Community structure and regeneration pattern of *Abies spectabilis* in Sagarmatha National Park, Central Himalaya, Nepal

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Community structure and regeneration pattern of *Abies spectabilis* was studied along the elevation gradient from 2750 to 3550 m asl in mixed forest of *A. spectabilis* in Sagarmatha National Park, eastern Nepal. Various community attributes (*viz.* importance percentage, species diversity and beta diversity) and population characteristics (e. g. density- diameter, bar diagram) were analysed. Out of the thirty-four species recorded from the study forest, *A. spectabilis* was the co-dominant species with high species diversity. Total tree density was the highest at 3450 m and the lowest at 3550 m. Elevation appeared to be the important environmental factor that affects the community attributes of the study forest. The curve for *A . spectabilis* solely was slightly deviated from the typical reverse J-shaped which indicates a discontinuous regeneration pattern. The distribution of the seedling and sapling distribution was not uniform. Seedling mortality was found relatively medium and development of seedlings into saplings was also low. The lower number of sapling might be due to moderate disturbance (grazing and trampling) by livestock or due to environmental factors. The use of *Abies* tree for construction and firewood might be the reason of unsustainability.

Key Words : *Abies spectabilis,* community structure, regeneration pattern, Sagarmatha National Park

Abies, a genus under the family Pinaceace, is a large group of soft wood tree with 48 species in the world (Farjon, 2010). It is also called Himalayan silver fir (Vidakovic, 1991) while local people called 'Talispatra'. *Abies* are slow growing, tall evergreen, pyramidal tree that attains a height of 60 m.

Its distribution in Nepal is restricted between the elevations of 2700 m and 3900 m above sea level (masl). The plants are found in moist open areas, woodland, garden, canopy zones. Three species are reported from Nepal *viz. Abies spectabilis, A. densa*, and *A. pindrow* (Anonymous, 2001; Hara *et al.,* 1982; Press *et al*., 2000). The common associates of the *A. spectabilis* forests are *Rhododendron*, *Betula*, *Acer* and *Sorbus* species (Stainton, 1972).

Natural regeneration is a process in which the plant species replace themselves to maintain the ecosystem. It is the most important course of action for ensuring the replacement of any member of a community that dies off after completing life cycle (Fatubarin, 1987). Undisturbed 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 for 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). Counting of seedlings and saplings and analysis of size class distribution are methods for the regeneration analysis (Vetaas, 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,

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acidic and neutral soil conditions (DPR, 2001). There are many similar attempts to study about the regeneration pattern of the different forest structure in the Himalaya (Ghimire and Lekhak, 2007; Kumar *et al.,* 2004; Mehraj and Kumar, 2010; Shrestha *et al.,* 2007; Tiwari, 2010).

A. spectabilis is the important timber and fuel wood tree in the temperate and sub- alpine area even up to the tree line. So, the demand of the *Abies* plant for construction and fuel wood, growth pattern, regeneration, impacts like grazing, trampling, etc. are being crucial concern for sustainable use of this preferred species.

The previous studies were focused mostly central and western Nepal (Acharya, 2004; Ghimire *et al.,* 2008; Ghimire and Lekhak, 2007). Likewise, some studies reveal that the biomass distribution and tree invasion vary significantly with elevation (Fadrique *et al.,* 2016). We have re- tested the hypothesis and have chosen some different locality to scrutinize new aspects of regeneration. Because the vegetation type, forest composition and climatic conditions are different in eastern, central and western Nepal (Stainton, 1972). In this context, the community structure of eastern Nepal with sustainability of *A. spectabilis* species is assessed in the designated field area which was situated along the trekking route of various tourist destinations in the foothills of the Himalayas. The study was focused only on narrow elevation zone due to technical hitches.

The general objective of the present study was to assess the vegetations of sub-alpine mixed *A. spectabilis* forest. The specific research questions that we tried to address were (i) What is the effect of altitude on community structure of sub-alpine mixed *A. spectabilis* forest in Sagarmatha National Park ? (ii) What is the effect of environmental parameters like rock cover, soil carbon and elevation on regeneration of *A. spectabilis* ? (iii) How is the regeneration pattern of mixed *A. spectabilis* forest in study area ?

