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Vegetation Dynamics in Treeline Ecotone of Langtang National Park, Central Nepal

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Abstract

A study was carried out at the treeline ecotone (3,730m-3,950m asl) of Langtang National Park in central Nepal with an aim to document the impact of climatic warming on ecological chracteristics. Three sampling sites were selected at Chaurikharka and Lauribina, where no serious anthropogenic pressure was noticed. The nearest meteorological station has records of climatic warming in recent years. Six tree species and three shrub species belonging to seven families were enumerated from the study plots. The average basal area for tree species was found to be 20.56 m^2 per ha while average tree density was found to be 734 trees per ha with *Abies spectabilis* as dominant species. The mean DBH (diameter at breast height) of tree species was found to be 15.8 cm (max. 115.5cm). Density of dead trees accounted 2 no. per ha with basal area 0.195m^2 per ha. Average sapling and seedling density of tree species per ha was observed to be 1,590 and 831 respectively. The average sapling and seedling density of *A. spectabilis* was 255 and 350 per ha respectively. Similarly, average shrub density (per ha) for the area was found to be 9,609 no/ha. The stand character showed that there was high level of recruitment of *A. spectabilis* in the recent years. The presence of sapling and seedling of *A. spectabilis* at higher altitude showing linear relationship with canopy coverage indicated prospects for a gradual and upward shift of *A. spectabilis* with increased temperature.

Key words: *Abies spectabilis*, regeneration, climate change, DBH

Introduction

Tree line, a life form boundary that limits regional tree growth irrespective of the species (Becker *et al.* 2007) and a sensitive biomonitor of past and recent climate change and variability (Kullman 1998), is ideally suited for climate change monitoring (Becker *et al.* 2007). Past studies on tree line have shown that population structures at tree line ecotones are good indicators of climate change, where trees often respond to climatic warming with increase in recruitment or tree-density, as well as upward advances in the tree line (Kullman 2002, Camarero & Gutiérrez 2004). As the location of northern hemisphere altitudinal and polar tree lines are much effected by heat deficiency, global warming is expected to cause tree lines to advance to higher elevations and more northerly latitudes (Grace *et al.* 2002).

Short term response of a year or less to climate change is reflected in individual trees, while medium-term response of some years to a few decades is mirrored in changing tree physiognomy (phenotypical response), tree-ring width and density, survival rate in seedlings and young trees, succession stage of the plant cover, etc. (Holtmeier & Broll 2005). Moreover, the age structure of a stand can provide a fairly accurate picture of temporal variations in the establishment rate i.e. a static age structure of living trees is the expression of change in the rate of tree recruitment and mortality over time (Harcombe 1987 cited in Wang *et al.* 2006)). However, literature on the impact of climate change on forest vegetation and their distribution in Nepal is scarce. An ecological study, thus, was proposed and carried out at the tree line ecotone of the Langtang

National Park (LNP) in central Nepal. The objective was to prepare baseline information on the tree line vegetation, their distribution pattern and regeneration of tree species for comparative studies.

Materials and Methods

Climate of study area

The meteorological station nearest to the study area of the LNP, was Kyanjing (3,920m asl) in Rasuwa district. Available data showed that average monthly total rainfall was maximum in August (172.76 mm) followed by July (171.14 mm) and the minimum was in December (2.57 mm). There was 0.163^0C per year increment in the winter minimum temperature and the increment was statistically significant($r=0.51$, $p=0.02$). Analysis of 20 years data from 1988 to 2007 showed mean monthly temperature of the hottest (July) and coldest (December) month was 9.5^0C and -0.1^0C, respectively.

Field survey and data collection

The field study was carried out during August and September in 2007 in three sites of tree line ecotone: (I) Chaurikharka, (II) between Chaurikharka and Lauribina, and (III) Lauribina of the LNP. The details of the plot locations are shown in Fig.1. The study sites were located on north and north-west aspect of the mountain, and the altitude ranged from 3,730m to 3,950m asl. The site had dense *Abies* forest with *Rhododendron* under-storey and above the tree line was rhododendron scrub.

