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Research article

Assessment of forest structure and woody plant regeneration on ridge tops at upper Bhagirathi basin in Garhwal Himalaya

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Abstract: Mechanism to maintain species coexistence in ridge top due to drastic climatic variation could be assessed by their forest structure and composition studies. Variations in forest composition, structure and their regeneration status are described here for four different ridge top sites of the Garhwal Himalaya. A total of 2439 individuals were recorded in the study area which belonged to 17 tree species in 16 genus and 9 families. The most abundant family was *Pinaceae* whereas Ericaceae and Rosaceae were found as co-dominant families. Simpson dominance value was highest on Sukhee top (0.84), moderate in Harshil (0.76) whereas lowest in Raithal (0.65). The total stem density was highest (710 stems ha^{-1}) at the Harshil and lowest (552 stems ha^{-1}) at the Sukhee top, and for total basal cover, the highest value (92.07 m^{2}.ha^{-1}) was recorded in Dharali whereas the lowest value (75.18 m^{2}.ha^{-1}) was found at Harshil ridge top. Importance Value Index showed that *Abies spectabilis, Betula utilis, Cedrus deodara, Pinus wallichiana*, *Acer caesium* and *Quercus semecarpifolia* are the dominant species of the ridge tops. *Taxus baccata, Acer acuminatum, Aesculus indica, Juglans regia, Ilex dipyrena* and *Sorbus cuspidata* were reported with poor regeneration status. The study seeks to understand the current forest composition of the ridge top but also may be helpful in predicting their adaptation to the climatic changes.
Keywords: Importance value index - Phyto-sociology - Ridge top - Species richness.

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INTRODUCTION

Numerous studies provide evidence for the ecological responses to recent climate change (Rosenzweig *et al*. 2007). Climate-induced species' range shifts have been reported along altitudinal (Cannone *et al*. 2007, Pauli *et al*. 2007, Holzinger *et al*. 2008) and latitudinal gradients (Lesica & McCune 2004, Walther *et al*. 2005, Lemoine *et al*. 2007). However, again not all the species seem equally responsive. It is expected that changing climate may shift the vegetation towards the ridge tops which may change the composition of the forests in near future (Singh *et al*. 2012). The ridge tops (having uniform environmental conditions) are the proper places, where the effects of climate change can be compared and monitored to predict the future migration of species. As high altitudinal vegetation are directly influenced by global warming (Korner 2003) so these habitats are therefore considered very sensitive to climatic change (Theurillat & Guisan 2001). Composition of vegetation and its analysis on ridge tops can effectively predict the influence of climate change on migration of woody species. The forest vegetation is positively correlated to changes in microenvironments, which are variable on different slope and in aspects. Plant life at high elevation is mostly governed by abiotic factors like temperature and snow fall so ridge top vegetation composition greatly affected by environmental factors (Kammer & Mohl 2002). Regeneration is a key process deciding the floristic composition of the community. It refers to recruitment, survival and growth of seedlings or sprouts (Lalfakawma 2010). The wealth of forest and the future composition of the forests depend on the potential regenerative status of tree species within a forest stand in space and time (Henle *et al*. 2004). Regeneration depends on the ability of a species to initiate new seedling and sapling; survival and then the ability of seedling and sapling to grow. Presence of sufficient number of seedlings, saplings, and young trees in a given population indicate a successful regeneration (Saxena & Singh 1984). Forest health and viability is observed by population structure like presence of sufficient number of seedlings, saplings and young trees in a given population (Pokhriyal *et al*. 2010) and the number of seedling of any species can be considered as the regeneration potential of that species (Negi & Nautiyal 2005). The density of species