The Park is managed by the Sagarmatha National Park Authority under the Department of National Parks and Wildlife Conservation, whereas, the buffer zone is managed by a Buffer Zone Management Committee (BZMC) within each village that takes care of location-specific issues by collaborating with the national park authority. For this, the BZMC is an apex body under which different Buffer Zone User Committees (BZUCs) and Buffer Zone User Groups (BZUGs) have been formed and institutionalized in Sagarmatha National Park and its Buffer Zone (SNP, 2003). The distribution of fuel wood and necessary timbers from logging trees are also managed by BZUCs. There are no stringent rules to control grazing in the settlement of protected areas of Himalaya regions according to Himalayan National Park Regulations (HNPR, 1997) and practically it is not apposite too.

Materials and methods

Study area

The 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 (Fig. 1) includes 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).

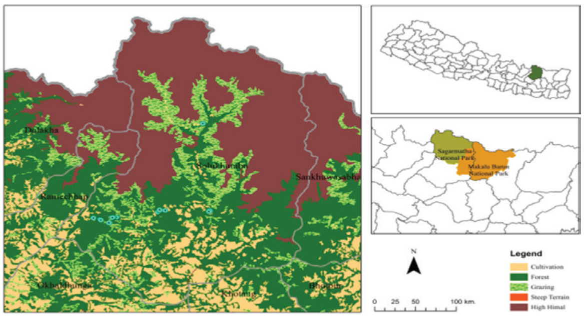

Fig. 1: Map of the study area

Sampling methods

Vegetation in the study area was sampled through systematic random sampling method (Vetaas, 2000). A total of 45 plots of 0. 1 ha (1000 m^2) were sampled between 2750 m to 3550 m each at 100 m elevation interval (Fig. 1). Nine vertical transects were defined within the study area and quadrats were located along each transect. Five sampling plots were laid in each elevation for one or both sides of the well-established footpath. The location for the first plot in 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. Other plots in the same elevation were laid at a distance of 30–200 m difference. The distance between the plots was determined on the basis of the accessibility and presence of *A. spectabilis* trees. If *Abies* trees were not observed along the sampling transect, a sidewise search was conducted on either side of the path at the same elevation.

The number of individuals of *A. 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 using dbh tape. All shrubs species present in the quadrat were recorded. 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 micro-environment. Lopping, logging and grazing were categorized as low, medium and high. Looping of 1–5 trees, 6–10 trees and more than 10 trees refers to low, meidum and high, respectively 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. We did a general discussion among the key stakeholders regarding the consumption of fire wood in different season of the year.

From each quadrat, 200 g soil sample was collected from the corners and centre of each quadrat at a depth of 30 cm and their physiochemical characteristics (Soil pH, Carbon and Nitrogen content) were analysed. Relative radiation index (RRI) was calculated from the values of aspect (Ω), slope (β) and latitude (Φ). The value ranges from +1 to -1. RRI was calculated following the formula given by Oke (1987) :

$$RRI= \text{Cos}(180-\Omega).\ \text{Sin}(\Phi) + \text{Cos}\beta.\ \text{Cos}\Phi.$$

Various community attributes like importance percentage, species diversity, beta diversity and population characteristics (e. g. density- diameter bar diagram) were analysed (Shannon and Warner, 1949; Simpson, 1949). Ordination methods were used to analyse species composition and to relate this to rock cover, soil carbon and elevation using "Vegan" package in R (Oksanen, 2015). Detrended corresponding analysis (DCA) was used to analyse sparse data matrices. DCA is a multivariate stastistical technique widely used by ecologist to find the main factors or gradients in large, species rich but usually sparse data matrices that typify ecological data. Ordination of the different characters and elevation on two axis DCA1 and DCA 2 are evaluated and explained in our study (Table 1).

Results and discussion

Results

Species composition

While observing species composition, *Daphne bholua*, *Tsuga dumosa, Berberis aristat*a dominated in elevation between between 2750 – 3150 m asl while *Abies spectabilis*, *Rhododendron arboreum*, *Quercus semicarpifolia* and *Juniperus indica* dominated between 3150 – 3550 m asl, *Rhododendron*, *Juniperus* etc. were the associated species of *Abies* Altogether thirty four species of trees and shrubs were recorded, of which, twelve species were tree while remaining were sapling. However, *A. spectabilis*, *Q. semicarpifolia* and *Pinus wallichina* reached to canopy layer. Remaining species were confined only to sub-canopy layer.

