FOREST STRUCTURE AND REGENERATION OF *Betula utilis* D. DON IN MANASLU CONSERVATION AREA, Nepal

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ESTD.2001

DECLARATION

I hereby declare that the work presented in the thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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LETTER OF APPROVAL

This dissertation entitled **"Forest Structure and Regeneration of *Betula utilis* D. Don in Manaslu Conservation Area, Nepal"**, submitted by Ms. Hishila Sujakhu has been carried out under our supervision. The entire work is based on the results of her research work and has not been submitted for any other degree or organization to the best of our knowledge. We recommend this dissertation work to be accepted for the partial fulfillment of Master of Science Degree in Environmental Science.

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LETTER OF ACCEPTANCE

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ABBREVIATIONS

ANOVA	:	Analysis of Variance
a.s.l	:	Above sea level
BA	:	Basal Area
cm	:	Centimeter
CV	:	Coefficient of Variance
D	:	Density
DBH	:	Diameter at Breast Height
˚C	:	Degree Centigrade
DHM	:	Department of Hydrology and Meteorology
DNPWC	:	Department of National Park and Wildlife Conservation
E	:	East
F	:	Frequency
Gm	:	Gram
Ha	:	Hectare
IVI	:	Important Value Index
Kg	:	Kilogram
M	:	Meter
m^2	:	Square meter
mm	:	Millimeter
MCA	:	Manaslu Conservation Area
N	:	North
NARC	:	National Agriculture Research Council

NAST	:	Nepal Academy of Science and Technology
NTNC	:	National Trust for Nature Conservation
OM	:	Organic Matter
%	:	Percentage
RF	:	Relative Frequency
RD	:	Relative Density
RBA	:	Relative Basal Area
SD	:	Standard Deviation
SPSS	:	Statistical Package for Social Science

ABSTRACT

Forest structure and regeneration of *Betula utilis* (D. Don) was studied in *Betula utilis* forest located in Samagaun area (3500 – 4000 m) of Manaslu Conservation Area. Vegetation sampling was done by quadrat method. Five vertical transects running parallel to each other were defined within the study area and the paired quadrats (10 m × 10 m) spaced horizontally about 100 m apart was sampled at every 100 m elevation increment from 3500 m up to 4000 m. Altogether 40 quadrats were sampled to determine the Importance Value Index (IVI) of tree species, distribution pattern of seedlings and saplings, and soil attributes .Regeneration was assessed by density - diameter curve. Number of tree species, number of individuals of each tree species, diameter at breast height (DBH) and height of each individual tree, number of seedlings and saplings of tree species were recorded in each quadrat. Twelve soil samples were taken for laboratory analysis. Four tree species were recorded from the forest. *Betula utilis was* the dominant tree species with the highest Importance Value Index (173.22) in mixed *Betula* forest and 262.96 in Pure *Betula* forest and *Abies spectabilis* was the co – dominant species (65.95) in mixed *Betula* forest while *Rhododendron campanulatum* was the co-dominant species (37.03) in pure *Betula* forest. Simpson's Index of Dominance was more than Shannon Wiener's Index. Species diversity of the forest was relatively low, which might be due to anthropogenic factors such as cattle grazing, fire wood collection and logging. Density of *Betula utilis* was increased with increase in altitude where as density of other tree species were decreased with increase in altitude. Mixed Betula forest at lower elevation was young. The density diameter curve of the tree population of *Betula utilis* both on mixed and pure forests deviated slightly from the typical reverse J shaped structure and hence did not show the sustainable regeneration. The sapling density was higher than seedling density. The distribution of seedlings and saplings were not uniform among the sampling plots. There were no saplings on 25% of the plots and seedlings on 60%. In lower elevation saplings of *Abies spectabilis* and *Larix himalaica* were higher than of *Betula utilis.* If not severely disturbed, mixed *Betula* forest may be replaced by Abies *spectabilis.*

Keywords: *Forest structure, Regeneration, Betula utilis, Seedlings and Saplings*

CHAPTER I
INTRODUCTION

1.1 Background of the Study

Forests can be described by their composition, function and structure (Franklin *et al*., 1981). 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 & Larson, 1990).

Community structure of forest is directly regulated by species diversity, and it is the biological basis to maintain ecosystem functions (Tilman & 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, wind and insolation 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 & 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 phenological 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).

Betula utilis D. Don (*bhojpatra* birch) forms tree line vegetation all along the Nepal Himalayas and extensive stands of this species can be found on northern shady slopes and ravine (TISC, 2002). It is the only broadleaved angiosperm tree species in the Himalayas which dominates an extensive area at subalpine altitudes (Zobel & Singh, 1997). *Betula* spp. show a high freezing tolerance (Sakai & Larcher, 1987) which enables them to form a tree line in the Himalayas as well as in the Scandinavian region (Cairns & Moen, 2004).

1.2 Justification of the study

High elevation ecosystems of Himalayan region are the most vulnerable geographic regions of the world and are important regions for detecting the patterns of climatic change on regional scale. Subalpine forest which is represented as the uppermost forest ecosystem along the elevation gradient is considered for studying climatic variation. There is a phenomenal increase in temperature as a result of global warming during the past few decades and which in turn has an influence in the distribution and regeneration of tree – line birch. The regeneration of *Betula utilis* is very low compared to *Abies spectabilis*, dominant tree – line species. The *Betula* tree line is slowing and being invaded by Abies tree – line (NAST, 2011).

Regeneration of *Betula utilis* forest and spatial patterns of seedling distribution in the Manaslu area have not been detailed studied. So this research is intended to have detail study on it.

1.3 Objectives of the study

The general objective of the present study was to analyze vegetation of birch forest. The specific objectives were:

1.3.1 To document the community structure of *Betula utilis* forest.

1.3.2 To study the sapling and seedling distribution in *Betula utilis* forest.

1.3.3 To study the regeneration pattern of *Betula utilis* forest.

1.4 Limitations of the study

1.4.1 Vegetation sampling was done up to 4000 m only.

1.5.2 Only 12 soil samples were taken for laboratory analysis.

CHAPTER II
LITERATURE REVIEW

2.1 *Betula utilis*

Betula utilis (Himalayan birch, *bhojpatra*, Sanskrit: Bhurja), a valuable timber tree of commercial importance commonly found in temperate broad-leaved forests at high altitudes (3500 – 4200 m), has its distribution range from Inner Mongolia north of China to Yunnan province in the south and over the Himalayan region of Afghanistan, Bhutan, India and Nepal. *Betula utilis* is the most ecologically important broad-leaved tree species along the Himalayan range. Over much of its range it is dominant in a belt just below the tree line, but in some places it tends to be mixed with *Rhododendron*, *Abies* species and *Pinus wallichiana*, and is particularly characteristic of gullies where the snow lies for a long time (Zobel & Singh, 1997).

Betula utilis D. Don (Betulaceae) is a moderate-sized tree that grows up to 20 m in height. The bark is shining, reddish-white or white, with white horizontals smooth, lenticels. The outer bark consists of layers, exfoliating in broad horizontal rolls. The leaves are ovate-acuminate, elliptic, and irregularly serrate. The flowers bloom in May June, in pendulous spikes. The flowers are monoecious (individual flowers are either male or female, but both sexes can be found on the same plant) and are pollinated by wind. Seeds are thin and winged. The plant prefers light (sandy), medium (loamy) and heavy (clay) soils, requires well-drained soil and can grow in heavy clay soil. The plant prefers acid, neutral and basic (alkaline) soils. It can grow in semi-shade (light woodland) or no shade. It requires moist soil (Bhattacharyya *et al*., 2006). Its therapeutic constitutes antiseptic, aromatic, carminative and contraceptive effects. Parts of the plant, including the fungal growth (*bhurja-granthi*) have also long been used in local traditional medicine (Singh *et al*., 2012).

2.2 Community Structure

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).

Only three species of tree were recorded in a sub-alpine forest on the southern slope of the dry Manang valley, central Nepal. In that forest *Betula utilis* was found at the upper belt on moist northern slope. Lower belt was dominated by *Abies spectabilis* and *Pinus wallichiana*. Deforestation has changed species composition and community structure of subalpine forest (Ghimire & Lekhak, 2007).

In a forest of Kumaun region of India at 3000 – 3200 m altitude, three tree species shared dominance with nearly equal importance value indices (IVI); they were *Abies pindrow* (IVI 49.32), *Betula utilis* (IVI 48.32) and *Acer caesium* (IVI 45.54) (Gairola *et al*., 2008).

Three tree species in sub alpine forest in central – Himalayan dry valley in central Nepal. In that area, the *Betula utilis* forest was present as continuous tree line vegetation on moist, north facing slopes interrupted by glaciers, landslides and rocky cliffs at some places. The associated species in mixed *Betula* forest were *Abies spectabilis* and *Pinus wallichiana*. The density of *Betula utilis* in mixed *Betula* forest (3500 – 3900 m) was 864 stems/ha and that in pure *Betula* forest (3900 – 4200 m) was 1207 stem/ha (Shrestha *et al*., 2007).

In coniferous forest of sub-alpine region there is characteristic decline in total tree density and total basal cover with increase in altitude. Total tree density ranged from 267 to 644 stems/ha in *Abies-Betula* forest of South-Western China (Taylor & Zisheng, 1988).

Six tree species in tree line ecotone of Langtang National Park were recorded. They were *Abies spectabilis, Betula utilis, Juniperus recurva, Rhododendron campanulatum, Salix* sp. and *Sorbus microphylla* (Gaire *et al*., 2010).

Maximum tree density for *Quercus floribunda- Rhododendron arboreum* group (181 and 175 trees/ha) and the minimum for *Abies pindrow–Betula utilis* group (151 and 85 trees/ha) were recorded in Kumaon Himalayan forest (Hussain *et al*., 2008).

Eleven species were recorded at the tree stage in *Abies spectabilis* forest in Langtang National Park. . However, only three species (*Abies spectabilis*, *Betula utilis* and *Acer* sp) reached to canopy layer. *A*bies *spectabilis* had the highest basal cover (0.65 %) of the all tree species (Tiwari, 2010).

Spatial patterns and associations in a *Quercus liaotungensis* and *Betula dahurica* forest done in northern China showed that *Betula* seedlings and saplings were positively associated with both live and dead trees of conspecific adults at small scales (<5 m) but negatively associated with live and dead trees of other species indicating sprouting as an important mechanism of reproduction (Hou *et al*., 2004).

2.2 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).

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 & 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).

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 & 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 & 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).

Size class diagram of *Betula utilis* in Manang, a trans-Himalayan dry valley of central Nepal, showed a reverse J-shaped structure in both mixed and pure forest. In mixed *Betula utilis* forest, the regeneration was higher. The distribution of seedlings and saplings was spatially heterogeneous and appeared to depend on canopy cover. It was found that partial canopy opening may induce seedling establishment and hence continuous regeneration of *Betula utilis* (Shrestha *et al*., 2007).

The density diameter curve of the tree population of *Abies spectabilis* resembled reverse J- shaped in Subalpine Forest of Upper Manang, North-central Nepal. The distribution of seedling and sapling was more or less uniform (Ghimire & Lekhak, 2007).

In tree line ecotone of Langtang National Park, the density diameter curve of *Betula utilis* was found to be bimodal and bell shaped. Average sapling density of *Betula utilis* was found to be 37 stems per hectare while seedling density was found to be 20 stem per hectare (Gaire *et al*., 2010).

Comparative study of vegetation structure and composition of two forests at Tamafok and Madimulkharka villages in the Piluwa micro-watershed showed that the regeneration potential was higher in the degraded Madimulkharka forest than in the relatively undisturbed Tamafok forest. Seedling-sapling density was lower in undisturbed and mature forest which had closed canopy (Koirala, 2004).

CHAPTER III
MATERIALS and METHODS

3.1 Study Area

The study area lies inside Manaslu Conservation Area. It lies in the Gorkha district, central Nepal. It covers an area of 1663 km^2. It was established in 2055 B.S. There are approx 2000 species of plants, 11 types of forests and over 50 species on useful plants. The bio-climatic zones vary from sub-tropical to Nival. An estimated 2,500 species of flora recorded in the area, including 587 vascular plants: 10 gymnosperms, 491 dicots, and 86 monocots. The vegetation of the area can be divided into three main categories, based mainly on the altitude, viz. Low hill, Middle mountain and High mountain types. Eleven types of vegetation are recorded in this area. They are: upper alpine meadow, moist alpine scrub, trans Himalayan steppe, trans Himalayan high alpine vegetation, birch- rhododendron forest, fir forest, larch forest, upper temperate blue pine forest, temperate blue pine forest, temperate mountain oak forest, lower temperate oak forest and chir pine and broad leaved forest (NTNC, 2011).