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regeneration is expected to vary spatially due to forest structure and phyto-geographical condition (Ward *et al*. 2006). A successful regeneration is indicated by. Natural regeneration is a central component for tropical forest ecosystem dynamics (Getachew *et al*. 2010) and is essential for preservation and maintenance of biodiversity (Rahman *et al*. 2011). Forest phytosociological assessment is very helpful to understand the status of tree population, regeneration and diversity for conservation purposes (Bajpai *et al*. 2012, Mishra *et al*. 2013a). In forest management, regeneration study show current status and hints the future of any forest (Mishra *et al*. 2013b). Climate has a large influence on plant recruitment (Adler & Lambers 2008), whereas; regeneration patterns of species population can address climate change by adaptive evolution or by migrating association to survive in their favourable climate. It is need of the time to understand evolution and associated migration potential of different life forms and their adaption to climate change and survival ship (Woodward & Kelly 2008), as forests are greatly affected by changes in climate water availability and temperature (Breckle 2002). Forest composition reflects population structure and deciding the regeneration potential of tree species. Although several studies on the structure of plant communities, and productivity on various aspects of temperate Himalayan forests have been carried out by numerous workers but ridge top forest structure and regeneration still needs to be evaluated. In Garhwal Himalayan region, fragmentary and scanty descriptions are available on the impact of Climate Change on vegetation and species migration. However, almost nothing is known about the response of forest ecosystems to warming temperatures due to lack of base line data from ridge top areas. Keeping in view the aforesaid facts, the present study was undertaken to assess the woody plant diversity, species composition and regeneration status on ridge top in Garhwal Himalaya to assess impact of climate change and species migration evaluation.

MATERIAL AND METHODS

Study area

In this study, we had selected four undisturbed ridge tops *viz.*, Raithal, Dharali, Sukhee top and Harshil (> 2500 m above sea level (asl)) in Uttarkashi district of Garhwal Himalaya, Uttarakhand, India (Fig. 1). Detail

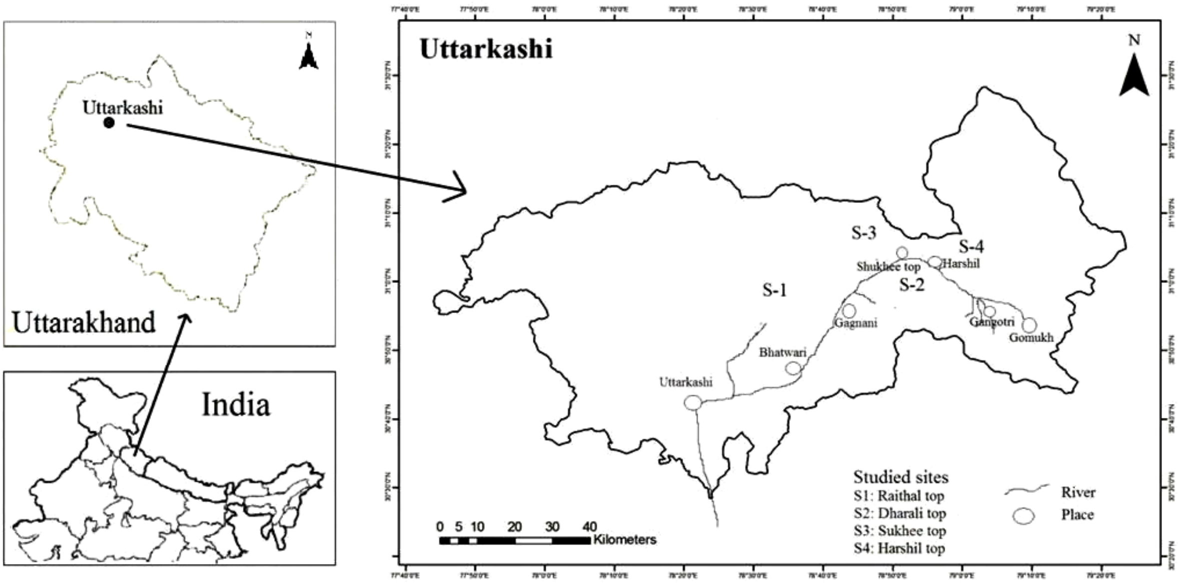

Figure 1. Map of the study area (District Uttarkashi, Uttarakhand) with locations of the ridge tops sites being studied marked as: S1-Raithal top; S2-Dharali top; S3-Sukhee top; S4-Harshil top.