Individuals of tree species were enumerated into three height classes: trees (> 2 m), saplings (0.5–2 m) and seedlings (< 0.5 m) following Wang *et al.* (2006) and Kullman (2007). Sampling was carried out in four rows: one at *Abies* tree line, one above the tree line, and two below the tree line, with each row at 50-m elevation intervals. Four plots (20m × 20 m) were established at each rows with first plot selected randomly from either side of the row of *Abies* limit. Second plot was selected systematically at 50m walking distance from the first plot and so on. Accordingly, four plots were also established next row at 30-50m contour difference from preceding and following rows. A total of 48 plots (20m×20 m), with 16 plots in the each site were established. The 20m x 20m plot nested with two subplots of 5m x 5m and 1m x 1m in two opposite corners was laid to study shrubs and sapling, and seedling, respectively.

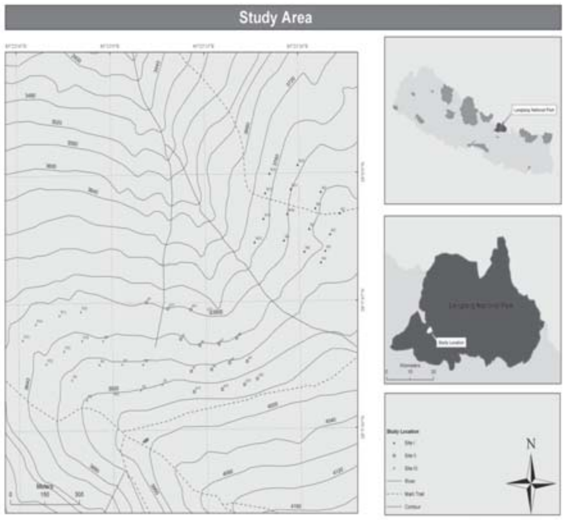


Fig. 1. Map showing study area and study sites

Data analysis

Data were analyzed using computer program MS Excel. The quantitative parameters viz., relative density, relative frequency, and relative basal area were calculated using standard formula (Ohsawa 1984).

Results and Discussion

Floral Composition and Stand Characteristics of Tree Species

Altogether 30 plants species were collected from the field survey at the three study sites: (I) Chaurikharka, (II) between Chaurikharka and Lauribina, and (III) Lauribina (Table1&3). They belonged to 23 families, 13 families were represented by one species each; the highest number of species (four) belonged to family Ericaceae followed by three species to family Compositeae. By habit, out of 30 species, six were tree, three shrubs, and 21 herbs. Six tree species recorded were *Abies spectabilis*, *Betula utilis*, *Juniperus recurva, Rhododendron campanulatum, Salix* sp. and *Sorbus microphylla* at site I i.e Churikharka. Sites II and III contained four tree species recorded in site I except *Juniperus recurva* and *Salix* sp.

In a study, Shrestha *et al.* (2007) recorded two tree species from treeline ecotone in Manang, trans-Himalaya of central Nepal, which is less than our observation from Himalayan treeline. Present studied tree species richness (six species) is equitable to the tree species richness (five species from Pangboche and Debuche) at tree line in Sagarmatha area of Eastern Himalaya of Nepal reported by Bhuju *et al.* (2010). The present study has recorded most of these species, except *Acer campbelli* and *R. campylocarpum*. Kharkwal *et al.* (2005) reported four tree species and 41 shrubs between 3600m and 3800m altitude in Central Himalaya (Kumaun area) of the India.

Table 1 presents various structural parameters of tree species in three sites. The basal area was found to be 20.18, 17.78 and 23.72 m^2 per ha in site I, II and III, respectively, with an average basal area 20.56 m^2 per ha. The total tree density ranged from 550 trees per hectare in site III to 954 trees per hectare in site II while average tree density for the area was found to be 734 trees per hectare. *Abies spectabilis* was most frequent tree species in sites II and III with an average frequency of 87.5% and 91.7% while *R. campanulatum* was most frequent tree species in site I (Freq. 62.5%). The *Salix* tree was least frequent species (Freq. 6.25%) and was only found in site I. The mean DBH of tree was 15.8 cm. Recorded highest DBH was 115.5cm for *A. spectabilis*. Similarly highest DBH of *B. utilis* and *J. recurva* was 50.0 cm and 90.4cm, respectively. Some dead or damaged trees were also recorded which accounted 2 trees per ha with basal area 0.22m^2 per ha in Chaurikharka and 2 trees per ha with basal area 0.7m^2/ha in Lauribina. In terms of Importance Value Index (IVI), *A. spectabilis* was the most important tree in site II and III and second most important species in site I.