The present study was carried out in *Betula utilis* forest in Samagaun of the conservation area. The study area (28˚ 34'58.6"N, 84˚ 38'28.2"E, elevation 3500 – 4000 m) lies on north facing slope with average inclination of 34˚. Samagaun is surrounded by High Mountain and traversed by Budhi Gandaki River. This area consists of schist, leucogranite, gneiss and quartzite rocks. The mean annual monsoon precipitation is 190 mm and mean annual temperature is 6 to 10˚C. It is covered by snow during winter. Snowmelt water is the main source of soil moisture for forest growth. Forest vegetation is mostly confined to the moist north facing slope of valley floor. However isolated stands of *Juniperus indica* are found at the lower elevation of southern slope. On the north facing slope, the lower belt (3500 m) has *Larix himalaica*, *Abies spectabilis*, *Sorbus microphyll*, *Salix* species, and *Juniper* forest while the upper belt (above 3800 m) has *Betula utilis* and *Rhododendron campanulatum*. Moist alpine scrub was dominated by *Rhododendron lepidotum, R. anthopogan, Astragalus* species, *Cotoneaster, Juniperus indica, Juniperus recurva, Berberis* species, *Caragana* species and *Ephedra*.

The area was slightly disturbed. Logging of *Betula utilis* and *Abies spectabilis* were found. Trees were felled down for timber and firewood. Local people preferred *Abies spectabilis* for timber and *Betula utilis* for firewood.

Based on the data of the nearest weather station (Larke Samdo), the average annual rainfall was 175.88 mm with the highest rainfall in the year 1995 and lowest was 40.86 mm in the year 2004 (figure 3.1). The following figure shows that the rainfall amount is decreasing.

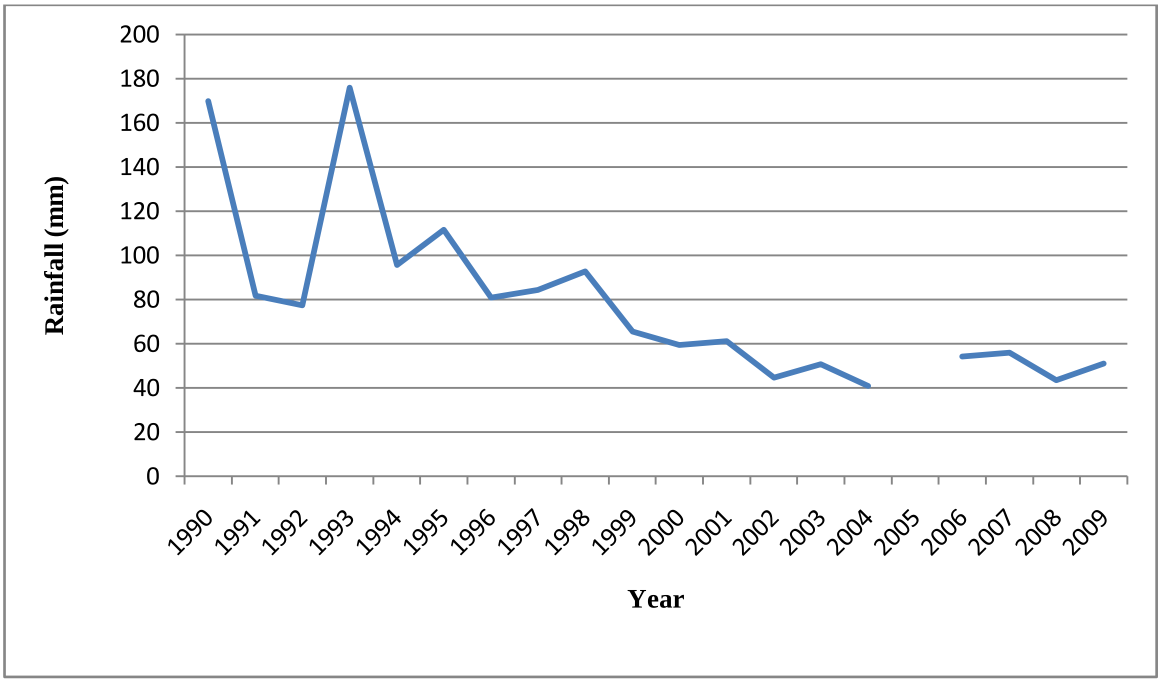

Figure 3.1 Average annual rainfall (mm) recorded at Larke Samdo weather station (85°37’E, 28°40’N and elevation 3650 m) between 1990 and 2010.

(Source: Department of Hydrology and Meteorology, Kathmandu)

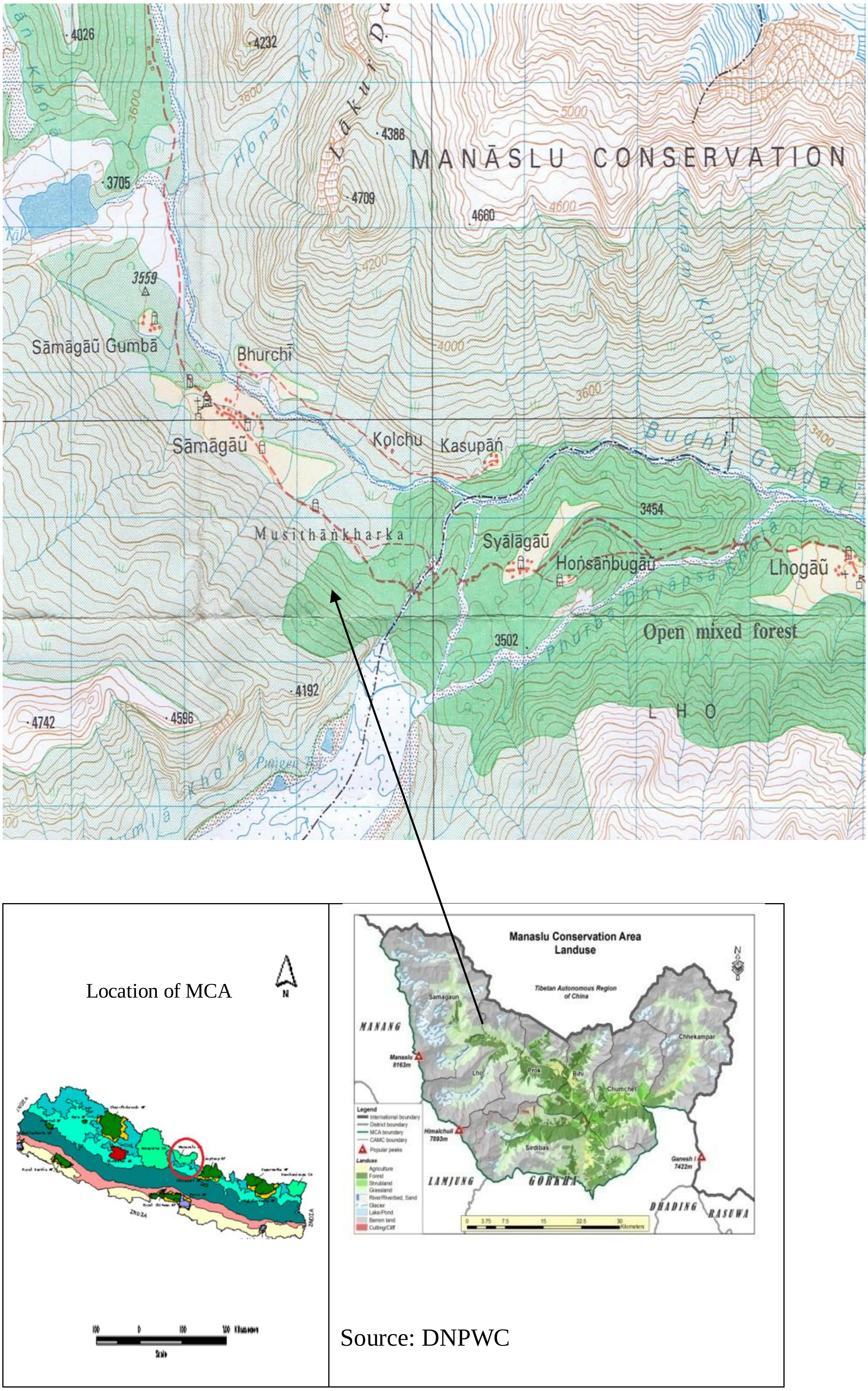

Figure 3.2 Maps Showing the Study Area

3.2 Sampling procedure

3.2.1 Field sampling: The study site was divided into 5 vertical transects, each representing both mixed and pure forests. In each transect, paired quadrats (10 m × 10 m) spaced horizontally about 100 m apart was sampled at every 100 m elevation increment from 3500 m up to 4000 m. Altogether 40 quadrats were sampled. In each square quadrat (10 m × 10 m), number of individuals of each species in tree stage were counted and diameter at breast height (DBH, measured at 137 cm above the ground) of each tree measured. Individuals of tree species were divided into three growth stages: trees (DBH>10 cm), saplings (DBH<10 cm, height > 30 cm) and seedling (height < 30 cm) (Sundryal & Sharma, 1996). All shrub species present in the quadrat were recorded. 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. If the individual plants had profuse branching from the basal region, they were included in shrub layer. Seedlings and saplings present inside the quadrat was counted within 10 X 10 m^2 since they were scattered. 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 were measured. All the tree species were divided into different size classes based on DBH of 5 cm difference and the size class diagram was developed to analyze regeneration pattern.

Soil samples were collected from 1 of the 2 (paired) quadrats in each elevation zone of each transects. In each sampling quadrat 4 soil samples (10–20 cm depth) collected each from 4 quarters and single samples from the center were mixed homogenously following Saxena (1990); 12 such samples were collected, air dried in shade, and stored in plastic bags until laboratory analysis.

For calculating soil moisture, 10 gm of soil was taken from each sampling plot and wrapped in aluminum foil till it was dried in oven.

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 = 12) at the Laboratory of Soil Science Division, National Agriculture Research Council (NARC), Lalitpur. 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).

Soil moisture was calculated after drying the soil in oven at 105 degree Celsius. It was calculated as follows:

$$\text{Moisture content (\%)} = \frac{(\text{Initial weight} - \text{final weight}) \times 100}{\text{Initial weight}}$$

3.4 Numerical Analysis

3.4.1 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.

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

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)

$\pi = 3.1416$

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

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.

$$IVI_i = RF_i + RD_i + RBA_i$$

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

ni = 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

3.4.2 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 pairs of variables, scatter diagrams were shown. Statistical Package for Social Sciences (SPSS, version 16) and Microsoft excel was used for all statistical analyses.

CHAPTER IV
RESULTS

4.1 Community Structure

Betula utilis was the dominant tree species with the highest important value index 173.32 in mixed forest and 262.96 in pure forest. *Abies spectabilis* was the co dominant tree species with IVI 65.95 in mixed forest and *Rhododendron campanulatum* with 38.06 in pure forest. *Abies spectabilis* and *Larix himalaica* were present up to 3800 m only. *Rhododendron campanulatum* were present above 3700 m. Tree species richness was very low, only four tree species in mixed forest and two in pure forest (Table 4.1(a) and 4.1(b)). In pure *Betula utilis* forest, *Rhododendron campanulatum* was present only in 20% of the sampling plot. Total tree density was more in mixed forest than in pure forest (2054 stems/ha in mixed forest and 1707 stems /ha in pure forest). The basal area of mixed forest was high (76.55 m^2/ha) than in pure forest 71.00 m^2/ha).

Table 4.1(a)

Vegetation Sampling in Mixed Betula Forest (3500 – 3800 m)

S. N	Plant Species	F (%)	RF (%)	D (stem/ ha)	RD (%)	BA (m^2/ha)	RBA (%)	IVI
1.	*Betula utilis*	100	33.33	1384	67.39	55.65	72.03	173.22
2.	*Abies spectabilis*	92	30.69	412	20.06	11.64	15.20	65.95
3.	*Larix himalaica*	88	29.33	226	10.99	7.84	10.20	51.12
4.	*Rhododendron campanulatum*	20	6.67	32	1.56	1.42	1.89	10.12
	Total	300		2054		76.55		

Table 4.1(b)

Vegetation Sampling in Pure Betula Forest (3800 – 4000 m)

S. N	Plant Species	F (%)	RF (%)	D (stem/ ha)	RD (%)	BA (m^2/ha)	RBA (%)	IVI
1.	*Betula utilis*	100	75	1654	96.87	64.67	91.09	262.96
2.	*Rhododendron campanulatum*	33.33	24.99	53	3.12	6.33	8.92	37.03
	Total	133.33		1707		71.00		

Frequency (F), Relative Frequency (RF), Density (D), Relative Density (RD), Basal Area (BA), Relative Basal Area (RBA) And Importance Value Index (IVI)

Density of *Betula utilis* was increased with increase in altitude where as density of other tree species were decreased with increase in altitude (Figure 4.3). The most densely populated plots were between 3700 – 3800 m and above 4000 m. The density of *Abies spectabilis and Larix himalaica* was highest between 3500 m – 3600 m. *Rhododendron campanulatum* was found more in between the altitude of 3700 m – 3800 m.