Table 1 : Summary of DCA result

Axis	Eigenvalues	Decorana values	Axis lengths
DCA1	0. 4666	0. 4797	3. 6192
DCA2	0. 1932	0. 2341	2. 3670
DCA3	0. 2083	0. 1549	2. 3504
DCA4	0. 14325	0. 09719	1. 95503
Sum of Eigen value	1. 011		

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 mixed *Abies spectabilis* forest of the study area

S. N.	Plant Name	F (%)	RF (%)	D (stem/ha)	RD (%)	BC (%)	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

Twenty two species were recorded in Shrub layer and mainly dominated by *D. bholua*, *B. aristata*, *Lonicera lanceolata* at lower altitude whereas higher altitude was dominated by *Juniperus* species and some of places by *Vibrurnum* species. *D. bholua* was the most frequently occurring (53. 3%).

The diversity dominance curve showed that out of twelve species, five species had IP less than 1% (Table 2).

The total number of woody species (trees and shrubs) recorded was 34. Among trees, *Rhododendron arboreum* had the highest IP (61. 91%) and then after *A. spectabilis* had 22. 72% IP (Table 2). 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 *A. spectabilis* than the seedling and tree ratio and seedling and sapling ratio.

The total tree density of various species was found to be 267. 11 stems/ha and the density of seedlings and saplings of *A. spectabilis* were 76. 89 and 28. 44 stems/ha respectively whereas total sapling and seedling density were 1086 and 524.2 stems/ha (Table 3).

The mean tree canopy cover was 53. 78% while the distribution pattern of seedling and sapling of *Abies* was 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 *A. spectabilis* trees. Total sapling density increased with altitude up to 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. 2), which was not a normal demographic development. The most densely populated plots were found between 3450 m and 3550 m. Total basal area of tree species was 2. 24 m^2/ha. In the highest elevation range, trees were small with lower basal area. The highest basal area of *Abies* tree was found at 3450 m (6.033m^2/ ha).

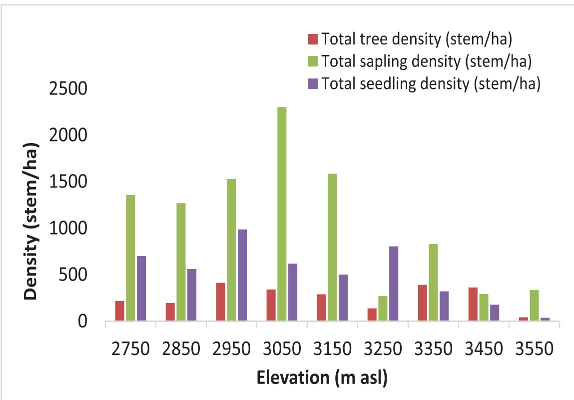

Fig. 2: Density of all species along elevation gradient

Intensity of grazing/trampling was relatively high in the study forest (Table 3). Soil of the forest under study was slightly acidic in nature with pH ranging from 4.2 to 5.93. Total carbon content in soil varied between 1.24% to 6.79% and nitrogen content in the soil was found between 0.11% and 0.52% (Table 3).