Table 1. Structural parameters of tree species in three sites

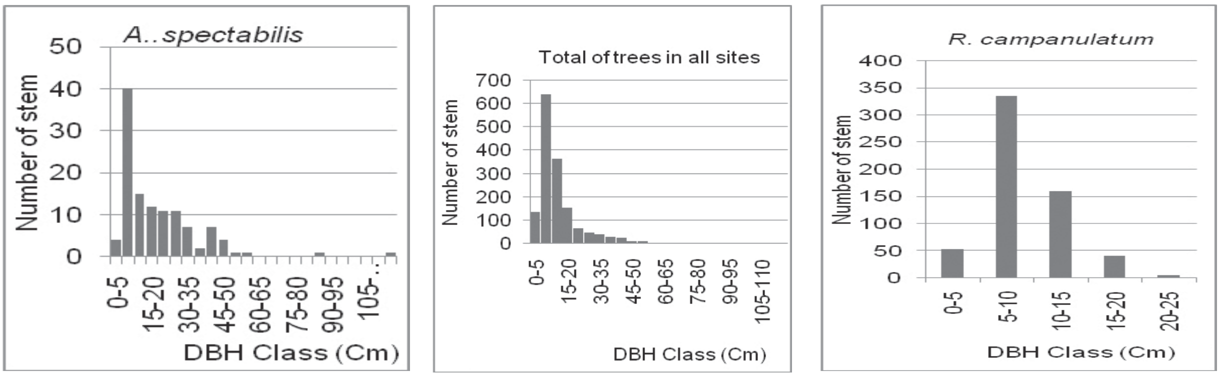
SN	Species	Basal Area		Stem Density		Frequency		DBH		IVI
Chaurikharka		m^2/ha	RBA (%)	per ha	RD (%)	F (%)	RF (%)	Mean (cm)	Max (cm)	
1	*Abies spectabilis*	9.83	48.72	172	24.76	62.5	26.3	18.4	115.5	99.7
2	*Rhododenderon campanulatum*	7.00	34.67	481	69.06	87.5	36.8	9.7	21.8	141
3	*Juniperus recurva*	2.84	14.05	34	4.93	43.75	18.4	14.2	90.4	37.4
4	*Sorbus microphylla*	0.12	1.9	5	0.67	18.75	7.89	15.8	24.5	10.5
5	*Betula utilis*	0.38	0.61	3	0.45	18.75	7.89	37.5	50	8.95
6	*Salix* sp.	0.01	0.04	2	0.22	6.25	2.63	8.5	8.5	2.89
	Total	20.18	100	697	100	237.5	100	17.3	115.5	300
1	dead *Betula utilis*	0.22	100	2	100	6.25	100	10.5	10.5	-
	dead Total	0.22	100	2	100	6.25	100	10.5	10.5	-
Between Chaurikharka and Lauribina										
1	*A. spectabilis*	9.40	52.8	354	37.1	87.5	29.8	17.2	72	95
2	*R. campanulatum*	5.32	29.9	423	44.3	87.5	29.8	11.2	29	74.5
3	*B. utilis*	2.38	13.4	131	13.7	62.5	21.3	20.3	40.8	39.3
4	*S. microphylla*	0.68	3.8	46	4.8	56.3	19.2	9.5	14.5	24.6
	Total	17.78	100	954	100	293.8	100	14.6	-	300
Lauribina										
1	*Abies spectabilis*	19.17	80.8	257	46.7	91.7	34.2	26.25	94	161.8
2	*Rhododenderon campanulatum*	2.39	10.1	233	42.4	66.66	25	8.17	20.2	77.4
3	*Betula utilis*	1.40	5.9	35	6.4	50.0	18.7	18.14	40.5	31.0
4	*Sorbus microphylla*	0.76	3.2	25	4.5	58.33	21.9	10.93	35	29.6
	Total	23.72	100	550	100	266.69	100	15.63	94	300
1	dead *Abies spectabilis*	0.17	100	2.1	100	6.25	100	32	32	-
	dead Total	0.17	100	2.1	100	6.25	100	32	32	-

