1. INTRODUCTION

1.1. Background

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, Xu *et al*. 2009), which has been considered as the most serious threat to mountain forests (Glatzel 2009). Subalpine forest represents the uppermost forest ecosystems along the elevation gradient in ecosystems. Major tree species of this forest have been used in dendrochronology to understand past climatic variation (e.g. Brauning 2006, Chhetri 2008, Bhuju *et al*. 2010). Sub alpine forests are not only vulnerable to natural variation in climate (Kullman 1988), it is also under high anthropogenic pressure (Stevens 2003, Sharma *et al*. 2009). Ecological study of this important forest ecosystem (i.e. subalpine forest) in the Nepal Himalaya is very scanty, though some initiatives have been taken in recent time (e.g. Shrestha *et al.* 2007, Ghimire *et al.* 2008). In this research work, community structure and regeneration pattern of subalpine *Abies spectabilis* forest in Langtang National Park, central Nepal, have been analyzed.

In the mountain ecosystem, community pattern varied according to altitude. Generally, it can be noticed that mountain ecosystems usually have distinct biological communities and high level of endemism due to their topography and history (Gairola *et al*. 2008). 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, Dolezal and Srutek 2002).

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

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

Abies spectabilis (D. Don) Mirb. (Himalayan silver fir) is a tall evergreen tree occurring from Afghanistan to Bhutan (Stainton 1972). *A. spectabilis* forest is the most extensive in subalpine region of central Nepal, which expands between 3000 m asl and the treeline. At moist sites, the *A. spectabilis* forest is superseded by *Betula utilis* forest near the treeline. 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).

1.2. Justification

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. Tree ring studies carried out in these forests is considered for studying climatic variation. Major tree species of subalpine forests like *Abies spectabilis* has been used in dendrochronology to understand past climatic variation. Therefore, subalpine forest could provide valuable information to evaluate the consequences of global change. However, the subalpine forests of the Nepalese Himalaya in general, and *Abies spectabilis* forests in specific are relatively less studied forest ecosystem. 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. This present study is pertaining to community structure and regeneration status of mature *A. spectabilis* forest inside the Langtang National Park, central Nepal, would be important to understand the impact of conservation to plant diversity and vegetation dynamics in the study area.

1.3. Hypothesis

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

- Regeneration of late successional tree species *Abies spectabilis* is continuous within its own canopy.

1.4. Objectives

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

1. To analyze community structure of subalpine *Abies spectabilis* forest in Langtang National Park;
2. To study the relationship between environmental factors and plant community attributes in *Abies spectabilis* forests;
3. To analyze regeneration pattern of *Abies spectabilis* forest.

2. LITERATURE REVIEW

2.1. Community Structure

Sub-alpine forest in the Himalaya is often dominated by conifers or broad leaved deciduous species (Qi-Jing 1997, 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 treeline) and to a woody shrub community and ultimately alpine meadows (Dolezal and Srutek 2002, Miyajima and Takahashii 2007). 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 (Qi- Jing 1997). This led a poor ground vegetation of herbs and shrubs. Dolezal and Srutek (2002) reported that species composition of *Acer* forests on south-east facing slope in Slovakia was influenced by soil depth and altitude. Vegetation height decreased linearly along the altitudinal gradient from 43 m (tall trees at low elevations) to 42 cm (tall grasses in exposed high mountain crests). As tree become larger, basal cover increases, canopy cover becomes denser, and low light intensity eliminates the reproduction of shade intolerant species which thus limits the late successional diversity (Connell 1978, Huston 1979, 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). But Dolezal and Srutek (2002) reported that species richness and diversity bore no distinct relationship to altitude in *Acer* forest of Slovakia, but tended to increase with the degree of tree/shrub canopy closure. In sub-alpine broad leaved coniferous forest, Jiangming *et al*. (2008) 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. Ghimire *et al*. (2008) reported only three species of tree in a sub-alpine forest on the southern slope of the dry Manang valley, central Nepal. In that forest only *Juniperus indica* was found at the highest altitude on the southern slope. Deforestation has changed species composition and community structure of subalpine forest (Ghimire and 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).

In coniferous forest of sub-alpine region there is characteristic decline in total tree density and total basal cover with increase in altitude (Gairola *et al.* 2008, Pandit 1999). Taylor *et al*. (2004) found total tree density from 267 to 644 stems/ha in *Abies-Betula* forest of South-Western China. In *Abies magnifica* forest of northern USA tree density and basal cover of *A. magnifica* was 375 stem/ha and 0.61%, respectively (Scholl and Taylor 2006). In conifer forest of Canada the basal cover was 0.15% (Kreyling *et al*. 2008). Mori and Takeda (2004) reported total tree density and total basal cover to be 1274 stem/ha and 0.46% respectively in sub-alpine *Abies mariesii* forest of central Japan. In a pure *Betula utilis* forest of Manang the basal cover was 2.3% (Shrestha *et al*. 2007). In this forest, the basal cover generally increased from 3500 to 4100 m. The total basal cover of *Juniperus indica* forest was 0.17% in mixed *Juniperus* forest (Ghimire *et al.* 2008). Total tree density in mixed forest of *Pinus wallichiana* and *Abies spectabilis* (3500 - 3800 m) ranged from 675 to 960 stem/ha (Ghimire and Lekhak 2007). In subalpine broad leaved forest, tree density decreased consistently from 800 to 2000 m but increased from 2000 to 2500 m, which corresponded to the reduction in the maximum trunk height (Miyajima and Takahashii 2007). Taller trees tended to be damaged at higher altitudes, and the tree couldn't grow in height near the timberline. Hussain *et al*. (2008) reported 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) in Kumaon Himalayan forest.

In broad-leaved forest, soil fertility is higher, and the light and temperature conditions are optimal for fast growing and light demanding herb and grass species (Mikola 1985). Understorey vegetation cover increased with increasing percentage of broad leaved trees and decreased with increasing litter cover (Malmivaara-Lamsa *et al*. 2008). Higher the temperature faster is the litter decomposition (Zhang and Zhao 2007). Soil organic matter is the result of decomposition of litter by soil micro-organisms. In northern slope of Changbai Mountain, China, the organic carbon and nitrogen in soil were found to be 7.45 % and 0.74%, respectively (Zhang and Zhao 2007). Shrestha *et al*. (2007) in mixed *Abies spectabilis* forest of Manang found soil organic carbon and nitrogen to be 1-8.9% and 0.1-0.7% respectively. Yoshida and Ohsawa (1999) reported that due to lower litter and vegetation cover, there was high density (1054 stem/ha) of seedlings of *Tsuga sieboldii* in conifer forest.

2.2. Regeneration

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, of the total population (Qiaoying *et al*. 2008). 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. 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 *Picea abies* forest of Slovenian Alps, seedling density of *Picea abies* was higher in depressions with a mean of 285000 per ha compared to slopes where the mean was 162000 per ha (Diaci *et al*. 2005); the lower density of seedlings on slopes was attributed to high solar radiation. In mixed *Abies spectabilis* forest on the southern slope of the Manang valley (central Nepal), seedling and sapling densities were nearly equal (Ghimire and Lekhak 2007). Seedling and sapling densities increased with altitude up to 3800 m elevation; then it decreased gradually to upper elevation. In fire damaged forest on the northern slope of the same valley (Manang), Acharya (2004) found the seedling density of *Abies spectabilis* to be 3923 stem/ha and sapling density to be 117 stem/ha. In mixed *Betula utilis* forest of the same valley, Shrestha *et al*. (2007) hypothesized found that partial canopy opening may induce seedling establishment and hence continuous regeneration of *Betula utilis* at mature stands. Galhidy *et al*. (2006) found more seedlings in small gaps than in large ones in European beech (*Fagus sylvatica*) forest of northern Hungary. Both crown closure and soil disturbance had significant effects on seedling densities in sub-boreal forest in Japan (Nakagawa *et al*. 2005).

The total density of seedlings (height 3 - 30 cm) was 33800 per ha in sub-alpine *Picea abies* forest of southern Finland (Kuuluvainen and Kalmari 2003). Seedling of *P. abies* was the most abundant (31133 stem/ha), which accounted 87% of the total seedlings, followed by *Sorbus aucuparia* and *Betula pubescens*. Small seedlings (height 3-5 cm) were most abundant. Seedlings were found less often under tree crown than in random pits.

Picea jezoensis var. *komarovii* and *Abies nephrolepis* had plenty of large saplings (height >1.5 m, DBH<8 cm) with the maximum values of 2686 and 320 stems/ha, respectively (Qi-Jing 1997). The sapling density in pure forest of *Betula utilis* was 913 stems/ha (Shrestha *et al*. 2007). Sapling density was found higher where the tree density and basal cover were low.

