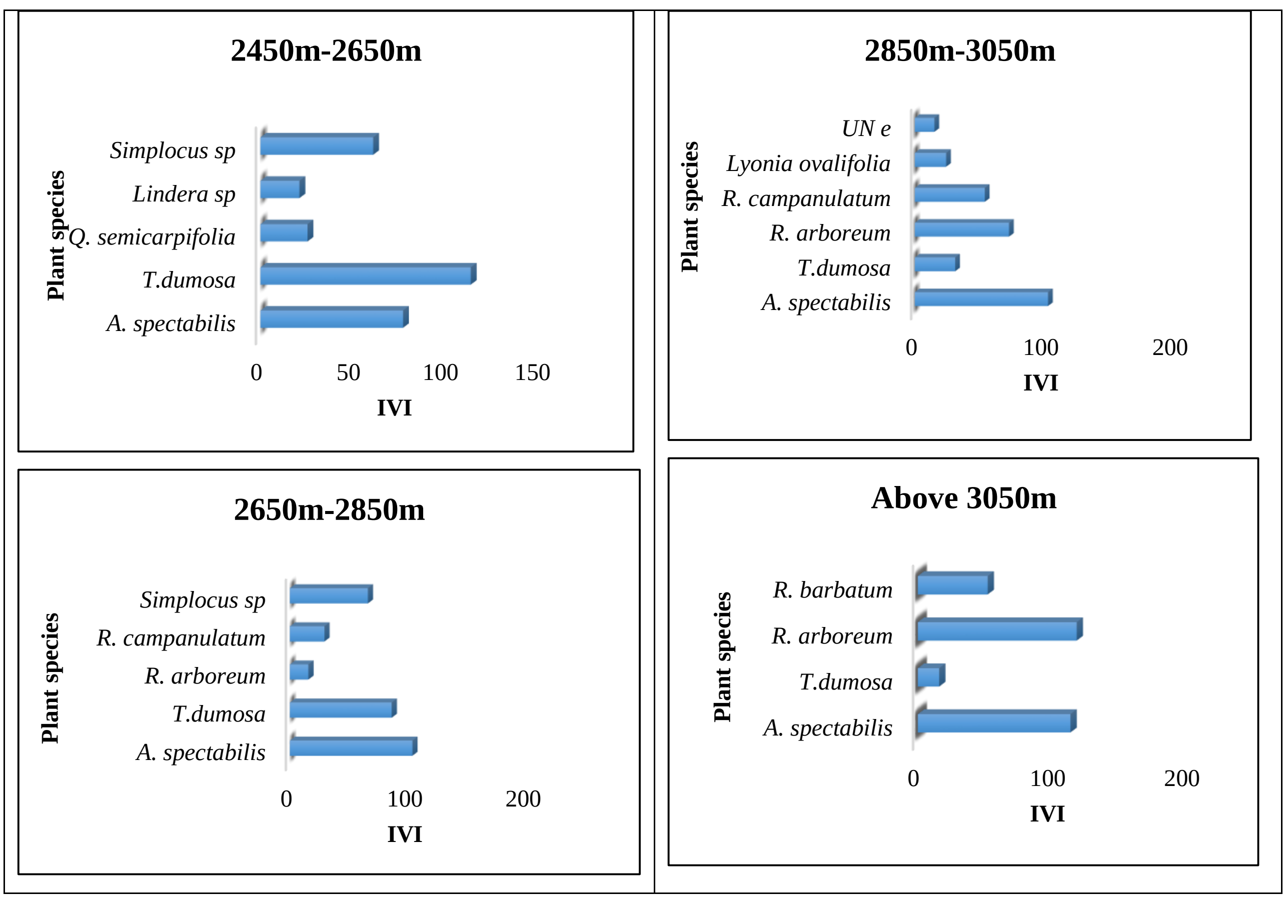

Figure 4.1. IVI of different tree species in different altitude in site –A (Northern aspect).

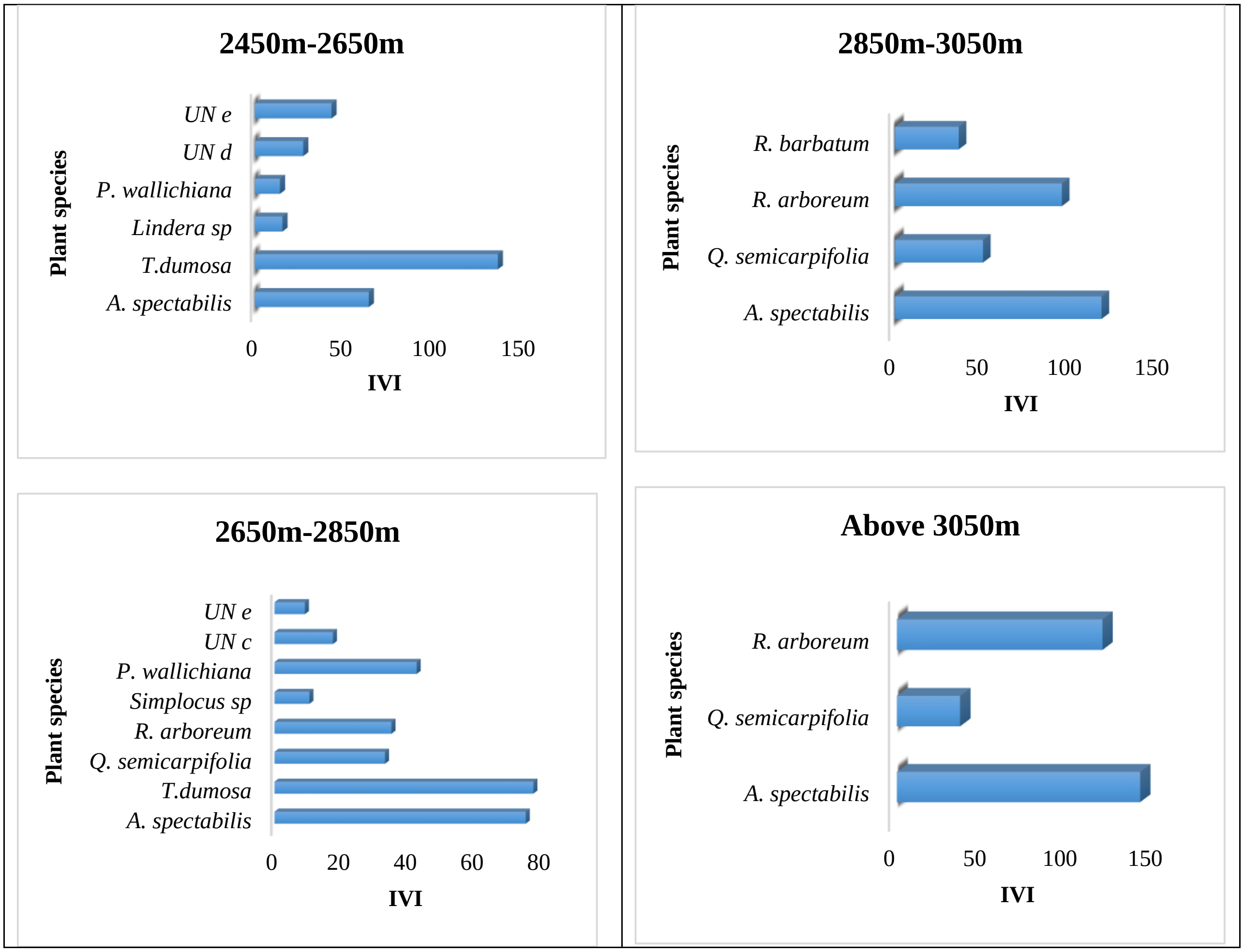

Figure 3.2. IVI of different tree species in different altitude in site –B (Southern Aspect).

In lower elevation in northern aspect *T. dumosa* had highest IVI (114.26) and most important species on site followed by *A. spectabilis* (77.45) and lowest IVI (21.19) was obtained for *Lindera* (Appendix IV). In an elevation range 2650m-2850m in northern aspect *A. spectabilis* had highest IVI (103.4) followed by *T. dumosa* (85.95) and *R.* arboreum had lowest IVI (15.65) (Appendix V). In an elevation range 2850m-3050m *A. spectabilis* had highest IVI (102.82) followed by *R. arboreum* (72.74) and UN e had lowest IVI (15.12) (Appendix VI). Similarly, in higher elevation above 3050m *R. arboreum* had highest IVI (118.35) followed by *A. spectabilis* (113.69) and *T. dumosa* (15.89) (Appendix VII).

In lower elevation in southern aspect the highest IVI was found for T. dumosa (136.67) followed by *A. spectabilis* (63.88) and *Pinus wallichiana* (14.03) (Appendix VIII). In an elevation range 2650m-2850m *T. dumosa* had highest IVI (77.51) followed by *A. spectabilis* (75.23) and *UN e* (9.06) (Appendix IX). In an elevation range 2850m-3050m, *A. spectabilis* had highest IVI

(118.06) followed by *R. arboreum* (95.33) and *R. campanulatum* had lowest IVI (36.38) (Appendix X). In higher elevation above 3050m *A. spectabilis* had highest IVI (142.58) followed by *R. arboreum* (120.44) and *Q. semicarpifolia* (36.98) (Appendix XI).

4.1.1. Vegetation in Shrub Layer

Composition of shrub layer was not much different along altitudinal gradient as well as on north and south aspects. Dominant species forming shrub layer were *Daphne bholua*, *Sarcococca sp.*, *Berberis sp.* etc. on the basis of IVI.

In lower elevation of northern aspect *Hypericum sp.* had highest IVI (44.14) followed by *Berberis sp.* (32.70) (Appendix XII). *Sarcococca sp.* had highest IVI (60.15) followed by *Berberis sp.* (47.48) in an elevation 2650m-2850m (Appendix XIII). *Berberis sp.* had highest IVI (90.11) followed by *D. bholua* (74.09) in an elevation 2850m-3050m (Appendix XIV). In higher elevation range *D. bholua* had highest IVI (48.03) followed by *R. barbatum* (43.26) (Appendix XV).

In case of southern aspect, *Berberis sp.* had highest IVI (87.42) followed by *Sarcococca sp.* (37.74) in lower elevation (Appendix XVI). *Berberis sp.* had highest IVI (63.56) followed by *Hypericum sp.* (50.71) in an elevation 2650m-2850m (Appendix XVII). In an elevation range 2850m-3050m *Berberis sp.* had highest IVI (76.34) followed by *D. bholua* (64.77) (Appendix XVIII). In higher elevation range *Berberis sp.* had highest IVI (91.44) followed by *D. bholua* (88.67) (Appendix XIX).

Dominant species forming shrub layer in the study area were *Berberis sp.*, *Daphne bholua*, *Sarcococca sp.*, *Gaultheria sp.*, *Smilax elegan*, *Mahunia nepalensis*, *Hypericum sp.* These species were common in both northern and southern aspect. Similarly, *R. arboreum*, was found at elevation range 2850m-3050m and above 3050m in both study sites. But, *R. campanulatum* was recorded only in northern aspect at elevation 2850m-3050m and *R. barbatum* was found at elevation above 3050m in northern aspect only.

4.1.2. Species Richness and Diversity

Average value of Simpson's index of Dominance (C) for tree in site – A was 0.66 and Shannon-wiener index (H) of species diversity was 1.23. Similarly, average value of Simpson's index of dominance (C) for tree in site – B was 0.68 and Shannon-wiener index (H) of species diversity was 1.30 (Table 4.1).