Table 3 : Descriptive statistics of all the variables used

Variables (*Unit*)	**Mean**	**Minimum**	**Maximum**	**SE**	**SD**	**Kurtosis**	**Skewness**
Total Tree Density (*Stem/ha*)	267.11	10	570	23.59	158.22	-1.05	0.10
Total Sapling Density (*Stem/ha*)	1086.44	70	3300	112.33	753.54	-0.05	0.59
Total Seedling Density (*Stem/ha*)	524.22	20	2230	80.30	538.65	2.79	1.69
Total Tree Basal Area (m^2)	2.24	0.173	6.033	0.24	1.58	-0.66	0.58
Abies Seedling Density (*Stem/ha*)	76.89	0	910	29.05	194.90	10.63	3.29
Abies Sapling Density (*Stem/ha*)	28.44	0	250	8.60	57.68	4.94	2.30
Elevation (m)	3150.00	2750	3550	38.92	261.12	-1.23	0.00
Total Species Richness (*Count*)	5.29	1	16	0.50	3.33	0.64	0.75
Tree (*Count*)	6.09	0	31	1.19	7.97	2.45	1.64
Sapling (*Count*)	2.84	0	25	0.86	5.77	4.94	2.30
Seedling (*Count*)	7.89	0	91	2.90	19.46	10.58	3.27
pH	5.17	4.2	5.93	0.06	0.39	0.34	-0.29
Soil Carbon content (%)	3.06	1.246	6.792	0.21	1.40	-0.19	0.59
Soil Nitrogen content (%)	0.27	0.112	0.518	0.01	0.09	0.54	0.72
Lopping (*categorical)*	1.11	1	2	0.05	0.32	4.77	2.56
Logging (*categorical)*	1.42	1	3	0.09	0.62	0.45	1.20
Grazing (*categorical)*	1.29	1	2	0.07	0.46	-1.12	0.96
Slope (°)	186.56	90	280	8.91	59.76	-1.16	0.09
Aspect (°)	34.58	10	45	1.30	8.72	0.25	-0.89
Litter (%)	2.16	1	3.8	0.09	0.58	0.18	0.51
Canopy (%)	53.78	5	80	3.10	20.81	-0.18	-0.78
Rock Cover (%)	16.44	0	80	2.73	18.33	3.22	1.80
Relative Refractive Index	0.02	-0.90	0.98	0.09	0.62	-1.37	0.13

Relation of the different community attributes with environmental variables The environmental parameters such as rock cover, soil carbon and elevation were fitted in this ordination diagram (Fig. 3).

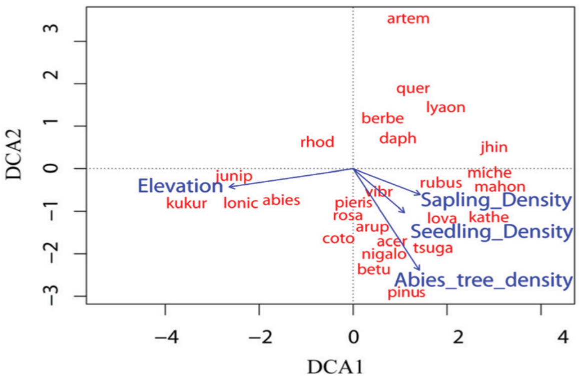

Fig. 3: Ordination diagram obtained by Detrended Correspondence Analyses (DCA)

Density of all species along with elevation (Fig. 2) and importance percentage of the *Abies* is shown (Fig. 4).

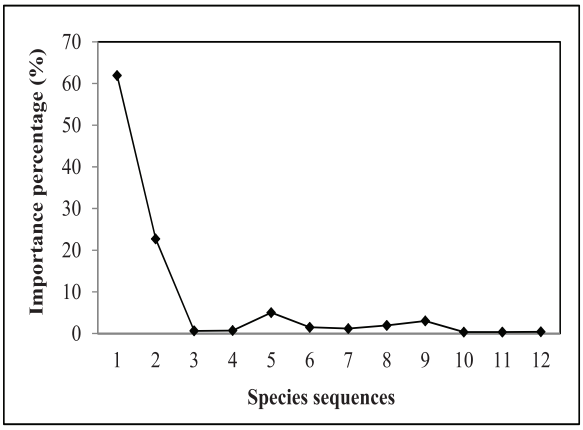

Fig. 4: Diversity-dominance curve for the tree species of the mixed *Abies spectabilis* forest

The bi-plot 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 relation of the different community attributes with environmental variables is explained (Fig. 5-14).