Regeneration is also affected by fire (Scholl and Taylor 2006, Coop and Schoettle 2009). On Rocky Mountain National Park of USA, Coop and Schoettle (2009) found limber pine (*Pinus flexilis*) regeneration increased in burned sites relative to unburned sites. In Temperate mixed conifer forest in the Bhutan Himalaya, Darabant *et al*. (2007), found seedling growth considerably higher in grazed plots regardless of tree species mainly due to increased light interception with reduced bamboo height as a result of grazing. There was significant influence of grazing on tree seedling species composition. In ungrazed plots, tree seedling species composition corresponded to the overstorey tree species composition in both hemlock and pine dominated openings. Grazing effects can have major effects on forest structure and composition at regional level (Tasker and Bradstock 2006).

In the timberline population of *Abies georgei* the number of seedlings accounted for 79% of the total population, which showed a good regeneration of this species (Qiaoying *et al*. 2008). Mortality of seedlings growing to the next stage was upto 88%, which became the first and the highest death peak during the population development. DBH class 15-20 cm exhibited the highest life expectancy. Survival curve of *Abies georgei* showed a high mortality of seedlings with only 12% surviving. Mortality of sapling declined and it became very low and stable for mature trees. Mortality and hazard rate curves showed same trend; both of them had two peaks with the first peak at age class 0-5 cm and second at 20-25 cm and 25-30 cm.

3. STUDY AREA

The study forest lies inside Langtang National Park in Nepal. The Langtang National Park, established in 1976, encompasses parts of Rasuwa, Sindhupalchok, and Nuwakot districts of the Bagmati zone. About 56 % of the park area lies in Rasuwa district, 38 % in Sindhupalchowk, and 6 % in Nuwakot. The Park headquarters is located at Dhunche, the district headquarter of Rasuwa. Elevational gradients coupled with complex topography and geology has produced a rich biodiversity and vegetation belts. Sub-tropical vegetation characterized by Sal (*Shorea robusta*) forest in the southern section of the park is gradually taken over by hill forest (2000-2600 m) consisting of *Pinus roxburghii*, *Rhododendron* spp. and *Alnus nepalensis* (Chaudhary 1998). The temperate zone (2600 - 3000 m) is covered mainly by oak (*Quercus* spp.) forest fading to old growth forest of *Abies spectabilis*, *Tsuga dumosa* and *Larix himalaica* in the lower sub-alpine zone (3000 - 3600 m). Tree species such as *Betula utilis, Abies spectabilis*, *Sorbus microphyla* and *Rhododendron campanulatum* are found near the tree line. Above 4000 m *Juniperus* and *Rhododendron* species slowly dissolve into the expansive alpine grassland meadows. The park is well known for its populations of red panda, Himalayan black bear, snow leopard, wild dog, goral, serow and bird species (Chaudhary 1998).

The present study was carried out in mature *Abies spectabilis* forest between Chandanbari and Lauribina region of the Park. The study area (85° 15’ - 86° E, 28° 0’ - 28° 20’ N, elevation 3100 - 4000 m) lies on north-east facing slope with average inclination of 28°. The study area was highly disturbed. Grazing was concentrated mainly in the months of July, August and September. About 600 to 700 yaks and sheep graze on that area every year. Logging of *Abies spectabilis* and *Rhododendron* species were found. Trees were felled down mainly for timber and fire wood. Local people preferred *A. spectabilis* for timber and *Rhododendron* species for fire wood. The hoteliers near that area got permission to collect dry wood from the forest. At some instances, the local people removed the bark of trees from the basal region to induce death of the trees; then the people used dead trees afterward as fire wood or timber. Cheese factory located at

Chandanbari (established in 1970A.D) also used a huge amount of fire wood which had been collected from the study area.

Based on the data of the nearest weather station (Dhunche, 1982 m), the annual rainfall was 2038 mm with the highest rainfall in the month of July (Figure 1). The highest average maximum temperature was recorded during June, and the lowest average minimum temperature during January.

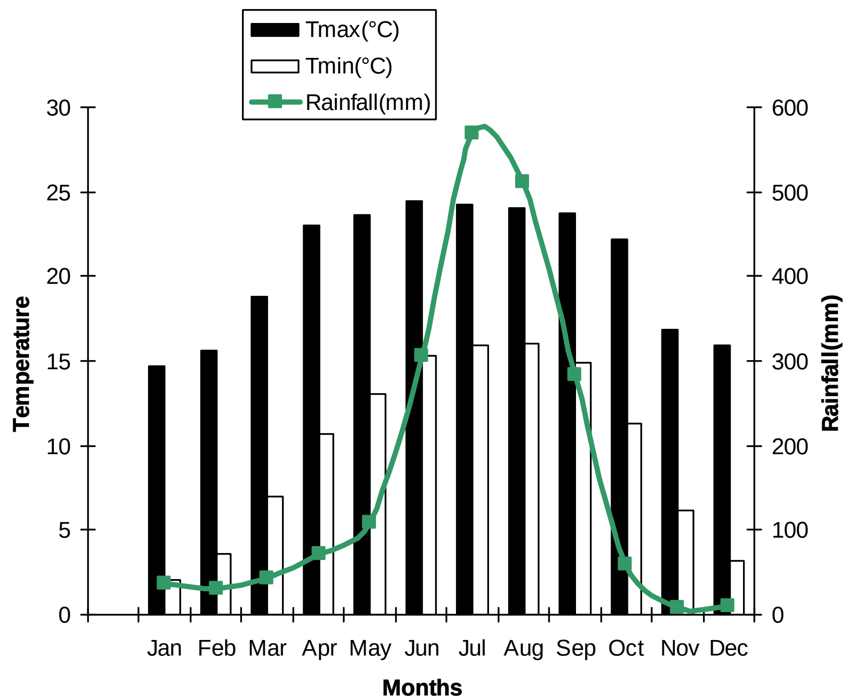
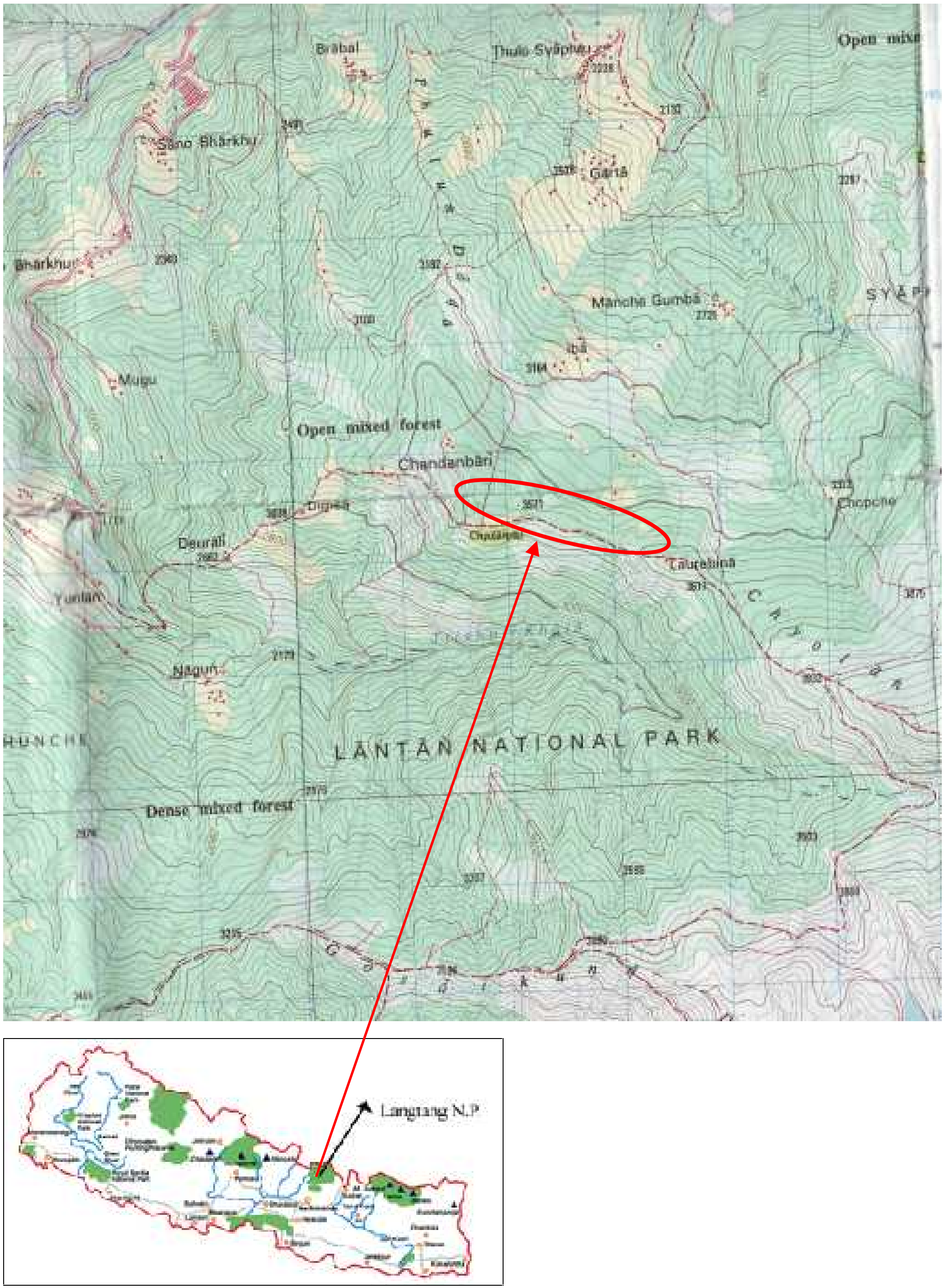


Figure 1. Average monthly temperature (°C) and rainfall (mm) recorded at Dhunche weather station (85°18'E, 28°06'N and elevation 1982 m) between 1999 and 2008. (Source: Department of Hydrology and Meteorology, Kathmandu).