Table 4.1. species richness and diversity of tree in different altitude of site A(North) and B(South).

Altitude(masl)	Simpson's index of dominance		Shannon-wiener index	
	Site-A(North)	Site-B(South)	Site-A(North)	Site-B(South)
2450-2650	0.68	0.71	1.28	1.39
2650-2850	0.69	0.80	1.39	1.75
2850-3050	0.64	0.65	1.23	1.15
Above 3050	0.62	0.56	1.04	0.90
Average	0.66	0.68	1.23	1.30

4.1.3. Density of trees at different altitudes

Total tree density increased with increase in altitude up to 2850m-3050m and get decreased above 3050m in northern aspect. The density of tress in northern aspect ranged from 265 stem/ha at altitude 2450m-2650m (Appendix III) to 609.6 stem/ha at altitude 2850m-3050m (Appendix VI). Paired t- test showed significant relation (*p*=.014) between tree density and altitude.

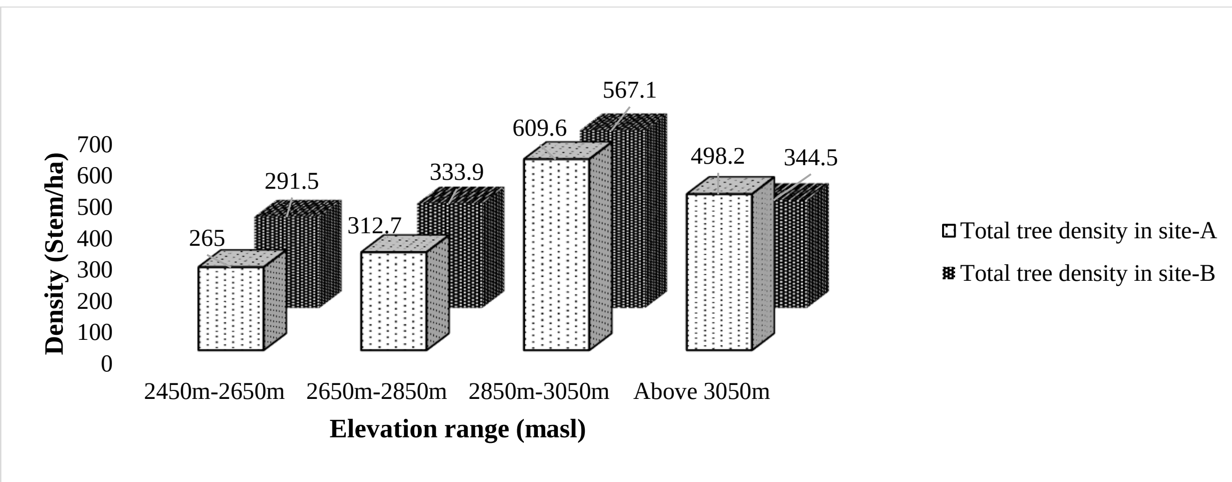

Figure 4.3. Total tree density in different altitudinal range of site- A (North) and site- B (South).

Similar trend was observed in southern aspect. The total tree density ranged from 291.5 stem/ha at altitude 2450m-2650m (Appendix VIII) to 567.1 stem/ha at altitude 2850m-3050m (Appendix X). Paired t- test showed significant relation (*p*=.009) between tree density and altitude.

Density of *A. spectabilis* was increased with increasing altitude up to an elevation range 2850m-3050m and get decreased in both northern and southern aspects. In northern aspect maximum density of *A. spectabilis* (249.1 stem/ha) was found at altitude 2850m-3050m (Appendix VI).

Similarly, the highest density of *A. spectabilis* (190.8) was found at an elevation range 2850m-3050m (Appendix VII) in southern aspect. Paired t- test showed significant relation (p=.023 and p=.027) between density of *A. spectabilis* and altitude in north and south aspect respectively.

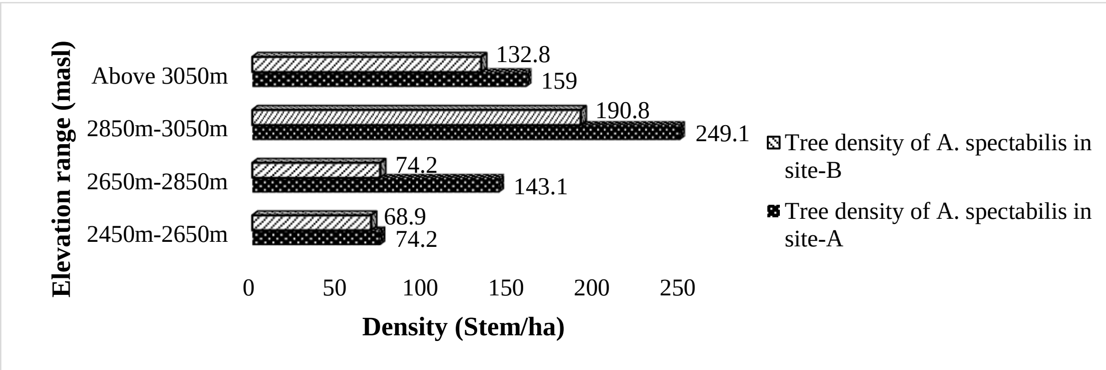

Figure 4.4. Density of *A. spectabilis* in different altitudinal range of site- A (North) and site- B(South).

4.1.4. Basal area of trees at different altitudes

Basal area of the tree was lower above and below an elevation 2650m-2850m in northern aspect. This clearly showed gradual decrease in basal area of tree on increasing elevation. In case of northern aspect total basal area of tree ranged from 14.47 m^2/ha at an elevation above 3050m (Appendix VII) to 24.91 m^2/ha at elevation 2650m-2850m (Appendix V).

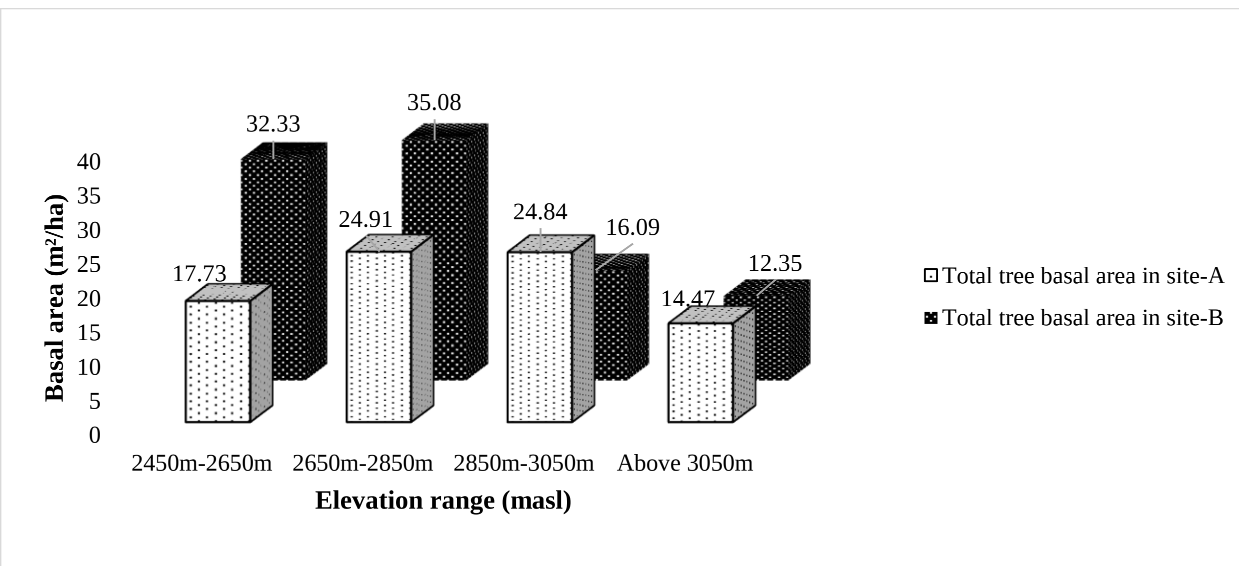

Figure 4.5. Total tree basal area in different altitudinal range of site- A (North) and site- B (South).

Similar trend of decrease in basal area on increasing elevation was observed in southern aspect as well. Basal area of the tree was lower above and below an elevation 2650m-2850m in southern aspect. The total tree basal area ranged from 12.35m^2/ha at elevation above 3050m (Appendix XI) to 35.08 m^2/ha at an elevation 2650m-2850m (Appendix IX). Paired t- test showed significant relation (p=.008 and p=.042) between tree basal area and altitude in north and south aspect respectively.

Basal area of *A. spectabilis* was lower above and below 2850m-3050m in northern aspect. Whereas, in southern aspect it was increased up to an elevation range 2650m-2850m and get decreased. Basal area of *A. spectabilis* was decreased with increase in altitude. In northern aspect the highest basal area (8.29 m^2/ha) of *A. spectabilis* was found at an elevation 2850m-3050m (Appendix VI). The highest basal area (10.25 m^2/ha) of *A. spectabilis* was found at elevation 2650m-2850m (Appendix IX) in southern aspect. Paired t- test showed significant relation (p=.011 and p=.018) between basal area and altitude in north and south aspect respectively.

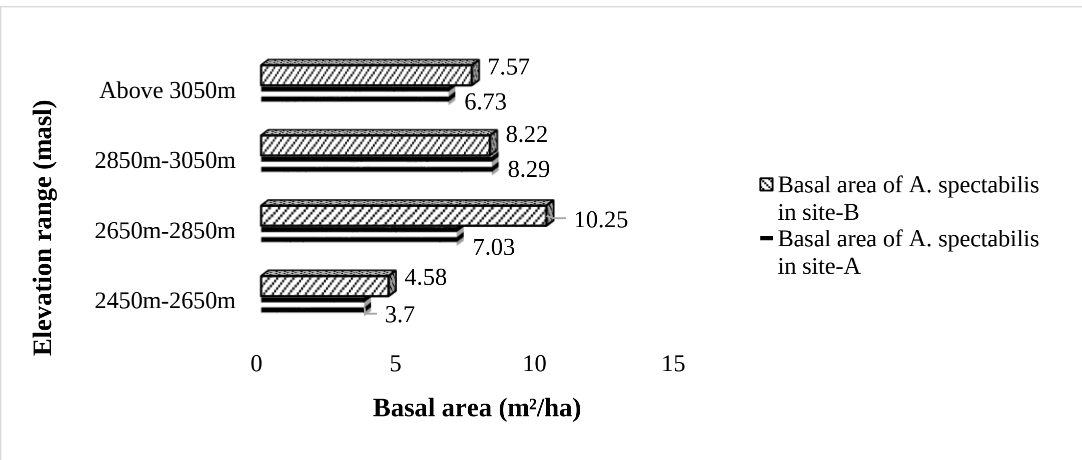

Figure 4.6. Basal area of *A. spectabilis* in different altitudinal range of site- A (North) and site- B (South).

4.1.5. DBH of *Abies spectabilis* in different altitudes

In northern aspect, mean DBH (cm) of *A. spectabilis* ranged from 20.72cm to 28.85cm. The DBH of tree was lowest at lower elevation and the DBH of tree was highest at elevation range 2850m-3050m and then get decreased (Table 2). There wass significant difference between DBH of trees at different altitudes.

