1. INTRODUCTION

1.1. Background

All ecosystems and human societies depend on a healthy and productive natural environment that contains diverse plants and animals**.** The Himalayas has attracted the attention of man since ancient times. The Himalayan ranges support a great variety of forests which vary in species composition from east to west and low to high elevations of north to south. The Himalayan region is known for its rich biological diversity and has always been botanists' paradise (Pande *et al*. 2002). High elevation ecosystems of Himalayan region are the most vulnerable geographic regions of the world outside of the polar region to climate change (Cavaliere 2009). The various changes in the Himalayan forests are appearing in their structure, density and composition due to global warming (Gaur 1982), uncontrolled lopping and felling of trees for fuel wood, fodder and grazing (Bargali *et al*. 1998, Kumar *et al.* 2004).

Forest covers extensive areas in different landscapes throughout the world and are of fundamental importance to their biodiversity, functionally and socio-economic value (Kreyer and Zerbe 2006). The role of these forests lies in the maintenance of biodiversity, watershed protection as well as supplying timber, non-wood forest products, grazing land for domestic animals (Roder *et al*. 2002), habitat for threatened fauna etc. The altitudinal (elevation) gradient is believed to be a mirror of the latitudinal gradient in species richness (Stevens 1992, Rahbek 1995, 1997, 2005). Subalpine forest represents the uppermost forest ecosystems along the elevation gradient in ecosystems.

Vegetation within a forest is greatly affected by differences in the microclimate, aspect and altitude (Pande *et al*. 1996, Chaudary 1999). The altitudinal gradient is believed to be a natural experimental station on each mountain (Korner 2007). Dendrochronology has been used to understand past climatic variation in major trees of this forest (Brauning 2006, Chhetri 2008, Bhuju *et al*. 2010). The Himalaya, one of the global biodiversity hotspots (including its central part, Nepal) are poorly explored in term of its biodiversity. The distributions of mountain vegetation is greatlyly influenced by the climatic parameters such as temperature, precipitation, wind and isolation that characteristically for mountain regions, postglacial succession and human disturbances also affect the vegetation pattern in many areas (Krauchi *et al*. 2000, Dolezal and Srutek 2000).

The community stability, seral stage, species diversity are the important parameters to characterize a community structure (Krauchi *et al*. 2000, Dolezal and Srutek 2000). Altitudinal gradients are complex gradients and involve many different co-varying factors such as topography, soil and climate (Austin *et al*. 1996). Natural disturbance plays a critical role in mediating old growth forest dynamics and disturbances vary widely in type, scale, and effect on stand structure (Henry and Swan 1974, Pickett *et al*. 1989). Species diversity and its distribution along the altitudinal gradient had been a subject of ecosystem. Though the plant community of a region is a function of time, nevertheless, altitude, slope, latitude, aspect, rainfall and humidity had played a role in the formation of community composition. Species richness is a simple and easily interpretable indicator of biological diversity (Peet 1974). Differences in altitude and slope influence the species richness (Ellu and Obua 2005).

Natural regeneration implies that the process of re-growing or reproducing of new individual plants by their juvenile in the community. Regeneration pattern determines the species composition and stability in the future. Natural regeneration is a slow process but important to maintain a stable age structure in any plant community. It is the most important process for ensuring the replacement of any member of community that dies off after completing life cycle (Fatubarin 1987). It is also important process to maintain the stable age structure in the species is directly or indirectly affected by various biological factors such as average seed output, variability of seed, seed dormancy, seed dispersal, seedling growth, environmental factors like light, water rainfall, temperature, aspect, slope, moisture, and edaphic factors like soil pH, soil nutrient status, litter accumulation. Population structure, characterized by the presence of sufficient population of seedlings, sapling and young trees indicate a successful regeneration of forest species (Saxena and Singh 1984). The micro-site requirements for natural regeneration vary from species to species, due to variations in seed size and environmental conditions for growth and survival. Regeneration by seeds is more risky on the higher than the lower slopes (Maruta 1983, 1994, Montalvo *et al.* 1991). Counting of seedlings and saplings and analysis of size class distribution are methods for the regeneration analyses (Vetaas 2000, Koirala 2004). Undisturbed old growth forest with sustainable regeneration found to have a reverse J-shaped size- class distribution (West *et al.* 1981). A bell shaped size-class distribution has been attributed to disturbed forest where regeneration is hampered (Saxena *et al.* 1984).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).

1.2. Biology of *Abies spectabilis* [D.Don.] Mirb

Abies spectabilis is commonly called Himalayan silver fir (Vidakovic 1991). Himalayan fir (locally called **Talispatra** or **Gobresalla**) are tall evergreen, pyramidal tree attaining in eastern Himalayan height of 60 m, growing at a slow rate, distributed in Nepal between the elevation 2700-3900 m (Shrestha 1999) and found in moist open areas, woodland, garden, canopy zones. Fir, a genus under the family Pinaceace, is a large group of soft wood tree with 36 species in the world. Mainly 3 species occurs in Nepal are *Abies spectabilis, A. densa* and *A. pindrow* (Anonymous 2001, Hara *et al*. 1982 and Press *et al*. 2000). Regeneration of *Abies* was high as it can stand long winters and heavy snow, shade light, under low light and seedling can thrive under closed canopy of other species. It prefers a good moisture but not water-logged soil, grows well in heavy clay, acidic and neutral soil conditions (Anonymous 2004). They are found in temperate, subalpine and alpine zones of eastern Asia, Himalayas from Afghanistan to Nepal (Afghanistan, China, India and Nepal). Human beings have always had strong connection with *Abies* as its wood is soft, white and used for construction and carpentry purposes such as planking, door and window frames, panel, furniture, paper pulp and packing cases. The wood of most firs is considered unsuitable for general timber use, and is often used as pulp or for the manufacture of plywood and rough timber. Because this species has no insect or decay resistance qualities after logging, it is generally recommended for construction purposes as indoor use. The leaves are used in astringent, carminative, expectorant, stomachic and tonic. The leaf juice was used in the treatment of asthma, bronchitis colds, rheumatism and nasal congestion (Shrestha 1999).

Essential oil is obtained from the *Abies* species. The dried leaves, mixed with other ingredients, are used in making incense. The wood is used for construction and thatching roofs. It is also used for fuel and used as scented plant due to bruised leaves are aromatic. Firs are long-lived, on average achieving reproductive maturity at 20 years, with an average life-span of 60 years. All fir species are indigenous to the northern hemisphere, being widely distributed over the eastern and western Hemispheres chiefly in the temperate and frigid regions, from sea level to altitudes of 4700 m. The common associates of the *A. spectabilis* forests are *Rhododendron* species (*R.barbatum, R. campanulatum, R. arboreum*), *Betula utilis*, *Acer* sp., and *Sorbus* sp. (Stainton 1972).

1.3. Justification

The impact of climate change are seen to be more pronounced and sensitive in the high altitude regions especially in the mountainous environments. During the past few years, tourism and adventure trekking has grown to such extend in the Himalayan region and caused significant damage to the forest and environment. The overuse of alpine shrubs and other plants for trekking and other tourism activities resulted in causing damage to the alpine ecosystem in the region (Byers 2005). Trees present in the upper ecotone areas are found to be more sensitive to global climate changes, so these can be used as potential specimens to study the variations in climate through analysing the tree ring data (Bhattacharyya *et al*. 2006). The past climate in an area can be detected from the change in growth of tree species, which can be estimated with the application of dendrochronology. Therefore, subalpine forest could provide valuable information to evaluate the consequences of global change. The development of comprehensive models to predict these changes is a key objective of current global impacts research, but these models are still largely based on correlation analysis of species and community relationships with present climates (Steffen *et al*. 1992). Similar to climate, soils are important in vegetation ecology and have been described even in early studies. Loss of biodiversity is an inevitable result of change in climate that has been experimentally proved (Silvertown *et al.* 2006). *Abies spectabilis* is one of the endemic tree species at timberline, but little research has been done about its timberline population. Yet, little research has examined the effects of natural disturbance on tree regeneration patterns and stand development in these forests (Pitcher 1987, Taylor and Halpern 1991, Chappell and Agee 1996). A few regeneration studies had been undertaken in mixed *A. spectabilis* forests (e.g. Acharya 2004, Shrestha *et al*. 2007, Ghimire and Lekhak 2007, Ghimire *et al*. 2008) but mature *A. spectabilis* forest has been relatively less studied.Such perspectives urged me to start research community structure and regeneration pattern of subalpine *Abies spectabilis* forest in Sagarmath National Park, eastern Nepal.

1.4. Hypothesis

The main research hypotheses considered in this work are as follows:

- Regeneration of *Abies spectabilis* tree species is continuous within its own canopy.
- The DBH of trees have decreased with increase in altitude.

1.5. Objectives

The general objective of the present study was to analyze vegetation of sub-alpine mixed *Abies spectabilis* forest. The specific objectives were:

1. To analyze the effect of altitude on community structure of subalpine mixed *Abies spectabilis* forest in Sagarmatha National Park.

2. To study the effect of environmental factors on regeneration of *Abies spectabilis.*

3. To analyze regeneration pattern of mixed *Abies spectabilis* forest.

2. LITERATURE REVIEW

2.1. Community Structure

The extent and diversity of Himalayan forests is well known and evidences indicate that these forests differ significantly from both tropical and temperate forests of the world. The sub-alpine forest represents a transition (ecotone) between alpine grassland and temperate forest ecosystems. As ecotones resulting from environmental gradients are hypothesized to be sensitive indicators of climate change (Lavoie and Payette 1992), such type of studies can provide important baseline information on vegetation parameters of sub-alpine forests. Sub-alpine forest in the himalaya is often dominated by conifers or broad leaved deciduous species (Qi-Jing 1997, Gairola *et al.* 2008).

The various changes in the Himalayan forests are appearing in their structure, density and composition due to global warming (Gaur 1982), uncontrolled lopping and felling of trees for fuel wood, fodder and grazing (Bargali *et al*. 1998, Kumar *et al.* 2004). The dominant plant cover changes from a deciduous broad-leaved forest to coniferous forest (forming climax treeline) with increasing altitude.

Mountain slopes with significant bioclimatic amplitude generally have more species at the bottom than the top (Vetaas and Grytnes 2002). 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). (Ellu and Obua 2005) have suggested that different altitudes and slopes influence the species richness and dispersion behaviour of tree species. Deforestation has changed species composition and community structure of subalpine forest (Ghimire and Lekhak 2007).