Source: DNPWC

Figure 2. Map showing the study area

4. MATERIALS AND METHODS

4. Materials and Methods

4.1. Field Sampling: Vegetation sampling was done by quadrat method, and the sample quadrats were located by systematic random sampling method. Nine vertical transects running parallel to each other were defined within the study area. All transects started from the lower edge of the study forest; four of them ended up at the top of hill while the remaining five ended up at treeline. The adjacent transects were at a horizontal distance of 200-300 m. Altogether 80 quadrats were sampled, and the number of quadrats in each transect varied from 7 to 12. In each transect quadrats were located at the interval of about 50 m altitude distance; the first quadrat in each transect was about 50 m above the forest edge. 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), samplings (DBH<10 cm, height>137 cm) and seedling (height<137 cm). All shrub species present in the quadrat were recorded. Due to variation in growth form some species were included both in tree and shrub layer. If the individual plant has no branching below breast height (137 cm from the base) and DBH exceed 10 cm, they were included in tree layer. If the individual plants had profuse branching from the basal region, they were included in shrub layer. Each quadrat was divided into four sub quadrats of 5 m | 5 m, and two subquadrats lying diagonally were selected randomly for sampling seedlings and saplings. In each subquadrat, height of seedlings, DBH of saplings, and their number were recorded. Canopy cover of each plot was determined by visual estimation. Litter cover, grazing and trampling were also noted. Soil pH was recorded by soil pH and moisture tester (Model DM 15, Takemura Electric Works Ltd, and Japan). From each quadrat, 200 g soil sample was collected from a depth of 15 cm at four corners and pooled together. The soil samples were air dried in shade and packed in air tight plastic bags until laboratory analysis.

Specimens of all the tree and shrub species from the quadrat were collected for identification. Most of the plant specimens were identified in the field with the help of standard reference (Stainton and Polunin 1987, Stainton 1988) and remaining specimens were identified in Central Department of Botany, Tribhuvan University, Kirtipur. Botanical nomenclature follows Press *et al*. (2000).

4.2. **Laboratory Analysis of soil**: Soil was analyzed for total nitrogen (N) and organic carbon (OC) at Ecology Laboratory of Central Department of Botany, Tribhuvan University, Kathmandu. Before analysis, the soil was passed through sieve of mesh size 0.5 mm.

Soil Organic Carbon: Organic carbon was determined by Walkley- Black Method (Gupta 2000). In this method, 0.25 g air dried soil was taken in a dry 500 ml conical flask. Then 10 ml 1 N potassium dichromate was pipetted in and swirled a little. 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.

$$\text{Organic carbon in soil (\%)} = \frac{N\,(B-S) \mid 0.003 \mid 100}{\text{Mass of dry soil}}$$

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.

Nitrogen: Total nitrogen content of the soil was determined by modified micro Kjeldahl method (Gupta 2000). This method includes the following steps: digestion, distillation and titration.

Digestion: One gram air dried and fine soil was taken in a dry Kjeldahl digestion flask (300 ml). Then 3.5 g potassium sulphate and 0.4 g copper sulphate (i.e. catalyst) were added to the Kjeldahl flask containing soil. To the mixture, 6 ml concentrated sulphuric acid was added with gentle shaking. The flask was placed on the heating mantle for digestion. The temperature was raised after 30 minutes of gentle heating. Near the end of digestion process the color changed from black to brownish and finally to greenish. Then the flask was removed immediately from the mantle and allowed to cool down. To the digest, 50 ml distilled water was added and the mixture was shacked. A blank without soil sample was run for each 20 samples of soil.

Distillation: The diluted digest was transferred to microKjeldahl distillation flask. A beaker (50 ml) with 10 ml boric acid indicator was placed below the nozzle of the condenser in such a way that the end of the nozzle dipped into the indicator solution. After the digest become warm, 30 ml 40% sodium hydroxide 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 40 ml.

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

Nitrogen content (%) = (S - B) ⎮ N ⎮ 1.40 / M

Where,

B = Volume of hydrochloric acid consumed with blank (ml).

S = Mean of the volume of hydrochloric acid consumed with the sample (ml).

N = Normality of hydrochloric acid

M = Mass of soil sample (mg)

4.3. Numerical Analysis

Relative radiation index (RRI): From the values of aspect (ϑ), slope (℘) and latitude (←), RRI was calculated following the formula given by Oke (1987): RRI = Cos (180⌈ - ϑ). Sin ℘ Sin ← + Cos ℘ Cos ←

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. The formulas used for calculation of these attributes are given below:

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

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

Basal cover (BC) of a tree was obtained by the following formula : $BC = \pi d^2/4$

d = DBH (diameter at the breast height)

$\pi = 3.1416$.

Basal cover of a species in each sampling plot was obtained by the summation of BC of all individuals of the species in that particular plot. To get community level BC of a species, BC of all individual trees of the species was summed and expressed as the percentage of the area sampled.

Basal cover of a species (%) = Total basal cover of a species | 100/Total area sampled

Importance percentage (IP) gives the overall importance of each species in the community structure. It was calculated by dividing the sum of relative values of frequency, density and basal cover by three.

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

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

$$\text{Relative Basal cover (RBC, \%)} = \frac{\text{Basal cover of individual species} \mid 100}{\text{Total basal cover of all species}}$$

Importance percentage (IP) = (RF + RD + RBC)/3

Species Diversity

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. Evenness is a maximum when all the species have same or nearly equal number of individuals. Species diversity can be expressed in single index number. Among the several indices most commonly used two indices are Simpson's index (Simpson 1949) and Shannon-Wiener's index (Shannon and Weaver 1949). Simpson's index (C) reflects the dominance because it is more sensitive to the most abundant species than the rare species.

Following relations were used to calculate Simpson's (C) and Shannon- Weiner (H') indices.

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

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

Where, s = total number of species

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

Life table and Regeneration

From the number of individuals of *Abies spectabilis* in different growth stage (seedlings, saplings and trees – further divided into various DBH classes with the interval of 10 cm), life table was prepared following the method described by Qiaoying *et al*. (2008).Total count of individuals of *Abies spectabilis* was obtained by summation of the number of individual from all sampling plots. Here, size classes were used as the surrogate of age classes. From the life table, survival and mortality curves were prepared.

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 curve was also obtained for entire forest. Number of seedlings and saplings per tree was calculated as the ratio of the number of seedling or sampling and the number of tree for each species. Scattered diagram was prepared to show the variation of seedling and sapling density of *Abies spectabilis* with total tree basal cover.

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 regression analysis. For some of the pairs of variables, for which regression was not significant, scatter diagrams were shown. Statistical Package for Social Sciences (SPSS, version 11.5) was used for all statistical analyses.

5. RESULTS

5.1 Environmental Conditions

Intensity of grazing/trampling was relatively high in the study forest. Fire wood collection and tree logging were also common. About 68 % of the quadrats (54 out of 80) had stumps. Soil was slightly acidic, and the soil pH showed the least variation (i.e. lowest CV). Soil N content showed the highest variation among the soil variables measured.

Table 1. Environmental variables of the *Abies spectabilis* forest in the study area

Environmental variables	Mean	Coefficient of Variation (%)	Range (Min. JMax.)
Grazing/trampling (0-3)	2.26	34	1-3
Litter cover (%)	48	25	10-95
Relative radiation index	0.58	14	0.35-0.75
Soil pH	6.35	4	5.50-6.80
Soil organic carbon (%)	7.24	23	2.70-10.50
Soil nitrogen (%)	0.44	32	0.04-0.69

5.2. Community Structure

5.2.1 Species Composition

Eleven species were recorded at the tree stage in *Abies spectabilis* forest of the study area. However, only three species (*Abies spectabilis*, *Betula utilis* and *Acer* sp) reached to canopy layer. Remaining eight species were confined only to sub canopy layer. Tree density of various species ranged from 1.25 to 603.75 stem/ha and basal cover from 0.00016% to 0.65%. The total basal cover of tree species was 0.68 %. *Abies spectabilis* was the dominant tree species with the highest importance percentage (84 %). *Rhododendron campanulatum* was the co-dominant tree species with importance percentage of 5 %. Out of 11 species, 6 species had importance percentage less than 1%.