Similarly, mean DBH (cm) of *A. spectabilis* in southern aspect ranged from 22.59cm to 36.33cm. The DBH of tree was lowest at lower elevation and the DBH of tree was highest at elevation range 2650m-2850m and then get decreased (Table 4.2). There was significant difference between DBH of trees at different altitudes.

Table 4.2. Mean and standard deviation of DBH of *A. spectabilis* in different altitude of site A(North) and B(South).

SN.	Altitude(masl)	Mean DBH(cm)	
		Site A	Site B
1	2450-2650	20.72±5.44*	22.59±5.74*
2	2650-2850	27.67±7.14	36.33±10.99*
3	2850-3050	28.85±11.79*	30.85±8.46
4	Above 3050	25.22±9.73	26.7±12.005*

*. The mean difference is significant at the 0.05 level.

In case of northern aspect one-way ANOVA showed that, there was significant difference among DBH (cm) of *A. spectabilis* according to altitude range in study area, at 95% confidence level since P value was less than 0.05. But, Tukey's post hoc test showed this difference in elevation range 2450m-2650m and 2850m-3050m (Table 4.2 and 4.3).

Table 4.3. Tukey's post hoc test of DBH of *A. spectabilis* in different altitudes in northern aspect (Site A).

(I) Altitude	(J) Altitude	Mean Difference (I-J)	Std. Error	Sig.
2450m-2650m	2650m-2850m	-6.95549	3.28942	.155
	2850m-3050m	-8.13602*	3.02129	.040
	Above 3050m	-4.50524	3.21175	.500
2650m-2850m	2450m-2650m	6.95549	3.28942	.155
	2850m-3050m	-1.18052	2.42530	.962
	Above 3050m	2.45026	2.65880	.793
2850m-3050m	2450m-2650m	8.13602*	3.02129	.040
	2650m-2850m	1.18052	2.42530	.962
	Above 3050m	3.63078	2.31887	.402
Above 3050m	2450m-2650m	4.50524	3.21175	.500
	2650m-2850m	-2.45026	2.65880	.793
	2850m-3050m	-3.63078	2.31887	.402

*. The mean difference is significant at the 0.05 level.

In case of southern aspect one-way ANOVA showed that, there was significant difference among DBH of *A. spectabilis* according to altitude range in study area, at 95% confidence level since P value was less than 0.05. Tukey's post hoc test showed this difference in elevation range 2450m-2650m and the elevation range 2650m-2850m and Above 3050m (Table 4.2 and 4.4).

Table 4.4. Tukey's post hoc test of DBH of *A. spectabilis* in different altitudes in southern aspect (Site B).

(I) Altitude	(J) Altitude	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2450m-2650m	2650m-2850m	-13.66063*	3.66950	.002	-23.2746	-4.0466
	2850m-3050m	-8.14484	3.23487	.064	-16.6201	.3305
	Above 3050m	-4.11569	3.40559	.623	-13.0383	4.8069
2650m-2850m	2450m-2650m	13.66063*	3.66950	.002	4.0466	23.2746
	2850m-3050m	5.51580	2.94432	.247	-2.1983	13.2299
	Above 3050m	9.54494*	3.13092	.016	1.3420	17.7479
2850m-3050m	2450m-2650m	8.14484	3.23487	.064	-.3305	16.6201
	2650m-2850m	-5.51580	2.94432	.247	-13.2299	2.1983
	Above 3050m	4.02914	2.60804	.416	-2.8039	10.8622
Above 3050m	2450m-2650m	4.11569	3.40559	.623	-4.8069	13.0383
	2650m-2850m	-9.54494*	3.13092	.016	-17.7479	-1.3420
	2850m-3050m	-4.02914	2.60804	.416	-10.8622	2.8039

*. The mean difference is significant at the 0.05 level.

4.1.6. Height of *Abies spectabilis* in different altitudes

Mean height (m) of *A. spectabilis* in northern aspect ranged from 8.55m to 16.18m. The height of tree was lowest at elevation range 2450m-2650m and the height of tree was highest at elevation range 2650m-2850m. The trees were smaller at lowest and highest altitudinal range. The height of tree increased up to an elevation range 2650m-2850m and then get decreased (Table 4.5). There was significant difference between heights of trees. Mean height (m) of *A. spectabilis* in southern aspect ranged from 9.72m to 17.97m. The height of tree was lowest at elevation range 2450m-2650m and the height of tree was highest at elevation range 2850m-3050m. The trees were smaller at lowest and highest altitudinal range. The height of tree increased up to an elevation range 2850m-3050m and then get deceased (Table 4.5). There was significant difference between heights of trees.

Table 4.5. Mean and standard deviation of height of *A. spectabilis* in different altitude of site A(North) and B(South).

SN.	Altitude(masl)	Mean Height(cm)	
		Site A	Site B
1	2450-2650	8.55±1.67*	9.72±3.03*
2	2650-2850	16.18±1.85*	15.35±3.21*
3	2850-3050	16.02±5.64*	17.97±5.42*
4	Above 3050	11.62±2.35*	10.82±2.27*

*. The mean difference is significant at the 0.05 level.

In case of northern aspect one-way ANOVA showed that, there was significant difference among height of *A. spectabilis* according to altitude range in study area, at 95% confidence level since P value was less than 0.05. Tukey's post hoc test showed this difference in elevation range 2450m-2650m and 2650m-2850m, in elevation 2450m-2650m and 2850m-3050m, in an elevation range 2650m-2850m and above 3050m, and in an elevation range 2850m-3050m and above 3050m (Table 4.5 and 4.6).

Table 4.6. Tukey's post hoc test of height of *A. spectabilis* in different altitudes in northern aspect (Site A).

(I) Altitude	(J) Altitude	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2450m-2650m	2650m-2850m	-7.63462*	1.31918	.000	-11.0746	-4.1946
	2850m-3050m	-7.47128*	1.21165	.000	-10.6309	-4.3117
	Above 3050m	-3.07333	1.28803	.086	-6.4321	.2854
2650m-2850m	2450m-2650m	7.63462*	1.31918	.000	4.1946	11.0746
	2850m-3050m	.16334	.97264	.998	-2.3730	2.6997
	Above 3050m	4.56128*	1.06628	.000	1.7808	7.3418
2850m-3050m	2450m-2650m	7.47128*	1.21165	.000	4.3117	10.6309
	2650m-2850m	-.16334	.97264	.998	-2.6997	2.3730
	Above 3050m	4.39794*	.92995	.000	1.9729	6.8230
Above 3050m	2450m-2650m	3.07333	1.28803	.086	-.2854	6.4321
	2650m-2850m	-4.56128*	1.06628	.000	-7.3418	-1.7808
	2850m-3050m	-4.39794*	.92995	.000	-6.8230	-1.9729

*. The mean difference is significant at the 0.05 level.

In case of southern aspect one-way ANOVA showed that, there was significant difference among height of *A. spectabilis* according to altitude range in study area, at 95% confidence level since P value was less than 0.05. Tukey's post hoc test showed this difference in elevation range 2450m-2650m and 2650m-2850m, in elevation 2450m-2650m and 2850m-3050m, in an elevation range 2650m-2850m and above 3050m, and in an elevation range 2850m-3050m and above 3050m (Table 4.5 and 4.7).

Table 4.7. Tukey's post hoc test of height of *A. spectabilis* in different altitudes in southern aspect (Site B).

(I) Altitude	(J) Altitude	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
2450m-2650m	2650m-2850m	-5.75566*	1.58351	.003	-9.9044	-1.6069
	2850m-3050m	-8.71677*	1.42546	.000	-12.4515	-4.9821
	Above 3050m	-1.56455	1.49706	.723	-5.4868	2.3577
2650m-2850m	2450m-2650m	5.75566*	1.58351	.003	1.6069	9.9044
	2850m-3050m	-2.96111	1.19444	.070	-6.0905	.1683
	Above 3050m	4.19111*	1.27903	.008	.8401	7.5422
2850m-3050m	2450m-2650m	8.71677*	1.42546	.000	4.9821	12.4515
	2650m-2850m	2.96111	1.19444	.070	-.1683	6.0905
	Above 3050m	7.15222*	1.07720	.000	4.3300	9.9745
Above 3050m	2450m-2650m	1.56455	1.49706	.723	-2.3577	5.4868
	2650m-2850m	-4.19111*	1.27903	.008	-7.5422	-.8401
	2850m-3050m	-7.15222*	1.07720	.000	-9.9745	-4.3300

*. The mean difference is significant at the 0.05 level.

4.2. Soil Analysis

Soil characters (pH, Organic matter, Nitrogen, Phosphorus and potassium) of every 200m altitudinal interval were analyzed for both the sites. pH of the soil indicated that it was slightly acidic in nature. pH of site A (North) ranged from 5.39 to 5.68. Where as in site B (South) it ranged from 5.30 to 5.82 (Table 4.8). There was no significant difference (*P*=.170) role of pH with altitude on both sites (Appendix XX). Organic matter of site A (North) ranged from 3.57% to 3.77%. Similarly, organic matter of site B (South) ranged from 3.69% to 3.78% (Table 4.8). There was no significant difference (*P*= 0.717) role of organic matter with altitude on both sites (Appendix XX). Total Nitrogen in the soil ranged from 0.30% to 0.32% in site A (North). Whereas it was found 0.32% in site B (South) (Table 4.8). There was no significant relation (*P*=.849) of Nitrogen with altitudes on both the sites (Appendix XX).

The total available Phosphorus in site A (North) ranged from 13.09 kg/ha to 18.38 kg/ha. Similarly, in site B (South) it ranged from 12.65 kg/ha to 18.38 kg/ha (Table 4.8). There was no significant relation (*P*=.739) of Phosphorus with altitude on both the sites (Appendix XX). The total Potassium content in soil ranged from 149.2 kg/ha to 454.8 kg/ha in site A (North). Similarly, in site B (South) it ranged from 370.8 kg/ha to 6.02 kg/ha (Table 4.8). The highest Potassium content was 602 kg/ha in site A (North) and lowest potassium content was 149.2 kg/ha in site B (South). There was no significant relation (*P*=.161) of Potassium with altitude on both the sites (Appendix XX). For correlation of soil and other parameters see correlation table (Table 4.11 and 4.12).

Table 4.8. Average value of different soil parameters in different altitudes of site A(North) and B(South).

Altitude(masl)	**Ph**		**OM(%)**		**N(%)**		**P(kg/ha)**		**K(kg/ha)**	
	Site-A	**Site-B**	**Site-A**	**Site-B**	**Site-A**	**Site-B**	**Site-A**	**Site-B**	**Site-A**	**Site-B**
2450-2650	5.68	5.30	3.57	3.77	0.30	0.32	14.1	17.36	394	418
2650-2850	5.39	5.54	3.77	3.69	0.32	0.32	18.38	15.84	454.8	486.8
2850-3050	5.59	5.82	3.70	3.78	0.32	0.32	13.95	12.65	149.2	370.8
Above 3050	5.46	5.58	3.76	3.76	0.31	0.32	13.09	13.73	327.6	602

4.3. Forest regeneration

4.3.1. Life form diagram

In case of northern aspect there were 435 stem/ha seedlings, 323 stem/ha saplings, 265 stem/ha trees in an elevation range 2450m-2650m and 721 stem/ha seedlings 223 stem/ha saplings and 313 stem/ha trees in an elevation range 2650m-2850m. Similarly, there were 801 stem/ha seedlings, 371 stem/ha saplings and 610 stem/ha trees in an elevation range 2850m-3050m and 573 stem/ha seedlings, 514 stem/ha saplings and 498 stem/ha trees were recorded at an elevation range above 3050m (Figure 4.7).