2.2. Regeneration

Successful tree regeneration requires both successful seedling establishment and subsequent survival and growth sufficient to ensure recruitment. Therefore, understanding the role of micro sites such as litter, bare mineral soil, nurse logs, moss layers on the early stages of seedling establishment and their survivorship play an important role in the future development of forests and its compositions (Simard *et al*.

2003, Gratzer *et al.* 1999). The effect of dispersal agents, role of understorey, density dependent mortality, seed rain, seed bank density (Lambers and Clark 2003), the role of herbaceous vegetation (Gratzer *et al*. 2001), shade, moss competition and substrate (Weber *et al*. 2003) show that these factors are important part of the ecosystem functioning.

The number of individuals reduced sharply with the increase of diameter. Reverse J-shaped size class diagram is the indicative of sustainable regeneration (Vetaas 2000). Size class diagram of *Abies spectabilis* in Manang, a trans-Himalayan dry valley of central Nepal, showed a reverse J-shaped structure (Ghimire and Lekhak 2007, Shrestha *et al*. 2007). (Acharya 2004), in mixed *Abies spectabilis* forest of Manang, found high human interference as the main factor leading to the destruction of species of high girth classes. There was less natural regeneration of *Abies spectabilis* due to radiation, low moisture and high human pressure. In the Baima snow mountain timberline population of *Abies georgei*, the number of seedlings accounted for 79% and 9.4% respectively of 0–5 cm and 5–10 cm diameter classes which showed good regeneration of this population. The diameter class structure of *Abies georgei* population showed a reverse J-shape, and the smallest two diameter classes (0-5 cm and 5-10 cm) accounted for 79% and 9.4%, respectively (Qiaoying *et al*. 2008). The number of individuals reduced sharply with the increase of diameter. Towards both high and low altitudes of west-central Bhutan the young tree density tended to decrease either due to human influence or naturally due to climatic conditions (drought) and biological interactions (Wangda and Ohsawa 2006). In mixed *Abies spectabilis* forest on the southern slope of the Manang valley, seedling and sapling densities were nearly equal (Ghimire and Lekhak 2007). Seedling and sapling densities increased with altitude up to 3800 m elevation and then it decreased gradually to upper elevation in fire damaged forest on the northern slope of the Manag valley and recorded the seedling density of *Abies spectabilis* to be 3923 stem/ha and sapling density to be 117 stem/ha (Acharya 2004). In mixed *Betula utilis* forest of the same valley, (Shrestha *et al*. 2007) hypothesized that partial canopy opening may induce seedling establishment and hence continuous regeneration of *Betula utilis* at mature stands. Seedling density of *Picea abies* was higher where mean was 162000 per ha in *Picea abies* forest of Slovenian Alps (Diaci *et al*. 2005). Bhuju *et al.*(2010) recorded total basal area of 11.2 m^2/ha and density of 445 stem/ha, basal area of 18.6 m^2/ha and density of 1034 stem/ha from timberline region of SNP. Tiwari (2010) reported seedling and sapling density were 4012 stem/ha and 70 stem/ha respectively in forest of Langtang.

3. MATERIALS AND METHODS

3.1. Study area

The present study was carried out along an altitudinal gradient in the subalpine forest of Sagarmatha National Park (SNP).The study was carried out in mixed *Rhododendron arboreum* and *Abies spectabilis* forest of Solukhumbu district, eastern Nepal, owes its high floral and faunal diversity to its strategic location. The district bounds its northern side Tibet, eastern side Sankhuwasabha and Bhojpur districts, southern side Khotang district and western side Dolakha and Ramechhap districts. It is the mountainous area with an area of 3312 sq.km and has many higher peaks with highest peak in the world, Mt.Everest (8848 m). Numerous streams and rivers dissect the topography of the area. Dudhkoshi is the major river system in the district while Lumding, Inkhu, Hongu, Selu and Rawa are other small rivers. The rivers formed from the glacier of the high Himalayas. Generally the climate of Solukhumbu district ranges from subtropical to alpine type. Such a wide variation in altitude ranging from 1500 m to 8848 m asl. The areas lower than 2900 m have a warm temperate climate whereas the upper parts have the cool temperate climate. In general, the area has the monsoon climate with 80% of the rainfall occurring in summer (May to October). Snowfall occurs during winter above 2300 m asl. Solukhumbu, through is a cold area, the precipitation is also higher than in lower parts of the country.

Khumbu meterological station which is the closest station to the study area.The metrological data of the year 2007 A.D. shows that the highest average maximum temperature reaches up to 11.78◦C during June and minimum temperature up to -11.19◦C during February. Similarly highest mean precipitation was recorded during July (6.12 mm), followed by 3.36 mm and 3.10 mm, there was no precipitation during January, November and December (Source DHM).

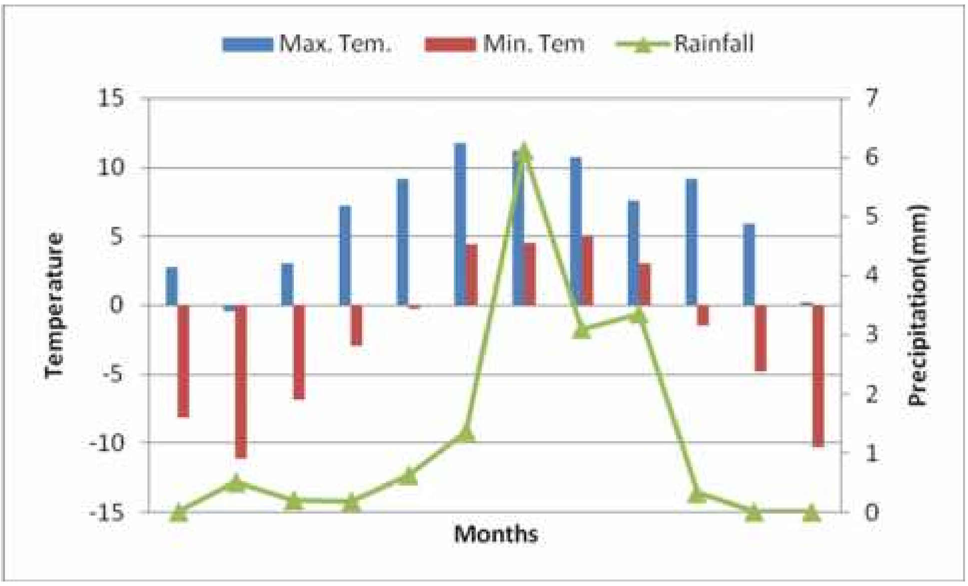


Fig. 1: Average monthly temperature (°C) and rainfall (mm) recorded at Khumbu weather station (85°18'E, 28°06'N and elevation 3600 m) between 2007 (Source: Department of Hydrology and Meteorology, Kathmandu).

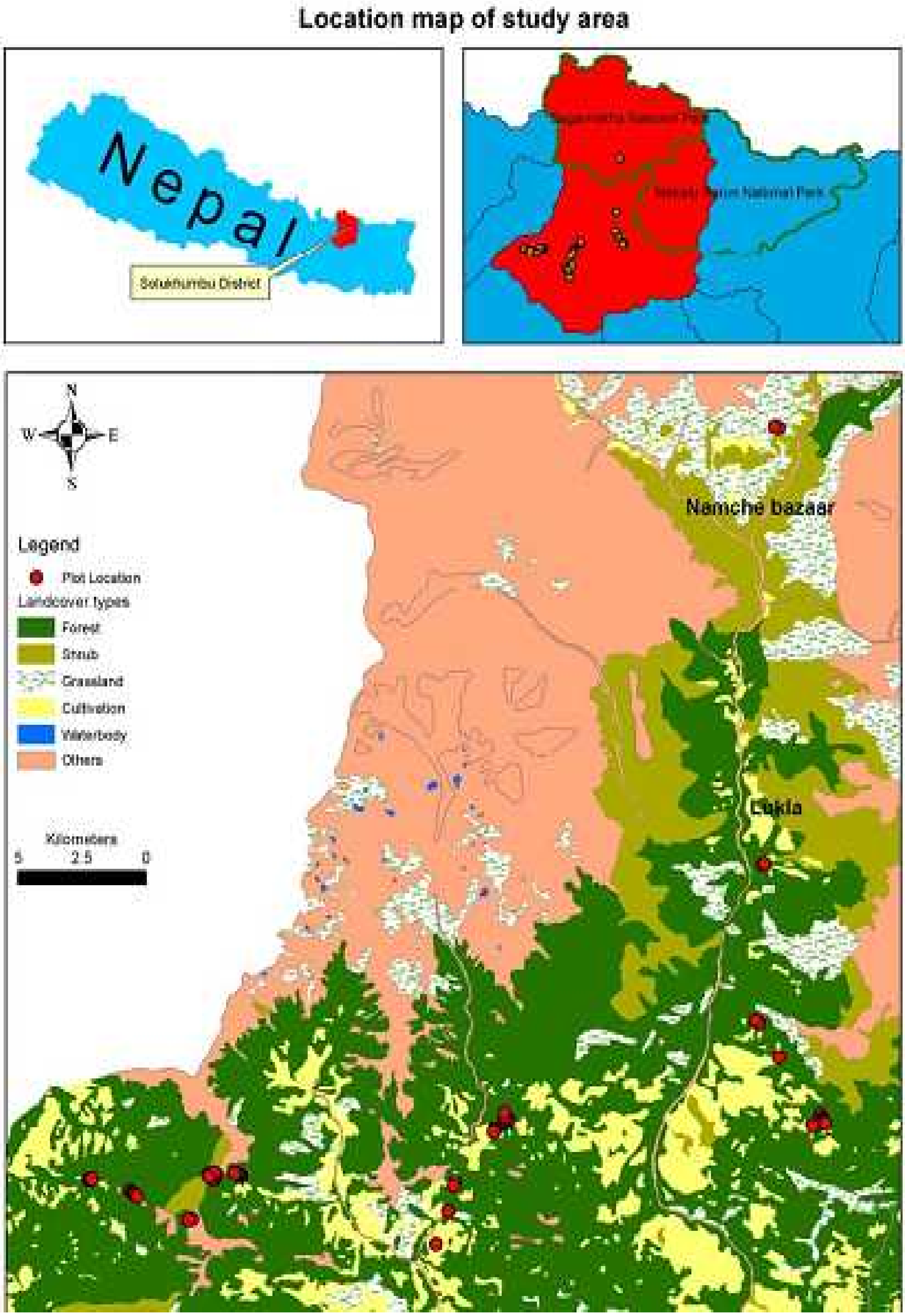


Fig. 2: Map of the study area showing plot locations

3.2. Phytogeography

Abies spectabilis is native of Himalayan fir, has bright silver underside of leaves. The distribution of *Abies* in Nepal Himalaya is in between 2800-3800 m asl elevation. However, the pure fir forest was found at between 3000-3500 m (Smidt-vogt 1990). It can stands long winter and heavy snow. It thrives in cold damp area facing south which grows up to 60m high approximately in native habitat.