Table 2. 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 *Abies spectabilis* forest of the study area.

S.N	Plant species	F (%)	RF (%)	D (Stem/ha)	RD (%)	BC (%)	RBC (%)	IP (%)
1	*Abies spectabilis* (D.Don.) Mirb	98.75	69.29	603.75	86.25	0.6518	96.19	83.91
2	*Rhododendron campanulatum* D. Don	12.50	8.77	37.50	5.35	0.0052	0.76	4.96
3	*Betula utilis* D.Don	12.50	8.77	22.50	3.21	0.0121	1.79	4.59
4	*Rhododendron barbatum* Wall. ex. G. Don	5.00	3.50	15.00	2.14	0.0019	0.29	1.97
5	*Salix* sp.	3.75	2.63	6.25	0.89	0.0006	0.09	1.20
6	*Rhododendron arboreum* Sm.	2.50	1.75	6.25	0.89	0.0009	0.12	0.92
7	*Acer* sp.	2.50	1.75	2.50	0.35	0.0017	0.25	0.78
8	*Hydrangea aspera* Buch-Ham. ex. D.Don	1.25	0.87	2.50	0.35	0.0008	0.12	0.45
9	*Elaeagnus parvifolia* Wall. ex. Royle.	1.25	0.87	1.25	0.17	0.0018	0.26	0.43
10	*Sorbus microphylla* Wenz.	1.25	0.87	1.25	0.17	0.0004	0.06	0.37
11	*Lyonia ovalifolia* (Wall.) Drude	1.25	0.87	1.25	0.17	0.0002	0.02	0.35
Total		142.50	99.96	700	99.99	0.6774	99.98	99.97

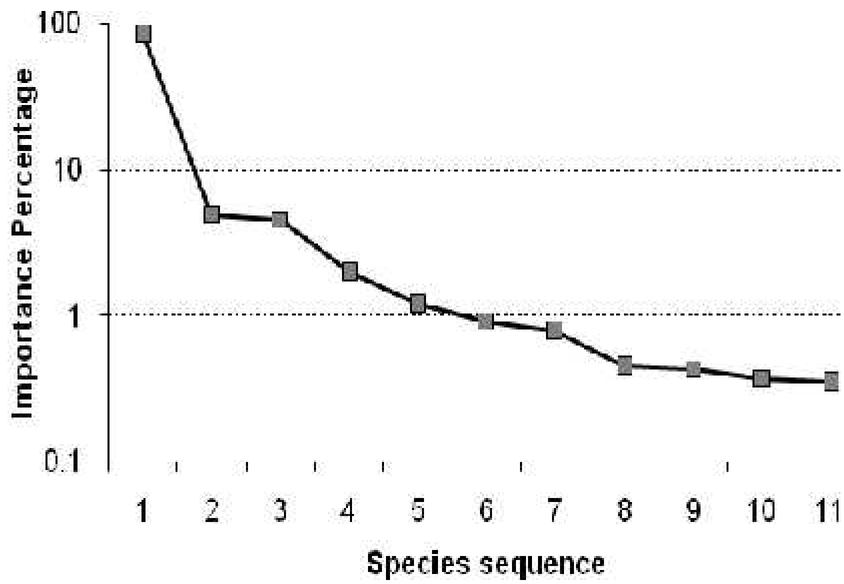


Figure 3. Diversity-dominance curve for the tree species of the *Abies spectabilis* forest. The numbers in species sequence indicate the same species as in Table 2.

Twenty one species were recorded in shrub layer. Among them *Rhododendron campanulatum* was the most frequent (80%) (Table. 3).Other common species were *Viburnum erubescens, Daphne bholua, Berberis* sp., etc.

Table 3. Plant species forming shrub layer in *Abies spectabilis* forest.

SN	Name of the shrub species	Frequency (%)
1	*Rhododendron campanulatum* D.Don	80.0
2	*Viburnum erubescens* Wall ex. Dc	41.2
3	*Daphne bholua* Buch.-Ham. ex. D.Don	28.7
4	*Berberis* sp.	26.2
5	*Spiraea bella* Sims.	16.2
6	*Arundinella* sp.	15.0
7	*Lonicera acuminata* Wall.	10.0
8	*Smilax aspera* L.	10.0
9	*Rhododendron barbatum* Wall. ex. G.Don	8.7
10	*Lyonia ovalifolia* (Wall.) Drude	6.2
11	*Elaeagnus parvifolia* Wall. ex. Royle	5.0
12	*Rhododendron lepidotum* Wall. ex. G.Don	3.7
13	*Salix* sp.	3.7
14	*Sorbus microphylla* Wenz.	2.5
15	*Artimisia* sp.	2.5
16	*Agapetes* sp.	2.5
17	*Rhododendron anthopogan* D.Don	2.5
18	*Jasminum humile* L.	1.2
19	*Rhododendron arboreum* Sm.	1.2
20	*Ribes orientale* Desf.	1.2
21	*Rubus hypargyrus* Edgew.	1.2

Table 4. Community attributes of the *Abies spectabilis* forest in the study area

Community attributes	Mean	Coefficient of variation (%)	Range (min.-max.)
Tree canopy (%)	70	24	13-96
Species richness of trees (species/100 m^2)	1.44	48	1-4
Species richness of shrub (species/100 m^2)	2.79	84	0-12
Species richness of woody species (species/100 m^2)	4.23	65	1-14
Basal cover of trees (%)	0.68	57	0.02-2.22
Total tree density (stem/ha)	700	51	100-1600
Tree density of *Abies spectabilis* (stem/ha)	604	50	0-1300
Sapling density of *A. spectabilis* (stem/ha)	70	361	0-2000
Seedling density of *A. spectabilis* (stem/ha)	4012	137	0-31000

In *Abies spectabilis* forest the mean tree canopy cover was 70%. The total basal cover of tree species was 0.68%. *A. spectabilis* had the highest basal cover (0.65 %) of the all tree species. The density of seedlings and saplings of *A. spectabilis* were 4012 and 70 stem/ha, respectively. Tree canopy showed the least variation (i.e. lowest CV) among the community attributes measured. Spatial variation in sapling density of *A. spectabilis* across the sampling plots was the highest (CV= 361).

5.2.2 Species Richness and Diversity

The total number of woody species (trees and shrubs) recorded was 25. Tree species richness was 1.44 species/100 m^2 and shrub species richness 2.79 species/100 m^2. Simpson's index of dominance (C) for tree was 0.75 and Shannon- Wiener index (H') of species diversity was 0.63.

5.3. Community attributes vs. Environmental variables

Elevation appeared to be the most important environmental factor that affected community attributes of the study forest. Tree density was lowest at around 3550 m asl and it increased to both upper and lower elevation regions within the study range of elevation (Figure 4). The species richness of shrubs alone and all woody species also followed the same pattern but they were asymmetric with higher value towards the region of lower elevation than towards the upper (Figure 5-6).

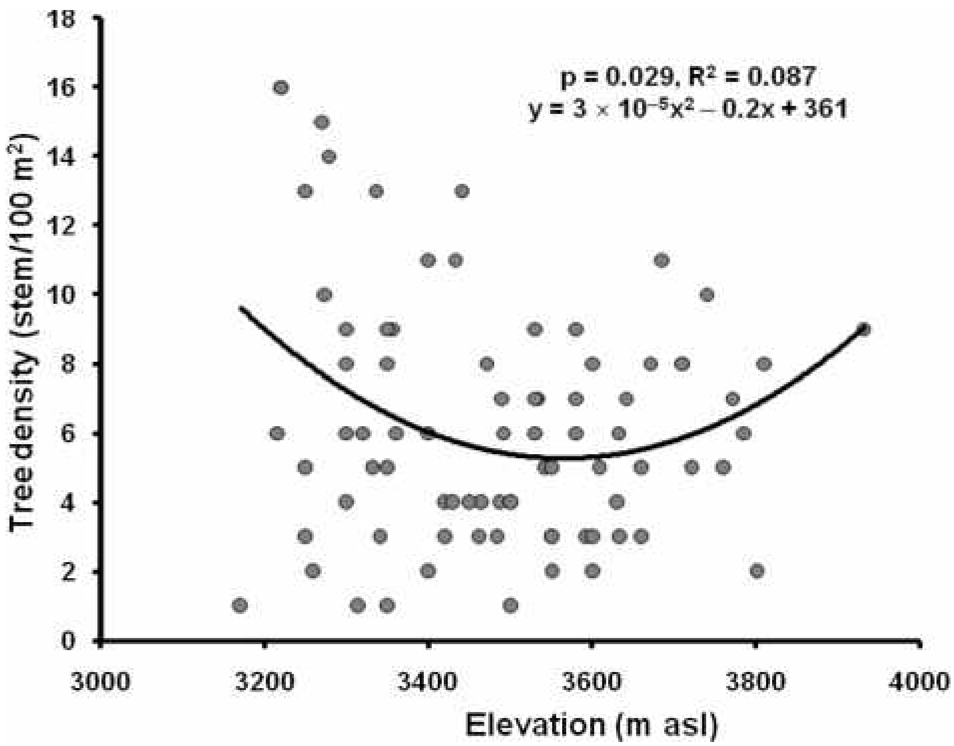


Figure 4. Relationship between tree density (all species combined) in *Abies spectabilis* forest and elevation. The fitted line was obtained from quadratic regression model.