In case of southern aspect, there were 106 stem/ha seedlings, 244 stem/ha saplings and 292 stem/ha trees in an elevation range 2450m-2650m. 737 stem/ha seedlings, 281 stem/ha saplings and 334 stem/ha trees were found in elevation range 2650m-2850m. Similarly, there were 620 stem/ha seedlings, 398 stem/ha saplings and 567 stem/ha trees in an elevation range 2850m-3050m and 769 stem/ha seedlings, 742 stem/ha saplings and 345 stem/ha trees were recorded at elevation Above 3050m (Figure 4.7).

In case of *A. spectabilis* there were no seedlings and saplings at elevation 2450m-2650m in both northern and southern aspect. There were 74 stem/ha and 69 stem/ha trees in northern and northern aspect respectively. Similarly, 424 stem/ha seedlings, 42 stem/ha saplings and 143 stem/ha trees were found in northern aspect and 286 stem/ha seedlings, 21 stem/ha saplings and 74.2 stem/ha trees were found in southern aspect at elevation 2650m-2850m. There were 514 stem/ha seedlings, 148 stem/ha saplings and 249 stem/ha trees in northern aspect and 557 stem/ha seedlings, 180 stem/ha saplings and 191 stem/ha trees in southern aspect at elevation 2850m-3050m. At elevation above 3050m there were 472 stem/ha seedlings, 313 stem/ha saplings and 159 stem/ha trees in southern aspect whereas, 525 stem/ha seedlings, 557 stem/ha saplings and 133 stem/ha treesin southern aspect were recorded. Tree density of *A. spectabilis* was higher at each elevation in northern aspect than in southern aspect. At elevation range 2650m-2850m, seedling and sapling density was higher in northern aspect than in southern aspect. But, seedling and sapling density was higher at elevation range 2850m-3050m and above 3050m in southern aspect than in northern aspect (Figure 4.7).

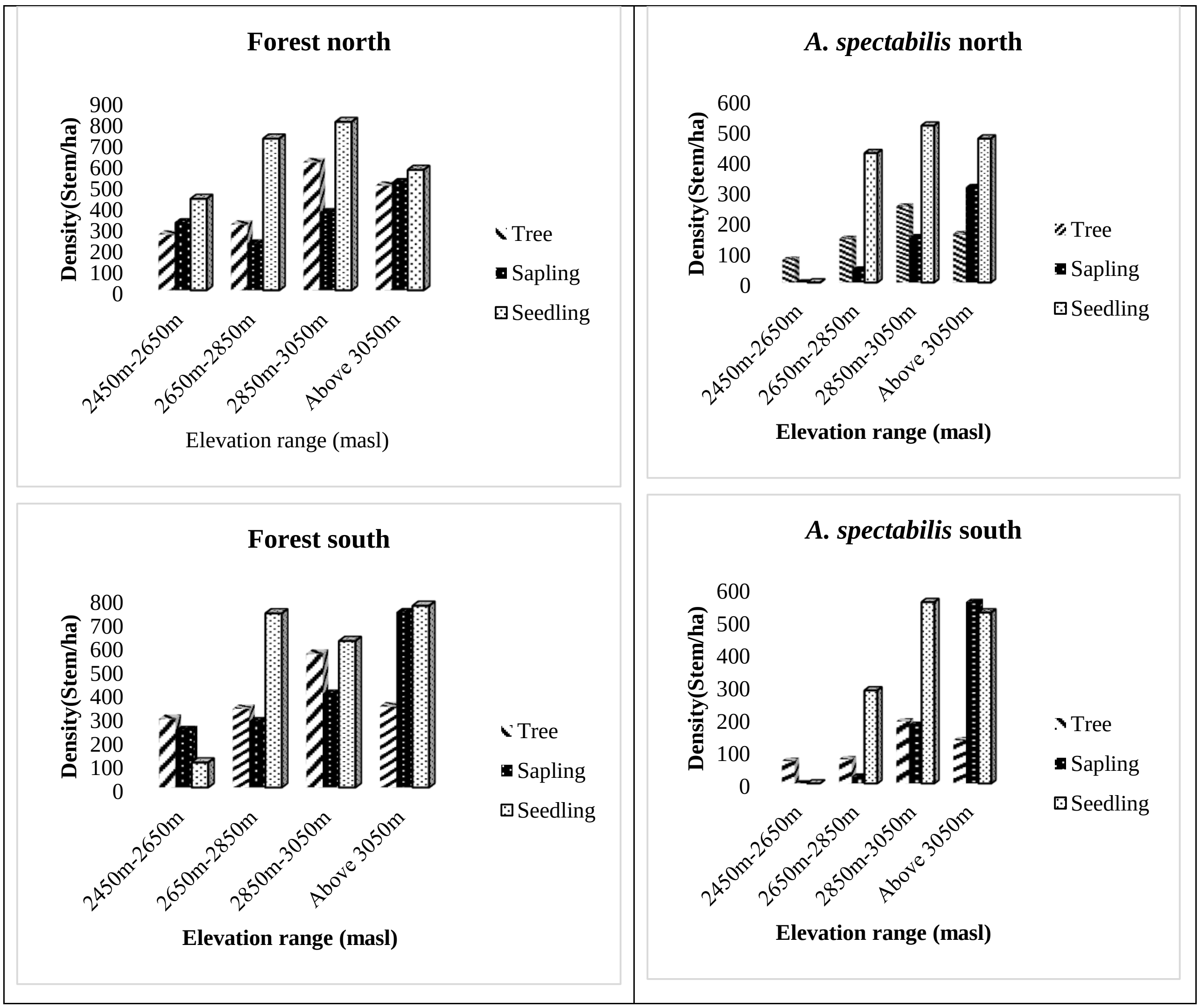

Figure 4.7. Life form diagram to show the regeneration status of forest and dominant tree species in northern and southern aspect.

4.3.2. Size class distribution

The size class diagram showed that the density of trees with smaller girth size was higher than larger girth size revealing clear reverse J shaped structure of overall forest in both aspects and which is the indication of regeneration.

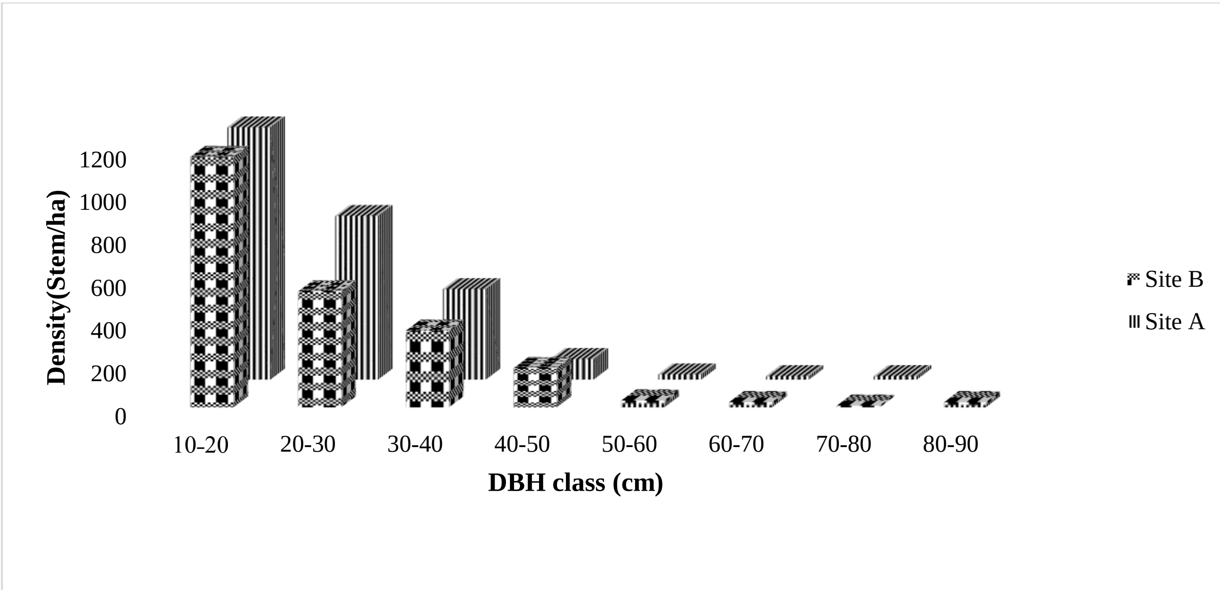

Figure 4.8. Density-diameter curve of overall forest of site A(North) and B(South).

In case of *A. spectabilis* all the trees were divided into different size classes based on DBH of 10 cm intervals. Density diameter curve of tree population of *A. spectabilis* showed more or less reverse J shaped structures in both sites, which is indication of regeneration (Vetaas 2002). The size class 20-30 cm consists of maximum number of individuals and size class 10-20 cm consists of fewer individuals in site A(North). While in site B(South) density of trees with DBH 30-40 cm were highest. Trees were smaller in site – B (DBH 10-50 cm) than in site – A (DBH 10-60 cm). This indicates that trees in site B(South) are younger than in site A(North). Cut stumps of large trees were observed in both the sites.

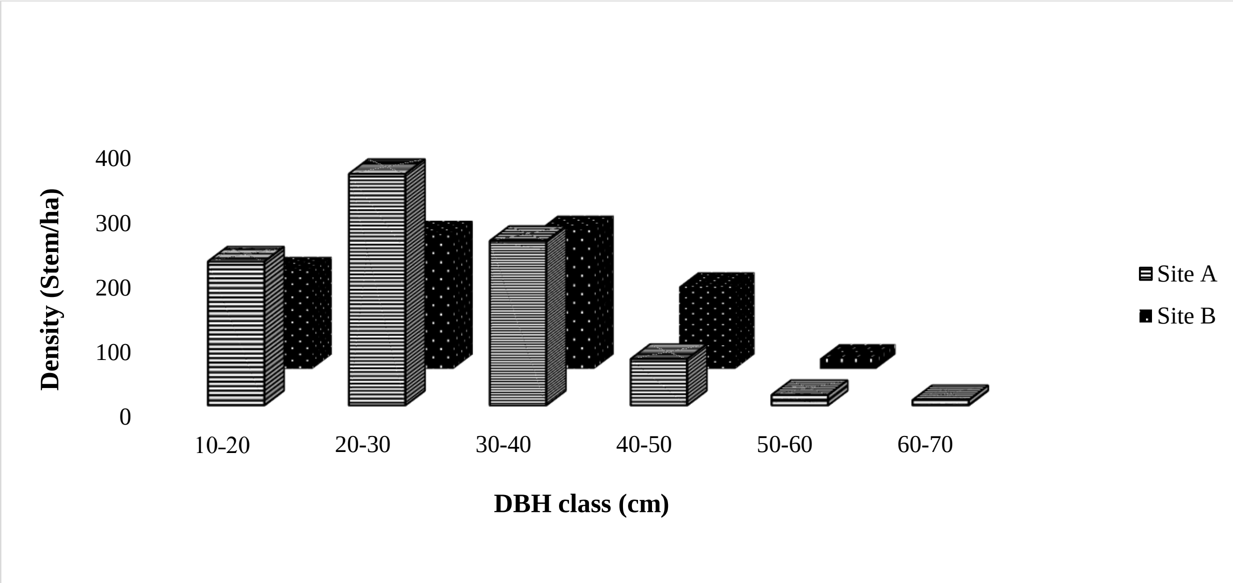

Figure 4.9. Density-diameter curve of *A. spectabilis* of site A(North) and B(South).