The present study was conducted above 2750 m in mixed forest of *A. spectabilis* and *Rhododendron arboreum* while the shrubs are mainly *Juniperus* species, *Caragana*, *Lonicera*, *Berberis* etc. It commonly occurs as a canopy dominant species in very wet forest, accompanied by species of *Rhododendron* including *R. companulatum, R. lepidetum* and *R. anthopogen* as well as *Betula utilis* (Chhetri 2008).

3.3. Cultural landscape

The study area was the cultural landscape where pastoralism and agriculture are the major land use by local people. Forests were fragmented and encroached for the agricultural purposes. Most of the people in lower parts have herds of cows and goats while there are herds of yaks, cows, goats and horses in the higher regions. Thus cattle grazing was the common phenomenon in the forests. Collection of fuel wood, timber, fodder and grazing were the major disturbance in the forest ecosystem. The area was the precious trekking route and the increasing tourism has increased the use of timber and fuel wood. There were many tourist hotels along the trekking route where mainly *Abies* and *Rhododendron* wood had used for cooking and heating purposes and wood of *Abies* was used for construction purpose. Being a colder area, people needed a great amount of firewood in winter for heating purpose. Sherpa people live in the northern and higher parts of the district while Rai and Lama people live in the south eastern and lower parts of the district in association with other people. Sherpa follows the Buddhism and has made many monasteries in the district which may have historical importance.

3.4. Site characteristics

The present study was carried out in mixed forest of *Abies spectabilis* and *Rododendron arboreum* between Guranse danda and Khumjung of the Sagarmatha National Park. The study area included the mainly *Rhododendron* and *Abies* forest along the trekking routes from Guranse danda (2750 m asl), Gouyam (3040 m asl) to Lamjura (3500 m asl) and Khumjung (3550 m asl). The study was conducted on north-east facing slope with inclination of 35˚ (27°30' - 50' N and 86° 40' - 50' E, elevation 2750-3550 m). Being close to the trekking routes and settlements, the forests were disturbed because of fuel wood and fodder collection and grazing. The *Abies* was abundant in the north facing slopes. In order to describe the site and microsite conditions of the study area the following features recorded for every plots were coordinated using GPS, Altitude, Aspect, Slope gradient, Slope position, Depth of litter and disturbance agents both anthropogenic and natural such as trampling, grazing pressure.

3.5. Research design and data collection

The sampling method was followed as Vetaas (2000) and carried out in the study area which was in the *Abies* and *Rhododendron* mixed forest of Solukhumbu district. Field study was carried out in April- May 2009. Sampling was carried out only from 2750 to 3550 m asl though the nine transects. Vegetation sampling was done by quadrat method and the sample plots located by systematic random sampling method.

Altogether 45 plots of 0.1 ha (33m x 33m) were sampled in each 100 m elevation interval starting from 2750 m to 3550 m. Five sampling plots were laid in each elevation one or the both side of the trekking route. Each elevation was chosen on the side of the path where there was at least one mature *Abies spectabilis* tree. The distance between two transects were between 30-200 m. The distance between the plots was determined on the basis of the accessibility and presence of *Abies spectabilis* trees. Sampling in such away that if *Abies* were not observed in one side, a search was conducted on either side of the path and also in another location with the same elevation. Elevation and location of each plot were recorded by altimeter and GPS (Garmin) respectively.

The number of individuals of *Abies spestabilis* at all life stages as tree, sapling and seedling were recorded and diameter at breast height (dbh) measured at 137 cm above the ground of tree in each plot by using dbh tape. All shrubs species present in the quadrat were recorded. Individual of each tree species were grouped into tree (dbh>10 cm), sapling (dbh<10cm, height>30cm) and seedling (height <30cm) (Sundriyal and Sharma 1996).The predictor variables as slope, litter content, aspects, rock cover and land use pattern (tree lopping, logging, trampling evidences of human disturbances and cattle grazing) by visual estimation were also recorded to study the microenvironment. Lopping, logging and grazing were categorized as low, medium and high. For lopping, low mean 1- 5 trees lopped, medium mean 6-10 trees lopped and high mean more than 11 trees lopped in each plot. Further low is coded as 1, medium as 2 and high as 3. Similar scale was used for logging and grazing. Grazing pattern was categorized based on the number of piles of cattle dung present within the plots. From each quadrat, 200 g soil sample was collected from the corners and centre of each quadrat at a depth of 30 cm and mixed them. Soil samples were collected from each study site was air dried in shade for week and packed in air tight plastic bags until laboratory analysis. Species of tree and shrub species from the quadrat were collected for identification. Most of the plant species were identified in the field with the help of local names provide by local people and standard reference (Stainton and Polunin 1987, Stainton 1988 and Shrestha 1998).

3.6. Laboratory Analysis of soil

The collected soil samples were analyzed for nitrogen (N) and soil organic carbon (OC) at laboratory of ecology unit of Central Department of Botany, Tribhuvan University, Kirtipur, and Kathmandu.

Nitrogen: Soil nitrogen is the most important substance, which is found in different form in soil like ammonia, nitric acid, nitrate etc. The soil nitrogen was determined by micro Kjeldahl method (Gupta, 2000). This method includes the following steps: Digestion, Distillation and Titration.

Digestion: 1 gm air dried and sieved soil (using 0.5 mm sieve) was taken in a dry Kjeldahl digestion flask (300 ml). Then 3.5 gm potassium sulphate and 0.4 gm copper sulphate (i.e catalyst) were added to the Kjeldahl flask containing soil. To the mixture, 6 ml conc. H_2SO_4 was added to the same flask with gently shaking. Then, the flask was placed on the preheated ($30^{o}C$) heating mantle for digestion. The temperature was raised to about 70-80 ^{0}C. At the end of the digestion process, the colour changed from black to brownish and at the end it became greenish. Then the flask was removed immediately from the mantle and allowed to cool down. 50 ml distilled water was added to the digest and mixture was shook. A blank without soil sample was prepared for each 10 soil samples as reference solution.

Distillation: The diluted digest was transferred to micro Kjeldahl distillation flask. A beaker (100 ml) with 10 ml boric acid indicator was placed bellow the nozzle of the condenser in such a way that the end of the nozzle dipped into the indicator. After the digest became warm, 30 ml 40% NaOH was added. The distillate began to condense and the colour of boric acid indicator changed from pink to green. The distillation was continued until the volume of distillate in beaker reached to about 50 ml.

Titration: The distillate was titrated with HCl (0.01N). The volume of acid consumed by both blank and samples were noted and the total nitrogen content (N %) was calculated by using following:

Soil Nitrogen was calculated using formula:

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

Where, N = Normality of HCl

S = Volume of HCl consumed with sample (ml)

B = Volume of HCl Consumed with Blank (ml)

M = Mass of Soil taken (mg)

Soil Organic Carbon: Organic carbon was determined by Walkley Black Method (Gupta 2000). 0.25g air dried soil was taken in a dry 500 ml conical flask. Then 10 ml potassium dichromate (1N) was pipette in and swirled a litter. To the mixture 20 ml of concentrated sulphuric acid was added. The flask was allowed to cool down for 30 minutes and then 200 ml distilled water was added. After that 10 ml orthophosphoric acid and 1 ml diphenylamine indicator were added successively in the conical flask containing the mixture. Finally, the content was titrated with 0.5 N ferrous ammonium sulphate till the colour changed from blue violet to green. A blank was also run simultaneously.

$$\text{Organic carbon in soil (\%)} = \frac{N(B - S) \times 0.003}{M} \times 100$$

Where, N= Normality of ferrous ammonium sulphate (0.5 N).

B=Volume of ferrous ammonium sulphate for blank titration.

S= Volume of ferrous ammonium sulphate for sample titration.

Soil PH: Soil pH of each soil sample was determined by using Fischer's Digital pH meter in 1:2 ratio of soil and distilled water. Before measurement, the pH meter was calibrated using buffer solutions made by buffer tablets of known pH (pH 4 and pH 7) in 100 ml distilled water. During the pH measurements, 25 g of soil sample was poured into 50 ml of distilled water in clean beaker. The mixture was stirred at least 30 minute using a magnetic stirrer and then allowed to settle down for few minutes. The calibrated electrode was dipped into the mixture and reading of pH was noted.

3.7 Numerical Analysis

From the field data, density (stems/ha), frequency (%), basal area (m^2/ha) of trees were calculated following (Zobel *et al*. 1987).The density of seedling and sapling of trees were also calculated. Density- diameter curves were developed to access regeneration status of tree species of *Abies spectabilis*.

Mean values were calculated for each environmental variable and community attribute. Correlation coefficient matrix was analysed among different variables. Species composition was checked by Detrended correspondence analysis (DCA). DCA was used to explore the species composition of all plots. The ordination DCA was performed using *CANOCO*, version 4.5 and ordination plot was drawn by *CANODRAW* version 4.5, ter Braak and Smilauer (2002). Variation among community attributes abundance of recruits (Density of saplings and seedlings) and the environmental variables were analyzed by regression analysis. The generalized linear model (GLM) was used to examine the relationship between population density of seedling, sapling and trees of *Abies spectabilis* along an elevation and also with other environmental and edaphic predictor variables. The models were checked up to the third order polynomials regressions and used "F" test to test the significance of the models.

During the regression analysis using forward selection, the response variables were fitted into the models to see the combined effect of the variables. All the analyses were performed using the statistical computer programme "R for windows 9.2".