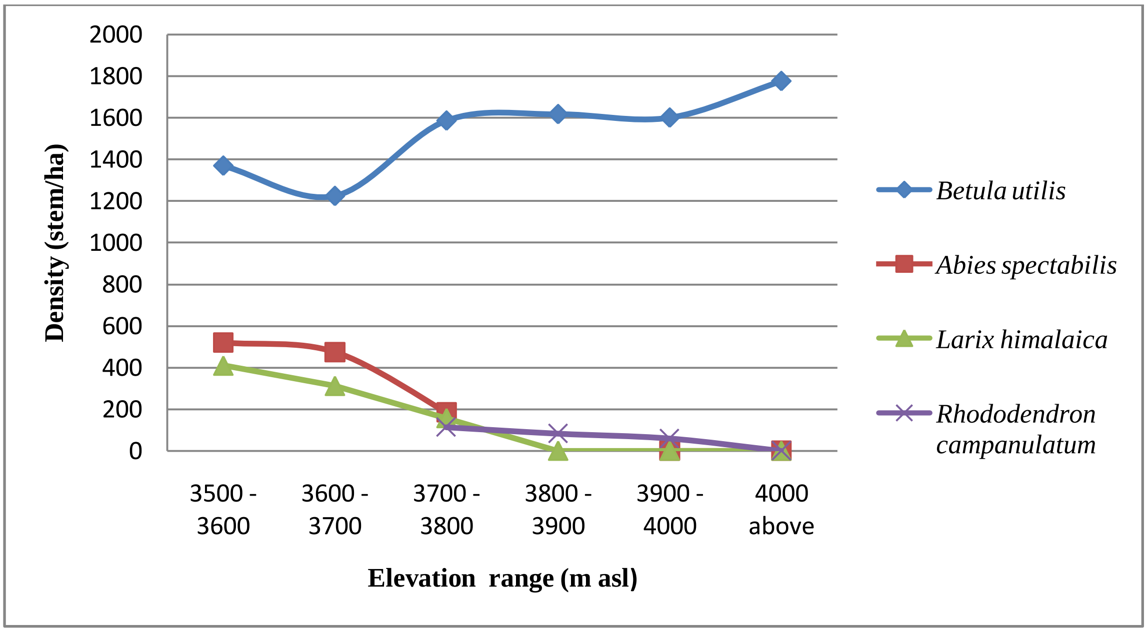

Figure 4.3 Density of different tree species in different elevation.

The tree basal areas of *Betula utilis* increased from 3500 m to 3800 m and then get decreased above 3800 m. Similarly the tree basal area of *Abies spectabilis* and *Larix himalaica* also get decreased with increase in altitude. *Betula utilis* in lower altitude (3500 – 3600 m) were small with lower basal area than in other altitude.

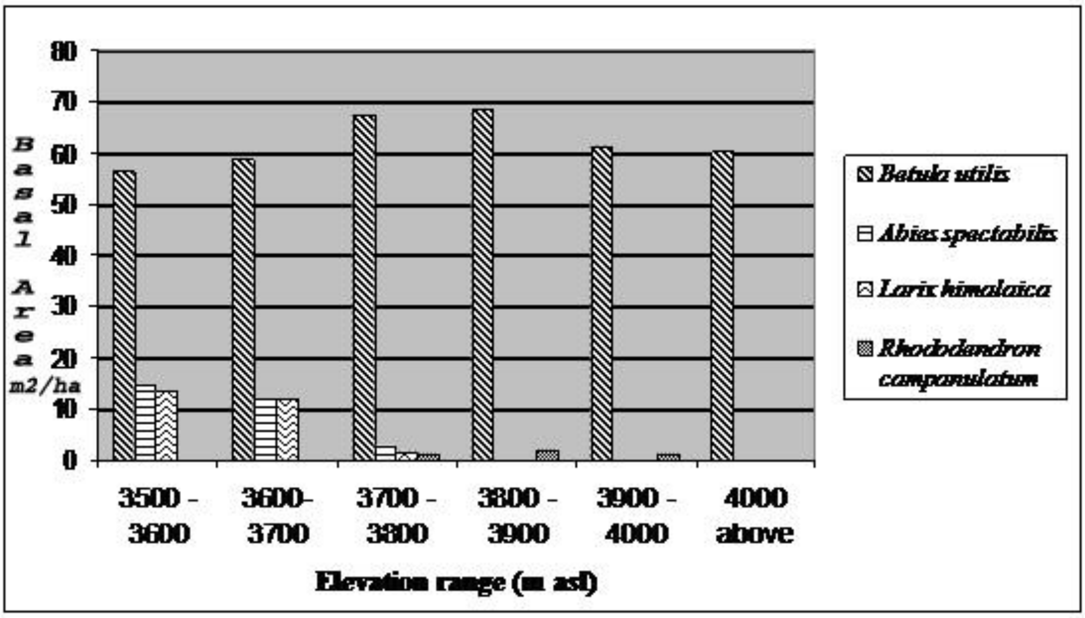

Figure 4.4 Basal Area (BA) of individual tree species in different elevation range.

4.1.1 Comparison of DBH (cm) in Different Altitude

Results of comparison of DBH (cm) of birch found in different altitude using one way ANOVA is given in Table 4.2. P value for comparison of height is .273 which is greater than 5 percent level of significance (α =0.05). This implies that there is no significant difference between DBH of *Betula utilis* in different altitudes.

Table 4.2

Results of ANOVA for comparing DBH at different altitudes

Source	Degrees of freedom	Sum of squares	Mean square	F	Significance (P value)
Between altitude	5	101.176	20.235	1.334	.273
Error	34	515.570	15.164		
Total	39	556.783			

From table 4.3, it can be seen that the DBH of tree is lowest at altitude 4000 m and the DBH of tree is highest at 3700 m. The DBH of tree is increased from 3500 m to 3700 m and then gets decreased. But there is no significant difference between DBH of trees at different altitude. The trend is also clear from figure 4.5.

Table 4.3

Mean and standard deviation of DBH (cm) of Betula utilis in different altitude

S.N	Altitude (m)	Mean DBH (cm)	Standard Deviation
1.	3500	21.302	5.008
2.	3600	22.350	1.043
3.	3700	24.679	4.816
4.	3800	22.566	3.491
5.	3900	21.495	1.467
6.	4000	20.555	3.882

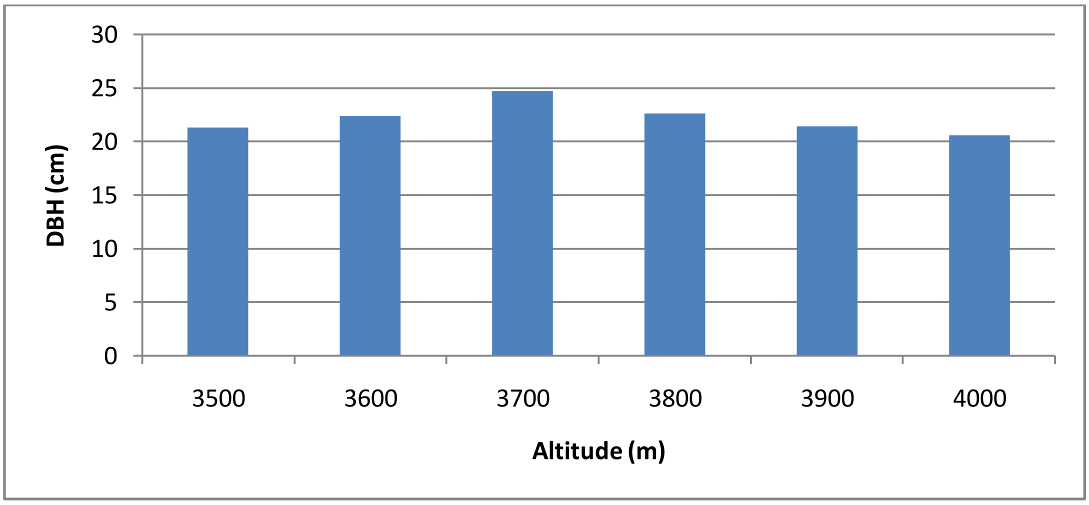

Figure 4.5 DBH (cm) of *Betula utilis* found in different altitude.

4.1.2 Comparison of Height in Different Altitude

Results of comparison of height (m) of birch found in different altitude using one way ANOVA is given in Table 4.4. P value for comparison of height is .199 which is greater than 5 percent level of significance (α =0.05). This implies that there is no significant difference between heights of *Betula utilis* in different altitudes.

Table 4.4

Results of ANOVA for comparing Height at different altitudes

Source	Degrees of freedom	Sum of squares	Mean square	F	Significance
Between altitude	5	2.423	.485	1.557	.199
Error	34	10.580	.311		
Total	39	21.584			

From table 4.5, it can be seen that the height of tree is lowest at altitude 4000 m and the height of tree is highest at 3700 m. The trees are smaller in lowest and highest altitude. In mixed *Betula* forest, the height of trees is increased from 3500 m to 3700 m and then in pure *Betula* forest the height of trees gets decreased from 3800 m to 4000 m. There is no significant difference between heights of trees in 3700 m and 3800 m. The trend is also clear from figure 4.6.

Table 4.5

Mean and standard deviation of height (m) of Betula utilis in different altitude

S.N	Altitude (m)	Mean height (m)	Standard Deviation
1.	3500	5.67	0.862
2.	3600	6.39	0.346
3.	3700	6.70	0.906
4.	3800	6.60	0.303
5.	3900	5.90	0.463
6.	4000	5.40	0.318

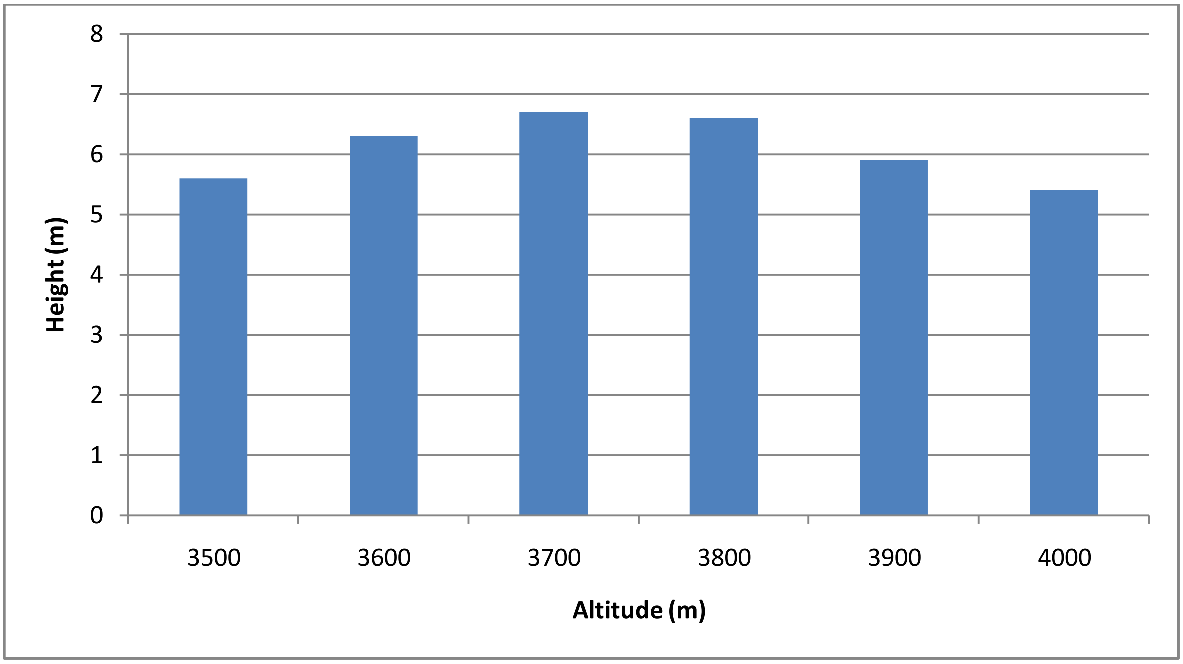

Figure 4.6 Height (m) of *Betula utilis* found in different altitude.