4.3.4. Seedling and Sapling Density

The distribution of saplings and seedlings of *A. spectabilis* were not uniform among sampling plots. There were no seedlings and saplings of *A. spectabilis* in lower elevation of northern and southern aspects. The seedling density of *A. spectabilis* in northern aspect ranged from 424.25 stem/ha at elevation 2650m-2850m to 514.40 stem/ha at elevation 2850m-3050m. Whereas density of sapling ranged from 42.42 stem/ha at elevation 2650m-2850m to 312.88 stem/ha above 3050m elevation range (Table 4.9).

In case of southern aspect, seedling density of *A. spectabilis* ranged from 286.37 stem/ha at elevation 2650m-2850m to 556.83 stem/ha at elevation 2850m-3050m. Similarly, sapling density ranged from 21.21 stem/ha at 2650m-2850m to 556.83 stem/ha above 3050m elevation range (Table 4.9).

Seedling density of *A. spectabilis* was lower below and above an elevation 2850m-3050m in both northern and southern aspect. Similarly, sapling density of *A. spectabilis* was lower below an elevation above 3050m.This indicates that the density of *A. spectabilis* saplings increased with increase in elevation (Table 4.9). Paired t- test showed there was no significant relation (p=.06 and p=.077) between seedling density and altitude in north and south aspect respectively. Similarly, paired t- test showed there was no significant relation (p=.172 and p=.241) between sapling density and altitude in north and south aspect respectively.

Table 4.9. Seedling and sapling density of *A. spectabilis* in different altitudes of site A and B.

Altitude(masl)	Seedling density(stem/ha)		Sapling density(stem/ha)	
	Site-A(North)	Site-B(south)	Site-A(North)	Site-B(South)
2450-2650	-	-	-	-
2650-2850	424.25	286.37	42.42	21.21
2850-3050	514.40	556.83	148.49	180.31
Above 3050	471.98	525.01	312.88	556.83

Pearson's correlation showed that the tree density is negatively correlated with organic matter present in the soil in northern aspect. However, effect of other soil nutrients and physical parameters were not significant (Table 4.10 and 4.11) in both study sites.

Table 4.10. Correlation of seedling, sapling and tree density of *A. spectabilis* with environmental factors of northern aspect (Site A).

	Tree density	sapling density	seedling density	Altitude	pH	OM	N	P	K	BA
Tree	1	.868	.016	.139	.977	-1.000**	.375	-.489	-.959	.949
density		.331	.990	.911	.135	.005	.755	.675	.183	.905
sapling	.868	1	.510	.613	.953	-.864	-.135	-.858	-.973	.666
density	.331		.659	.580	.196	.335	.914	.344	.148	.536
seedling	.016	.510	1	.992	.226	-.009	-.921	-.880	-.299	-0.301
density	.990	.659		.079	.855	.995	.254	.315	.807	.805
Altitude	.139	.613	.992	1	.345	-.132	-.866	-.932	-.414	-.181
	.911	.580	.079		.776	.916	.333	.237	.728	.884
pH	.977	.953	.226	.345	1	-.976	.171	-.662	-.997*	.861
	.135	.196	.855	.776		.140	.891	.539	.048	.340
OM	-1.000**	-.864	-.009	-.132	-.976	1	-.381	.483	.957	-.951
	.005	.335	.995	.916	.140		.751	.679	.188	.200
N	.375	-.135	-.921	-.866	.171	-.381	1	.625	-.096	.649
	.755	.914	.254	.333	.891	.751		.570	.939	.551
P	-.489	-.858	-.880	-.932	-.662	.483	.625	1	.716	-.188
	.675	.344	.315	.237	.539	.679	.570		.492	.879
K	-.959	-.973	-.299	-.414	-.997*	.957	-.096	.716	1	-.820
	.183	.148	.807	.728	.048	.188	.939	.492		.388
BA	.949	.666	-.301	-.181	.861	-.951	.649	-.188	-.820	1
	.205	.536	.805	.884	.340	.200	.551	.879	.388	

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

.OM=Organic matter, N=Nitrogen, P=Phosphorus, K=Potassium, BA=Basal area.

Table 4.11. Correlation of seedling, sapling and tree density of *A. spectabilis* with environmental factors of southern aspects (Site B).

	Tree density	**Sapling density**	**Seedling density**	**Altitude**	**pH**	**OM**	**N**	**P**	**K**	**BA**
Tree	1	.915	.289	.500	.924	.952	.000	-.983	-.502	-.726
density		.265	.813	.667	.249	.198	1.000	.117	.665	.483
Sapling	.915	1	.651	.807	.692	.994	-.404	-.973	-.110	-.942
density	.265		.549	.402	.514	.067	.735	.147	.930	.218
Seedling	.289	.651	1	.974	-.098	.568	-.957	-.460	.683	-.868
density	.813	.549		.147	.938	.616	.187	.696	.521	.331
Altitude	.500	.807	.974	1	.132	.741	-.866	-.650	.498	-.959
	.667	.402	.147		.916	.469	.333	.549	.668	.184
pH	.924	.692	-.098	.132	1	.764	.381	-.839	-.794	-.409
	.249	.514	.938	.916		.447	.751	.366	.416	.732
OM	.952	.994	.568	.741	.764	1	-.305	-.992	-.214	-.901
	.198	.067	.616	.469	.447		.802	.080	.863	.285
N	.000	-.404	-.957	-.866	.381	-.305	1	.183	-.865	.688
	1.000	.735	.187	.333	.751	.802		.883	.335	.517
P	-.983	-.973	-.460	-.650	-.839	-.992	.183	1	.335	.840
	.117	.147	.696	.549	.366	.080	.883		.783	.365
K	-.502	-.110	.683	.498	-.794	-.214	-.865	.335	1	-.231
	.665	.930	.521	.668	.416	.863	.335	.783		.852
BA	-.726	-.942	-.868	-.959	-.409	-.901	.688	.840	-.231	1
	.483	.218	.331	.184	.732	.285	.517	.365	.852	

.OM=Organic matter, N=Nitrogen, P=Phosphorus, K=Potassium, BA=Basal area.

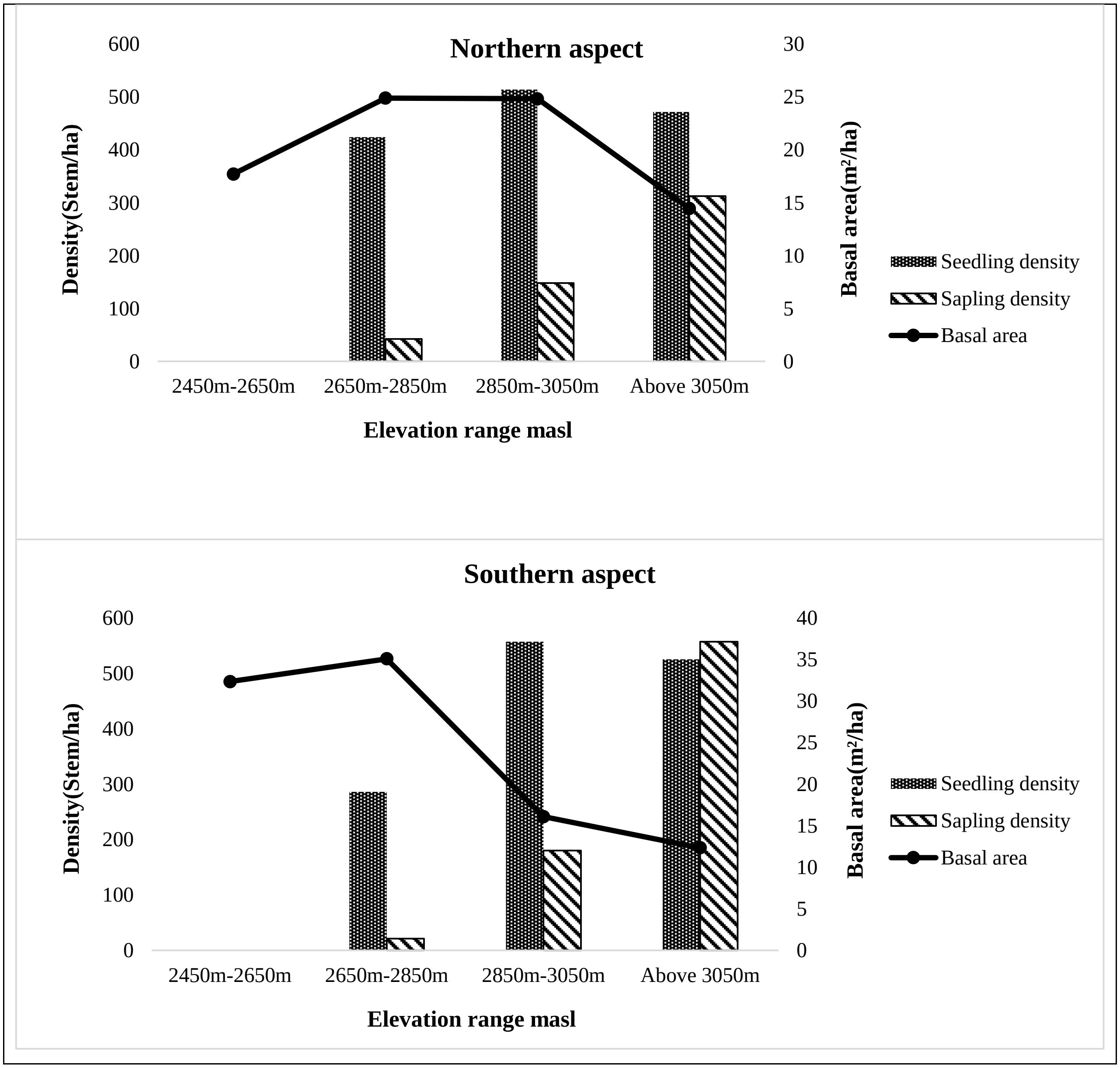

Figure 4.10. Variation of seedling and sapling density of *A. spectabilis* with total tree basal area in Site A(North) and Site B(South).

CHAPTER 5: DISCUSSION

5.1. Community structure

Vegetation composition of two sites was not so much contrasting. The study area mainly included temperate and subalpine type of vegetation with dominance of *Abies spectabilis, Tsuga dumosa,* and *Rhododendron* species. Similarly, composition of the shrub species also not much different along the altitudinal gradient as well as on the north and south aspect.

In the forest, plant community consists of trees, shrubs, herbs etc. They form different layers on the forest. The top canopy layer consists of tall trees like *A. spectabilis* and *T. dumosa* which receive the light directly from the sun. The sub canopy was occupied by different species of *Rhododendron* along with several other plant species. The third layer was made up of shrub species like *Berberis sp, Sarcococca sp., Daphne bholua etc.*

Total tree density of all tree species combined was ranged from 265 stem/ha to 609.6 stem/ha in site A and 291.5 stem/ha to 567.1 stem/ha in site B. This range of total tree density was more or less same as reported by Dang *et al.,* (2010) in *A. fargesii* forest in Shennongjia Mountain China. Sharma *et al.,* (2014) reported total tree density ranged from 552 stem/ha to 710 stem/ha from an assessment of forest structure and woody plant regeneration on the ridge at upper Bhagirathi basin in Garhwal Himalaya. Ghimire *et al.,* (2008) reported that total tree density ranged from 375 plant/ha to 845 plant/ha in *Juniperus* forest Manang. These values were higher than the density of present study forest. This variation may be due to variation in environmental condition.