Note: RBA= Relative Basal Area, RD= Relative Density, F=Frequency, RF= Relative Frequency, DBH= Diameter at Breast Height, IVI= Importance Value Index

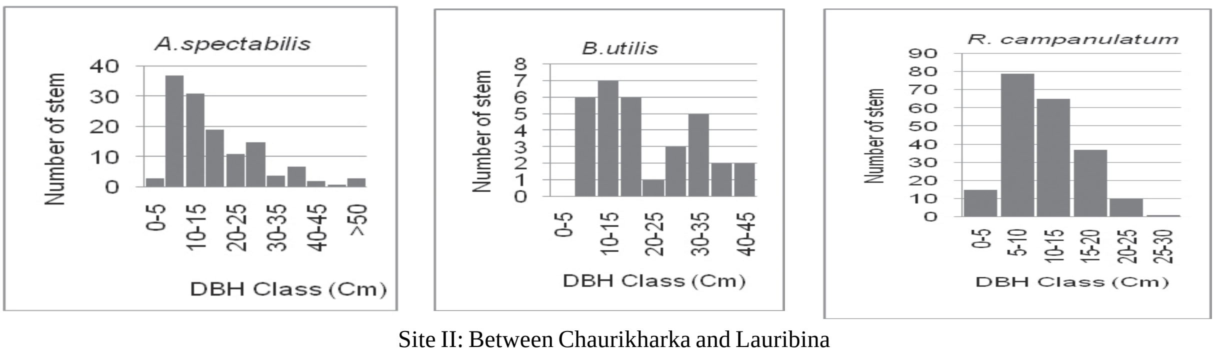
Tree density (734 stem per hectare) in present study was higher than tree density observed by Bhuju *et al*. (2010) from treeline of Sagarmatha National Park. Bhuju *et al*. (2010) recorded total basal area of 11.2m^2 ha^{-1} and a density of 445 stems ha^{-1}, from treeline and basal area of 18.6 m^{2}ha^{-1} and a density of 1,034 stems ha^{-1} from timberline region. In the present study, the higher tree density than that of eastern Himalaya may also be because of its lower elevation. The DBH (115.5cm) of *A. spectabilis* in present study was higher than that observed from other treeline regions of Nepal (e.g. Shrestha *et al.* 2007, Bhuju *et al.* 2010) which indicates continuous establishment of tree from long time back in this area. The basal area ratio at treeline ecotone in present study is less than the basal area ratio reported by Shrestha *et al.* (2007). From a study in trans- Himalayan treeline, Shrestha *et al.* (2007) reported *B. utilis* as dominant tree species in the north facing treeline. In a study from Annapurna range, Ghimire and Lekhak (2007) reported *B. utilis* as dominant tree above 3,800m belt and *Pinus wallichiana* and *A. spectabilis* as dominant trees in 3,500-3,800m belt. This study observed decrease of tree density with increase in altitude which is similar to the observation of Shrestha *et al.* (2007) in the trans-Himalayan treeline and Bhuju *et al.* (2010) in Eastern Himalayan treeline. In a study from Pisang of Annapurna conservation area, Acharya *et al.* (2007) reported the highest IVI of *P. wallichiana* followed by *A. spectabilis*.