From the values of aspect (Ω), slope (β) and latitude (Φ), Relative Refractive Index (RRI) was calculated with formula given by Oke (1987):

$$RRI = \cos(180^\circ - \Omega).\ \sin\beta.\ \sin\Phi + \cos\beta.\ \cos\Phi$$

Species Diversity

Beta diversity (β) is the indication of homogeneous or heterogeneous vegetation pattern. Higher value of beta diversity indicates the heterogeneity and lesser value of beta diversity indicates homogeneity of the stands. Species diversity is the combination of species richness and species evenness. Species richness is the number of species per sampling unit. Species evenness is the distribution of individuals among the species. Species diversity can be expressed in single index number. Among the several indices most commonly used two indices are Simpson’s index (Simpson 1949) and Shannon-Wiener’s index (Shannon and Weaver 1949). Simpson’s index (C) reflects the dominance because it is more sensitive to the most abundant species than the rare species. Following relations were used to calculate Simpson’s (C), Shannon- Weiner (H') indices and Beta-diversity (β).

$$C = \sum_{i=1}^{s} (Pi)^2$$

$$H' = - \sum_{i=1}^{s} (Pi) (\ln Pi)$$

Where, s = total number of species

Pi = proportion of all individuals in the sample that belongs to species i

$$\beta = (s/\alpha) - 1$$

Where, s = total number of species

α = mean species richness

Regeneration

Density-diameter curve was used for predicting regeneration status of trees. All the trees of *Abies spectabilis* were divided into DBH classes of 10 cm interval and density of tree in each diameter class was calculated. Density-diameter curve was obtained by plotting diameter class on X- axis and density on Y- axis. Combining data of all tree species, density-diameter bar diagram was also obtained for entire forest. Number of seedlings and saplings per tree and number of seedling per sapling for each species were calculated as

Seedling tree ratio = Number of seedling/Number of tree

Sapling tree ratio = Number of sapling/Number of tree

Seedling sapling ratio = Number of seedling/Number of sapling

4. RESULTS

4.1. Environmental Conditions

Intensity of grazing/trampling was relatively high in the study forest. Collection of fire wood and tree logging was also common. Soil of the forest under study was slightly acidic in nature with pH ranged in between 4.2 to 5.93 (Table 1). Total carbon content in soil between 1.24% to 6.79% and nitrogen content in the soil was found between 0.11% to 0.52%.

Table1. Environmental variables of the mixed *Abies spectabilis* forest in the study area.

Environmental variables	Mean	Range (Min-Max.)
Grazing/trampling (1-3)	1.28	1-3
Litter cover (cm)	2.16	1-3.8
Relative radiation index	0.07	-0.90-1
Soil pH	5.16	4.2-5.93
Soil organic carbon (%)	3.05	1.24-6.79
Soil nitrogen (%)	0.27	0.11-0.52

Table 2 . Community attributes of the mixed *Abies spectabilis* forest in the study area.

Environmental variables	Mean	Range (Min-Max.)
Total tree density(stem/ha)	267.1	10-570
Total sapling density(stem/ha)	1086	70-3300
Total seedling density(stem/ha)	524.2	20-2230
Total tree basal area(m^2)	2.24	0.73-6.03
Abies seedling density(stem/ha)	76.89	0-910
Abies sapling density(stem/ha)	28.44	0-250
Lopping	1.11	1-2
Loging	1.42	1-3
Slope(◦)	187	90-280
Canopy cover (%)	53.78	5-80
Rock cover (%)	16.44	0-80
Aspect(◦)	34.6	10-45

In study forest, the total tree density of various species was found to be 267.1 stem/ha and total basal cover of tree species was 2.24 $m^{2/}$ha. The density of seedlings and saplings of *A. spectabilis* were 76.89 and 28.44 stem/ha respectively where as total sapling and seedling were 1086 and 524.2 stem/ha. There was much difference between seedling and sapling density of *Abies spectabilis*. The mean tree canopy cover was 53.78% (Table 2). The distribution pattern of seedling and sapling of *Abies* were not uniform however 40% of the studied sub-plots were with seedlings while 66.67% of studied were without sapling and 40% of plot had no *Abies spectabilis* trees. Total sapling density increased with altitude upto 3050 m after that it decreased up to 3350 m . Total seedling density of all tree species was lower than that of sapling density (Fig. 3), which was not a normal demographic development. The most densely populated plots were found between 3450 m and 3550 m. In the highest elevation range trees were small with lower basal area. The highest tree basal area of *Abies* was found at 3450 m (6.033 m^2/ha) (Appendix 3)

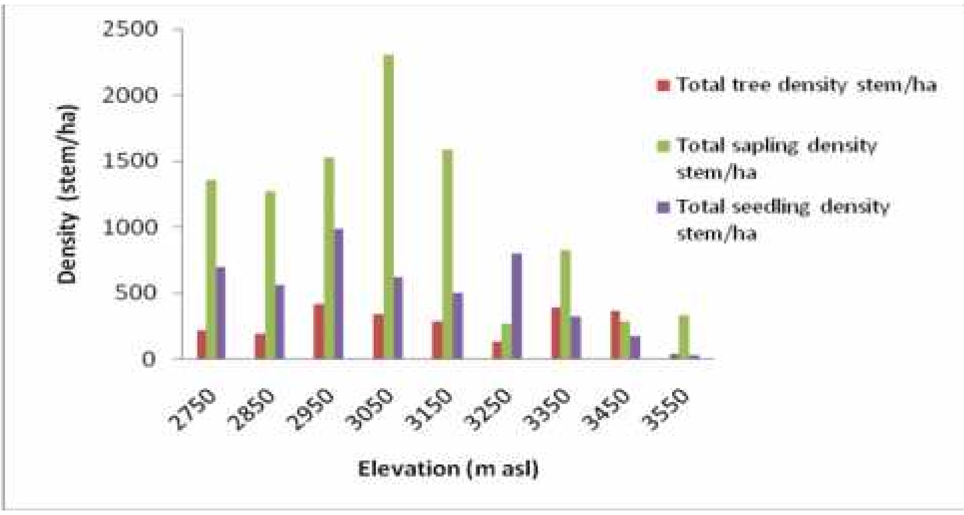


Fig. 3: Density of all species along with Elevation.

Environmental correlation with DCA axes

The summary of DCA results (Table 3) showed that axis-I have a high eigenvalue (0.41) and was correlated with elevation.The degree of divergence and heterogeneity increased with the elevation as indicated by the length of the gradients of the DCA axis-I and their eigen values.

The environmental parameters such as rock cover, soil carbon and elevation were fitted in this ordination diagram (Fig.4). The biplot diagram of species and elevation showed that elevation had strong correlation with respect to distribution of various species along axis I. The total seedling density decreases with increased elevation. The coverage of rock was higher in high elevation than lower elevation (Fig. 4).

Table 3. DCA summary from dataset

Axes	I	II	III	IV	Total inertia
Eigen values	0.41	0.17	0.09	0.05	1.653
Lengths of gradient	2.75	2.38	1.68	1.39	
Cum % variance of species data	25.2	35.6	41.2	44.4	
Sum of all eigen values	1.653				

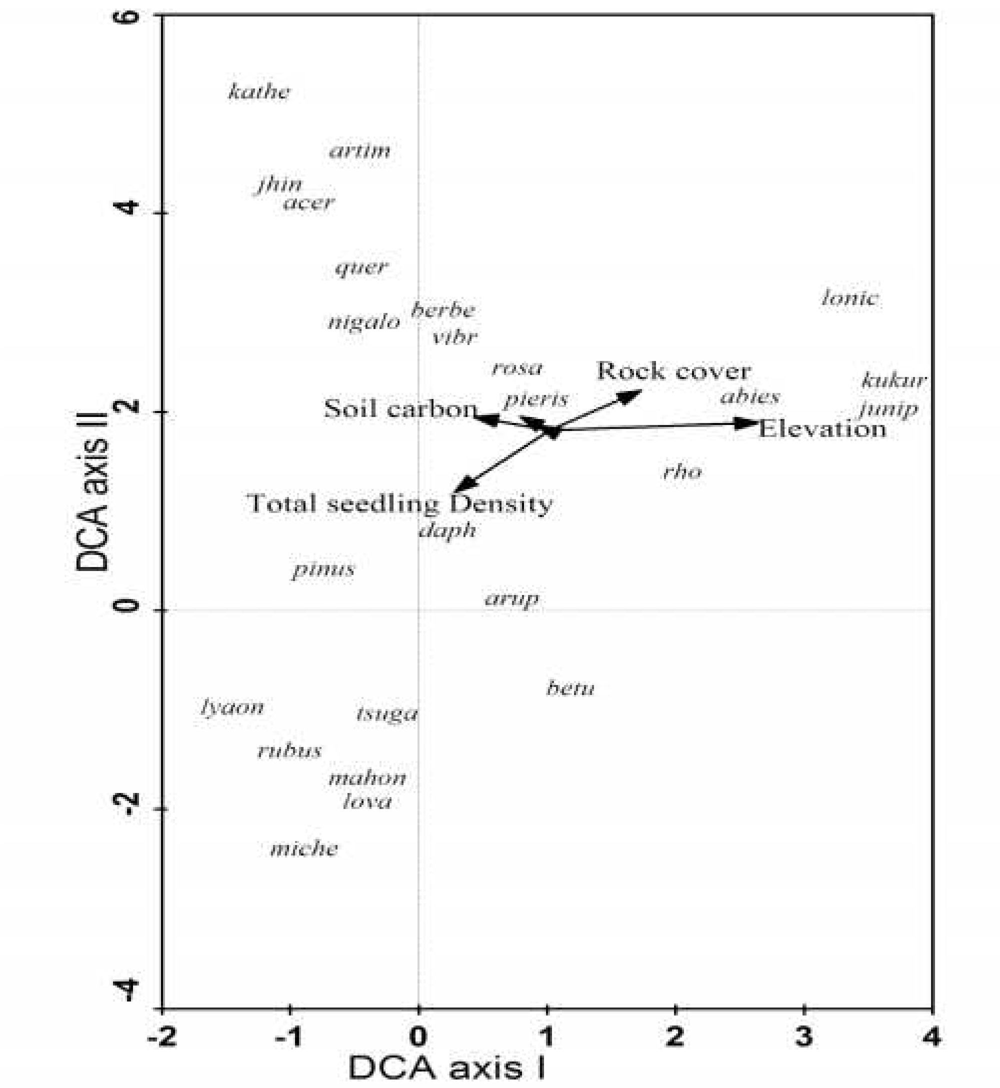


Fig. 4: Ordination diagram obtained by Detrended correspondence analyses (DCA).The diagram represents Species composition along with significant environmental parameters of study area.

4.2. Community Structure

4.2.1. Species Composition

Lower belt was dominated by *Daphne bholua*, *Tsuga dumosa, Berberis aristata* and the upper belt was dominated by *Abies spectabilis*, *Rhododendron arboreum* , *Quercus semicarpifolia* and *Juniperus indica* (Table 5). The associated species of *Abies* were *Rhododendron*, *Juniperus* etc. Altogether thirty four species of trees and shrubs were recorded. Among them, twelve species were tree form and other were sapling form in forest of the study area. However, *Abies spectabilis*, *Quercus semicarpifolia* and *Pinus wallichina* reached to canopy layer. Remaining species were confined only to sub canopy layer.