Tree density of *A. spectabilis* was ranged from 74.2 stem/ha to 249.1 stem/ha in site A and 68.9 stem/ha to 190.8 stem/ha in site B. In *A. spectabilis* forest of Langtang National Park the density of *A. spectabilis* was 604 stem/ha (Tiwari, 2010). This showed that study forest was not pure *A. spectabilis* forest. Density of *A. spectabilis* reported by Nagarkoti *et al.,* (2019) is lower than that of the present study site.

Total tree basal area of present study forest ranged from 14.47 m^2/ha to 24.91 m^2/ha in site A and 12.35 m^2/ha to 35.08 m^2/ha in site B. Hanief *et al.,* (2016) found total basal area of tree ranged from 28.78 m^2/ha to 49.14 m^2/ha in oak forest and 25.88 m^2/ha to 48.97 m^2/ha in mixed broad leaved forest. These values were higher comparable to our studied sites. This variation might be due to higher total tree density. Total basal area reported by Ghimire *et al.,* (2010) in Central Nepal is lower than present study sites (A and B). Although total tree density was high in both northern and southern aspects.

Basal area of *A. spectabilis* in present study sites ranged from 3.70 m^2/ha to 8.29 m^2/ha in site A and 4.58 m^2/ha to 10.25 m^2/ha in site B. Ghimire *et al.,* (2010) reported total basal area of *Pinus wallichiana* ranged from 2.26 m^2/ha to 18.6 m^2/ha. This value was higher than our study sites. This was due to higher tree density of *P. wallichiana* comparable to density of *A. spectabilis* of our study.

Simpson's index of Dominance for tree in site A was 0.66 and was 0.68 in site B. Similarly, Shannon-wiener index of species diversity was 1.23 in site A and 1.30 in site B in present study sites. At the study sites Simpson's index of Dominance for tree was found less than species diversity of the forest. Shannon-wiener index of species diversity was found 0.99 in *A. pindrow* forest Sharma *et al.,* (2009). This value was less than value of both study sites of present study. Shannon-wiener index of species diversity was found 3.48 in subalpine broad leaved forest of western China Jiangming *et al.,* (2008). In *Larix chinensis* forest Liyun *et al.,* (2006) found Shannon-wiener index of species diversity to be 4.75. Comparing with these values the present study value had far low value of Shannon-wiener index of species diversity.

5.2. Regeneration

Density diameter curves of *A. spectabilis* in both sites A and site B show slightly deviated inverse reverse J-shaped curve (Figure 4.9), so the forest is regenerated type but not sustainable one. Reverse J- shaped density diameter curve is the indication of sustainable regeneration vetaas (2000). Reverse J- shaped density diameter curve was reported by Ghimire and Lekhak (2007) for mixed *A. spectabilis* forest of Manang and similar result was reported by Shrestha *et al.,* (2007) for *B. utilis* forest of Manang. Bhuju *et al.,* (2010) found inverse J- shaped diameter class distribution of *A. spectabilis* in Sagarmatha National Park. Ghimire and Lekhak (2007) recorded highest DBH of 45 cm whereas highest DBH of *A. spectabilis* was 69 cm in site A and 58 cm in site B. In present study sites it was observed that there was lack of large girth size tree in both aspects. Human interference may be the main factor of destruction of big trees.

In case of both northern and southern aspect size class 10-20 cm have low density. This may be due to contribution of other species such as *R. campanulatum, R. arboreum* etc. which generally had smaller sized individuals. It was found that larger trees were cut off by people for timber and firewood in present study sites.

Seedling density of *A. spectabilis* was increased up to certain limit (up to 2850m-3050m) after that it decreased gradually in both sites of present study site. Similar trend for increase in sapling density with increase in altitude was found in both sites of present study site. There were no seedlings and saplings in lower elevation range (2450m-2650m) in both aspects of present study site (Figure 4.10). Ghimire and Lekhak (2007) also found the similar trend in case of seedling and sapling density in subalpine forest of upper Manang, Central Nepal.

Seedling of *A. spectabilis* in the study site ranged from 424.25 stem/ha to 514.40 stem/ha in site A and 286.37 stem/ha in site B. Similarly, sapling density ranged from 42.42 stem/ha to 312.88 stem/ha in site A and 21.21 stem/ha to 556.83 stem/ha in site B. Seedling density of *A. spectabilis* was higher than that of sapling density in both aspects of present study site. In the previous studies (Ghimire and Lekhak, 2007; Tiwari, 2010; Nagarkoti *et al.,* 2019) also reported that seedling density of *A. spectabilis* was higher than sapling density, which shows a normal demographic development (West *et al.,* 1981). Less sapling density of *A. spectabilis* in present study forest might be due to mechanical damage to seedlings of *A. spectabilis*. Grazing/trampling and human interference were also responsible for less density of sapling.

Sapling density was high on those plots where basal area was low in both northern and southern aspects. Whereas, seedlings did not show clear picture of it (Figure 4.10). Similar result for both seedling and sapling density was observed by Tiwari (2010) in Langtang National Park. This might be due to the less availability of resources.

5.3. Soli and forest regeneration

The forest was regenerated type but not sustainable one. Topography, stand structure, soil properties and litter were major factors influencing the regeneration (Liang and Wei, 2020). Whereas, result from present study site did not show strong correlation with any of the above mentioned factors but Correlation showed altitude may have such relation with regeneration. Ghimire and Lekhak (2007) reported that the available phosphorus of soil had correlation with regeneration. But, present study did not show any relation between phosphorus and regeneration.

The forest soil was slightly acidic in nature in both site A and site B. The pH value was in the range of 5.39 to 5.68 in site A and 5.30 to 5.82 in site B. Nagarkoti *et al.,* (2019) found soil pH ranging from 4.2 to 5.93. Tiwari *et al.,* (2010) reported that soil of *A. spectabilis* forest was slightly acidic in nature with pH range 5.50 to 6.80. Similar results were found in the alpine forest of Central Nepal (Shrestha *et al.,* 2007; Ghimire and Lekhak, 2007). Most of the conifer leaves contain acid substances and after decomposition of leaves it will keep soil slightly acidic or neutral (Zhang and Zhao, 2007).

Soil organic carbon of the present study forest ranged from 3.57% to 3.77% in site A and 3.69% to 3.78% in site B respectively. Soil nitrogen of present study sites ranged from 0.3% to 0.32%. In mixed *A. spectabilis* forest of Manang Shrestha *et al.,* (2007) reported soil organic carbon and nitrogen to be 1% to 8.9% and 0.1% to 0.7%. From *P. koraiensis* forest Zhang and Zhao (2007) reported soil organic carbon and nitrogen to be 7.24% and 0.74%. These values were higher than the value of present study forest. This may be due to low litter cover.

Potassium content and available phosphorus ranged between 149.2 kg/ha to 454.8 kg/ha and 13.09 kg/ha to 18.38 kg/ha in site A and 370.8 kg/ha to 602 kg/ha and 12.65 kg/ha to 17.36 kg/ha in site B respectively. Ghimire *et al.,* (2010) reported potassium content and available phosphorus was found between 6.12 kg/ha to 24.46 kg/ha and 57.93 kg/ha to 263.91 kg/ha respectively in subalpine forest of Manang. Shrestha *et al.,* (2007) reported the soil potassium content ranged between 7 kg/ha to 325 kg/ha. This value is less than that of present study site. This may be due to less mineralization process.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Community structure and regeneration status of *A. spectabilis* was studied. Altitudinal range of the study area was ranged from 2450m to above 3050m asl in both northern and southern aspects. Altogether 13 tree species and 27 species forming shrub layer includes both shrub and tree species were recorded from both northern and southern aspects and from all altitudinal range. There was no such a drastic variation in vegetation composition in both aspects. Forest of Shailung is dominated mainly by *A. spectabilis, T. dumosa* and different species of *Rhododendron*. *Berberis, D. bholua* and *Sarcococca* were dominant among shrub species in both aspects. There was no single species of tree and shrub that dominated community on both sites.

Total tree density increased up to certain limit (up to 280m-3050m) and then decreased gradually in both aspects. Total basal area of tree gradually decreased with increase in an elevation in both northern and southern aspects. Seedling and sapling density increased with increase in an elevation. Seedling and sapling density decreased with increase in basal area.

Density diameter curve for *A. spectabilis* was deviated from reverse J- shape and did not show sustainable and continuous regeneration. Large girth sized trees were very few in number in study sites which may be due to adverse climatic condition or might be due to disturbances. Soil factor did not show any significant correlation with seedling and sapling density.

6.2. Recommendations

Following recommendations have been suggested from this study:

- Unsustainable use of forest products (timber, firewood and fodder) should be checked and alternative energy sources like solar energy and hydropower should be developed to decrease the dependency of people to the forest.
- Livestock are dangerous for seedling establishment; hence it should be banned from the forest at least during period of seedling development.
- Illegal tree cutting should be stopped.

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APPENDICES

Appendix I: Data sheets used in field sampling

Date: ……………Investigator: ………………………District : ……………..

Municipality: …………………. Locality: ……………………. Altitude(m) :………….

Aspect :…………………..Slope:………………..Latitude:…………………………

Longitude:…………………………Forest type:………………………Canopy cover……

Disturbance level:(0 – 3):…..Litter cover:…….

Plot No: Quadrat No: Quadrat size: Transect No:

For trees

S. N.	Plant species	Local name	DBH (cm)	Height (m)	Remarks

For shrub

S. N.	Plant species	Local name	No. of species	Coverage	Remarks

Appendix II: Geographical position of quadrat with Aspect, Slope, Altitude and Disturbance level (1= low, 2 = medium, 3= high).