study of ridge tops location and dominant species composition shown in table 1. The ridge top selected had nearly similar type of edaphic-climatic conditions. The district lies in the upper catchment of two great rivers of India *viz.*, Ganges (called Bhagirathi towards upstream) and the Yamuna. The study area experienced a temperate monsoon climate with a mean annual rainfall of 2000 mm and three main distinct seasons in a year *i.e.*, cool and relatively dry winter (December to March); the warm and dry summer (mid-April to June); and a warm and wet period (July to mid-September) called as the monsoon or rainy season. Frost is common during winter season, while the higher elevations experience heavy spells of snowfall, which may persist up to April–May in shady locations. Mean minimum monthly temperature ranged from 7.12°C (Jan) to 23.20°C (Jul) and mean maximum monthly temperature ranged from 17.56°C (Jan) to 33.35°C (Jul) (Suyal *et al*. 2010). The area is characterized by undulating topography with gentle slopes on Northern, North eastern and North western faces and somewhat steep slopes on Southern and South western directions. The soil types found in the region are brown and black forest soils and podozolic soils. Soils are generally gravelly and large boulders are common in the area. Numerous high ridges, deep gorges and precipitous cliffs, rocky crates and narrow valleys are part of the topography of the region. Geologically, the rocks were complex mixture of mainly sedimentary, low grade metamorphosed with sequence capped by crystalline nappe (Valdiya 1980).

Table 1. Description of study sites location, distribution and dominant woody plant species in Bhagirathi Basin, Garhwal Himalaya.

Study site	Altitude (Above Sea Level)	Latitude	Longitude	Dominant tree species
Raithal	2962-3523 m	078°34' 55"-078°32' 53"	30°48'58"-30°50'48"	*Q. semecarpifolia*
Dharali	2740-3677 m	078°47' 35"-078°46' 31"	31°01'04"-31°03'02"	*A. spectabilis, C. deodara*
Sukhee top	2814-3222 m	078°43' 19"-078°43'26"	31°00'10"-31°59'57"	*P. wallichiana, A. spectabilis*
Harshil	2730-3460 m	078°44' 11"-078°44'03"	31°01'31"-31°01'18"	*A. spectabilis , B. utilis*

Phytosociological study

Phytosociological parameters were studied by laying out 10 permanent sample plots of .01 ha size for trees on the ridge top in each studied site. The data regarding regeneration status of sapling and seedling was collected by laying four quadrat of 5×5 m and eight quadrats of 1×1 m respectively. The size and number of quadrat were standardized using the species area curve (Misra 1968). Voucher specimens of plant species were collected from studied forests and identified with the help of Flora of Gangotri National Park (Pusalkar & Singh 2012) and herbarium of H.N.B. Garhwal University, Srinagar. Important community parameters such as frequency, density, abundance, basal area and importance value index (IVI) of all the plant species were worked out by following Misra (1968) and Muller–Dombois & Ellenberg (1974). The tree species diversity index (H') was determined by using Shannon Wiener information function H ($H = -\Sigma$ pi ln pi; where, pi= ni/N; and ni = number of each species, N= total number of all species) (Shannon & Wiener 1963). The dominance index was calculated by Simpson's index (1949) through the formula ($Cd = \Sigma (ni/N)^2$) (Simpson 1949). Hill equation use to calculate Hill diversity index N_0, N_1 & N_2 (Hill 1973).

Mean stem density (density/100 m^2) of tree, sapling and seedling were considered to calculate regeneration status. We follow (Uma Shankar 2001) to calculate regeneration status with in different categories of tree life form stages.