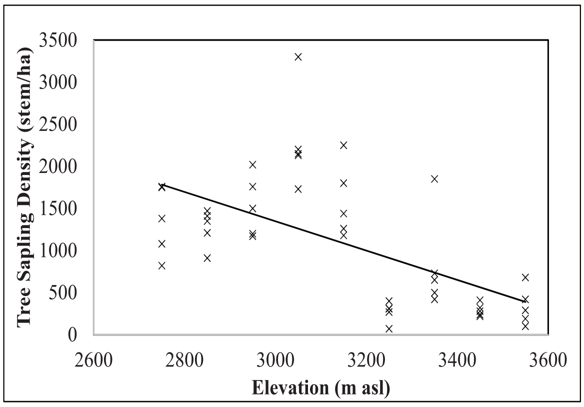

Fig. 5: Total Sapling density along with elevation gradient

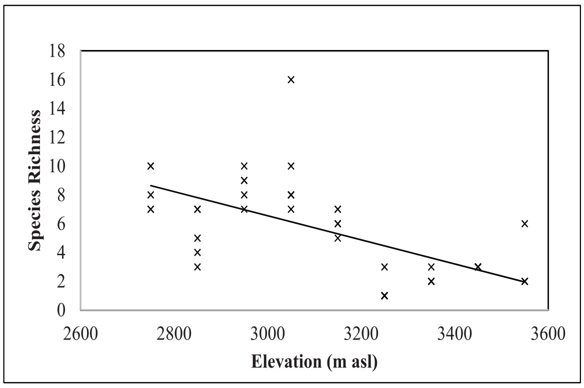

Fig. 6: Species richness along with elevation gradient

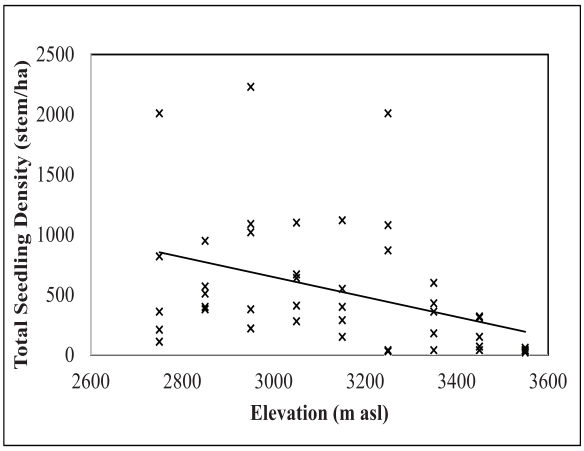

Fig. 7: Seedling densities of *Abies* along with elevation

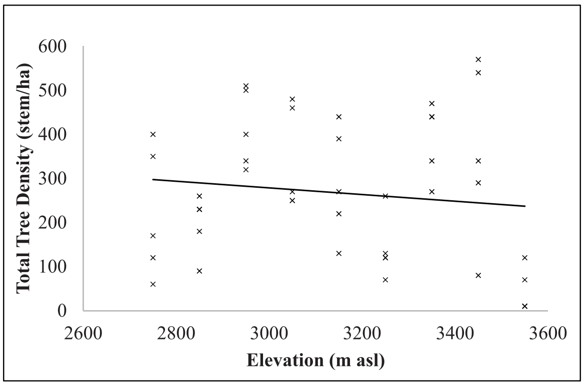

Fig. 8: Total tree density along with elevation

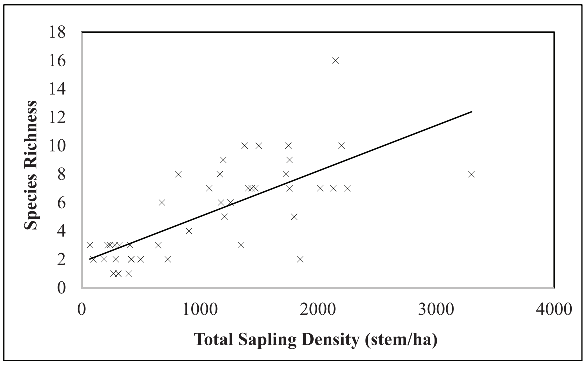

Fig. 9: Relationship between species richness and total sapling density

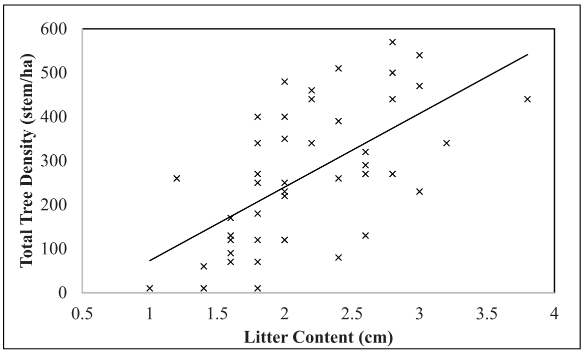

Fig. 10: Relationship between total tree density and litter content

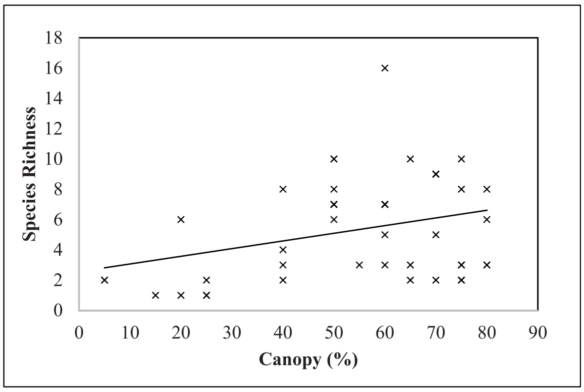

Fig. 11: Species richness *of Abies* tree along with canopy

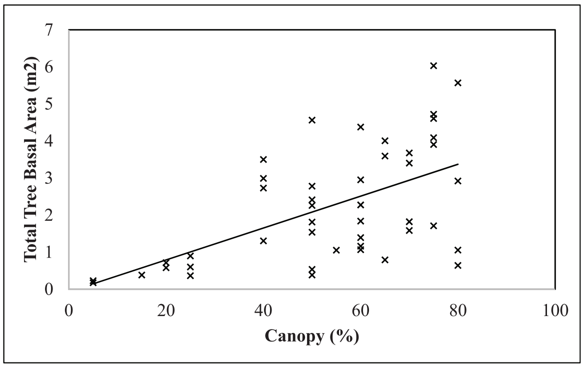

Fig. 12: Total tree basal area *vs* canopy (%)

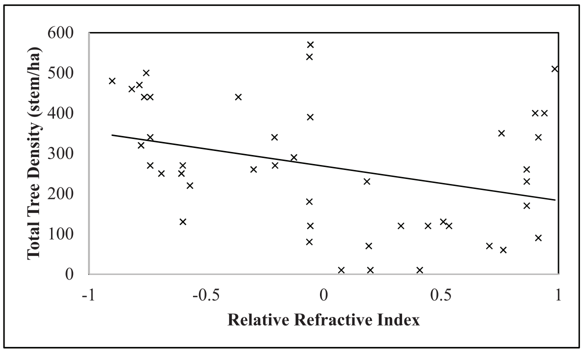

Fig. 13: Total tree density *vs* Relative Refractive Index