Diameter Class Distribution of Trees

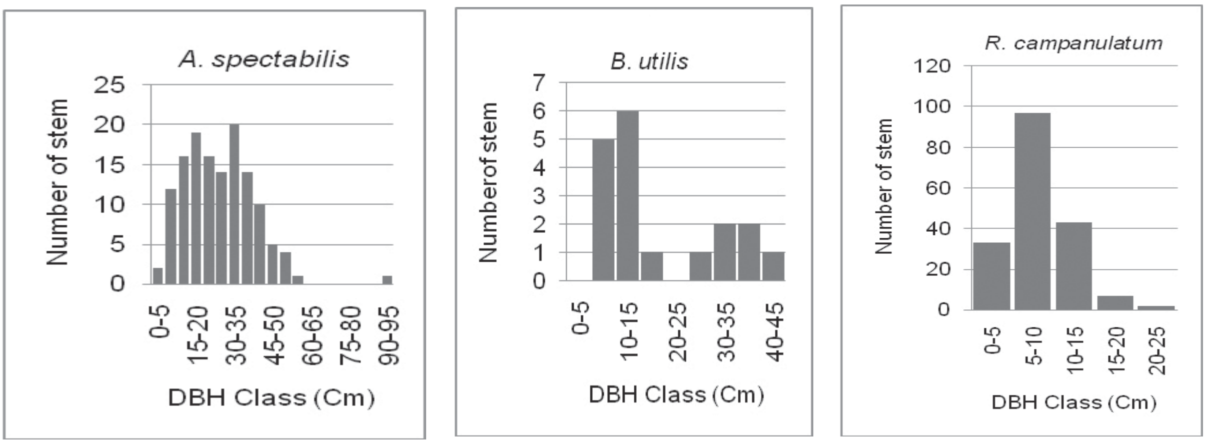
Fig.2. presents diameter class distribution of major tree species. The diameter class distribution of *A. spectabilis* was found an inverse J shaped in sites I and site II while bell shaped distribution in site III. Bimodal and bell shaped distribution of *B. utilis* was observed in both sites II and III while only few individuals were present in the site I. Inverse J shaped diameter class distribution was observed for *R. campanulatum* in all three sites. However, the trend is not continuous but shows gaps between the classes in individual species. Gaps in the diameter class-distribution indicate logging in the recent past or episodic recruitment of tree species. Site III (Lauribina) is situated near to the human settlement; gaps in distribution might be due to anthropogenic disturbances. Since, we took height as a criterion to separate tree individuals, observed low number of individuals in 0-5cm DBH class of most tree species may be due to that.



Site I: Churikharka



Site II: Between Chaurikharka and Lauribina



Site III: Lauribina

Fig.2. Diameter class distribution of major tree species

Regeneration of canopy dominants is commonly assessed by the distribution of size-classes measured as diameter at breast height (DBH) (West *et al.* 1981). There were some cut stumps in some plots of Lauribina site, which was reflected in bell shaped distribution of some species. The bimodal distribution might also be due to mixture of two kinds of sample population having two different mean. The diameter distribution of *A. spectabilis* at Lauribina site showed bell-shape curve which is not the indication of sustainable regeneration (Vetaas 2000) and it indicates some anthropogenic pressure or decreasing recruitment. Umans (1993) did not find successful regeneration of Himalay an silver fir (*A. spectabilis*) in lower subalpine zone of Nepalese Himalaya. In case of unsustainably regenerating forest the diameter distribution diagram shows a bell-shaped structure which means lack of young trees as well as old large tree. Ghimire and Lekhak (2007) found a total absence of higher girth class of *A. spectabilis* trees (above 45cm diameter) but present study recorded the diameter up to 115.5cm for same species. Similarly, from a study of high altitude forest, Bhuju *et al.* (2010) observed bell shaped diameter class distribution of *A. spectabilis* and inverse J shaped distribution of *B. utilis* at treeline (Pangboche) and Just reverse pattern of diameter distribution of these two species at timberline (Debuche). The same study recorded 99cm DBH of *A. spectabilis* and 63cm DBH of *B. utilis*.