Shrub layer was mainly dominated by *Daphne bholua* , *Berberis aristata***,** *Lonicera lanceolata* at lower altitude whereas higher altitude was dominated by *Juniperus* species and some of place by *Vibrurnum* species. Among trees, *Rhododendron arboreum* had highest IP (61.91%) and then after *Abies spectabilis* was 22.72% IP (Table 4).

Twenty two species were recored in shrub form. Among them *Daphne bholua* was the most frequent (53.3%) (Table 5). Other common species were *Lonicera lanceolata*, *Berberis aristata*, *Vibrurnum* species etc. The diversity dominance curve showed that out of 12 species, 5 species had IP less than 1% (Fig.5).

Table 4: **Frequency (F), Relative Frequency (RF), Density (D), Relative Density (RD), Basal Cover (BC), Relative Basal cover (RBC) and Importance Percentage (IP) of tree species in mixed *Abies spectabilis* forest of the study area.**

SN	Plant Name	F (%)	RF (%)	D stem/ha	R D (%)	B C (%)	RBC (%)	IP (%)
1	*Rhododendron arboreum* Sm.	100	42.86	184.88	79.26	1589.46	63.63	61.91
2	*Abies spectabilis* (D.Don.) Mirb.	60	25.71	60.88	11.9	763.66	30.57	22.72
3	*Michelia champaca* L.	2.22	0.95	0.44	0.18	20.29	0.81	0.64
4	*Lyonia ovalifolia* (Wall.) Drude	4.44	1.9	0.44	0.18	2.64	0.10	0.72
5	*Quercus semicarpifolia* Sm.	17.77	7.61	10.22	4.38	77.38	3.09	5.02
6	*Eurya acuminate* DC.	8.88	3.8	1.11	0.47	7.58	0.30	1.5
7	*Betula utilis* D.Don.	6.66	2.85	1.5	0.64	5.44	0.21	1.2
8	*Prunus cornuta* (Wall. Ex Royle)	11.11	4.76	1.77	0.75	8.57	0.34	1.95
9	*Juniperus indica* Bertol	15.55	6.66	4.22	1.81	15.72	0.62	3.03
10	*Tsuga dumosa* (D.Don) Eichler	2.22	0.95	0.22	0.09	1.57	0.06	0.36
11	*Acer* sp.	2.22	0.95	0.22	0.09	1.18	0.04	0.36
12	*Salix* sp.	2.22	0.95	0.44	0.18	4.22	0.16	0.43
Total		233.29	99.95	266.34	99.93	2497.71	99.93	99.84

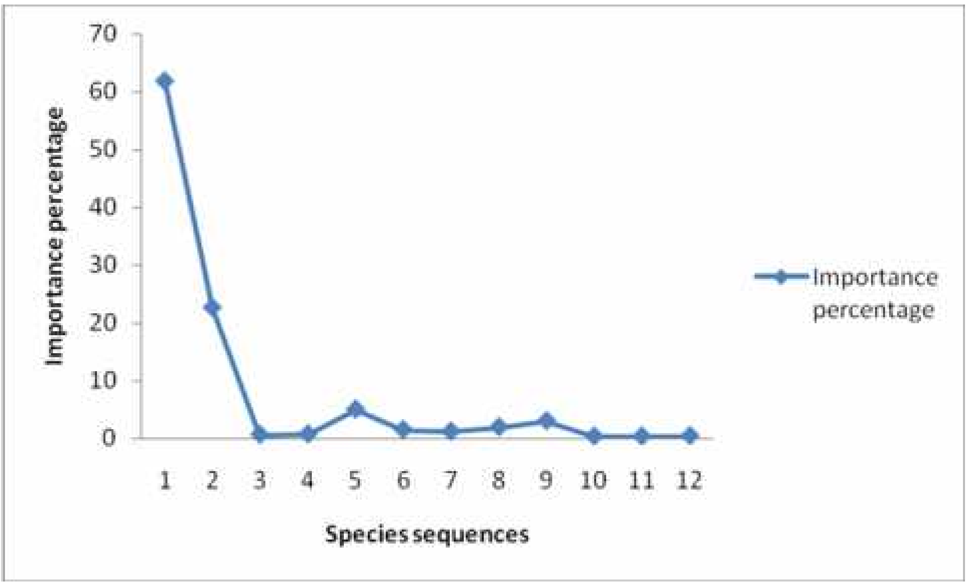


Fig. 5: Diversity-dominance curve for the tree species of the mixed *Abies spectabilis* forest. The numbers in species sequence indicate the same species as in Table 4.

Table 5: Plant species forming shrub/sapling layer in mixed *Abies spectabilis* forest.

S.N	Name of sapling and seedling species	Frequency
1	*Daphne bholua* Buch.-Ham. ex. D.Don	53.3
2	*Abies spectabilis* D.Don	28.89
3	*Berberis* sp.	53.3
4	*Viburnum erubescens* Wall ex. Dc.	46.7
5	*Artimisia* sp.	4.44
6	*Lonicera acuminata* Wall.	6.7
7	*Lyonia ovalifolia* (Wall.) Drude	26.7
8	*Pieris Formosa* (Wall.) D.Don.	31.11
9	*Cotoneaster* sp.	6.7
10	*Rhododendron campanulatum* D.Don.	8.88
11	*Rhododendron lepidotum* Wall. ex. G.Don.	8.88
12	*Rhododendron arboreum* Sm.	97.8
13	*Rubus hypargyrus* Edgew.	4.44
14	*Rosa* sp.	20.0

15	*Smilax* sp.	2.22
16	*Acer* sp.	2.22
17	*Quercus semicarpifolia* Sm.	15.6
18	*Drepanostachyum intermedium* (Muro) keng f.	6.7
19	*Juniperus* sp.	26.7
20	*Eurya acuminate* Dc.	2.22
21	*Mahonia nepalensis*	6.7
22	*Tsuga dumosa* (D.Don) Eichler	6.7

4.2.2. Species Richness and Diversity

The total number of woody species (trees and shrubs) recorded was 34 (Table 4 and 5). Average species richness for tree was found to be 130 species/ha and shrub species richness was 108 species/ha. Beta diversity for tree was 1.26. Simpson's index of dominance (C) for tree was 0.44 and Shannon-Wiener index (H') of species diversity was 1.21. The sapling and tree ratio was lowest for *Abies spectabilis* than the seedling and tree ratio and seedling and sapling ratio (Table 6).

Table 6. Number of seedlings and sapling per individual tree of the tree species in the study forest.

Tree Species	Seedlings/tree	Sapling/tree	Seedling/Sapling
Rhododendron arboretum	2.30	2.09	1.1
Abies spectabilis	1.29	0.46	2.77
Michelia champaca	0.00	0	0
Lyonia ovalifolia	4.50	3.5	1.28
Quercus semicarpifolia	0.95	0.51	1.86
Eurya acuminate	0	0.6	0
Betula utilis	0	0	0
Prunus cornuta	0	0	0
Juniperus indica	3.44	5.31	0.3
Tsuga dumosa	23	10	2.3
Acer sp.	24	2	10
Salix sp.	0	1	0

4.3. Community attributes vs. Environmental variables

Elevation appeared to be the important environmental factor that affected the community attributes of the study forest. Since all the life forms had the unimodal distribution, the modal was further analyzed with forward selection method. Species richness in the studied forest decreased with increase of elevation (Fig.7). The analysis, based on the Akie value (201.32, which was lowest) showed that the total sapling density has the highest impact on species richness followed by elevation (Fig.10). The total sapling density, seedling density of *Abies* and total density of trees were decreased along with elevation (Fig. 6,8 and 9). Seedling density, population of *Abies* tree and total basal area were increased along with canopy (Fig.12,13 and 15). Total tree density increased with little content but decreased with relative refractive index (Fig.11 and 14).

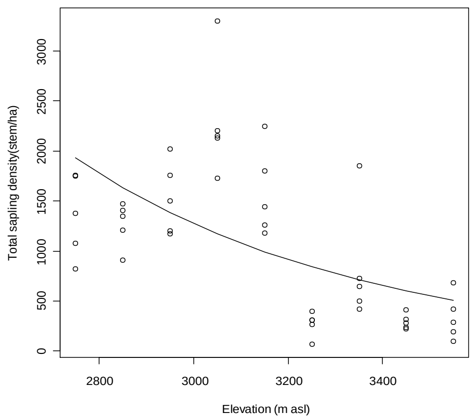


Fig.6: Total Sapling density along with Elevation.

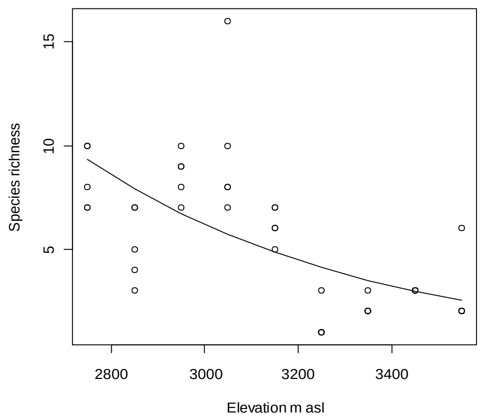


Fig.7: Species richness along with Elevation

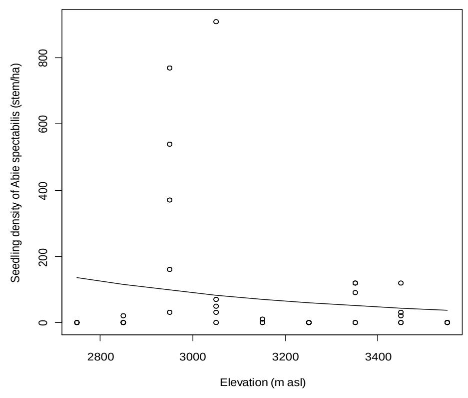


Fig.8 Seedling density of *Abies* along with elevation

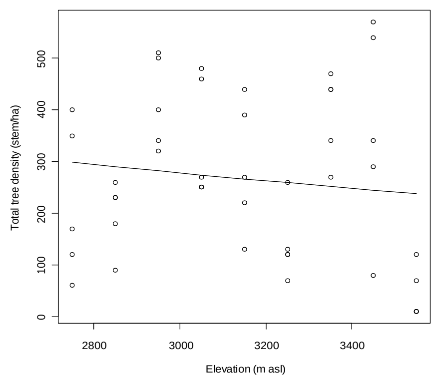
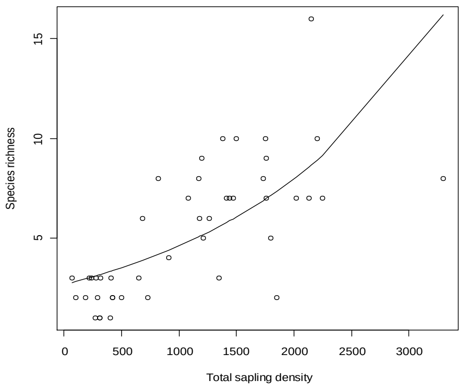