4.1.3 Vegetation in Shrub Layer

Six species were recorded in shrub layer. Among them *Rhododendron anthopogan* was the most frequent (50%) (Table 4.6). Others Shrubs present in mixed forest of *Betula utilis* are *Rhododendron lepidotum*, *Berberis* species, *Arudinaria*, *Salix* species and *Sorbus microphylla.*

Table 4.6

Plant species forming shrub layer in Betula utilis forest

S.N	Plant species	Frequency (%)
1.	*Rhdodendron anthopogan*	50
2.	*Rhododendron lepidotum*	47.5
3.	*Salix* species.	25
4.	*Sorbus microphylla*	20
5.	*Arudinaria* species.	15
6.	*Berberis* species.	12.5

4.2 Species Richness and Diversity

Simpson's Index of Dominance (C) for tree was 0.50 and Shannon- Wiener Index (H') of Species diversity was 0.69 in mixed *Betula utilis* forest while Simpson's Index of Dominance (C) for tree was 0.83 and Shannon- Wiener Index (H') of species diversity was 0.44 in pure *Betula utilis* forest. In pure *Betula utilis* forest only few individuals of *Rhododendron campanulatum* was present.

4.3 Soil Analysis

Soil of the forest under study was slightly acidic in nature. The pH ranged in between 5.94 to 7.28. Soil pH declined with increasing elevation ($r = -.957$, $p = 0.01$). Moisture content of the soil was high and ranged between 49.9 to 75.99%. Soil moisture increased with increasing elevation ($r = .972$, $p = 0.01$) and tree basal area increased with increasing soil moisture ($r = .640$, $p = 0.05$) (Table 4.9). Total organic matter in the soil ranged between 4.18 to 6.60%. Similarly, nitrogen content, available phosphorus and potassium content in the soil was found between 0.154 to 0.58 %, 31.64 to 94.82 kg/ha and 219.46 to 378.12 kg/ha respectively. Soil N content showed the highest variation and soil pH showed the least variation among the soil variables measured.

Table 4.7

Environmental variables of the Betula utilis forest in the study area

Environmental variables	Mean	Coefficient of variance (%)	Range Minimum – Maximum
Litter Cover	48	25	30 – 70
Soil Moisture (%)	62.67%	14.59	47.36 – 75.12
Soil pH	6.56	8.04	5.94 – 7.28
Soil Organic matter (%)	5.42	14.14	4.18 – 6.60
Soil Nitrogen (%)	0.38	36.30	0.154 – 0.58
Soil Phosphorous (P_2O_5Kg/ha)	72.06	26.88	31.64 – 94.82
Soil Potassium (K_2O kg/ha)	300.04	18.56	219.46 – 378.12

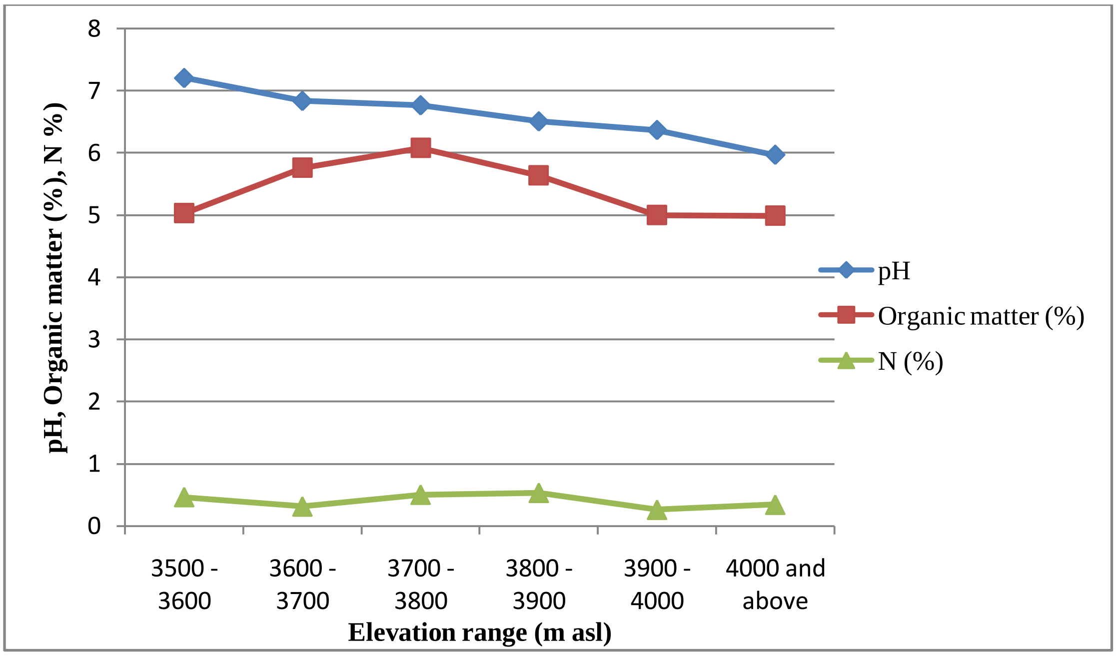

Figure 4.7 Soil pH, total nitrogen N (%) and organic matter (%).

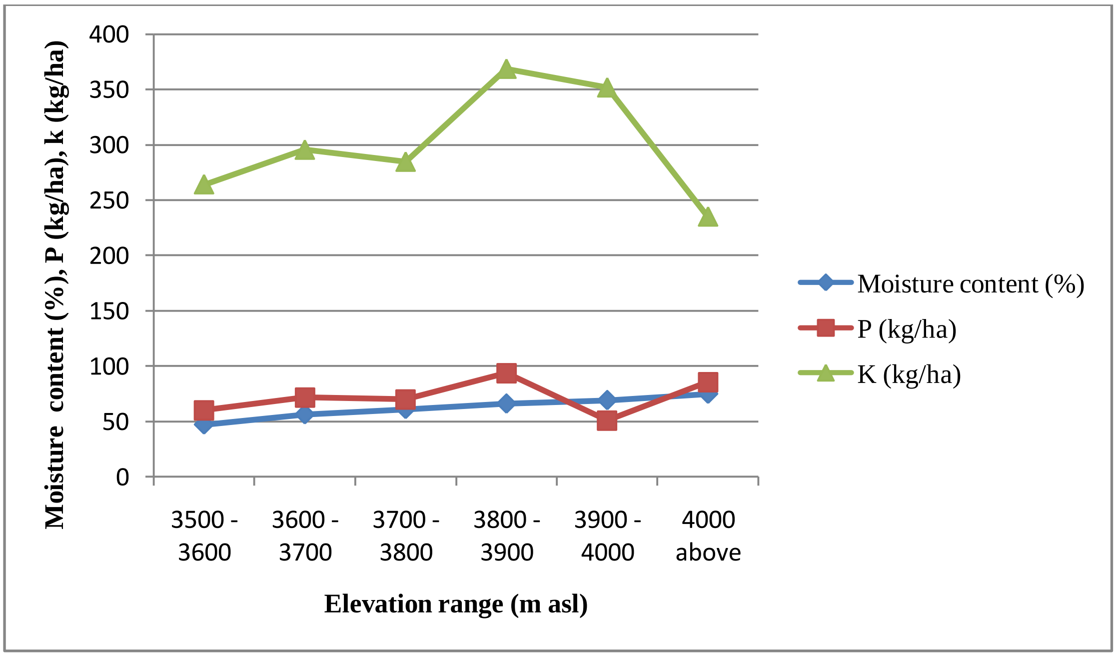

Figure 4.8 Soil moisture content (%), soil phosphorus (P_2O_5, kg/ha), soil potassium (k_2O, kg/ha).

Soil sample samples were collected from different elevations. Each value is the mean of duplicate samples.

4.4 Regeneration and Size Class Distribution

The density diameter curve of the tree population of *Betula utilis* both on mixed and pure forests deviated slightly from the typical reverse J shaped structure (Figure 4.5 and 4.6) which is the indication of regeneration (Vetaas 2002). The size class 15 – 20 cm consists of maximum number of individuals and class 10-15 cm consists of fewer individuals in mixed forest while in pure forest density of trees with DBH 20 – 25 cm were highest. Only Eight size classes were found in mixed Betula forest while ten size classes were found in pure Betula forest. Trees were smaller in the mixed forest (DBH 10 – 50 cm) than in pure forest (DBH 10 – 60 cm). This indicates that the trees in mixed forest are younger than in pure forest. Cut stumps of large trees were observed in mixed *Betula* forest during the study period.

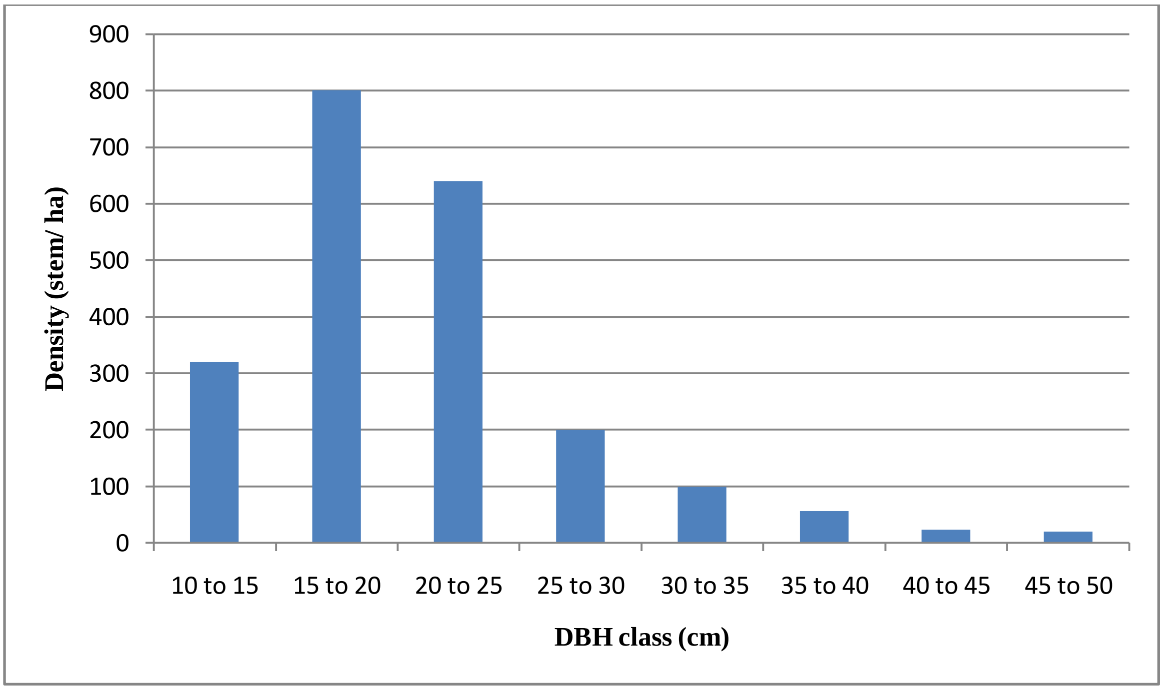

Figure 4.9 Density – diameter curve of *Betula utilis* in mixed forest.

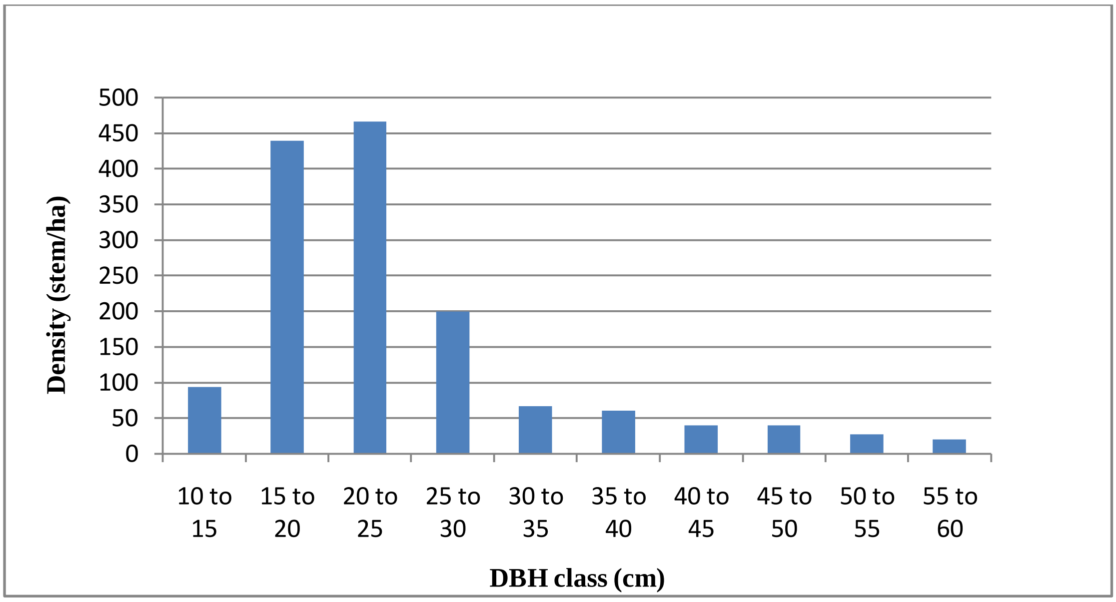

Figure 4.10 Density – diameter curve of *Betula utilis* in pure forest.