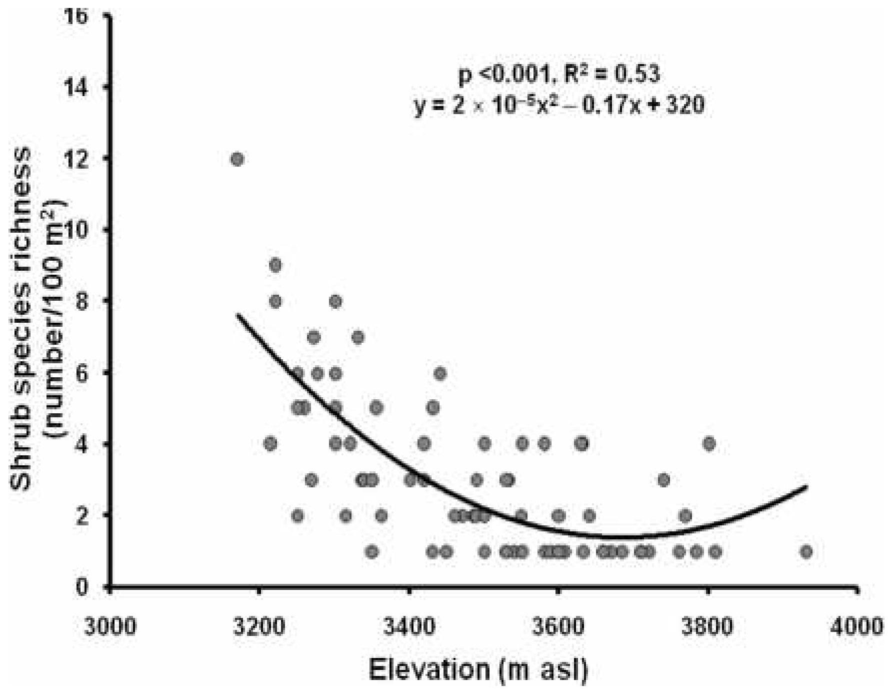


Figure 5. Relationship between shrub species richness in *Abies spectabilis* forest and elevation. The fitted line was obtained from quadratic regression model.

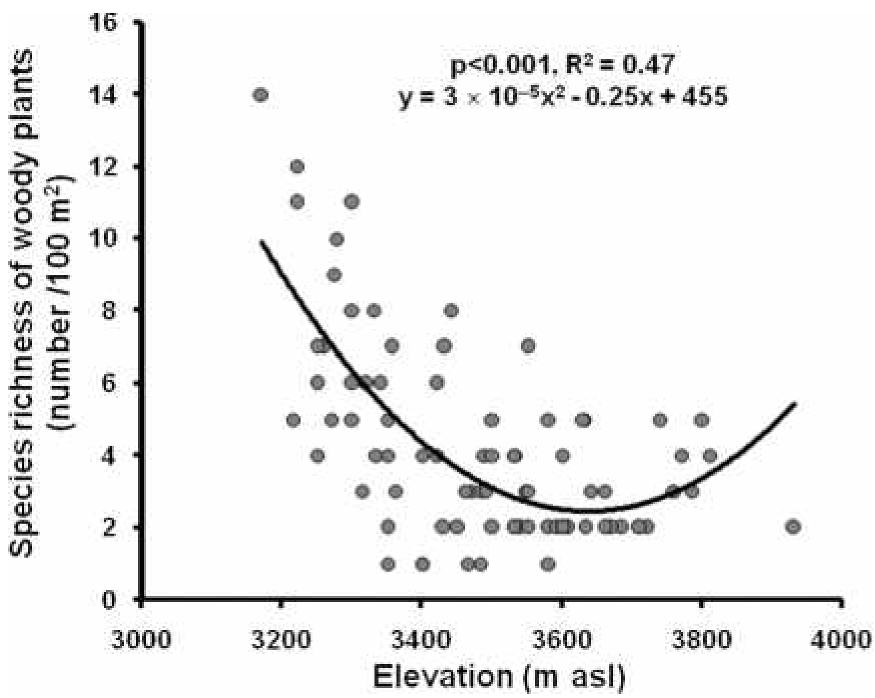


Figure 6. Relationship between species richness of woody plants in *Abies spectabilis* forest and elevation. The fitted line was obtained from quadratic regression model.

5.4. Population structure and Regeneration

Static life table: In the population of *Abies spectabilis*, the seedling accounted 85.6 %, sapling 1.5 % and the tree 12.9 %. Therefore, seedling had the highest share in the population of this species, and sapling the lowest. Mortality of seedlings was 98%, which became the first death peak during the population development. Only 2% of the seedlings developed into sapling stage. Sapling exhibited the highest life expectancy.

Table 5. Static life table of *Abies spectabilis* in forest of Langtang*

Size (DBH) classes	a_x	l_x	d_x	q_x	L_x	T_x	e_x
Seedlings	3210	1000.00	982.55	0.98	508.72	667.60	0.67
Saplings	56	17.45	-14.95	-0.85	24.92	158.88	9.11
10-20 cm	104	32.40	-10.59	-0.33	37.69	133.96	4.13
20-30 cm	138	42.99	11.21	0.26	37.38	96.26	2.24
30-40 cm	102	31.76	7.79	0.25	27.88	58.88	1.85
40-50 cm	77	23.99	14.02	0.58	16.98	31.00	1.29
50-60 cm	32	9.97	4.67	0.47	7.63	14.02	1.41
60-70 cm	17	5.30	3.74	0.71	3.43	6.39	1.21
70-80 cm	5	1.56	0	0	1.56	2.96	1.90
80-90 cm	5	1.56	0.93	0.60	1.09	1.40	0.90
90-100 cm	2	0.62	0.62	1.00	0.31	0.31	0.50

*Here, a_x the survival individuals; l_x proportion of individuals surviving from the beginning to age *x*, $l_x = a_x/a_0$ *1000; d_x shows number of dead individuals from age x to x+1, $d_x = a_x - a_{x+1}$; q_x shows mortality from x to x+1, $q_x = d_x / l_x$; L_x shows the mean number of survival individuals from age x to x+1, $L_x = (l_x + l_{x+1}) /2$, T_x = Total number of survival individuals from age x, $T_x = \Sigma L_x$; e_x is the life expectancy at age x, $e_x = T_x / l_x$.

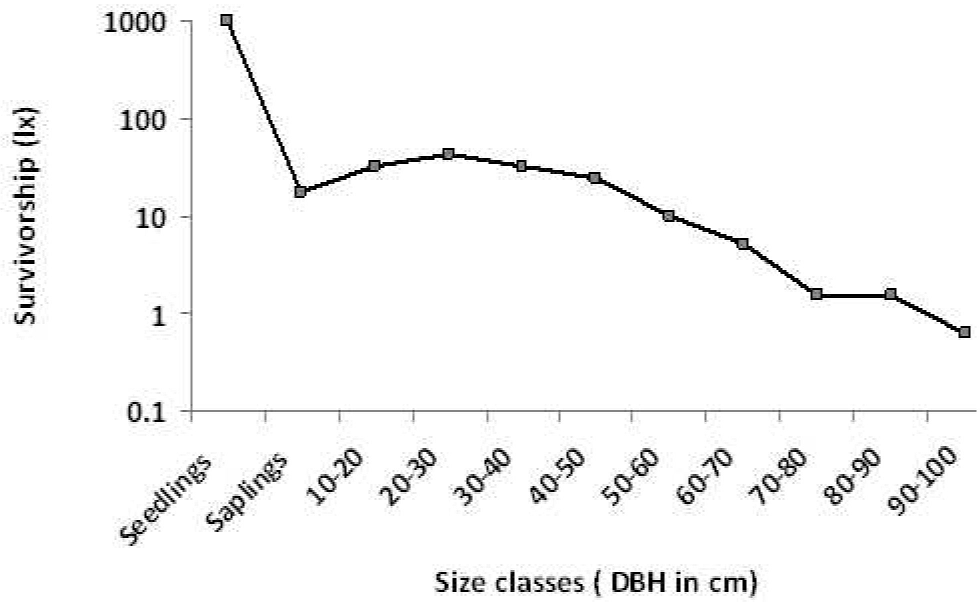


Figure 7. Change in proportion (ò1000) of individual surviving (l_x) with size classes of *Abies spectabilis* in Langtang.