Fig.9 Total tree density along with elevation



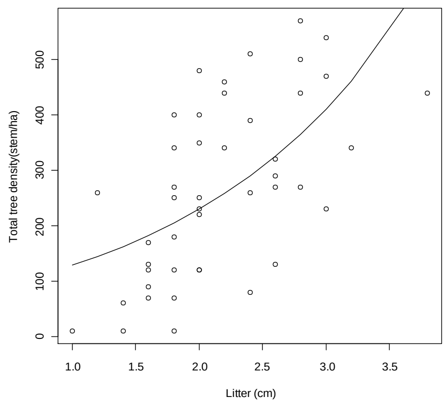
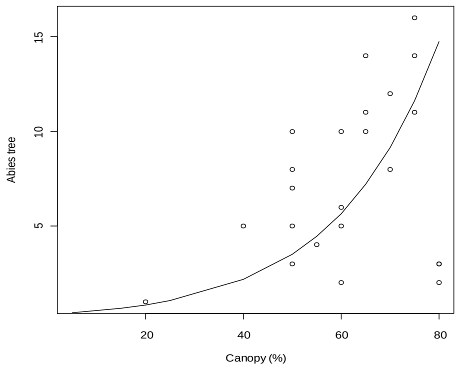


Fig. 10: Species richness along with Total sapling density **Fig. 11: Total Tree density along with Litter content**



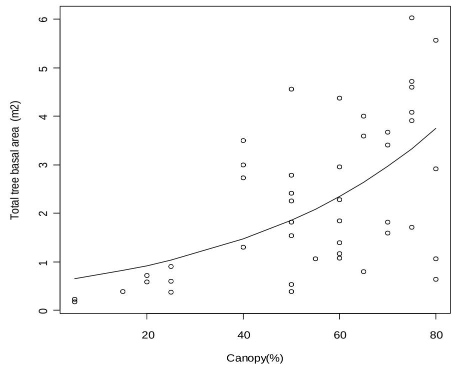
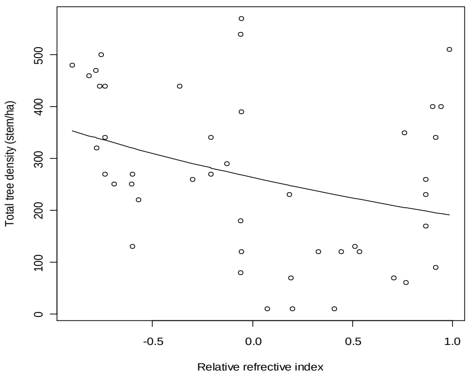


Fig. 12: Population of *Abies* Tree along with Canopy. Fig.13: Total Tree basal area along with canopy



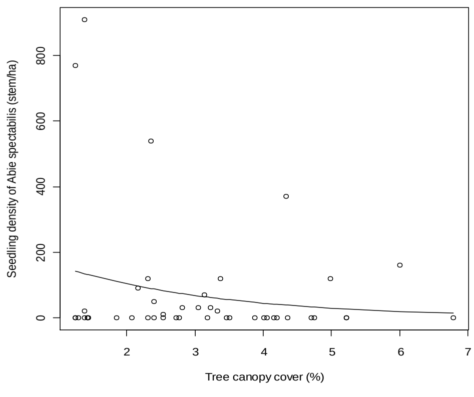


Fig.14: Total Tree density along with RRI. **Fig.15: Seedling density of *Abies* along with canopy**

4.4. Regeneration and size class distribution

Density-diameter curve for all tree species combined was nearly reverse J-shaped indicating continuous regeneration (Fig. 16). The curve of *Abies spectabilis* deviated slightly from the typical reserve J- shape due to the density of smaller class size (10-20) was lower than the density of next class size (20-30) and size 40-50 was lower than next size 50-60.

Density of seedlings of *Abies spectabilis* declined with increasing height classes. There was gradual decline in density from first to last height class.

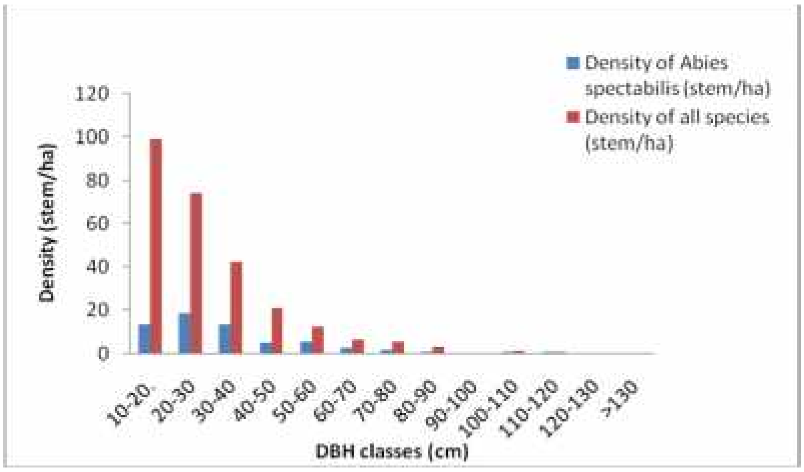


Fig. 16: Density-diameter curve for *Abies spectabilis* alone as well as all tree species of the forest.

4.5. Population density and land use Environmental correlation

Different plant species and life stages of a species coexist in any habitat and they may have both inter-specific, intra-specific interaction and different relationship with the environment. The population dynamics of any plant species thus is affected by different factors within its habitat. There was a highly significant correlation (r = 0.73) between the total sapling vs. species richness, sapling population of *Abies* vs. *Abies* seedling density, seedling population of *Abies* vs. *Abies* sapling density, seedling population vs. tree population of *Abies* and canopy cover vs. total tree density (Table 7). Seedling population of *Abies spectabilis* showed significant positive correlation with the tree population (r = 0.73) and saplings of *Abies* (r = 0.37). The number of seedling was higher where the tree and sapling were high. Species richness(r = -0.66), total sapling density (r = -0.6) and total seedling density (r = -0.4) showed negatively significant correlation with elevation. Similarly total tree density (r = 0.61), total tree basal area (r = 0.47) and number of *Abies* trees(r = 0.41) were significant with litter content in soil. Species richness (r = 0.32), total tree density(r = 0.73) and total basal area(r = 0.57) were positively significant correlation with canopy cover of trees.

Table 7: Summary of environmental correlation matrix among the explanatory variables (n>100, P ≤ 0.05, r ≥ |0.195|)

	Ele	spp	ttD	tsaD	tseD	ttBA	AseD	AsaD	Tre	Sap	Sed	PH	C	N	Lop	Log	Gra	Lit	Cano	Rock	rri
Ele	1	*-0.66	-0.12	*-0.6	-0.4	0.02	-0.16	-0.23	0.11	-0.23	-0.17	-0.39	-0.2	0.18	-0.33	-0.25	-0.17	0.12	-0.28	0.45	-0.31
spp		1	0.23	*0.73	0.25	0.05	0.28	0.45	0.06	0.45	0.29	0.3	0.11	-0.06	-0.14	0.08	0.05	-0.14	0.32	-0.22	0.03
ttD			1	0.27	-0.04	*0.58	0.39	0.36	0.62	0.36	0.4	0.05	0.25	-0.04	-0.22	0.2	-0.02	*0.61	*0.73	-0.13	-0.34
tsaD				1	0.31	0.07	0.33	0.36	0.07	0.36	0.34	0.05	0.16	-0.18	-0.06	0.21	0.24	-0.02	0.41	-0.37	-0.24
tseD					1	-0.1	0.21	0.26	-0.08	0.26	0.23	-0.17	-0.06	-0.12	-0.1	-0.25	-0.13	0.02	-0.11	-0.36	-0.04
ttBA						1	0.08	-0.03	0.37	-0.03	0.08	0.02	0.26	-0.1	-0.25	0.11	0.03	0.47	*0.57	0.01	-0.31
AseD							1	*0.73	0.36	*0.73	1	-0.11	-0.19	-0.24	-0.14	0.12	0	0.08	0.14	-0.23	-0.19
AsaD								1	0.31	1	*0.73	-0.1	0.1	-0.12	-0.18	0.08	-0.15	0.08	0.2	-0.28	-0.09
Tre									1	0.31	0.37	-0.11	-0.03	-0.1	-0.27	-0.04	-0.11	0.41	*0.5	-0.23	-0.19
Sap										1	0.73	-0.09	0.1	-0.12	-0.18	0.08	-0.15	0.08	0.2	-0.28	-0.09
Sed											1	-0.09	-0.2	-0.25	-0.14	0.11	0.02	0.08	0.14	-0.24	-0.21
PH												1	0.08	-0.05	0.12	0.27	0.22	-0.16	0.03	0.12	0.37
C													1	0.27	-0.23	0.08	-0.26	0.26	0.27	-0.17	0.12
N														1	-0.18	-0.16	-0.27	0.02	-0.06	0.23	0.16
Lop															1	0.33	0.4	-0.17	-0.06	-0.13	0.11
Log																1	0.28	-0.22	0.1	-0.18	0.01
Gra																	1	-0.18	-0.02	0.06	-0.18
Lit																		1	0.54	-0.1	-0.47
Cano																			1	-0.08	-0.24
Rock																				1	0.12
rri																					1

Astrike entries are statistically significant coefficients.

Full forms of the variables are given in Abbreviations and Acronyms.

5. DISCUSSION

5.1. Soil

The soil of study area was also slightly acidic in nature with pH ranging from 4.2 to 5.93. Similarly acidic nature of soil was also reported in *Abies* forest of Langtang by Tiwari (2010) and in mixed *Abies spectabilis* forest of Manang reported by Ghimire and Lekhak (2007). Similarly, Shrestha *et al*. (2007) reported that soil of mixed *Betula utilis- Abies spectabilis* forest was slightly acidic with pH 5-7. The acidic nature of soil was also reported by several other workers for oak dominated and oak-pine mixed forests of Garhwal Himalaya (Bhandari *et al*. 2000, Dhanai *et al.* 2000, Kumar *et al.* 2004 and Mehraj *et al*. 2010). Most conifer foliage contain acid substances and after decomposition of leaves it will keep soil slightly acidic or neutral Zhang and Zhao (2007). The pH range of 5.5 to 6.5 may provide most satisfactory plant nutrient and is most suitable for most plants Brady and Well (1984).