RESULTS AND DISCUSSION

On the basis of phytosociological study overall woody plant species richness was observed to be highest with 11 species in Sukhee top, whereas, lowest 6 species in Harshil. The mean stand stem density was 613 stem ha^{-1} (which ranged between 552–710 stem ha^{-1}) and mean value of Total Basal Area (TBA) was 84.37 $m^2.ha^{-1}$ (which ranged from 75.18–92.07 $m^2.ha^{-1}$) which is quite similar to Pandey (2001) who reported stem density as 792–1111 stem ha^{-1} and TBC 56–126 $m^2.ha^{-1}$ from Garhwal Himalaya whereas Gairola *et al.* (2011) reported high tree girth ranging between 84.25 to 35.08 $m^2.ha^{-1}$ and low total stem density (990–1470 stem ha^{-1}) from moist temperate forest in the Garhwal region. A monotonic decline in the number of species with increasing elevation has often been considered a general pattern (Brown 1988, Stevens 1992). Therefore, limitation of species in hot spot area show the high altitude effect and almost similar results 17 species richness of study on ridge site of Garhwal Himalaya (Rawat & Chandra 2014). A total of 2439 individuals were recorded in the study area which belonged to 17 tree species in 16 genus and 9 families. The most abundant family was Pinaceae with 6 species whereas Ericaceae and Rosaceae were co-dominant families represented by 2 species each. Forests in the study area were mature high girth values as they were undisturbed. According to Saxena *et al*. (1978) trees with higher girth point out the best presentation of a species in a particular environmental setup whereas lower girth either separate the chance occurrence of the species in the area or showed presence of the biotic disturbances in the past. Simpson dominance index was highest in Sukhee top (0.84), moderate in Harshil (0.76) whereas; lowest in Raithal (0.65). Along the altitude, the geographic and climatic conditions change sharply (Kharkwal *et al*. 2005). The dominance values in this study are much higher than of 0.31 to 0.42 (Mishra *et al*. 2000) and 0.11 to 0.93 (Tiwari & Singh 1985) which were reported from different parts of Uttarakhand Himalaya. Sorensen similarity value was higher in Dharali-Harshil whereas lowest similarity was found in Raithal-Harshil (Table 2). Raithal forest was dominated by *Quercus semecarpifolia* (IVI 167.33), Sukhee top forests dominated by *Pinus wallichiana* (IVI 86.15) whereas Dharali and Harshil were similarly dominated by *Betula utilis, Abies spectabilis and Pinus wallichiana.* Importance value index of most common dominant species of four forest sites are depicted in figure 2, which shows *Abies spectabilis*, *Betula utilis*, *Cedrus deodara*, *Pinus wallichiana*, *Acer caesium* and *Quercus semecarpifolia* are the main dominated forest species

Table 2. Phytosociological description of ridge top composition of four different sites in Bhagirathi Basin.

S. N.	Studied parameters	Raithal	Dharali	Sukhee top	Harshil
1	Studied qua	20	28	24	16
2	Covered Area (ha.)	0.5	0.7	0.6	0.4
3	Species richness	8	8	11	6
4	Density (stem ha^{-1})	552	634	565	710
5	TBC ($m^2.ha^{-1}$)	84.32	92.07	89.9	75.18
6	Simpson Index	0.65	0.78	0.84	0.76
7	Shannon Index	1.47	1.66	2.07	1.50
8	Hill Index				
	H0	8	8	11	6
	H1	4.35	5.26	7.92	4.48
	H2	1.54	1.28	1.19	1.54
9	Jaccard Similarity				
	Raithal	1.00	0.33	0.18	0.27
	Dharali			0.46	0.75
	Sukhee Top				0.54
	Harshil				1.00