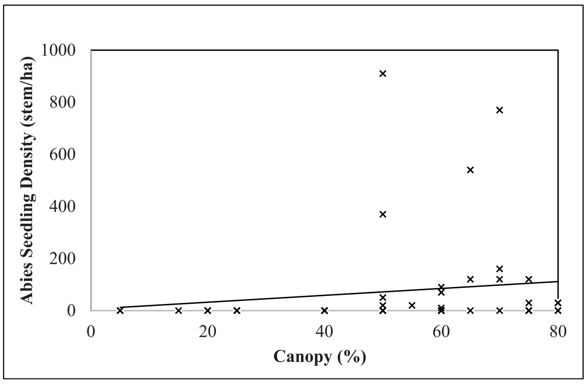

Fig 14: Seedling density of *Abies spectabilis vs* canopy (%)

Elevation appeared to be the important environmental factor that affected the community attributes of the study forest. The total sapling density, seedling density of *Abies* and total density of trees decreased along with elevation. Seedling density, population of *Abies* tree and total basal area were increased along with the canopy (Figs. 11, 12 and 14). Total tree density increased with litter content but decreased with relative refractive index.

Density of seedlings of *A. spectabilis* declined with increasing height classes. There was gradual decline in density from first to last height class (Fig. 14). Density-diameter curve for all tree species combined was nearly reverse J-shaped indicating continuous regeneration (Fig. 15). Also it was observed that medium girth trees were used by people mainly for construction and firewood.