Bar graph of height of *Betula utilis* shows that the density of trees having height 6 to 7 m is the maximum. Small trees of height less than 1m is less in mixed forest (Figure 4.11) and completely absent in pure forest (Figure 4.12). This shows that the mixed forest is young compare to the pure forest.

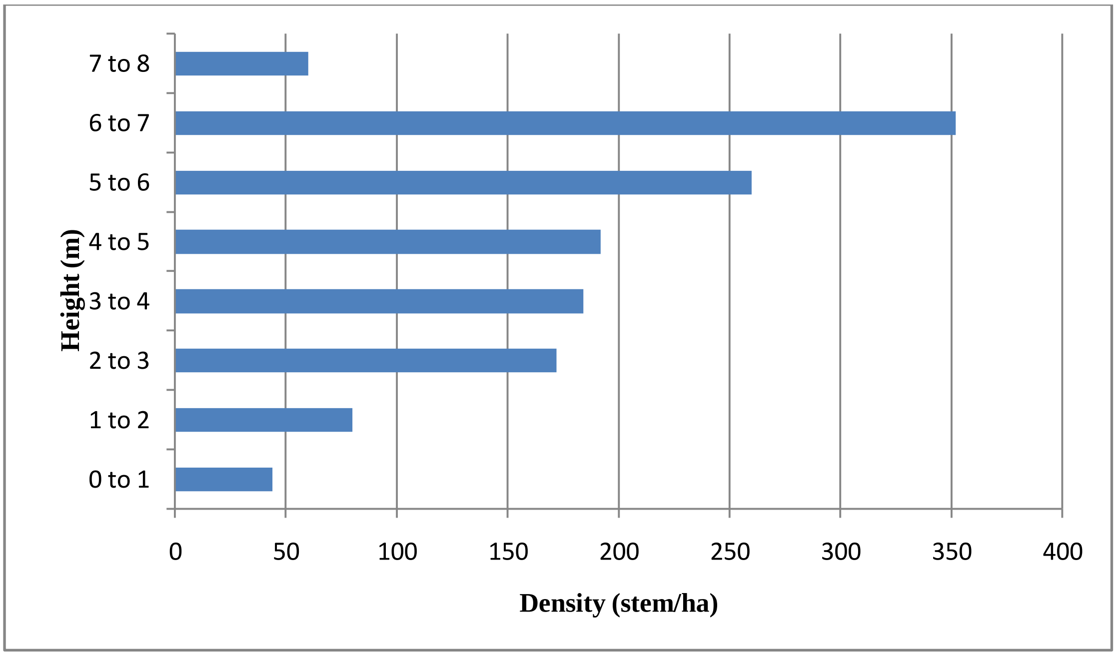

Figure 4.11 Density of trees with different height in mixed *Betula* forest.

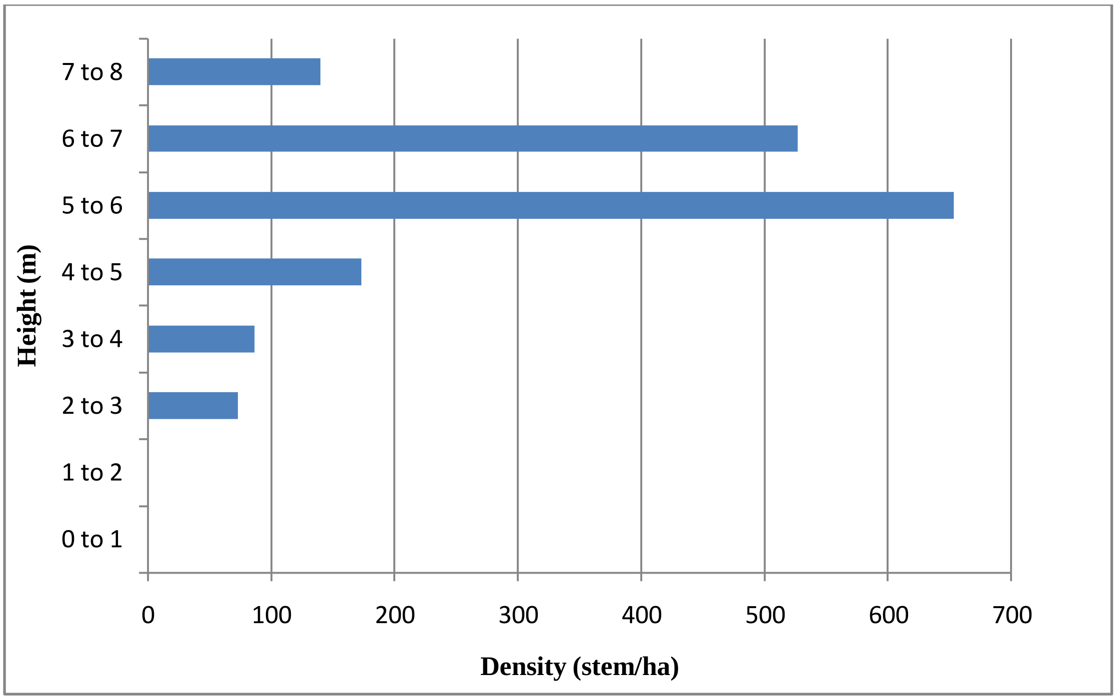

Figure 4.12 Density of trees with different height in pure *Betula* forest.

4.5 Seedling and Sapling Density

The distribution of saplings and seedlings were not uniform among the sampling plots. There were no saplings on 25% of the plots and seedlings on 60%. The sapling density in mixed forest was 1136 stems per hectare and that in pure forest were 147 stems per hectare. The seedling density was 156 stems per hectare in mixed forest while that in pure forest was 33 stems per hectare.

The sapling density of *Abies spectabilis* was 648 stems per hectare and that of *Larix himalaica* was 416 stems per hectare. The sapling density of both species declined with increase in altitude. The sapling density of *Betula utilis* was highest at 3500–3600 m and lowest at 4000 m. The sapling density of *Betula utilis* decreases with increase in altitude (Figure 4.13).

The seedling density of *Abies spectabilis* and *Larix himalaica* were found to be greater than that of *Betula utilis* in mixed forest and that of *Rhododendron campanulatum* was also more than that of *Betula utilis* in pure forest (Figure 4.14).

The density of *Betula utilis* seedlings was highest at the lowest elevation, but it was absent above 4000 m. Both seedling and sapling density decreases with increase in tree density and basal area (Figure 4.15, 4.16, 4.17 and 4.18).

Table 4.8

Density of seedling, sapling and tree species in the study forest

S.N	Plant Species	Mixed Betula forest			Pure Betula forest		
		Seedling density (Stem//ha)	Sapling density (Stem/ha)	Tree density (Stem/ha)	Seedling density (stem/ha)	Sapling density (Stem/ha	Tree density Stem/ha)
1.	*Betula utilis*	156	1136	1384	33	147	1513
2.	*Abies spectabilis*	372	648	412	0	0	0
3.	*Larix himalaica*	276	416	226	0	0	0
4.	*Rhododendron campanulatum*	36	36	32	47	73	53

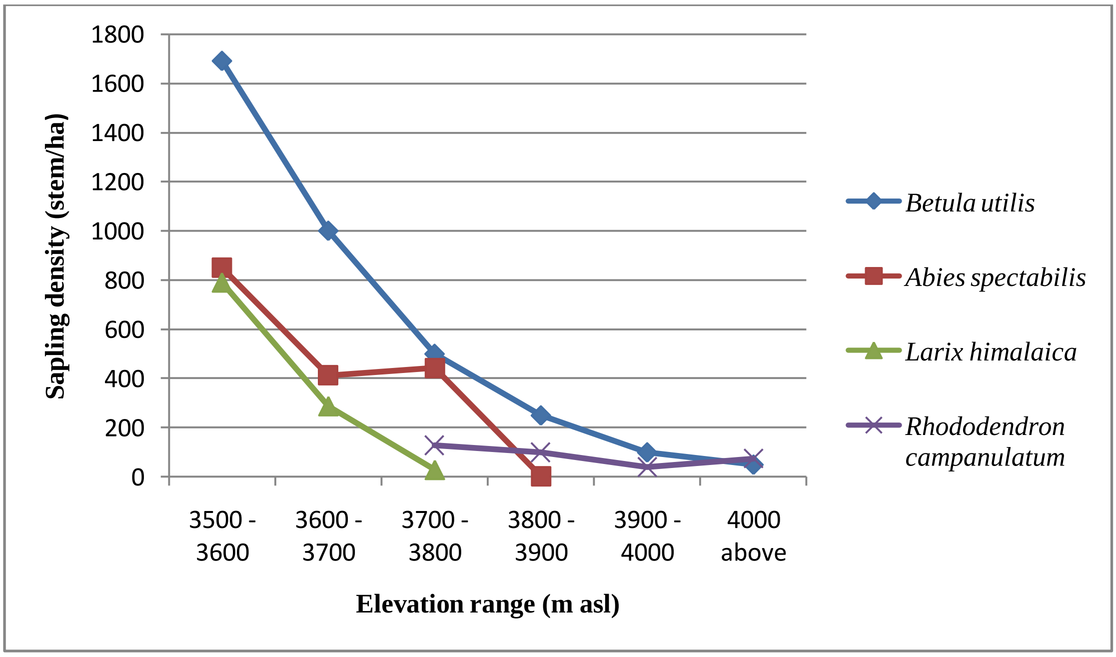

Figure 4.13 Density of saplings in different elevation ranges.

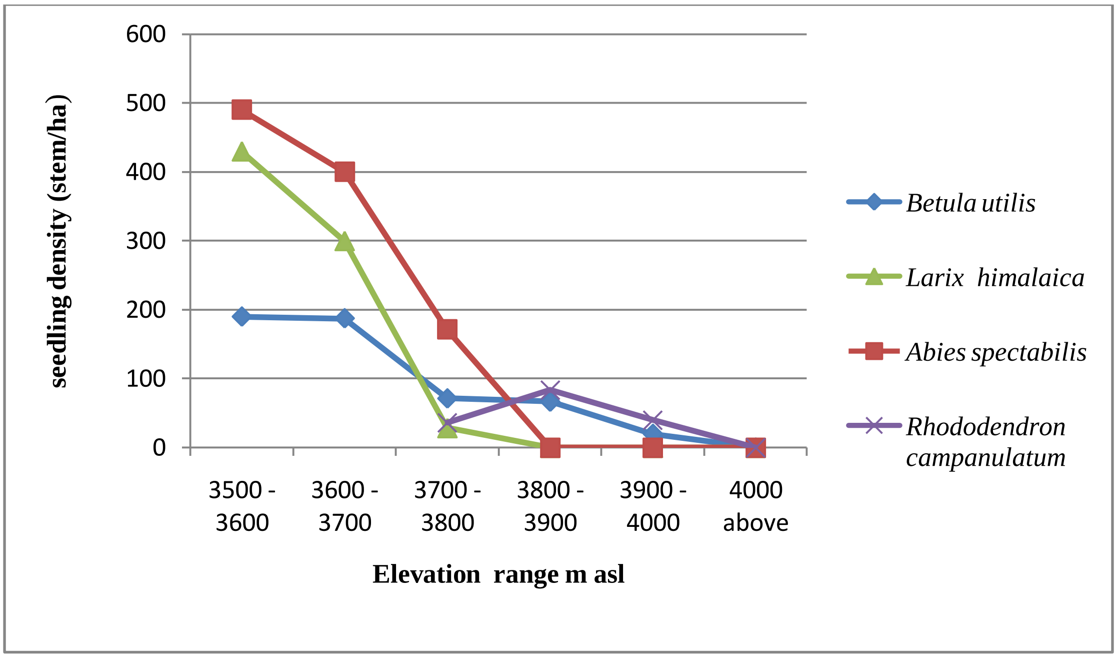

Figure 4.14 Density of seedlings in different elevation ranges.