The mean soil organic carbon (OC) and nitrogen were 3.06% and 0.27% respectively recorded in the study area. Zhang and Zhao (2007) reported 0.74% of nitrogen in a *Pinus koraiensis* forest China. Likewise Tiwari (2010) found soil organic and nitrogen were found 7.24% and 0.44% in *Abies* forest of Lantang respectively. The nitrogen and average soil OC higher in oak forest (2.19%) followed by pine (1.63%) values reported (0.10 to 0.20 %) for temperate forest of Garhwal Himalaya Kumar *et al.* (2004). Shrestha *et al.* (2007) reported soil OC and nitrogen to be 1-8.9% and 0.1-0.7% respectively in mixed *Abies spectabilis* forest of Manang. Both soil OC and nitrogen content in the present study forest were relatively low. This might be due to wide spacing of trees which provide low input litter cover to the soil (2.16 cm).

5.2. Community Structure

Dominance of tree species were observed by calculating the Importance percentage and result are depicted in (Table 4). Study revealed that *Rhododendron arboreum was* the dominant tree species with maximum IP value (61.91 %) and followed by *Abies spectabilis* with IP value 22.72 %. Since, *Rhododendron arboreum* and *Abies spectabilis* contributed 61.91% and 22.72% of the IP values respectively. Therefore the study forest can be considered as the mixed forest. Goirola *et al.* (2008) reported

Abies pindrow as dominant species (IP=16.44%) and *Betula utilis* as co-dominant species (IP=16.10%) in north-western slope of mixed *Abies-Betula* forest of Indian Himalaya. Two tree species shared nearly equal dominance in the community in that forest.

In present study forest, the average total density of all tree species combined was 267.1 stem/ha. The maximum mean density of trees was 414 stem/ha at 2950 m and minimum mean density found was 44 stem/ha at 3550 m. The result indicates that the total density decreased with increased elevation within the range of present study which is similar to the observation of Shrestha *et al*. (2007) in the trans- Himalayan treeline and Bhuju *et al*. (2010) in Eastern Himalayan. In upper Manang mixed forest, Ghimire (2005) found that the total tree density ranged from 375 pl/ha at altitude 3800-4000 m to 845 pl/ha at 3300-3500 m. In mixed *Abies spectabilis* forest of Manang, Acharya (2004) found that the total tree density was 900 stem/ha. Mori and Takeda (2004) reported total tree density of 1274 stem/ha in sub alpine *Abies mariesii* forest of central Japan. Qi- Jing (1997) reported total tree density 759 stem/ha in sub-alpine coniferous forest on Changbai Mountain, China. Tree density (267.1 stem/ha) in present study was lower than tree density (445 stem/ha) recorded by Bhuju *et al.* (2010) from treeline of SNP. These values were higher than the density of present study forest. Lower value of total tree density in the study site might be due to maximum tree species were encountered by logging and high disturbance due to grazing and trampling. In the present study forest, tree density of *Abies spectabilis* was 76.89 stem/ha. Acharya (2004) reported density of *Abies spectabilis* was 360 stem/ha in mixed *Abies spectabilis* forest of Manang . Scholl and Taylor (2006) found tree density of *Abies magnifica* to be 375 stem/ha in *Abies magnifica* forest of northern USA. These values of tree density of *Abies* were higher than the value of studied forest. This showed that the study forest was not pure *Abies spectabilis* forest.

The average total tree basal cover of the present study forest was 2.24 m^2/ha. Bhuju *et al*. (2010) recorded total basal area of 11.2m^2/ ha and a density of 445 stems/ ha, from treeline and basal area of 18.6 m^2/ ha and a density of 1034 stems/ha from timberline region. Ghimire (2005) reported the total tree basal area ranged from 0.674 m^2/ha at 3500-3800m to 16.815 m^2/ha at 3300-3500m. Acharya *et al.* (2007) found the average basal area of trees in sites of Manang districts were 3.08 m^2/ha and 2.87 m^2/ha respectively. Scholl and Taylor (2006) found total tree basal area was 61.8 m^2/ha.

Taylor *et al.* (2004) found total basal cover (0.47%) in *Abies faxoniana* forest of south western China. That value was lower due to lower total tree density of *Abies faxoniana*. The trend was similar in this present study. Qi-Jing (1997) found total basal cover of tree 0.48% in *Picea jezoensis –Abies nephrolepis* forest. This value was lower than our studied forest. Ghimire *et al*. (2008) found that total basal cover of *Juniperus indica* forest was 17.4819 m^2/ha (3300-3800 m) in southern slope of mixed *Juniperus* forest. Although, total tree density (1819.98 m^2/ha) was high but total basal cover was very low in that dominant *Juniperus* forest.

Average Beta diversity (β),Simpson's Index of Dominance (C) for tree and Shannon-Wiener Index (H') of species diversity was 1.26, 0.44 and1.21 respectively in the present study forest. Tiwari (2010) found dominance and diversity were 0.74 and 0.63 respectively. Ghimire *et al.* (2008) reported beta-diversity (β), concentration dominance (cd) and Shannon- Wiener Index (H') for tree was 0.5,2.03 and1.66 respectively. At study site Simpson's index of dominance for tree was found higher than species diversity of the forest. Sharma *et al.* (2009) reported Shannon- Wiener Index (H') of species diversity to be 0.99 in *Abies pindrow* forest. This value was more than the value of the present study site. 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. Species diversity in forest edge was higher than that in pure forest which was possibly caused by edge effect Liyun *et al*. (2006).

Comparing with these values, the present study forest had lower 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, and the diversity-dominance curve. 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 decrease of temperature Qi-Jing (1997).

5.3. Regeneration

Density-diameter curve for all tree species combined was nearly reverse J-shaped, indicating sustainable regeneration. But the curve for *Abies spectabilis* alone deviated slightly from the typical reverse J-shape. Reverse J- shaped density-diameter curve is the indication of sustainable regeneration Vetaas (2000). This similar trend was reported by Shrestha *et al.* (2007) for *Betula utilis* forest in a trans-Himalayan dry valley and by Ghimire *et al.* (2007) for mixed *Abies spectabilis* forest of Manang Qiaoying *et al.* (2008) also found similar result and reported that the diameter class structure of *Abies georgei* population showed a reverse J-shaped and 0-5 cm and 5-10 cm diameter classes accounted for 79% and 9.4% respectively. Acharya (2004) reported that less number of individuals of middle girth classes (30-80) were found for *Abies spectabilis* in *Abies* and *Pinus* forests in Pisang, Manang district. The whole DBH classes of *Abies spectabilis* was higher density as compared to whole forest (Fig. 16). Bhuju *et al*. (2010) observed bell shaped diameter class distribution of *A. spectabilis* and inversed J shaped distribution of *B. utilis* at treeline (Pangboche).The same study recorded 99 cm DBH of *A. spectabilis*. Recorded highest DBH of *Abies spectabilis* was 120 cm in present study. It was observed that medium girth trees were cut off by people for mainly construction and firewood. The result indicated that density of the trees having larger girth size was higher than that of the smaller girth size in whole mixed *Abies spectabilis* forest. *Abies spectabilis* curve slightly fluctuated from the typical reverse J-shape which didn't indicate sustainable regeneration.

Average sapling density of *Abies spectabilis* was found to be 28.44 stem/ha and similarly average seedling density of all tress was found to be 524.2 stem/ha. Aspect of the study area might be a reason in the variation in the seedling distribution, besides the tree canopy coverage. The higher seedling and sapling density of *Abies spectabilis* was 910 stem/ha and 250 stem/ha at 3050m and 2950 m respectively. In *A. spectabilis* the seedling density (76.89 stem/ha) was higher than that of sapling density (28.44 stem/ha) which shows a normal demographic development (West *et al*. 1981) which was similar to the result of Ghimire and Lekhak (2007). Tiwari (2010) reported seedling and sapling density were 4012 stem/ha and 70 stem/ha respectively. Ghimire (2005) reported the average seedling density of *Pinus wallichiana* in two sites of Manang district ranged from 180 pl/ha at 3900-4000 m and to 3500 pl/ha at 3500-3600m. In *Abies spectabilis* forest on the northern slope of the Manang valley (north-central Nepal), Acharya (2004) reported density of seedlings of *Abies spectabilis* to be 3923 stem/ ha and sapling density 117 stem/ha. In *Picea abies* forest (Norway spruce), seedling density of *Picea abies* was higher in depressions with a mean of 285000 stem/ha compared to slopes where the mean was 162000 stem/ha, Diaci *et al*. (2005). The value of seedling density of the present study forest was very low comparing with these values. Less sapling density (28.44 stem/ha) in the present forest might be due to higher seedling mortality because of unsuitable environment. Mechanical damage to seedlings of *Abies spectabilis* due to intense grazing and trampling may lead to high seedling mortality. Seedling density of *Abies* also declined with increasing canopy (Fig.15). Seedling generally preferred high soil moisture, moderate pH and moderate canopy cover. As *Abies spectabilis* is shade tolerant species it can regenerate under a densely closed canopy reported by Qi-Jing (1997). High frequency of saplings of *Abies spectabilis* under dense canopy has been also inferred in mixed *Betula utilis-Abies spectabilis* forest of Manang, Shrestha *et al.* (2007). However, in the present studied forest, frequency (28.89%) of saplings were very low, and it was absent in homogeneity stands. The seedling and sapling ratio shows higher proportion of sapling than seedling in *A. spectabilis* for which seedling is higher than sapling indicating recent regeneration. Intensity of grazing and trampling was relatively medium (2.26 out of 3) in the studied forest. There was significant influence of grazing on tree seedling species composition, Darabant *et al*. (2007).

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

Abies spectabilis was the codominant species among trees and *Rhododendron arboreum* was most dominant tree. *Daphne bholua* was most dominant among shrub species**.** The seedling density was higher than that of sapling density which shows a normal demographic development . Woody species richness decreased smoothly with elevation but the highest species richness at 3050 m and decreased towards the treeline. Species diversity of the forest was relatively medium, which might be due to the anthropogenic factors such as cattle grazing, fire wood collection, logging and competition between species. Beta diversity indicated the more or less heterogeneity in study forest.