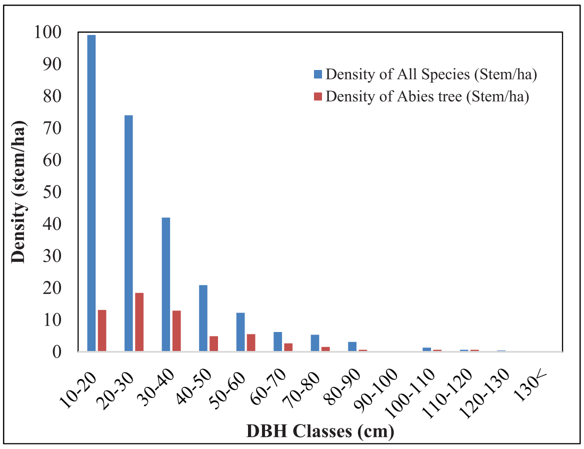

Fig. 15: Density-diameter curve for *Abies spectabilis* alone as well as all tree species of the forest

Correlation test was done among population density and environmental variables to evaluate the relationship of various variables with species richness. Summary of environmental correlation matrix among the explanatory variables are shown (Annex- 1). 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. Seedling population of *A. spectabilis* showed significant positive correlation with the tree population (*r* = 0. 73) and saplings of *Abies* (*r* = 0.37). The number of seedlings was higher where the trees and saplings 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. The summary of DCA results showed that axis-I have a high Eigen value (0.46) and was correlated with elevation (Table 1). 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 (Table 1).

Discussion

The average tree density showed that the number decreases along with elevation within the range of study area which is also similar to the observation (Shrestha *et al*., 2007) in the trans- Himalayan tree line and in Eastern Himalayan (Bhuju *et al*. 2010). In upper Manang mixed forest, it was found that the total tree density ranged from 375 plants/ha at altitude 3800–4000 m to 845 plants/ha at 3300-3500 m. In mixed *A. spectabilis* forest of Manang, the total tree density was found 900 stem/ha (Acharya, 2004). Whereas total tree density was found 1274 stem/ha in sub alpine *A. mariesii* forest of central Japan (Mori and Takeda 2005) and 759 stem/ha in sub-alpine coniferous forest on Changbai Mountain, China (Qi- Jing, 1997). Tree density (267.1 stem/ha) in present study was lower than tree density 445 stem/ha (Bhuju *et al*., 2010) from tree line of Sagarmatha

National Park. Lower value of total tree density in the study site might be due to logging and high disturbance due to grazing and trampling. Also, the study area was near to trekking route so it might be the impact of tourism. In general discussion with local people, it was found that the rate of consumption of fire wood was high during the winter season and months of September to November which is the most favourable time for visitors. It was also visualized that the use of *Abies* as timber tree was common in hotel area than other regions.

In the present study, tree density of *A. spectabilis* was found less (76.89 stems/ha) than previous studies (Acharya, 2004; Scholl and Taylor, 2006). This showed that the study forest was not pure *A. spectabilis* forest and co dominant by observing.

Density-diameter curve for all tree species combined was nearly reverse J-shaped, indicating sustainable regeneration. But, the curve of *A. spectabilis* alone deviated slightly from the typical reverse J-shape. Reverse J- shaped density-diameter curve is the indication of unsustainable regeneration (Vetaas, 2000). Similar trend was reported by (Acharya, 2004; Shrestha *et al*., 2007; Ghimire *et al.,* 2008; Qiaoying *et al.,* 2008). Some observation (Bhuju *et al.,* 2010) found bell shaped diameter class distribution of *A. spectabilis* and inversed J shaped distribution of *B. utilis* at tree line (Eastern Nepal). The same study recorded 99 cm DBH of *A. spectabilis* whereas the highest DBH of *A. spectabilis* was 120 cm in present study. The result indicated that density of the trees having larger girth size was higher than that of the smaller girth size in whole mixed *A. spectabilis* forest. *A. spectabilis* curve slightly fluctuated from the typical reverse J-shape which did not indicate sustainable regeneration of co-dominant species *A. spectabilis*. However, sustainability of whole forest might be of further research interest.

Lower sapling density (28. 44 stems/ha) in the present forest might be due to higher seedling mortality because of several disturbances. Mechanical damage to seedlings of *A. spectabilis* due to intense grazing and trampling may lead to high seedling mortality. Seedling density of *Abies* also declined with increasing canopy (Fig. 14). Seedling generally preferred high soil moisture, moderate pH and moderate canopy cover. As *A. spectabilis* is shade tolerant species it can regenerate under a densely closed canopy (Qi-Jing, 1997). High frequency of saplings of *A. spectabilis* under dense canopy has been also inferred in mixed *Betula utilis-A. spectabilis* forest of Manang (Shrestha *et al.,* 2007). However, in the present study, frequency (28.89%) of saplings was 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 sapling is higher than seedling indicating recent regeneration. There was significant influence of grazing on tree seedling species composition (Darabant *et al*., 2007). Intensity of grazing and trampling was relatively medium (2.26 out of 3) in the studied forest.