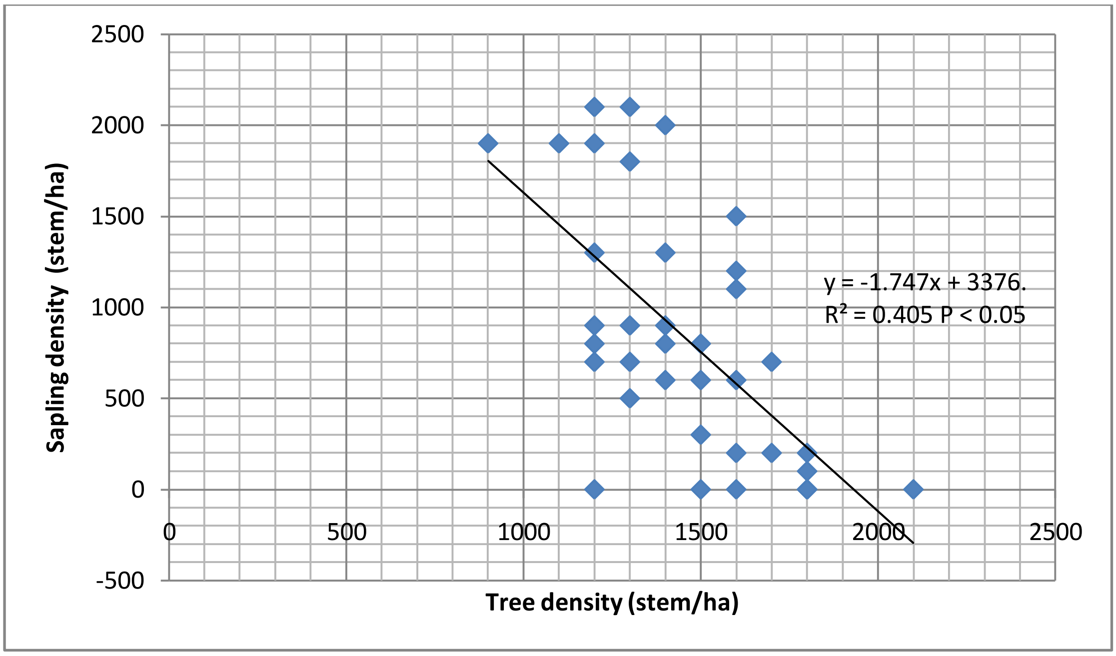

Figure 4.15 Scatter diagram showing variation of sapling density with tree density

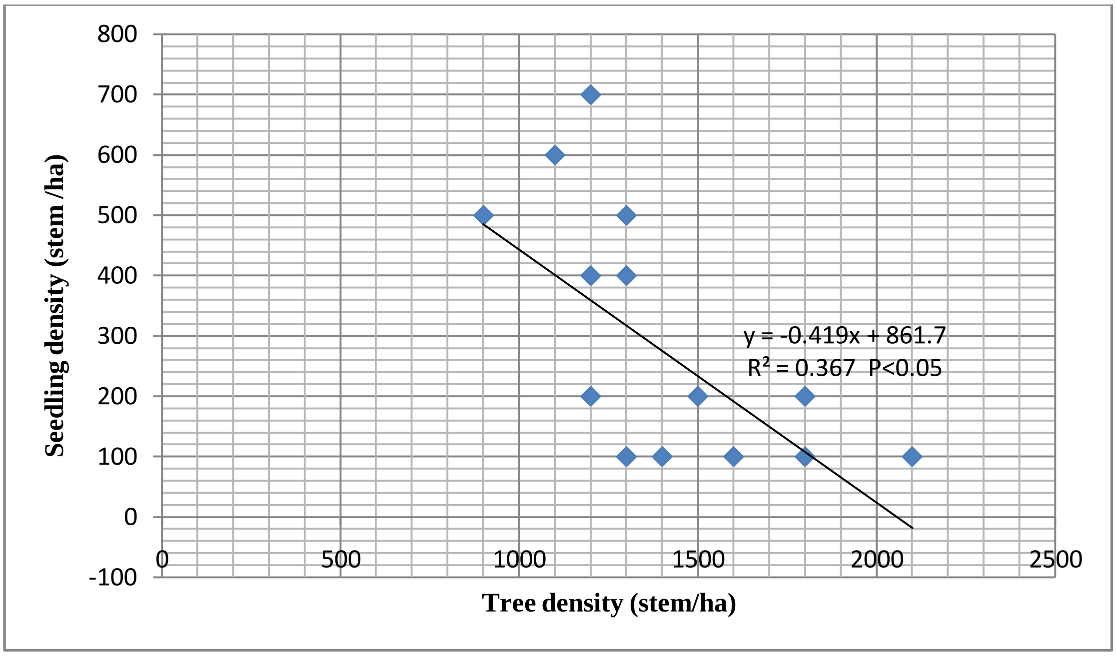

Figure 4.16 Scatter diagram showing variation of seedling density with tree density.

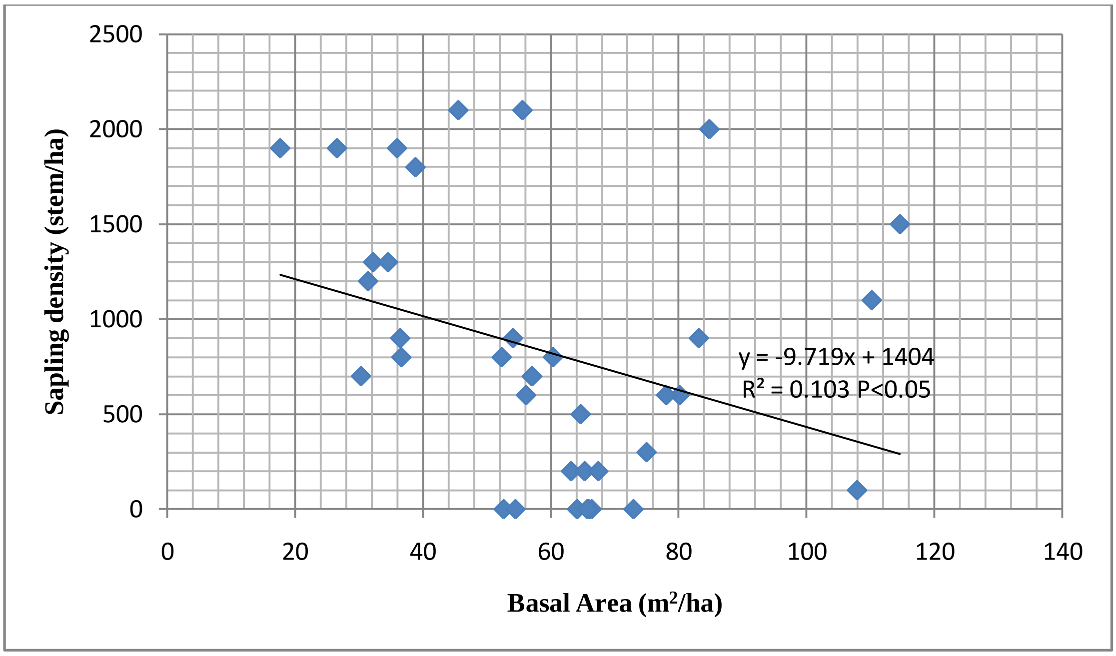

Figure 4.17 Scatter diagram showing variation of sapling density with basal area.

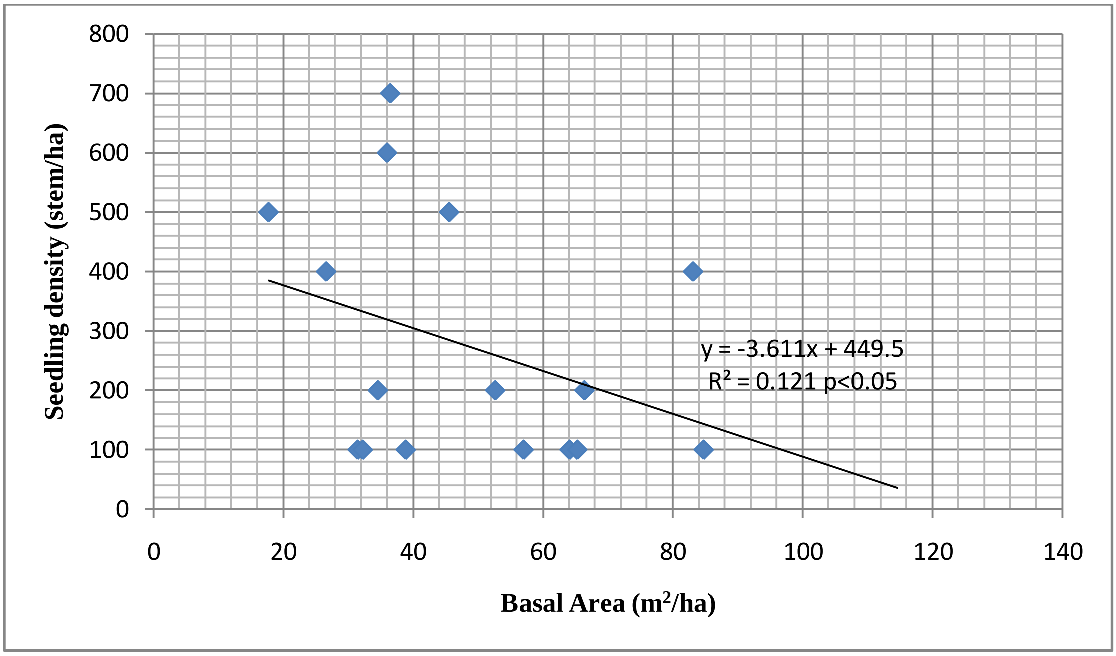

Figure 4.18 Scatter diagram showing variation of seedling density with basal area.

In both mixed and pure *Betula* forest, densities of trees were found to be higher than that of saplings and seedlings. Tree density was higher in pure *Betula* forest than in mixed *Betula* forest. Similarly saplings and seedlings densities were high in mixed *Betula* forest than in pure *Betula* forest (Figure 4.19).

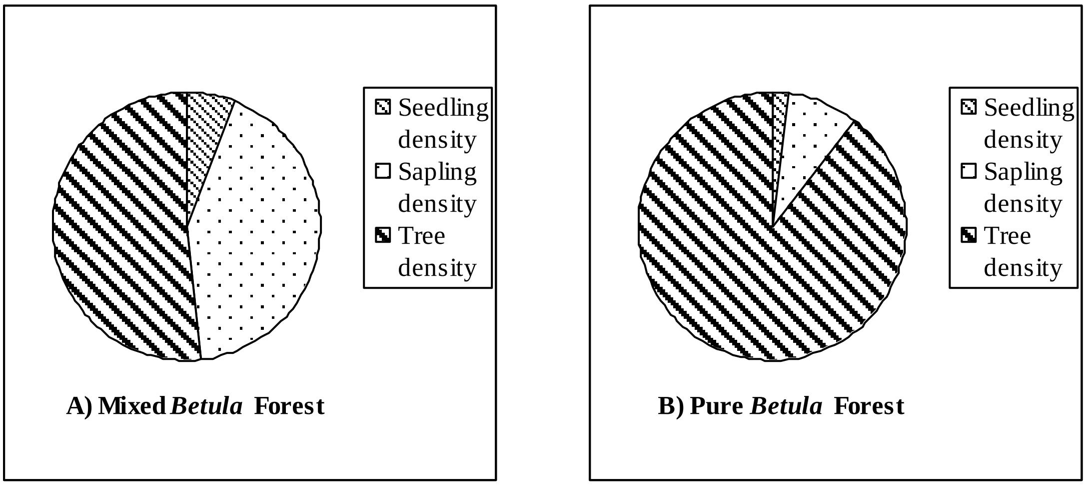

Figure 4.19 Seedlings, saplings and tree density of *Betula utilis*.