Regeneration of tree species

Table 2 presents densities and frequency of seedling and sapling of tree species. Average per hectare sapling density of tree species was observed to be 1590 with 3045, 595 and 1130 saplings per hectare at sites I, II and III, respectively. Average sapling density of *Abies spectabilis* was found to be 255 saplings/ha and ranged from 228 in Lauribina to 275 saplings/ha in Chaurikharka site. Saplings of *B. utilis* and *S. microphylla* were absent in Site I while that of *J. recurva* were absent in site II. Table 2 shows high heterogeneity in sapling densities of tree species. Similarly, average seedling density of tree species was observed to be 831, with 614, 619 and 1261 seedlings/ha for sites I, II and III, respectively. There was a high variation in the seedling densities among different trees as well as among sites. Seedlings of *B. utilis* were absent in Site I while that of *J. recurva* were absent in site II. Average per hectare seedling density of *A. spectabilis* was found to be 350 which ranged from 256 in Lauribina to 479 in between Chaurikharka and Lauribina site. Aspect of the area might be a reason in the variation in the seedling distribution, besides the tree canopy coverage. In some species seedling density of tree species was higher than that of saplings while in some species vice versa was true. In case of *A. spectabilis* the seedling density was higher than that of sapling density in all three sites while other species had no such specific trend.

Table 2. Status of seedling and sapling in study area

SN	Name of Species	Sapling Density (saplings/ha)				Seedling Density (seedlings/ha)			
		I	II	III	Average	I	II	III	Average
1	*Abies spectabilis*	272	265	228	255	315	479	256	350
2	*Betula utilis*	0	6	106	37	0	21	39	20
3	*Juniperus recurva*	198	0	16	71	53	0	91	48
4	*Rhododendron campanulatum*	2575	288	694	1186	238	27	839	368
5	*Sorbus microphylla*	0	36	86	41	8	92	36	45
	Total	3045	595	1130	1590	614	619	1261	831

Sapling and seedling distribution of tree species was spatially heterogeneous. Spatial heterogeneity in sapling and seedling distribution may be determined by light availability caused by canopy cover, inability of seedling to grow in its upper distribution limit, unavailability of seeds, etc. Total seedling density of all tree species was lower than that of sapling density (Table 4), which is not a normal demographic development. However, there is variation in seedling and sapling density among tree species, and average seedling density (330 per ha) of *A. spectabilis* was higher than that of sapling (255 per ha), which is a normal demographic development (West *et al.* 1981), and is similar to the result of Ghimire and Lekhak (2007). The seedling and sapling ratio of tree species shows higher proportion of sapling than seedling in most species except for *A. spectabilis* for which seedling is higher than sapling indicating recent regeneration.

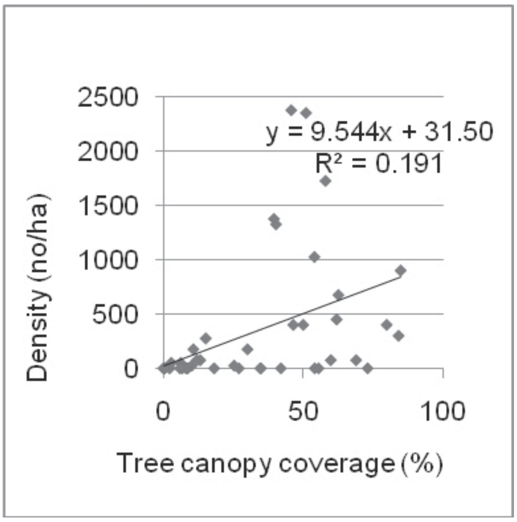


Fig. 3. Relationship between seedling density and tree canopy coverage.

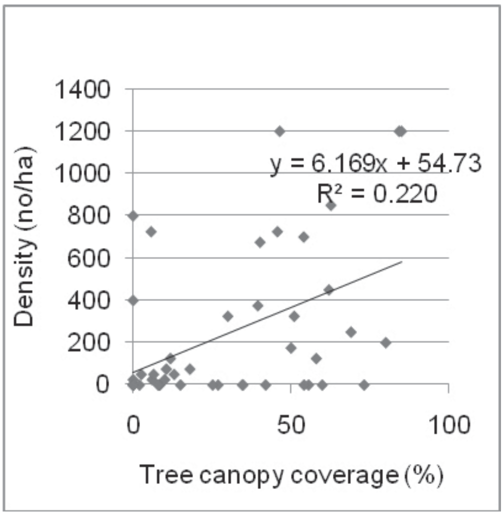


Fig.4. Relationship between sapling density and tree canopy coverage.