Density-diameter curve for all tree species combined was nearly reverse J-shaped, indicating sustainable regeneration. But density-diameter curve for *Abies spectabilis* was not continuous which didn’t show sustainable regeneration.

Due to medium grazing and trampling, felling down of trees for timber and fire wood collection. Number of fallen logs and stump used for construction were found in the study area. Therefore there was medium diversity of woody species.This showed that forest was moderately disturbed.

6.2. Recommendation

Following recommenation have been suggested on the basis of the results of present study.

- Unsustainable use of forest products such as timber, firewood and fodder should be checked and facility of alternative energy sources should be provided to decrease the dependency upon forest.
- Regeneration of *Abies spectabilis* was not sustainable. Therefore, grazing pressure should be minimised at April- May during the period of seedling development.

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Appendix I: Population of *Abies spectabilis* along the environmental variables

Ele	Tre	Sap	Se	PH	C	N	Lop	Log	Gra	Slo(˚)	Asp(˚)	Li(cm)	Can(%)	Ro (%)	Long	Lat	RRI
2750	0	0	0	5.66	1.44	0.15	1	1	1	230	42	2	40	0	27.59˚	86.74˚	0.53
2750	0	0	0	5.63	4.36	0.41	1	1	1	270	30	1.6	50	20	27.59	86.74	0.86
2750	0	0	0	5.93	6.79	0.21	1	2	1	280	25	2	75	30	27.59	86.74	0.90
2750	0	0	0	5.62	5.22	0.32	1	2	2	265	40	2	60	20	27.59	86.74	0.75
2750	0	0	0	5.7	1.29	0.22	2	1	2	270	40	1.4	50	30	27.59	86.74	0.76
2850	0	0	0	5.48	5.22	0.34	1	1	1	270	30	3	60	20	27.59	86.07	0.86
2850	0	1	2	5.32	1.38	0.36	1	1	1	260	20	1.6	50	25	27.59	86.74	0.91
2850	0	0	0	4.92	3.51	0.25	2	1	2	200	45	2	80	5	27.58	86.45	0.18
2850	0	0	0	5.64	2.08	0.24	2	3	2	180	45	1.8	40	5	27.58	86.45	-0.06
2850	0	0	0	5.21	1.43	0.11	2	2	2	160	45	2.4	60	0	27.58	86.45	-0.29
2950	5	16	37	4.89	4.34	0.2	1	1	1	120	30	2.6	50	5	27.59	86.62	-0.77
2950	10	13	54	4.2	2.35	0.17	1	1	1	130	20	2.8	65	0	27.59	86.62	-0.75
2950	30	16	77	5	1.25	0.15	1	1	1	260	15	1.8	70	5	27.59	86.61	0.94
2950	8	25	16	5.27	6	0.29	1	2	1	260	20	1.8	70	0	27.59	86.61	0.91
2950	31	6	3	5.75	2.82	0.28	1	2	1	275	10	2.4	75	0	27.59	86.61	0.98
3050	2	0	3	4.73	3.23	0.17	1	2	1	130	42	1.8	80	5	27.59	86.62	-0.60
3050	5	10	7	4.96	3.14	0.52	1	1	1	120	40	2	60	5	27.59	86.62	-0.69
3050	3	6	5	5.25	2.4	0.17	1	1	1	140	30	2.6	50	5	27.59	86.62	-0.60
3050	7	3	9	5.8	2.77	0.18	1	1	2	90	35	2.2	50	5	27.59	86.63	-0.81
3050	8	16	91	5.75	1.38	0.18	1	3	2	100	25	2	50	5	27.6	86.62	-0.90
3150	3	0	0	5.37	4.15	0.27	1	2	1	180	40	2.4	80	20	27.58	86.51	-0.05
3150	2	0	0	4.99	4.2	0.34	1	2	1	140	30	1.6	60	20	27.58	86.51	-0.59
3150	10	1	0	5.25	3.46	0.22	1	2	2	140	35	2	50	5	27.58	86.51	-0.56
3150	20	0	0	5.03	3.88	0.29	1	2	2	160	25	2.2	70	5	27.58	86.51	-0.36
3150	6	0	1	4.98	2.54	0.21	1	2	2	170	30	1.8	60	10	27.58	86.51	-0.20
3250	5	0	0	4.7	2.72	0.27	1	2	1	270	30	1.2	40	5	27.57	86.47	0.86
3250	0	0	0	5.05	4.75	0.45	1	1	1	220	30	2.6	25	5	27.57	86.47	0.50
3250	0	0	0	4.41	1.85	0.25	1	1	1	210	40	2	25	10	27.57	86.47	0.32
3250	0	0	0	5.32	4.06	0.32	1	1	1	280	45	1.6	15	5	27.57	86.47	0.70
3250	0	0	0	5.02	2.4	0.29	2	3	1	220	40	1.8	20	10	27.57	86.47	0.44
3350	16	0	0	5.1	4.02	0.13	1	1	1	90	40	3.8	75	10	27.58	86.5	-0.76
3350	23	0	0	4.9	4.71	0.25	1	1	1	100	38	3	75	10	27.58	86.5	-0.78
3350	12	7	12	4.26	4.98	0.32	1	1	1	110	40	3.2	70	5	27.06	86.5	-0.73
3350	11	0	12	4.82	2.31	0.5	1	1	1	110	40	2.8	65	20	27.58	86.5	-0.73
3350	10	0	9	4.93	2.17	0.25	1	1	2	110	40	2.8	60	0	27.58	86.5	-0.73
3450	3	3	3	5.4	3.05	0.34	1	2	1	180	30	2.8	80	60	27.58	86.5	-0.05
3450	14	0	12	5.39	3.37	0.41	1	1	1	180	35	3	75	30	27.58	86.5	-0.06
3450	4	5	2	5.23	3.32	0.31	1	1	1	175	40	2.6	55	40	27.58	86.5	-0.12
3450	14	0	0	5.07	1.25	0.32	1	1	1	170	30	2.2	65	50	27.58	86.5	-0.20
3450	11	0	0	5.3	1.25	0.18	1	1	1	180	35	2.4	75	20	27.58	86.5	-0.06
3550	0	0	0	5.09	3.18	0.35	1	1	1	200	42	1.8	25	25	27.56	86.49	0.19
3550	0	0	0	5.12	2.54	0.22	1	1	1	220	45	1.4	5	30	27.56	86.49	0.40
3550	0	0	0	5.07	2.31	0.24	1	1	1	190	40	1	5	10	27.56	86.49	0.07
3550	1	0	0	5.09	1.43	0.27	1	1	2	200	45	1.8	20	65	27.83	86.73	0.19
3550	0	0	0	4.98	1.38	0.27	1	1	2	180	42	1.6	40	80	27.83	86.73	-0.05

Appendix II: Frequency of shrubs along the elevation gradient

Plots	dhe	abi	berb	vib	arti	loni	lyo	pie	coto	r cam	r lap	r abo	rubu	rosa	acer	quer	drep	eury	moho	tdumo	juni	smilax
2701	1	0	1	1	1	0	0	0	0	0	0	1	1	0	0	1	0	0	1	1	0	0
2702	1	0	1	1	0	0	0	1	0	0	0	1	1	0	1	0	0	0	1	0	0	0
2703	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0
2704	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
2705	1	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2801	1	0	1	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2802	1	1	1	1	0	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0
2803	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0
2804	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
2805	1	0	1	0	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0
2901	1	1	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2902	1	1	1	1	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	0
2903	1	1	1	0	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0
2904	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	0	0
2905	1	1	1	1	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	1	0
3001	1	0	0	1	0	0	1	1	1	0	0	1	0	1	0	0	0	0	0	0	1	0
3002	1	1	1	1	0	0	1	1	1	0	0	1	0	1	0	0	1	0	0	0	0	0
3003	1	1	1	1	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
3004	1	1	1	1	0	0	1	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0
3005	1	1	1	1	0	0	1	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0
3101	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3102	1	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0
3103	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3104	1	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3105	1	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0
3201	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3202	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3203	0	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3204	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3205	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3301	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3302	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3303	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
3304	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3305	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3401	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
3402	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
3403	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
3404	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
3405	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
3501	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
3502	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
3503	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0
3504	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
3505	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
	24	13	24	21	2	3	12	14	3	4	4	44	2	9	1	7	3	1	3	3	12	1
F	53	29	53	47	4.4	6.7	27	31	6.7	8.89	8.9	98	4.44	20	2.2	15.6	6.7	2.2	6.7	6.7	27	2.22

Appendix III: Density and Basal area along the elevation gradient

t tD s/h	t sap D	t seD	t t.B.A m2	abi se D	abi sa D	Ele
120	820	2010	2.992	0	0	2750
170	1750	820	2.781	0	0	2750
400	1380	210	4.089	0	0	2750
350	1760	110	2.953	0	0	2750
60	1080	360	0.383	0	0	2750
230	1410	380	1.393	0	0	2850
90	1470	950	0.535	20	10	2850
230	1350	510	1.055	0	0	2850
180	910	570	1.304	0	0	2850
260	1210	400	2.275	0	0	2850
320	2020	2230	2.414	370	160	2950
500	1500	1090	4.006	540	130	2950
400	1760	1020	1.821	770	160	2950
340	1200	380	1.584	160	250	2950
510	1170	220	1.712	30	60	2950
250	3300	410	0.641	30	0	3050
250	2150	670	1.067	70	100	3050
270	1730	640	1.538	50	60	3050
460	2200	1100	1.812	0	30	3050
480	2130	280	2.259	910	160	3050
390	1180	150	5.569	0	0	3150
130	1440	550	1.839	0	0	3150
220	1260	290	4.562	0	0	3150
440	1800	400	3.677	0	0	3150
270	2250	1120	4.377	10	10	3150
260	70	40	2.731	0	0	3250
130	310	1080	0.6	0	0	3250
120	400	2010	0.365	0	0	3250
70	310	870	0.383	0	0	3250
120	270	30	0.578	0	0	3250
440	500	40	4.722	0	0	3350
470	420	360	4.606	0	0	3350
340	1850	600	3.402	120	70	3350
440	730	430	3.596	120	0	3350
270	650	180	1.162	90	0	3350
570	320	310	2.919	30	30	3450
540	220	70	6.033	120	0	3450
290	240	150	1.054	20	50	3450
340	280	320	0.79	0	0	3450
80	410	40	3.904	0	0	3450
10	190	40	0.897	0	0	3550
10	100	40	0.173	0	0	3550
10	290	30	0.229	0	0	3550
70	680	20	0.717	0	0	3550
120	420	60	3.501	0	0	3550