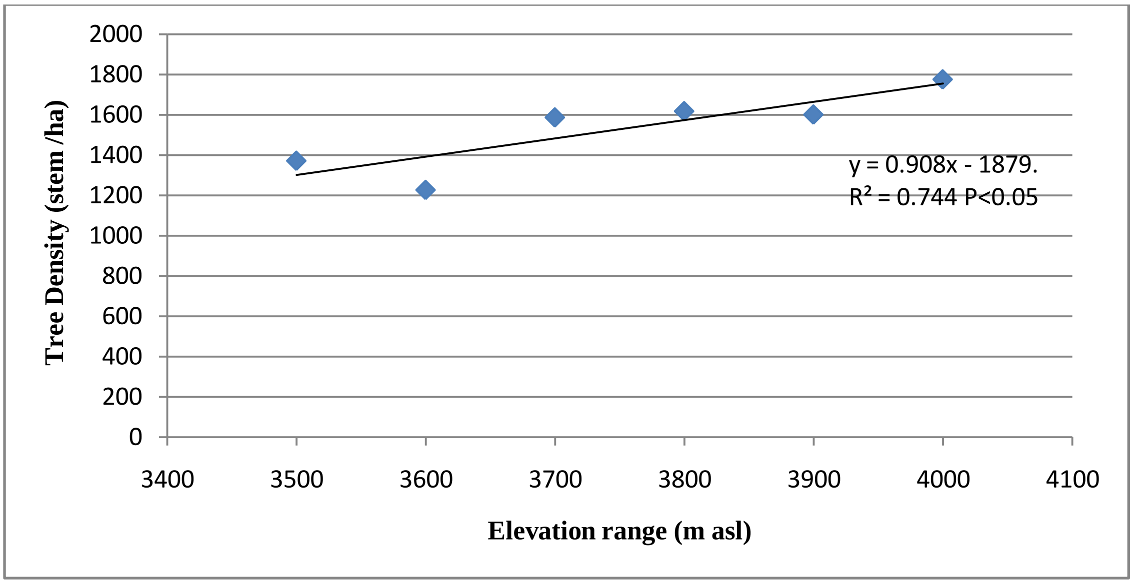

Figure 4.20 Scatter diagram showing variation of tree density of *Betula* with elevation

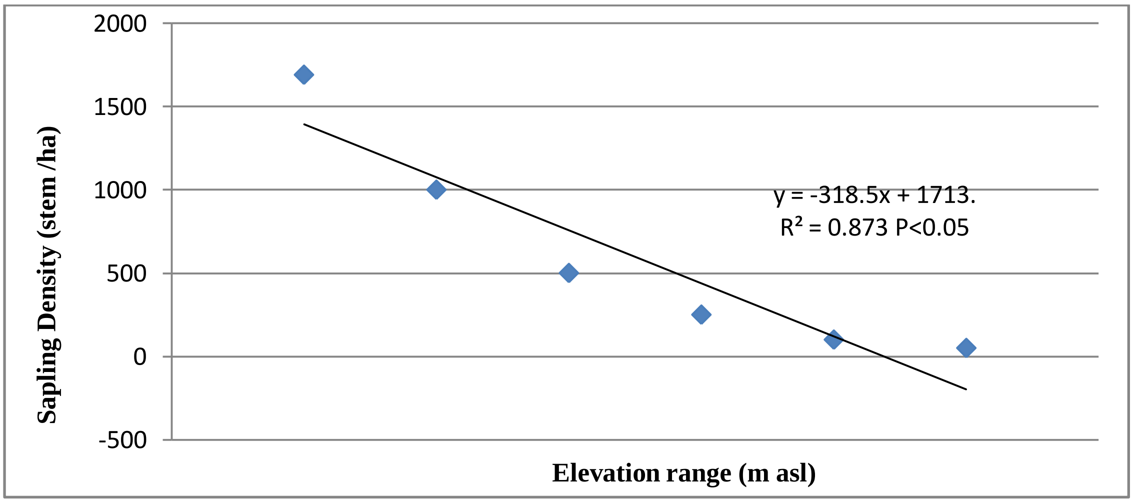

Figure 4.21 Scatter diagram showing variation of sapling density with elevation.

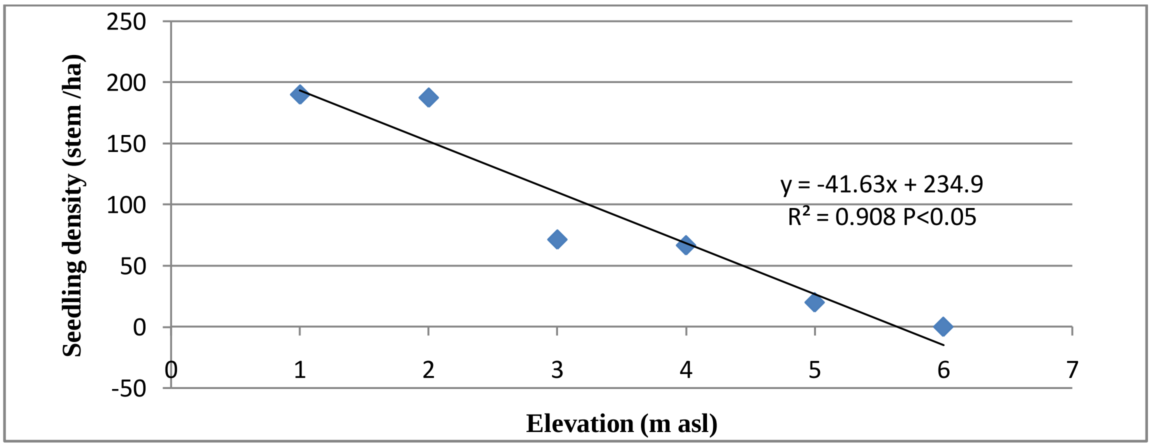

Figure 4.22 Scatter diagram showing variation of seedling density with elevation.

Table 4.9

Correlation of seedling, sapling and tree density of Betula utilis with environmental factors

	Tree density	Sapling density	Seedling density	Altitude	Slope	Organic matter	Nitrogen	Potas sium	Phos phate	pH	Basal area	Moisture content
Tree density	1	-.074	-.453	.312*	.273	.079	.219	.009*	.421	-.331	.279	.420
Sapling density	-.074	1	.446	-.246	-.024	-.145	.288	-.738**	.079	-.263	-.188	.078
Seedling density	-.453	.446	1	-.208	-.235	-.854	.063	-.811	-.856	.734	-.500*	-.788
Altitude	.312*	-.246	-.208	1	.526**	-.193	-.210	.104	.225	-.957**	.263	.972**
Slope	.273	-.024	-.235	.526**	1	-.195	.211	-.073	-.073	-.505	-.057	.665*
Organic matter	.067	-.184	-.981*	-.147	-.074	1	-.021	-.34	.397	.046	.077	-.107
Nitrogen	.219	.288	.063	-.210	.211	-.101	1	.099	.181	.264	.127	-.196
Potassium	-.658*	-.321	.912	-.290	-.251	-.034	.126	1	-.240	-.054	-.524	-.264
Phosphate	.421	.079	-.856	.225	-.073	.256	.181	.209	1	-.389	.364	.267
pH	-.077	-.579	-.009	-.256	.248	.046	.550	-.054	-.169	1	-.022	-.221
Basal area	.279	-.188	-.500*	.263	-.057	.210	.127	.205	.364	-.642*	1	.640*
Moisture content	.420	.078	-.788	.972**	.665*	-.200	-.196	.162	.267	-.939*	.640*	1

*. Correlation is significant at the o.o5 level (2-tailed)

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

CHAPTER V
DISCUSSION

5.1 Community Structure

The forest is clearly differentiated into two stands. Lower belt (3500 – 3800 m) is mixed *Betula* forest whereas upper belt shows the dominance of *Betula utilis*. The observation of various forests of the subalpine region of Manang revealed that the tree species such as *Betula utilis* generally preferred moist northern slope. In present study also, forest of *Betula utilis* was found only in the north facing slope. It forms a continuous tree line on the north facing slope of the valley where the soil receives snowmelt water from high mountains (> 7000 m asl) covered by permanent snow and snow moisture increased with elevation. On the dry, south facing slope of the valley, with seasonal (winter) snow on the hilltop, *Betula utilis* was present in a few moist pockets. Horizontal distribution of *Betula utilis* in the Manang valley thus appears to be governed by soil moisture, which in turn is controlled by aspect and water source (Shrestha *et al*., 2007). *Betula* tree was found to be associated with other tree species like *Abies spectabilis*, *Larix himalaica* and *Rhododendron campanulatum* up to 3800 m. and above 3800 m pure *Betula utilis* was observed. Distribution of *Betula utilis* up to higher is seen in Himalaya as it is adapted well in cold climate. The north facing slope of the main Himalayas receives only a small part of the monsoon rain and the main source of soil moisture is snowmelt water from high mountains. Dry soil on the valley floor (3300 – 3400 m) and on lower parts of the slope (3300 – 3600 m) is suitable for conifers like *Pinus wallichiana* but not for *Betula utilis*. From this belt to the tree line, soil temperature may not be low enough to prevent tree growth but the soil is sufficiently moist to support the growth of *Betula utilis*.

Tree density of *Betula utilis* is low in mixed forest than in pure forest. This type of result was also found in dry valley of Central Nepal (Shrestha *et al*., 2007) where density in mixed forest is 864 stem/ha and that in pure forest is 1207 stem/ha, which were very low in comparison to our study (Table 4.1a and 4.1b). In Birch dominated forest of Manang, the total tree density was 612 stem/ha (Ghimire & Lekhak, 2007). Similarly the tree density for *Betula utilis* was found to be 85 stem/ha in Kumaon Himalayan forest (Hussain *et al*., 2008).

The total tree basal cover of the present study forest was 59.35 m^2/ha. Hou *et al.* (2004) found total basal cover (4.74 m^2/ha) in *Quercus*- *Betula* forest in north China.

The basal cover was lower due to lower total tree density (230 stem/ha) of *Betula dahurica* forest comparable to ours. Shrestha *et al*. (2007) found total basal cover of tree 0.57% in mixed *Betula* forest and 2.2% in Pure *Betula* forest. Total basal area of trees was high (76.55 m^2/ha) in mixed forest than that (71 m^2/ha) in pure forest. It is due to higher tree density (2054 stem /ha) in mixed forest than in pure forest where tree density was (1707 stem /ha).

Simpson's Index of Dominance (C) for tree (0.50) was found to less than species diversity (0.69) in mixed *Betula* forest while Simpson's Index of Dominance (C) for tree was 0.83 and Shannon- Wiener Index (H') of species diversity was 0.44 in pure *Betula* forest. Tree density and diversity were low in Pure *Betula* forest as diversity and richness decrease in higher elevation (Singh et al., 1994). 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 the present study forest had far low value of Shannon – Wiener Index (H') of species diversity. There was high concentration of dominance to single dominant species (i.e. low evenness) which was indicated by higher value of Simpson's index than of Shannon-Wiener index. This showed that the dominance in the present study forest was concentrated to single species *Betula utilis.* Decrease in Species diversity of the forest may be due to the over exploitation of trees and habitat destruction. Species richness usually reduces along the vertical gradient and it is caused by the temperature decrease (Qi-Jing, 1997).

Three tree species were found up to 3700 m and four species were found between the elevations of 3700 m to 3900 m. This shows that the species richness is decreases with the elevation (Colwell and Hurt, (1994). They suggested that mid-elevation peaks in species richness arise because of the increasing overlap of species ranges towards the centre of the domain, as the extent of the elevation ranges of species is bounded by the highest and lowest elevations. Basal area of *Betula utilis* was found to be more in elevation range 3700 m to 3800 m.

Diameter and height has also been used as a basis for distinguishing developmental stages in natural forests. These factors determine the forest stand structure. And forest stand structure is also known to change with elevation (Kruspan, 2009). Most of the studies show that height and diameter of trees decrease with elevation and the decrease in height observed along the altitudinal gradient may be due to the past felling of trees from the region. However it can be also due to 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 in higher altitudes (Stevens & Fox, 1991). But in the present study diameter and height was increasing trend up to 3700 m i.e., in mixed forest. As we go up both diameter and height decreases. Presence of smaller trees in lower belt (3500 m) might be due to falling down of mature trees by local people. Trees were found to be undisturbed at 3700 m altitude, so the trees were taller. The decrease in height of trees above this elevation might be due to climatic factors.

5.2 Regeneration

Density diameter curves of both mixed and pure *Betula utilis* forest show slightly deviated inversed J shaped curve, so the forest is regenerated type but not sustainable one. The mixed forest was young with smaller individuals as in the *Betula* forest of dry valley of central Nepal and might have developed after clear cutting of large *Abies spectabilis* trees (Shrestha *et al*., 2007). The regeneration potential of mixed *Betula* forest was higher than that of pure *Betula* forest. 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 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 early successional *Betula* species. (Carlton & Bazzaz, 1998). Thus human activities such as timber harvesting have reduced tree BA, and changed species composition and the seral stage of the forest.

Sapling and seedling distribution of *Betula utilis* was spatially heterogeneous, which may be relatively common under natural conditions. Spatial heterogeneity in sapling and seedling distribution appeared to be determined by light availability caused by variation in canopy cover. The stands with the highest sapling and seedling densities have less tree density and low basal area. The abundant growth of saplings and seedlings near the open edges of such forest stands indicated that the seed source was not the limiting factor for low recruitment in closed canopy stands. According to Carlton and Bazzaz (1998) lack of birch regeneration can be attributable to poor seedling growth and survival rather than inadequate seed dispersal. Low light and thick litter may be the major constraints for seedling establishment of *Betula utilis* under its own canopy. In experimental seed dispersal of 3 birch species, none of the seedlings survived in the forest understory.

The successful establishment and survival of *Betula* seedlings might be affected by other site-specific abiotic factors. Seiwa & Kikuzawa (1996) speculated that *Betula* spp. could not establish unless soil was exposed in canopy gaps. The death of young *Betula* trees in the study plot and the unimodal population size structure of this species indicate that the present environmental conditions of the stand are not favorable for the establishment and recruitment of *Betula* from seeds. *Betula* most likely requires large-scale disturbances for a new cohort of seedlings to become established, resulting in temporal patterns of intermittent regeneration. Positive associations among young *Betula* trees and both live and dead conspecific trees at local scales revealed that sprouting rather than seedling recruitment was an important regeneration strategy for this species. *Betula* sprouts can recruit quickly to the canopy following the death of an adult canopy tree.