The study area was also slightly acidic in nature with pH ranging from 4.2 to 5.93. Most conifer foliage contains acid substances and after decomposition of leaves it will keep soil slightly acidic or neutral. 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). Similar results were found in the alpine forest of central Nepal (Ghimire and Lekhak 2007; Shrestha *et al*., 2007; Tiwari 2010) and Garhwal Himalaya, India (Kumar *et al.,* 2004; Mehraj *et al.,* 2010). Both soil organic carbon (OC) and nitrogen (N) content (3.06% and 0.27% respectively) 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).

The study forest can be considered as the mixed forest. The previous similar study on *A. pindrow* has shown as dominant species (Importants Percentage=16.44%) and *Betula utilis* as co-dominant species (IP=16.10%) in north-western slope of mixed *Abies-Betula* forest of Indian Himalaya (Gairola *et al.,* 2008). However, we found *A. spectabilis* as co-dominent species after *Rhododendron arboreum* (With IP 22.72% and 61.91%, respectively).

The trend of average total basal area of study area showed similarities with previous studies, (Qi-Jing 1997; Scholl and Taylor 2006; Bhuju *et al.* 2010). 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 and 1.21 respectively in the present study forest. The result was compared with previous studies (Liyun *et al*., 2006; Ghimire *et al*., 2008; Jiangming *et al.,* 2008; Sharma *et al*., 2009; Tiwari, 2010) where, species diversity in forest edge was higher than that in pure forest which was possibly caused by 'edge effect'. This is the effect that changes in population or community structures that occur at the boundary of two habitats. Species richness usually reduces along the vertical gradient and it is caused by the decrease of temperature (Qi-Jing, 1997).

The higher seedling and sapling distribution found were 910 stems/ha and 250 stems/ha at 3050 and 2950 m, respectively. In the previous studies (West *et al.,* 1981; Acharya, 2004; Diaci *et al*., 2005; Ghimire and Lekhak 2007; Tiwari 2010), the seedling density of *Abies* was found higher than that of sapling density which shows a normal demographic development. The differences in different attributes of *Abies* tree might be due to various geological circumstances, mostly temperature, rainfall and clamminess of study sites which we have considered here unvarying while comparing.

Conclusions

Abies spectabilis was the co-dominant species among trees after *Rhododendron arboreum* tree. The seedling density was higher than that of sapling density which shows a normal demographic development. Density-diameter curve for all tree species combined was nearly reverse J-shaped, indicating sustainable regeneration. But density-diameter curve for *A. spectabilis* was not continuous which did not show sustainable regeneration. So that the cutting of timber to build house and for firewood should be controlled by concerned Authority, Grazing pressure should be minimised at April-May during the period of seedling development and human pressure should be controlled. The BZUCs and BZUGs should be categorized as the forests and land use for conservation, community use and for grazing under the rules of the National Parks and Wildlife Conservation Act (NPWCA, 1973), the Himalayan National Park Regulations (HNPR, 1979) and the Buffer Zone Management Guidelines (BZMG, 1999) the community user groups should make the local people aware for sustainable use of forest products which can provide the legal basis for protection of the flora and fauna as well.

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Annex 1: Summary of environmental correlation matrix among the explanatory variables (n>100, P ≤ 0. 05, r ≥ |0. 195|) (*) indicate the level of significance at P ≤ 0. 05.

	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	-0.60	-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	0.40	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	0.00	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

Notes : Ele = Elevation, Spp = Species, ttD= Total tree density, tsaD = Total Sapling Density, tseD = Total Seedling Density, ttBA = Total tree Basal Area, AseD = Abies Seedling Density, AsaD = Abies sapling Density, Tre = tree, Sap= Sapling, Sed= seedling, C= Carbon, N=Nitrogen, Lop= Lopping, Log= Loging, Gra =Grazing, Lit = litter, cano= canopy, rri= Relative reflective ind