Transect/plot	Latitude(°N)	Longitude (°E)	Altitude(m)	Aspect	Slope(°)	Disturbance level
T1P1 north	27.59806	85.97583	2452	304	32	1
T1P2 north	27.59806	85.97611	2455	302	35	1
T1P3 north	27.59806	85.97583	2461	28	34	1
T1P4 north	27.59806	85.97639	2450	8	30	1
T1P5 north	27.59778	85.97611	2455	14	20	1
T1P6 north	27.5975	85.97583	2460	322	27	1
T2P1 north	27.59111	85.97611	2654	352	20	2
T2P2 north	27.59083	85.97639	2650	314	25	2
T2P3 north	27.59111	85.97667	2660	324	20	1
T2P4 north	27.59139	85.97694	2651	342	33	2
T2P5 north	27.59083	85.97722	2670	350	37	2
T2P6 north	27.59889	85.97472	2663	25	37	1
T3P1 north	27.57889	85.97639	2861	61	31	1
T3P2 north	27.57861	85.97639	2852	14	32	0
T3P3 north	27.57861	85.97667	2857	33	24	1
T3P4 north	27.57833	85.97667	2870	5	26	0
T3P5 north	27.57778	85.97694	2859	19	28	1
T3P6 north	27.57472	85.97667	2875	338	30	0

T4P1 north	27.56778	85.9775	3050	14	25	0
T4P2 north	27.56778	85.97778	3053	344	34	0
T4P3 north	27.56778	85.9775	3057	338	26	0
T4P4 north	27.56806	85.97778	3070	353	22	0
T4P5 north	27.56861	85.97722	3061	359	19	0
T4P6 north	27.56778	85.97806	3065	347	32	0
T1P1 south	27.59	85.98833	2450	123	38	1
T1P2 south	27.59	85.98889	2456	132	34	1
T1P3 south	27.59	85.98889	2471	143	28	3
T1P4 south	27.59	85.98889	2465	167	29	3
T1P5 south	27.58417	85.98806	2456	150	21	2
T1P6 south	27.58417	85.98778	2479	142	22	2
T2P1 south	27.59889	85.98111	2658	126	17	1
T2P2 south	27.6	85.96722	2670	117	18	1
T2P3 south	27.59972	85.9675	2685	136	19	1
T2P4 south	27.59944	85.9675	2660	120	18	1
T2P5 south	27.59972	85.96694	2652	113	15	0
T2P6 south	27.59972	85.98333	2665	120	25	1
T3P1 south	27.57889	85.98111	2850	132	37	1
T3P2 south	27.57889	85.97806	2865	118	32	1
T3P3 south	27.57889	85.97861	2881	114	37	1
T3P4 south	27.57917	85.97833	2864	157	33	1
T3P5 south	27.57861	85.97833	2853	130	26	0

T3P6 south	27.57889	85.97806	2870	162	30	1
T4P1 south	27.58333	85.9775	3057	180	18	1
T4P2 south	27.56917	85.97722	3067	160	20	0
T4P3 south	27.56861	85.97806	3074	170	24	0
T4P4 south	27.56806	85.97778	3071	145	30	0
T4P5 south	27.5675	85.97778	3057	144	22	1
T4P6 south	27.56694	85.97833	3055	202	34	1

Appendix III: Total number of individuals of *Abies spectabilis* present in each plot. Adult's population is further divided into DBH classes.

Transects/Plots	Seedling	Sapling	Tree	DBH classes (cm) for tree					
				10-20	20-30	30-40	40-50	50-60	60-70
T1P1 north	0	0	2	1	1	0	0	0	0
T1P2 north	0	0	3	3	0	0	0	0	0
T1P3 north	0	0	2	0	2	0	0	0	0
T1P4 north	0	0	2	2	0	0	0	0	0
T1P5 north	0	0	2	0	3	0	0	0	0
T1P6 north	0	0	3	0	3	0	0	0	0
T2P1 north	5	0	10	3	3	4	0	0	0
T2P2 north	40	0	2	0	0	2	0	0	0
T2P3 north	10	0	10	0	6	4	0	0	0
T2P4 north	7	2	1	0	0	1	0	0	0

T2P5 north	12	3	2	0	0	2	0	0	0
T2P6 north	6	3	1	0	1	0	0	0	0
T3P1 north	13	4	4	2	1	0	0	0	1
T3P2 north	40	7	5	1	0	3	1	0	0
T3P3 north	12	4	6	0	3	3	0	0	0
T3P4 north	23	13	10	5	3	0	2	0	0
T3P5 north	0	0	4	1	2	0	0	1	0
T3P6 north	9	0	18	2	7	6	2	0	0
T4P1 north	9	8	11	0	6	5	0	0	0
T4P2 north	0	7	5	3	1	1	0	0	0
T4P3 north	20	9	3	0	2	1	0	0	0
T4P4 north	5	5	4	0	2	2	0	0	0
T4P5 north	0	0	4	1	0	3	0	0	0
T4P6 north	30	30	3	1	0	1	0	1	0
T1P1 south	0	0	2	2	0	0	0	0	0
T1P2 south	0	0	3	2	1	0	0	0	0
T1P3 south	0	0	2	0	2	0	0	0	0
T1P4 south	0	0	1	0	0	1	0	0	0
T1P5 south	0	0	3	1	1	1	0	0	0
T1P6 south	0	0	2	1	1	0	0	0	0
T2P1 south	42	0	5	5	0	0	0	0	0
T2P2 south	4	2	3	1	1	0	0	1	0
T2P3 south	5	0	3	0	0	1	2	0	0

T2P4 south	3	0	1	0	0	1	0	0	0
T2P5 south	0	2	2	0	2	0	0	0	0
T2P6 south	0	0	2	0	0	2	0	0	0
T3P1 south	14	0	5	0	0	2	3	0	0
T3P2 south	21	0	4	0	1	3	0	0	0
T3P3 south	13	11	7	2	3	2	0	0	0
T3P4 south	6	6	6	2	3	1	0	0	0
T3P5 south	8	3	8	0	3	3	2	0	0
T3P6 south	43	14	6	0	2	4	0	0	0
T4P1 south	15	16	6	3	0	2	1	0	0
T4P2 south	12	11	3	0	2	1	0	0	0
T4P3 south	9	12	4	3	0	0	1	0	0
T4P4 south	27	34	2	0	0	1	1	0	0
T4P5 south	17	20	4	0	2	0	2	0	0
T4P6 south	19	12	6	3	2	1	0	0	0

Appendix IV: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude 2450m-2650m of northern aspect (site - A).

SN.	**Plant species**	**F(%)**	**RF(%)**	**D(stem/ha)**	**RD(%)**	**BA(m^2/ha)**	**RBA(%)**	**IVI**
1	*A. spectabilis*	100	28.57	74.2	28	3.70	20.88	77.45
2	*T. dumosa*	100	28.57	127.2	48	6.68	37.68	114.26
3	*Q. semicarpifolia*	50	14.28	15.9	6	0.94	5.29	25.57

4	*Lindera sp.*	33.33	9.52	10.6	4	1.36	7.67	21.19
5	*Simplocus sp.*	66.67	19.04	37.1	14	5.05	28.47	61.52
	Total	**350**		**265**		**17.73**		

Appendix V: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude 2650m-2850m of northern aspect (site - A).

SN.	**Plant species**	**F(%)**	**RF(%)**	**D(stem/ha)**	**RD(%)**	**BA(m^2/ha)**	**RBA(%)**	**IVI**
1	*A. spectabilis*	83.33	29.41	143.1	45.76	7.03	28.23	103.40
2	*T. dumosa*	66.67	23.52	53	16.95	11.33	45.47	85.95
3	*R. arboreum*	16.67	5.88	15.9	5.08	1.17	4.68	15.65
4	*R. campanulatum*	33.33	11.76	42.4	13.56	0.95	3.82	29.15
5	*Simplocus sp.*	83.33	29.41	58.3	18.64	4.43	17.78	65.83
	Total	**283.33**		**312.7**		**24.91**		

Appendix VI: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude 2850m-3050m of northern aspect (site - A).

SN.	**Plant species**	**F(%)**	**RF(%)**	**D(stem/ha)**	**RD(%)**	**BA(m^2/ha)**	**RBA(%)**	**IVI**
1	*A. spectabilis*	100	28.57	249.1	40.87	8.29	33.38	102.82
2	*T. dumosa*	33.33	9.52	15.9	2.61	4.72	18.98	31.12
3	*R. arboreum*	83.33	23.80	233.2	38.26	2.65	10.67	72.74
4	*R. campanulatum*	83.33	23.80	95.4	15.65	3.62	14.58	54.04
5	*Lyonia ovalifolia*	16.67	4.76	5.3	0.87	4.60	18.52	24.15

6	*UN e*	33.33	9.52	10.6	1.74	0.96	3.86	15.12
	Total	**349.99**		**609.6**		**24.84**		

Appendix VII: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude above 3050m of northern aspect (site - A).

SN.	**Plant species**	**F(%)**	**RF(%)**	**D(stem/ha)**	**RD(%)**	**BA(m^2/ha)**	**RBA(%)**	**IVI**
1	*A. spectabilis*	100	35.29	159	31.91	6.73	46.48	113.69
2	*T. dumosa*	16.67	5.88	5.3	1.06	1.29	8.94	15.89
3	*R. arboreum*	100	35.29	254.4	51.06	4.63	31.99	118.35
4	*R. barbatum*	66.67	23.52	79.5	15.96	1.82	12.58	52.06
	Total	**283.34**		**498.2**		**14.47**		

Appendix VIII: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude 2450m-2650m of southern aspect (site - B).

SN.	**Plant species**	**F(%)**	**RF(%)**	**D(stem/ha)**	**RD(%)**	**BA(m^2/ha)**	**RBA(%)**	**IVI**
1	*A. spectabilis*	100	26.09	68.9	23.64	4.58	14.16	63.88
2	*T. dumosa*	100	26.09	132.5	45.45	21.06	65.13	136.67
3	*Lindera sp*	33.33	8.69	10.6	3.63	0.99	3.08	15.41
4	*P. wallichiana*	16.67	4.35	5.3	1.81	2.55	7.87	14.03
5	*UN d*	50	13.04	26.5	9.09	1.59	4.94	27.07
6	*UN e*	83.33	21.73	47.7	16.36	1.56	4.82	42.92
	Total	**383.33**		**291.5**		**32.33**		

Appendix IX: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude 2650m-2850m of southern aspect (site - B).

SN.	**Plant species**	**F(%)**	**RF(%)**	**D(stem/ha)**	**RD(%)**	**BA(m^2/ha)**	**RBA(%)**	**IVI**
1	*A. spectabilis*	83.33	23.81	74.2	22.22	10.25	29.20	75.23
2	*T. dumosa*	83.33	23.81	111.3	33.33	7.15	20.37	77.51
3	*Q. semicarpifolia*	33.33	9.52	21.2	6.35	6.00	17.11	32.98
4	*R. arboretum*	50	14.28	47.7	14.29	2.23	6.34	34.90
5	*Simplocus sp.*	16.67	4.76	10.6	3.17	0.86	2.47	10.41
6	*P. wallichiana*	33.33	9.52	47.7	14.29	6.54	18.64	42.45
7	*UN c*	33.33	9.52	15.9	4.76	1.10	3.16	17.44
8	*UN e*	16.67	4.76	5.3	1.59	0.95	2.71	9.06
	Total	**349.99**		**333.9**		**35.08**		

Appendix X: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude 2850m-3050m of southern aspect (site - B).

SN.	**Plant species**	**F(%)**	**RF(%)**	**D(stem/ha)**	**RD(%)**	**BA(m^2/ha)**	**RBA(%)**	**IVI**
1	*A. spectabilis*	100	33.33	190.8	33.64	8.22	51.09	118.06
2	*Q. semicarpifolia*	66.67	22.22	68.9	12.15	2.55	15.85	50.21
3	*R. arboreum*	100	33.33	270.3	47.66	2.31	14.34	95.33
4	*R. campanulatum*	33.33	11.11	37.1	6.54	3.01	18.73	36.38
	Total	**300**		**567.1**		**16.09**		

Appendix XI: Density (D), Frequency (F), Basal Area (BA), Relative Density (RD), Relative Frequency (RF), Relative Basal Area (RBA) and Importance Value Index (IVI) of trees at altitude above 3050m of southern aspect (site - B).