Main focus of the study was in *A. spectabilis*. Hence, the relationship between seedling density and tree canopy cover as well as between sapling density of *A. spectabilis* and tree canopy cover were analyzed and Figs.3 and 4 present it. Irrespective of sites, in present study there was positive linear relationship between seedling density and tree canopy cover which was statistically significant (r=0.44, P=0.002) while the linear relationship between sapling and tree canopy was also significant (r=0.47, P=0.001). This shows those saplings are more sensitive with tree canopy cover because it might provide shelter against snowfall damage. For seedling the shrub may provide shelter during harsh period. Koirala (2004) found seedling-sapling density lower in undisturbed and mature forest which had closed canopy and Shrestha *et al.* (2007) reported heterogeneous distribution of seedling and sapling linked with canopy cover.

Quantitative study of shrubs

Table 3 presents various floral composition and structural parameters of shrub species in the sites. Altogether three shrub species were recorded viz. *Berberis* sp., *Rhododendron anthopogan* and *R. lepidotum* at site I i.e Churikharka and site III i.e. Lauribina. The site II contained only two species namely: *R. anthopogan* and *R. lepidotum*. The total shrub density ranged from 6,363 in site I to 11,288 per ha in site III while average shrub density for the area was found to be 9,609 per ha. *R. lepidotum* was most frequent shrub species in sites II and III with an average frequency of 75% and 82% while *Berberis* sp. was least frequent shrub species in the study area. Average canopy coverage of shrub species was observed to be 32.6% of the ground or plots area and which ranged from 14.4% to 66.1%.

Table 3. Floral composition and structural parameters of shrub species in the study sites

	SN	Name of Species	Freq. (%)	RF (%)	Density (stem/ha)	RD (%)	Crown Cov. (%)	RC (%)	IVI
Site I	1	*Rhododendron anthopogan*	40.6	31.8	2,100	33	5.8	40.5	105
	2	*Rhododendron lepidotum*	37.5	29.3	1,475	23.2	3.7	25.5	78
	3	*Berberis* sp.	50	39	2,788	43.8	4.9	34	117
		Total	128	100	6,363	100	14.4	100	
Site II	1	*R. anthopogan*	75	31.6	6775	*61*	*12.4*	71.3	163.5
	2	*R. lepidotum*	75	31.6	4400	*39*	*5.0*	28.7	99.7
		Total	150	63.2	11175	99.9	*17.4*	100	
Site III	1	*R. anthopogan*	78	42	*7475*	66.2	34.6	*52.4*	160.6
	2	*R. lepidotum*	82	46	*2850*	25.2	28.6	*43.3*	114.5
	3	*Berberis* sp.	22	12	*962.5*	8.5	2.9	*4.32*	24.8
		Total	184	100	*11288*	100	66.1	*100*	

Note: RF= Relative Frequency, RD= Relative Density, RC= Relative Cover, IVI= Importance Value Index

The studied area was less rich in the shrub species in comparison to other similar study (eg. Kharkwal *et al*. 2005). *Berberis* is an unpalatable species. The dominance of this species in some site indicates this site might be under the pressure of cattle grazing. In a study conducted in Khumbu region, Buffa *et al.* (1998) reported that the overgrazed areas are colonized by unpalatable plants like *Cotoneaster* and *Berberis*. In a study from Uttaranchal, Central Himalaya, India, Ram *et al.* (2004) found total shrubs and herbs richness significantly decreased with increasing tree cover. Although there is no severe direct human disturbance in the study site, other disturbance like grazing, trampling etc were present which may have adverse effect in the forest structure and species richness of this area. Grazing was present in upper plots of site I and III. In upper part of study area where grazing and trampling was seen, the sapling and seedling of conifer was lower than broad leaved *Rhododendron*. Similarly, Roder *et al.* (2002) reported that the removal of herbaceous biomass by grazing enhance regeneration of conifer species, reduce damage done by small rodents and grazing diminishes the number and the density of broad leaved species. Human trampling also contributes in species richness and diversity but it also affects the succession through soil compaction (Bhuju & Ohsawa 1998).

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