The density of trees has been increased with increase in elevation (Figure 4.20). In general there was negative relationship of seedling, and seedling densities with elevation. Sapling and seedling densities were decreased with increasing elevation; the decrease was statistically significant (Figures 4.21 & 4.22). However, there was some site specific variation on seedling and sapling density.

The establishment of seedling probably reflects soil or litter properties. Pearsons correlation showed that the density of sapling is negatively correlated with available potassium in the soil. However, the effect of other soil nutrients and physical parameters is not significant (Table 4.9). Less number and/ or altogether absence of seedling under its own canopy may be due to certain chemical restriction from the litter, either physical properties of the soil, such as moisture content, or chemical properties of litter as mentioned. If seedling is established successfully, sapling stage is reached.

Shrestha *et al*. (2007) found that sapling density of *Betula utilis* was highest at 3600 - 3700 m asl. and lowest at 4000 – 4100 m in the adjacent forest of upper Manang valley and they also reported that it did not show any regular pattern of change with altitude. Density of seedlings should be greater than the density of saplings for a normal demographic development (West *et al*., 1981) but in our present study, sapling density was found to be greater than seedling density (Table 4.9). Seedlings of the *Abies spectabilis* and *Larix himalaica* were more in number than that of *Betula utilis in* the lower elevation. Similarly in high altitude (>3900 m), the seedling and sapling density of *Rhododendron campanulatum* were higher than that of *Betula utilis*. The mixed forest of *Betula utilis* at lower elevations with high number of seedlings and saplings might have developed after large scale clear cutting of *Abies spectabilis* trees in the past. Open forest left after clear cutting became suitable for seed germination and seedling establishment of *Betula utilis* as *Betula is* shade intolerant species.

Large number of fallen logs and lopping of tree is observed in the field during the field visits. People near by the study area generally preferred timber of *Abies spectabilis* for construction of buildings and bridges. *Betula utilis* is generally preferred for fuel-wood. Less human interference is observed in *Betula utilis* forest than *Abies spectabilis* forest. It means that the human interference gradually decreased with increase of distance from the settlement. However, the forest degradation has been more pronounced in the past than at the present. *Abies spectabilis* and *Betula utilis* are not logged under the present land use regime. It is because this forest is now protected by local people.

Soil

Soil moisture increases with increase in altitude. It may be due to the effect of decreasing temperature and decreasing distance from water sources. Soil of study area was slightly acidic in nature (soil pH 6.56). Ghimire and Lekhak (2007) found soil pH ranging from 5 to 6 in mixed *Abies spectabilis* forest of Manang. Similarly, Shrestha *et al*. (2007) reported that soil of mixed *Betula utilis*- *Abies spectabilis* forest was slightly acidic with pH 5-7. Most conifer foliage contain acid substances and after decomposition of leaves it will keep soil slightly acidic or neutral (Zhang & 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 & Well, 1984).

Soil organic carbon of the present study forest was found 5.42%. Zhang and Zhao (2007) reported soil organic carbon as 7.45% in a *Pinus koraiensis* forest China. Their value was slightly higher than the value of present studied site. Shrestha *et al*. (2007) found soil carbon and nitrogen to be 1-8.9% and 0.1-0.7% respectively in mixed *Betula utilis* forest of Manang. Soil nitrogen of the present study forest was found 0.38%. Ghimire *et al*. (2010) reported total organic matter in the soil ranged between 3.37 to 4.77%. Similarly, nitrogen content, available phosphorus and potassium content in the soil was found between 0.17 to 0.24%, 57.93 to 263.91 kg/ha and 6.12 to 24.46 kg/ha respectively in sub alpine forest of upper Manang.

Shrestha *et al.* (2007) reported the soil potassium ranged between 7 kg/ha to 325 kg/ha. In present study, soil potassium content ranged between 219.46 kg/ha to 378.12 kg/ha. This value is somewhat higher than that in *Betula* forest of central Nepal. It may be due to the weathering of parent rocks rich in potassium like granite and gneiss. Low temperature in high altitude cause less mineralization process and hence results more nutrients in soil.

CHAPTER VI
CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Forest in Samagaun valley is dominated mainly by three tree species *Betula utilis, Abies spectabilis* and *Larix himalaica* up to 3800 m. Above it, there is Pure *Betula* forest with scattered tree species of *Rhododendron campanulatum*. *Rhododendron anthopogan* was dominant among shrub species**.** Seedling and sapling density decreased as tree density and basal cover increases. Woody species richness decreased with elevation but 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 *Betula utilis* was not continuous and show slightly deviated typical J – shaped structure and hence didn't show sustainable regeneration. Density of saplings was greater than the density of seedling. Absence of tree with high girth class (> 60 cm) indicates more disturbances in the forest.

Soil factors do not show any significant correlation with seedling and sapling density.

6.2 Recommendation

Following recommendation have been suggested on the basis of the results of presentstudy.

- Due to high human activities such cutting the tree species, density of trees is low. Therefore, human interference should be maintained to be controlled.

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ANNEX 1

GPS location of quadrats

Quadrat No.	Altitude (m)	Latitude (N)	Longitude (E)	Quadrat No.	Altitude (m)	Latitude (N)	Longitude (E)
1.	3545	28°34'58.00"	84°38'27.87"	21.	3756	28°34'47.59"	84°38'31.84"
2.	3559	28°34'56.72"	84°38'30.67"	22.	3747	28°34'46.15"	84°38'35.13"
3.	3562	28°34'55.79"	84°38'33.14"	23.	3746	28°34'44.64"	84°38'38.48"
4.	3559	28°34'54.98"	84°38'35.92"	24.	3715	28°34'43.51"	84°38'40.79"
5.	3551	28°34'53.72"	84°38'39.24"	25.	3762	28°34'42.18"	84°38'43.06"
6.	3568	28°34'51.99"	84°38'41.91"	26.	3802	28°34'40.63"	84°38'39.12"
7.	3567	28°34'50.59"	84°38'44.88"	27.	3810	28°34'41.57"	84°38'36.36"
8.	3572	28°34'49.39"	84°38'47.95"	28.	3812	28°34'42.94"	84°38'33.32"
9.	3574	28°34'48.10"	84°38'50.67"	29.	3824	28°34'43.99"	84°38'30.41"
10.	3582	28°34'46.70"	84°38'52.70"	30.	3828	28°34'45.79"	84°38'27.77
11.	3675	28°34'44.88"	84°38'47.83"	31.	3843	28°34'47.60"	84°38'24.55"
12.	3673	28°34'45.84"	84°38'45.64"	32.	3914	28°34'44.19"	84°38'22.50"
13.	3670	28°34'46.90"	84°38'42.66"	33.	3943	28°34'42.82"	84°38'26.01"
14.	3663	28°34'48.33"	84°38'40.04"	34.	3945	28°34'41.00"	84°38'28.64"
15.	3663	28°34'49.02"	84°38'36.81"	35.	3948	28°34'39.68"	84°38'31.50"
16.	3661	28°34'50.48"	84°38'33.92"	36.	3956	28°34'38.43"	84°38'34.19"
17.	3641	28°34'52.45"	84°38'31.08"	37.	4010	28°34'35.72"	84°38'31.03"
18.	3704	28°34'53.61"	84°38'28.20"	38.	4005	28°34'36.80"	84°38'28.35"
19.	3774	28°34'50.22"	84°38'26.26"	39.	4009	28°34'38.41"	84°38'25.28"
20.	3744	28°34'49.24"	84°38'29.51"	40.	4010	28°34'39.95"	84°38'22.12"

ANNEX 2

Number of trees, saplings and seedlings in different quadrats

Elevation (m asl)	QNo.	*Betula utilis*			*Abies spectabilis*			*Larix himalaica*			*Rhododendron campanulatum*		
		T	SP	SD	T	SP	SD	T	SP	SD	T	SP	SD
3500	1	11	19	6	8	3	5	4	9	5	-	-	-
	2	12	19	4	6	13	9	5	6	3	-	-	-
	3	16	12	1	3	11	9	2	11	1	-	-	-
	4	16	15	-	3	13	2	2	12	8	-	-	-
	5	16	11	-	1	18	15	6	6	1	-	-	-
	6	13	21	-	7	5	1	5	12	3	-	-	-
	7	14	27	5	7	3	2	3	8	5	-	-	-
	8	13	18	1	6	12	1	4	9	4	-	-	-
	9	14	20	1	3	8	3	4	6	7	-	-	-
	10	12	21	1	8	12	2	6	0	6	-	-	-
3600	11	14	8	-	4	8	7	5	4	4	-	-	-
	12	12	7	-	5	5	4	4	3	4	-	-	-
	13	12	9	-	4	7	4	2	4	6	-	-	-
	14	9	19	7	7	6	-	4	-	3	-	-	-
	15	12	13	5	6	-	5	3	1	3	-	-	-
	16	13	7	2	5	-	-	2	5	2	-	-	-
	17	12	8	1	3	4	8	3	-	1	-	-	-
	18	14	9	-	4	3	4	2	6	1	-	-	-
3700	19	15	8	-	-	9	5	-	-	-	2	-	1
	20	17	7	-	1	6	-	5	1	1	2	-	-
	21	14	6	-	3	9	-	3	-	1	-	3	5
	22	13	9	4	2	5	7	-	1	-	2	2	2
	23	21	-	1	3	2	-	1	-	-	1	3	-
	24	13	5	-	-	-	-	2	-	-		1	1

	25	18	-	-	4	-	-	-	-	-	1	-	-
3800	26	15	-	2	-	-	-	-	-	-	1	-	-
	27	18	-	2	-	-	-	-	-	-	2	-	-
	28	16	6	-	-	-	-	-	-	-	2	-	4
	29	18	-	-	-	-	-	-	-	-	-	5	1
	30	15	3	-	-	-	-	-	-	-	-	-	-
	31	15	6	-	-	-	-	-	-	-	-	1	-
3900	32	16	2	-	-	-	-	-	-	-	-	-	1
	33	18	2	-	-	-	-	-	-	-	-	2	1
	34	18	1	1	-	-	-	-	-	-	3	-	-
	35	16	-	-	-	-	-	-	-	-	-	-	-
	36	12	-	-	-	-	-	-	-	-	-	-	-
4000	37	17	2	-	-	-	-	-	-	-	-	3	-
	38	19	-	-	-	-	-	-	-	-	-	-	-
	39	18	-	-	-	-	-	-	-	-	-	-	-
	40	17	-	-	-	-	-	-	-	-	-	-	-

Q = Quadrat, T=Tree, SP= Sapling, SD=Seedling

ANNEX 3

Average DBH and Height of Betula utilis in each quadrat

Elevation (m asl)	Quadrat No	Average DBH (cm)	Average height (m)	Elevation (m asl)	Quadrat No	Average DBH (cm)	Average height (m)
3500	1.	20.31	5.9	3700	21.	25.17	7.1
	2.	20.12	5.8		22.	24.42	6.6
	3.	22.05	6.0		23.	25.18	6.4
	4.	21.11	5.8		24.	24.32	6.5
	5.	20.32	5.6		25.	24.15	6.5
	6.	19.92	5.5	3800	26.	22.19	7.2
	7.	21.75	5.3		27.	23.46	7.0
	8.	20.00	5.3		28.	21.07	6.5
	9.	21.12	5.4		29.	23.16	6.4
	10.	20.13	5.2		30.	23.54	6.3
3600	11.	21.63	6.4		31.	23.05	6.2
	12.	21.45	6.5	3900	32.	22.48	5.6
	13.	21.03	6.4		33.	21.28	5.5
	14.	22.47	6.8		34.	21.05	5.9
	15.	23.05	6.0		35.	22.30	6.0
	16.	23.89	5.9		36.	20.12	6.5
	17.	22.32	6.0	4000	37.	20.54	5.3
	18.	22.17	6.3		38.	20.36	5.4
3700	19.	24.05	6.5		39.	19.90	5.5
	20.	25.68	7.2		40.	20.58	5.4

ANNEX 4

Local Names of plant species found in study area

S.N	Scientific Name	Nepali Name	Local Name
1.	*Abies spectabilis*	Talispatra	Kalda
2.	*Betula utilis*	Bhojpatra	Takpa
3.	*Larix himalaica*	Langtang salla	Jesingh
4.	*Rhododendron campanulatum*	Chimal	Ratuk
5.	*Rhododendron lepidotum*	Sunpati	Silu
6.	*Rhododendron anthopogan*	Bhale sunpati	Bhaalu

ANNEX 5

Plate no.1 Study Area at Samagaun

Plate no.2 Making quadrat at elevation 3700 m

Plate no.3 Measuring DBH of *Betula utilis* at 3500 m

Plate no. 4 Measuring height of *Betula utilis* using Clinometer

Plate no.5 Collecting soil sample from 3500 m elevation

Plate no.6 Cut stumps of *Betula utilis* at 3500 m

Plate no.7 *Betula utilis* in 3500 m

Plate no.8 *Betula utilis* collected for firewood