SN.	Plant species	F(%)	RF(%)	D(stem/ha)	RD(%)	BA(m^2/ha)	RBA(%)	IVI
1	*A. spectabilis*	100	42.86	132.5	38.46	7.57	61.26	142.58
2	*Q. semicarpifolia*	33.33	14.29	26.5	7.69	1.85	14.99	36.98
3	*R. arboreum*	100	42.86	185.5	53.85	2.93	23.74	120.44
	Total	**233.33**		**344.5**		**12.35**		

Appendix XII: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude 2450m-2650m of northern aspect (site - A).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Gaultheria sp.*	4.44	4.68	5.65	14.78
2	*Hypericum sp.*	11.11	19.30	13.73	44.14
3	*Berberis sp.*	11.11	12.86	8.72	32.70
4	*symplocos sp.*	2.22	1.17	4.85	8.24
5	*Linder asp.*	2.22	1.17	1.61	5.01
6	*Q. semicarpifolia*	2.22	0.58	1.61	4.42
7	*R. arboreum*	2.22	0.58	1.61	4.42
8	*Rubus fruticosus*	11.11	12.86	4.85	28.82
9	*Mahunia nepalensis*	4.44	2.92	4.36	11.73
10	*Smilax elegan*	11.11	9.36	2.91	23.37
11	*Lyonia ovalifolia*	4.44	1.75	10.50	16.70
12	*T. dumosa*	6.67	4.09	9.69	20.45
13	*Daphne bholua*	4.44	5.85	8.72	19.01
14	*Sarcococca sp*	6.67	10.53	6.46	23.65
15	*UN a*	4.44	7.60	9.37	21.42

16	*UN b*	4.44	2.34	1.29	8.07
17	*Rosa sp.*	2.22	1.17	0.81	4.20
18	*Eurya sp.*	2.22	0.58	0.81	3.61
19	*Phyllanthus sp.*	2.22	0.58	2.42	5.23

Appendix XIII: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude 2650m-2850m of northern aspect (site - A).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Sarcococca sp.*	19.35	39.66	1.13	60.15
2	*Berberis sp.*	19.35	25.29	2.83	47.48
3	*Rubus fruticosus*	16.13	8.05	22.68	46.86
4	*UN b*	3.22	1.15	2.46	6.83
5	*Daphne bholua*	16.13	14.95	1.51	32.59
6	*Smilax elegan*	6.45	2.30	0.94	9.70
7	*UN a*	3.22	1.15	26.46	30.84
8	*Lyonia ovalifolia*	3.22	0.57	34.03	37.83
9	*Hypericum sp.*	3.22	4.02	0.94	8.19
10	*Gaultheria sp.*	6.45	1.72	6.05	14.22
11	*Mahunia nepalensis*	3.22	1.15	0.94	5.32

Appendix XIV: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude 2850m-3050m of northern aspect (site - A).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Berberis sp.*	22.22	42.42	25.46	90.11
2	*Daphne bholua*	22.22	31.13	20.74	74.09
3	*Rosa sp.*	3.70	0.34	0.67	4.72
4	*R. arboreum*	22.22	10.61	3.20	36.03
5	*R. campanulatum*	18.52	10.61	23.10	52.23
6	*Smilax elegan*	3.70	1.37	4.21	9.29

7	*Mahunia nepalensis*	3.70	0.68	0.67	5.06
8	*Rubus fruticosus*	3.70	3.42	21.92	29.05

Appendix XV: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude above 3050m of northern aspect (site - A).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Daphne bholua*	17.39	26.62	4.03	48.03
2	*R. arboretum*	13.04	15.32	8.72	37.09
3	*Smilax elegan*	13.04	10.48	19.46	42.99
4	*Sarcococca sp.*	4.35	8.06	2.35	14.76
5	*Vibernum sp.*	13.04	8.87	9.06	30.98
6	*R. barbatum*	13.04	8.06	22.15	43.26
7	*Mahunia nepalensis*	8.69	8.06	6.71	23.47
8	*Berberis sp.*	13.04	12.09	10.74	35.88
9	*Hypericum sp.*	4.35	2.42	16.78	23.55

Appendix XVI: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude 2450m-2650m of southern aspect (site - B).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Hypericum sp.*	6.45	6.59	5.87	18.91
2	*Berberis sp.*	19.35	41.10	26.96	87.42
3	*Daphne bholua*	3.22	3.88	3.26	10.36
4	*Sarcococca sp.*	16.13	19.00	2.61	37.74
5	*UN a*	3.22	1.55	4.35	9.12
6	*Smilax sp*	6.45	349	3.04	12.98
7	*Smilax elegan*	6.45	3.88	16.74	17.07
8	*UN e*	12.90	5.04	1.09	19.03
9	*Rosa sp.*	6.45	5.82	3.69	15.96
10	*UN d*	6.45	4.26	9.13	19.85

11	*T. dumosa*	3.22	0.77	4.35	8.35
12	*Mahunia nepalensis*	3.22	1.94	15.22	20.38
13	*Rubus fruticosus*	6.45	2.71	3.69	12.86

Appendix XVII: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude 2650m-2850m of southern aspect (site - B).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Gaultheria sp.*	10	11.07	12.29	33.36
2	*Berberis sp.*	20	31.27	12.29	63.56
3	*Hypericum sp.*	13.33	14.33	23.04	50.71
4	*Sarcococca sp.*	16.67	25.41	0.31	42.38
5	*Rubus fruticosus*	13.33	3.91	1.84	19.08
6	*smilax elegan*	3.33	0.32	16.90	20.56
7	*Daphne bholua*	13.33	12.05	23.81	49.19
8	*UN d*	6.67	1.30	4.15	12.12
9	*T. dumosa*	3.33	0.32	5.38	9.03

Appendix XVIII: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude 2850m-3050m of southern aspect (site - B).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Berberis sp.*	23.99	45.37	6.96	76.34
2	*Daphne bholua*	19.99	13.12	31.64	64.77
3	*Rubus fruticosus*	15.99	4.92	3.16	24.08
4	*Hypericum sp.*	7.99	9.29	4.11	21.41
5	*Smilax elegan*	7.99	3.28	22.47	33.75
6	*R. arboreum*	3.99	1.09	11.71	16.80
7	*UN d*	11.99	20.23	14.24	46.47
8	*Smilax sp.*	3.99	2.19	3.16	9.35
9	*A. spectabilis*	3.99	0.55	2.53	7.07

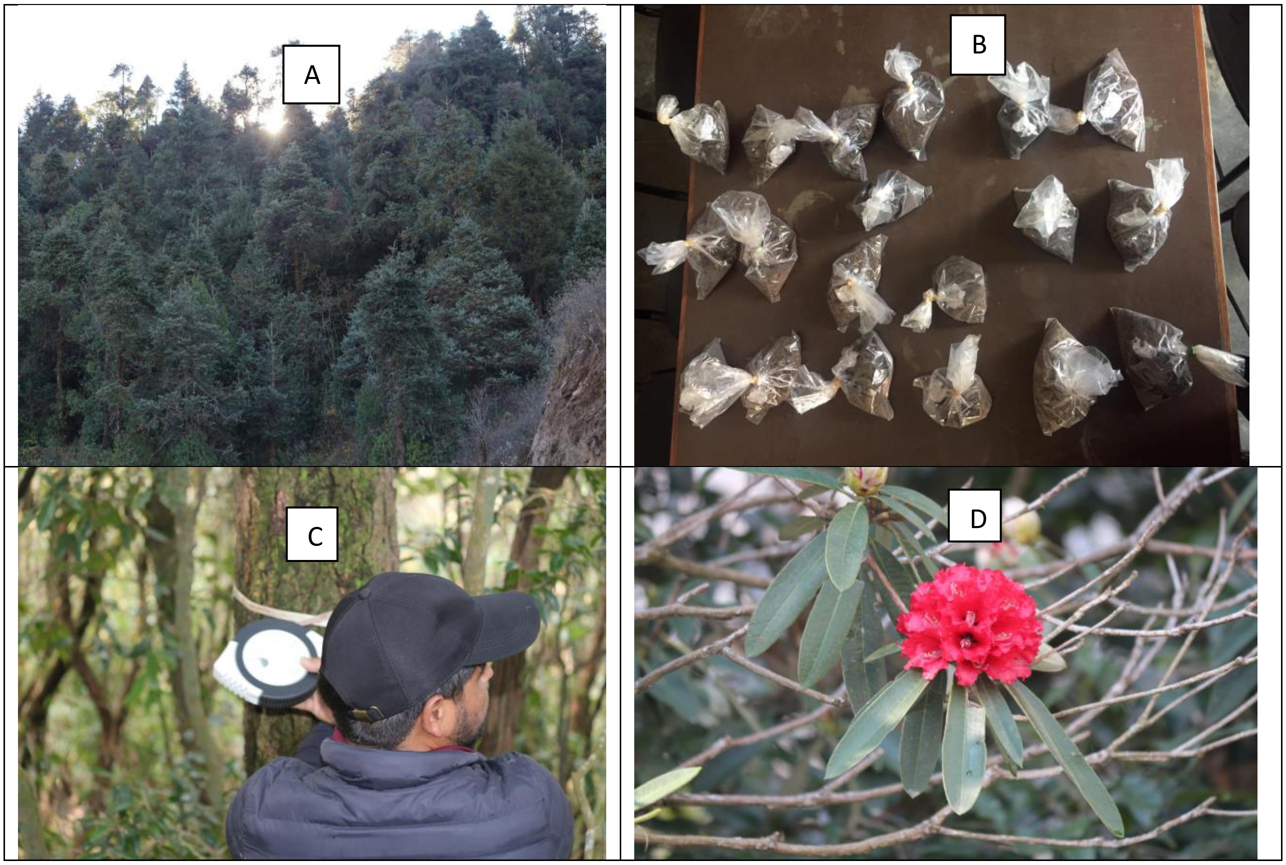
Appendix XIX: Relative Frequency (RF), Relative Density (RD), Relative Coverage (RC) and Importance Value Index (IVI) of shrubs at altitude above 3050m of southern aspect (site - B).

SN.	Plant species	RF(%)	RD(%)	RC(%)	IVI
1	*Hypericum sp.*	4.54	2.90	2.79	10.24
2	*Berberis sp.*	27.27	36.51	27.65	91.44
3	*Daphne bholua*	27.27	37.09	24.30	88.67
4	*R. arboreum*	22.73	10.43	1.40	34.56
5	*Cotoneaster sp.*	9.09	8.11	31.01	48.21
6	*Mahunia nepalensis*	4.54	2.32	3.35	10.21
7	*Vibernum sp.*	4.54	2.90	9.50	16.94

Appendix XX: ANOVA for comparing relation of different soil parameters with altitude.

		Sum of Squares	df	Mean Square	F	Sig.
pH	Between Groups	.220	3	.073	1.855	.170
	Within Groups	.790	20	.040		
	Total	1.010	23			
OM	Between Groups	.028	3	.009	.454	.717
	Within Groups	.411	20	.021		
	Total	.439	23			
N	Between Groups	.000	3	.000	.266	.849
	Within Groups	.004	20	.000		
	Total	.005	23			
P	Between Groups	62.022	3	20.674	.423	.739
	Within Groups	977.450	20	48.873		
	Total	1039.472	23			
K	Between Groups	173082.240	3	57694.080	1.906	.161
	Within Groups	605435.520	20	30271.776		
	Total	778517.760	23			

Appendix XXI: Selected photo plates.



In the above photo-plates, A= Landscape of the study site, B= Collected soil samples, C= Measuring DBH of tree, D= Flowering *Rhododendron sp.*