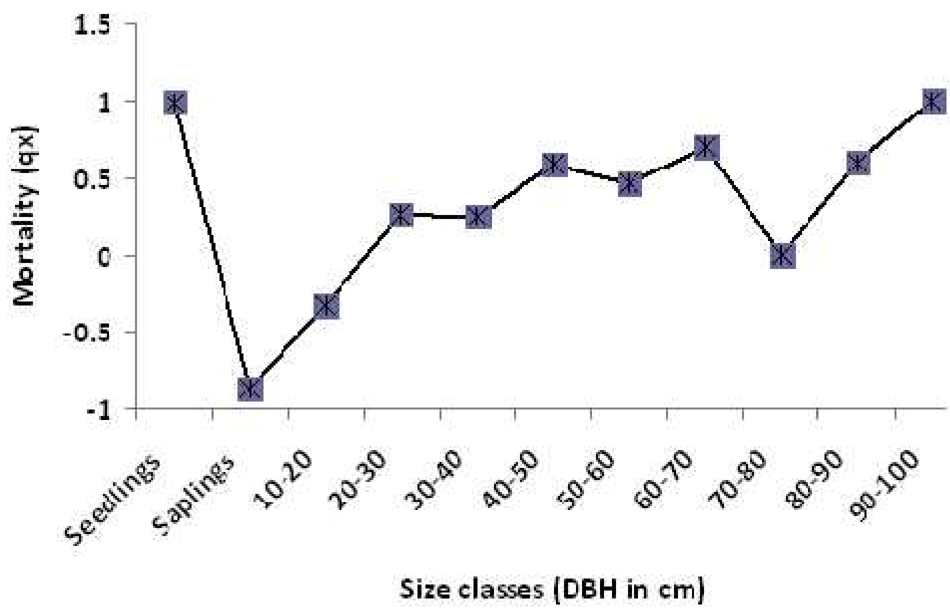


Figure 8. Mortality (q_x) curve of *Abies spectabilis* in Langtang.

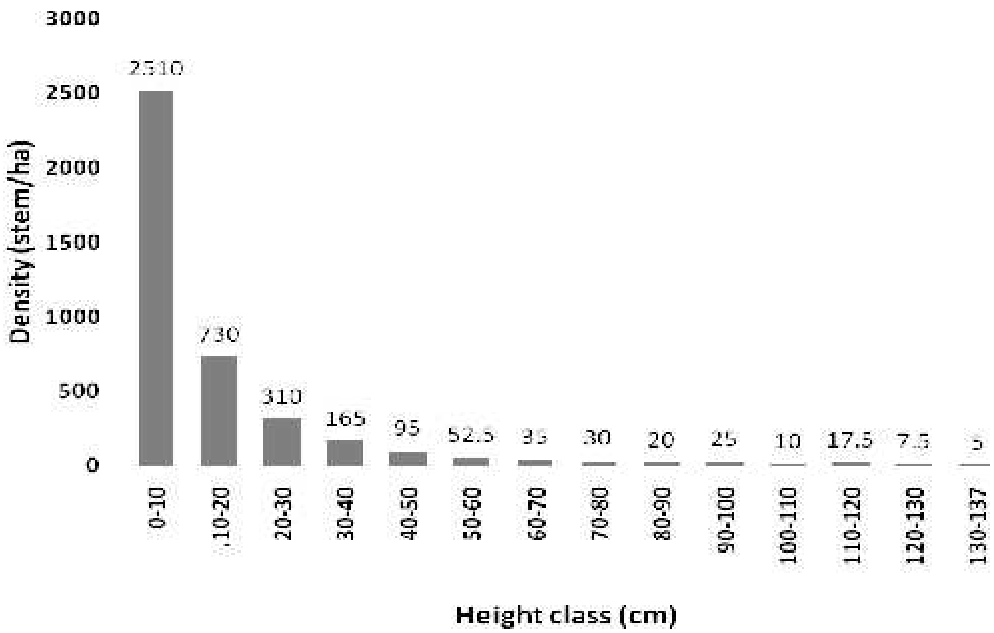


Figure 9. Density of different height classes of seedling of *Abies spectabilis* in Langtang.

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

Tree species	Seedlings/tree	Saplings/tree
Abies spectabilis	6.65	0.11
Rhododendron campanulatum	0.53	0
Betula utilis	0	0
Rhododendron barbatum	0	0
Salix sp.	0	0
Rhododendron arboreum	0	0
Acer sp.	0	0
Hydrangia aspera	0	0
Sorbus microphylla	4	0
Lyonia ovalifolia	0	0
Elaegnus parviflora	0	0

Density of seedlings of *Abies spectabilis* declined with increasing height classes. There was sharp decline in density from first height class to second; afterward the decline was gradual. Density of the largest height (130-137 cm) class was only 0.2% of the density of the smallest height class (0-10 cm).

In addition to *Abies spectabilis*, seedlings of *Rhododendron campanulatum* and *Sorbus microphylla* were also present; other tree species did not have seedling. Except *A. spectabilis*, other tree species did not have saplings in the sampling plots.

Density-diameter curve for all tree species combined was nearly reverse J-shaped, indicating continuous regeneration. But the curve for *Abies spectabilis* alone deviated slightly from the typical reverse J-shape; density of the smallest size class (10-20 cm) was lower than the density of the next size class (20-30 cm).

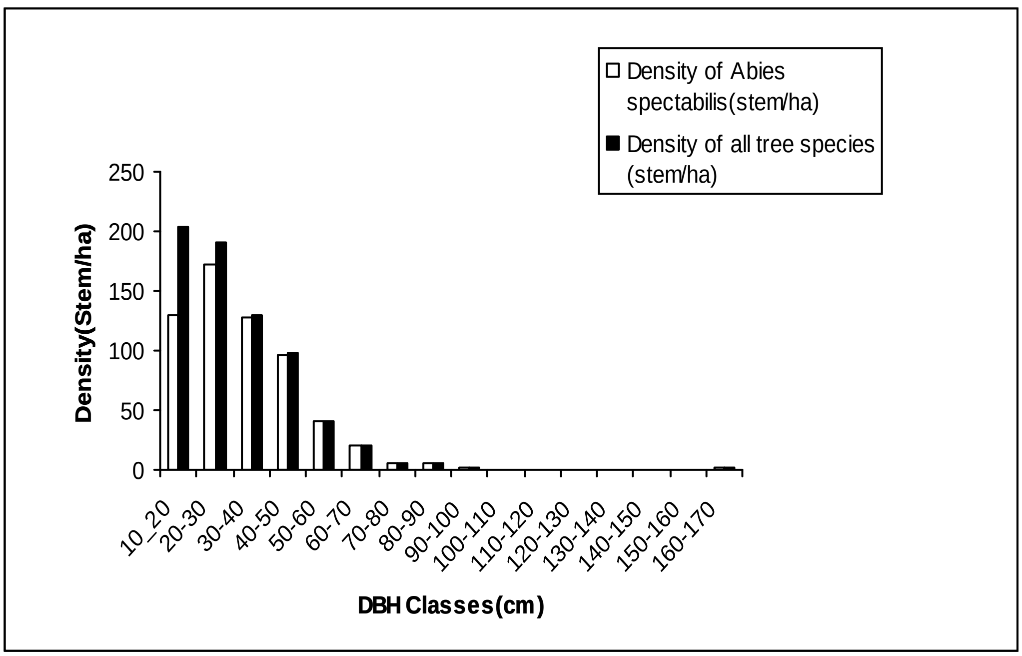


Figure 10. Density-diameter curve for *Abies spectabilis* alone as well as all tree species of the forest.

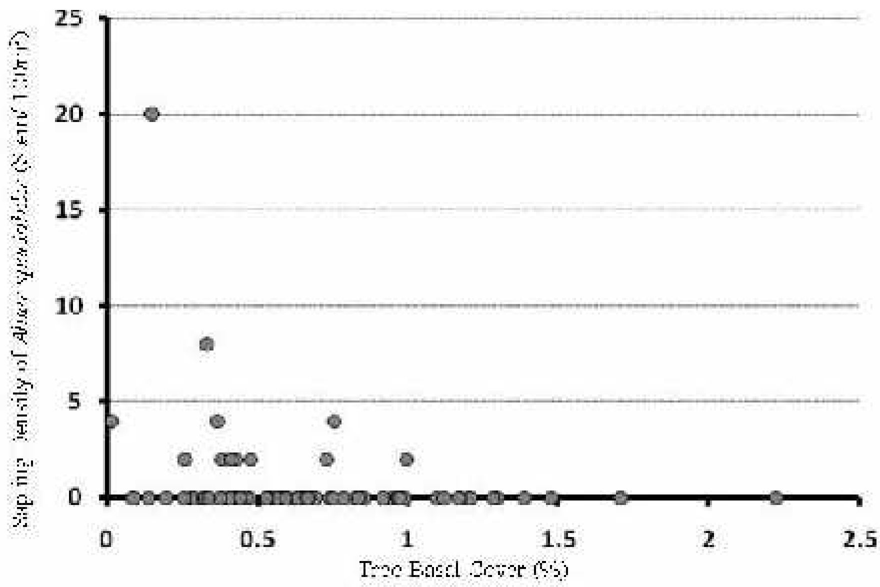


Figure 11. Variation of sapling density of *Abies spectabilis* with total tree basal cover combined for all species.

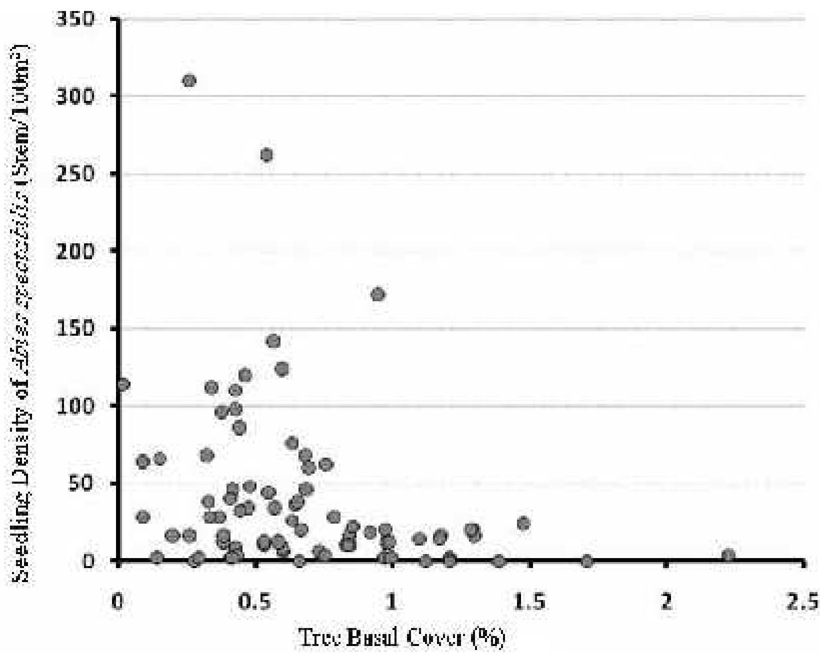


Figure 12. Variation of seedling density of *Abies spectabilis* with total tree basal cover combined for all species.

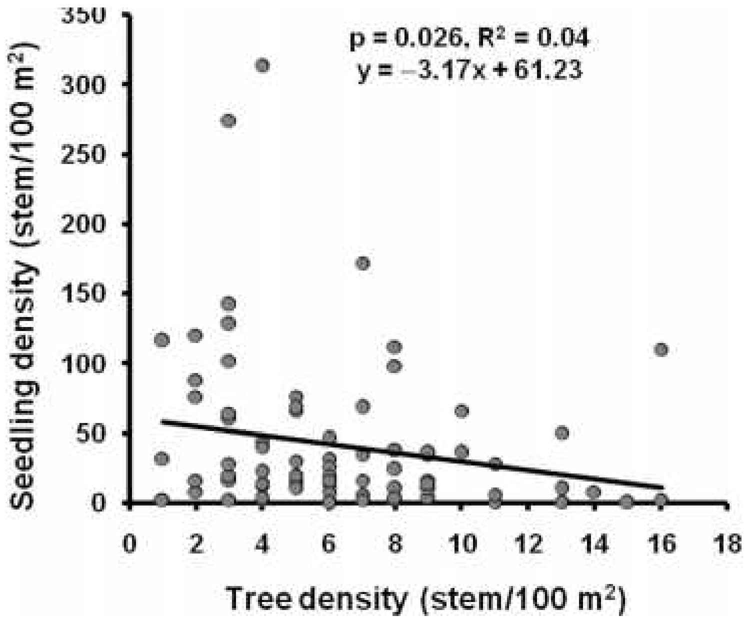


Figure 13. Relationship between seedling density and tree density. The data for all tree species were pooled.

Out of 80 plots sampled, saplings of *Abies spectabilis* were present only in 11 (14%) plots (Figure 11). Saplings was absent in plots having basal cover >1% and seedling of *Abies spectabilis* were present in 74 plots and absent in 6 plots (Figure 12). Seedlings were almost absent in plots having basal cover >1.5%. Generally density of saplings and seedlings of *A. spectabilis* were lower when basal cover was high. Seedling density combined for all species also declined with increasing tree density (Figure 13). Seedling density of *A. spectabilis* did not vary with elevation and tree canopy cover (Figures 14-15). However, some of the plots having the highest density of seedlings of *A. spectabilis* were from the mid elevation region within the study range.

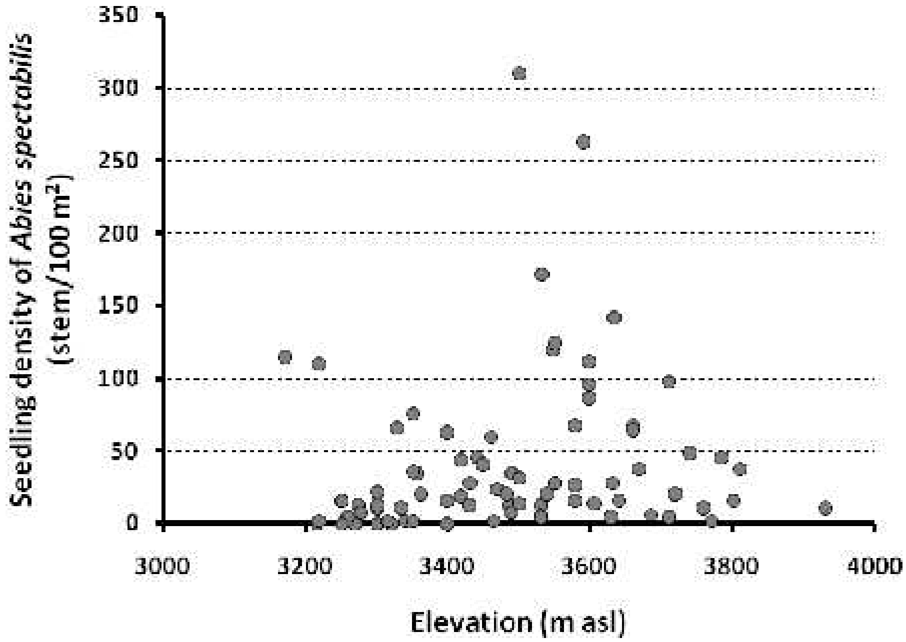


Figure 14. Variation in seedling density of *Abies spectabilis* with elevation.

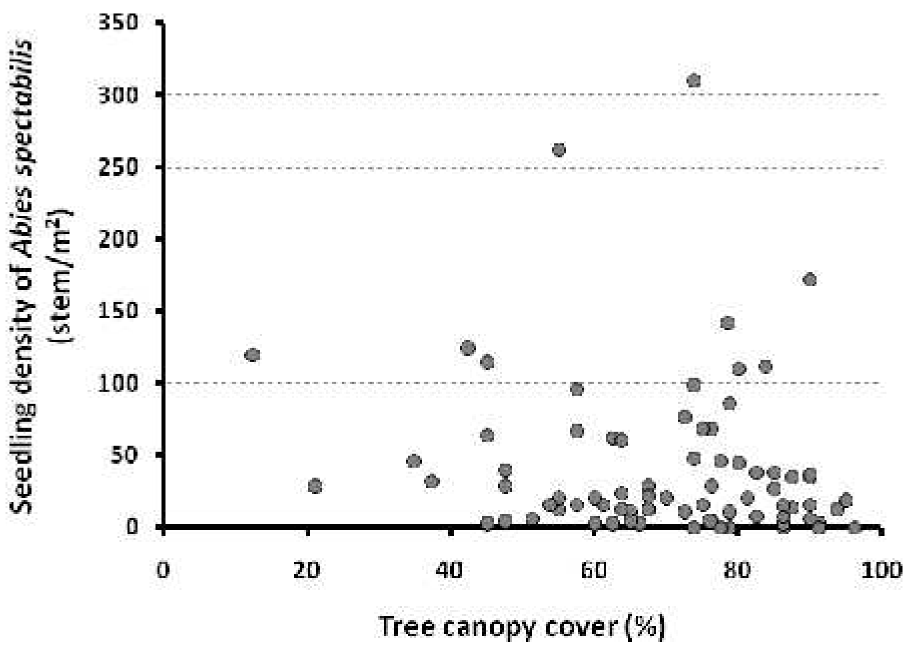


Figure 15. Variation of seedling density of *Abies spectabilis* with tree canopy cover

6. DISCUSSION

6.1. Soil

Soil of study area was slightly acidic in nature (soil pH 5.50-6.80).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 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).

Soil organic carbon of the present study forest was found 7.24%. 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 *Abies spectabilis* forest of Manang. Soil nitrogen of the present study forest was found 0.44%. Zhang and Zhao (2007) reported 0.74% of nitrogen in a *Pinus koraiensis* forest China. Both soil carbon and nitrogen content in the present study forest were relatively low. This may be due to the lower litter cover (48%).

6.2. Community Structure

Abies spectabilis was the dominant tree species with the highest importance percentage (84 %). *Rhododendron campanulatum* was the second dominant tree species with importance percentage of 5 %. Since, *Abies spectabilis* contributed > 80% of the importance percentage, the present forest can be considered as the monodominant *Abies spectabilis* forest. Goirola *et al.* (2008) reported *Abies pindrow* as dominant species (importance percentage 16.44%) and *Betula utilis* as co-dominant species (importance percentage 16.10%) in north-western slope of mixed *Abies*-*Betula* forest of Indian Himalaya. In that forest the two tree species shared nearly equal dominance in the community. .

The total density of all tree species combined was 700 stem/ha. In mixed *Abies spectabilis* forest of Manang, the total tree density was 900 stem/ha (Acharya 2004). Qi-Jing (1997) found total tree density 759 stem/ha in sub-alpine coniferous forest on Changbai Mountain, China. Mori and Takeda (2004) reported total tree density of 1274 stem/ha in sub alpine *Abies mariesii* forest of central Japan. These values were higher than the density of present study forest. Lower value of total tree density in the present study site might be due to logging of trees and high disturbance due to grazing and trampling. Total tree density decreased with elevation but at next ecotone region began to increase again (Figure 4). It is generally due to increase in the number of species in the ecotone region than in the communities (Odum 1971). Tree density of *Abies spectabilis* was 604 stem/ha in the present study site. In mixed *Abies spectabilis* forest of Manang, the density of *Abies spectabilis* was 360 stem/ha (Acharya 2004). 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 lower than the value of studied site. This showed that the dominance in the present study forest was concentrated to single species *Abies spectabilis*.

The total tree basal cover of the present study forest was 0.68%. Taylor *et al.* (2004) found total basal cover (0.47%) in *Abies faxoniana* forest of south western China. The basal cover of Taylor *et al.* (2004) was lower due to lower total tree density of *Abies faxoniana* forest comparable to ours. Qi-Jing (1997) found total basal cover of tree 0.48% in *Picea jezoensis –Abies nephrolepis* forest. This value was also low than our studied forest. Total basal cover of *Juniperus indica* forest was 0.17% in a mixed *Juniperus* forest (Ghimire *et al*. 2008). Although, total tree density (2700 stem/ha) was high in this *Juniperus* forest but total basal cover was very low. Study area of Ghimire *et al.* (2008) was concentrated on southern slope and dominant tree (*Juniperus indica)* has usually low tree diameter as comparable to *Abies spectabilis*.

Simpson's Index of Dominance (C) for tree was 0.74 and Shannon- Wiener Index (H') of species diversity was 0.63 in the present study forest. 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 sub-alpine 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, 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 temperature decrease (Qi-Jing 1997). Species richness in the studied forest decreased with elevation at first and began to increase later (Figure 5 and 6). Species diversity in forest edge was higher than that in pure forest which was possibly caused by edge effect (Liyun *et al*. 2006).

6.3. Regeneration and Life table

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). Reverse J- shaped density-diameter curve was reported by Ghimire and Lekhak (2007) for mixed *Abies spectabilis* forest of Manang and by Shrestha *et al.* (2007) for *Betula utilis* forest. 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 (30-40, 40-50, 50-60 60-70 and 70-80) were found for *Abies spectabilis* in *Abies* and *Pinus* forests in Pisang, Manang. Smaller DBH classes (10-20 cm and 20-30) of *Abies spectabilis* have lower density as compared to whole forest (Figure 10). This difference in small size classes was due to contribution of other species such as *Rhododendron campanulatum, R. barbatum, Sorbus microphylla* etc. which generally had smaller sized individuals. There was almost absence of high girth classes of *Abies spectabilis* (Figure 10). It was found that larger trees were cut off by people for the timber and firewood. The result showed that for the whole *Abies spectabilis* forest density of the trees with smaller girth size was higher than that of the larger girth size. But for *Abies spectabilis* curve deviated slightly from the typical reverse J-shape which didn't indicate sustainable regeneration.

Seedling density of *Abies spectabilis* in the study site was 4012 stem/ha and sapling density was 70 stem/ha. In *Picea abies* forest (Norway spruce) (Slovenian Alps), 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). Comparing these values the seedling density of the present study forest was low. 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. Seedling density of *Abies spectabilis* in the present studied forest was higher than that reported by Acharya (2004) but sapling density was quite low in the present forest. Less number of sapling (70 stem/ha) in the present forest was mainly due to higher seedling mortality (98%) (Figure 8). Mechanical damage to seedlings of *Abies spectabilis* due to intense grazing and trampling may lead to high seedling mortality (Figure 8). Generally seedling and sapling density was high on those plots where basal cover was low (Figure 11 and 12). This might be due to the less availability of resource and low light penetration due to high canopy cover.

Density of seedlings of *Abies spectabilis* declined with increasing height classes of the seedling. Density of the largest height (130-137 cm) class was only 0.2% of the density of the smallest height class (0-10 cm). It implies that only 0.2 % of the seedling that emerged immediately after seed germination would grow into large seedlings.

Seedling densities of *Abies spectabilis* were high on those plots where basal cover was low (Figure 12). Total seedling densities for whole forest also declined with increasing tree density (Figure 13). 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 (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 study forest, frequency (14%) and density (70 stem/ha) of saplings were very low, and it was absent in dense stands.

Intensity of grazing/trampling was relatively high (2.26 out of 3) in the studied forest. There was significant influence of grazing on tree seedling species composition (Darabant *et al*.2007). Acharya (2004) reported less natural regeneration of *Abies spectabilis* due to high radiation index, low moisture and high human pressure.

Mortality of the seedlings was the highest (98%) in the population of *Abies spectabilis*, and only 2% of the seedlings survived to sapling stage (Figure 7, Table 5). In a population of timberline, *Abies georgei*, on the north facing slope of Baima Snow Mountain (SW China), the seedling mortality was 88 % (Qiaoying *et al.* 2008). In the population of *Abies spectabilis* in the present study area, the diameter class 10-20 cm exhibited the highest life expectancy among trees. In the population of *Abies georgei*, diameter class 15-20 cm exhibited the highest life expectancy (Qiaoying *et al.* 2008). They reported that mortality of seedling was mainly due to extreme cold condition. Survivorship curve of the studied site was not continuous (Figure 7). Highest life expectancy was for sapling and it went on decreasing towards higher size classes of the trees. This may be due to death of juvenile due to high grazing and trampling. Grazing /trampling and also human interference may be the factor for the high seedling mortality. Logging of trees may also be the factor for seedling mortality. Logging of trees not only reduced tree density but also hamper regeneration directly by mechanical damage to recruits and indirectly by reducing the seed production. These may be the reason for gaps in the size class diagrams.

Very high mortality of seedlings of *Abies spectabilis* (98%), low density of saplings (70 stem/ha) and deviation of density-diameter curve from reverse J- shape indicates that regeneration of this species was not sustainable in the study forest. Anthropogenic disturbance appeared to be more important than community attributes for unsustainable regeneration. Therefore, the hypothesis that 'the regeneration of *Abies spectabilis* is sustainable under its own canopy' has been rejected.

7. CONCLUSION AND RECOMMENDATION

7.1. Conclusion

Abies spectabilis was the most dominant species among trees and *Rhododendron campanulatum* was dominant among shrub species**.** Seedling and sapling density decreased as basal cover increases. Woody species richness decreased with elevation but near the treeline it began to increase again. Species diversity of the forest was relatively low, which might be due to the anthropogenic factors such as cattle grazing, fire wood collection and logging.

Density-diameter curve for all tree species combined was nearly reverse J-shaped, indicating sustainable regeneration. But for *Abies spectabilis* density-diameter curve was not continuous and didn't show sustainable regeneration. Population life table showed that seedling mortality was extremely high (98%). Sapling showed highest life expectancy. Absence of tree with high girth class indicates more disturbances in the forest.

Due to high grazing/trampling, felling down of trees for timber and fire wood collection there was low diversity of woody species and high mortality of seedlings in the study area. Large numbers of fallen logs and stump were found in the study area. This showed that forest was highly disturbed.

7.2 Recommendation

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

- Due to high grazing/trampling species diversity was low and regeneration of *Abies spectabilis* was not sustainable. Therefore, grazing pressure should be maintained to minimum, if not possible to ban.

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