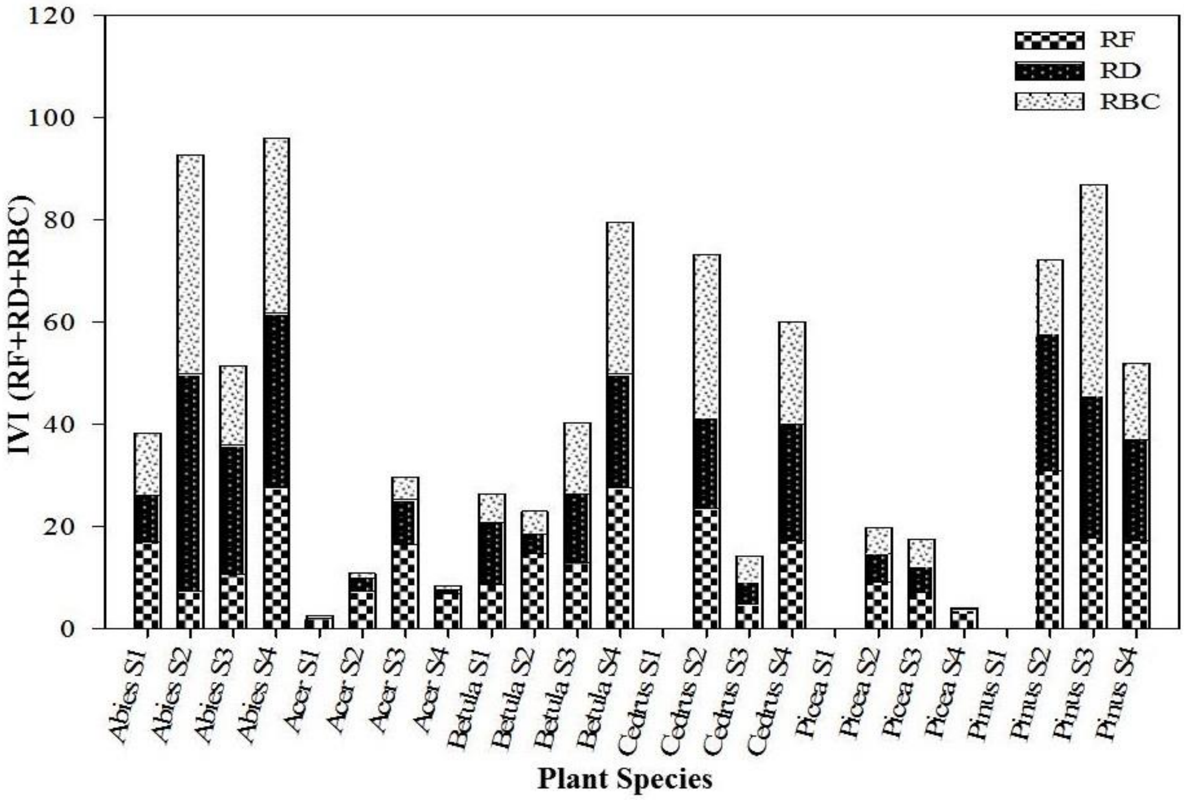

Figure 2. Important Value Index of most common dominant tree species of the ridge tops.

which survived and adopted themselves in ridge top area. High frequent distribution on ridge top was shown by species *viz*., *Quercus semecarpifolia* in Raithal, *Pinus wallichiana* and *Cedrus deodara* in Dharali, *Acer caesium* in Sukhee top whereas *Abies spectabilis* and *Betula utilis*. Details of forest phytosociological attribute frequency, density (stem ha^{-1}), TBC ($m^2.h^{-1}$) and importance value index of different ridge tops are shown in table 3.

Ridge top population structure

Population structure and regeneration status of tree species in terms of proportions of seedlings, saplings and adults varied greatly (Table 4). The tree density and species richness in different diameter classes showed a reverse J-shaped pattern on the ridge tops, whereas, on Sukhee top forest DBH (Diameter at breast height) class density pattern was bell shaped (Fig. 3 & 4). Shrestha *et al*. (2007) and Ghimire & Lekhak (2007) have already defined such shape size-class distribution in Himalayan region. *Abies spectabilis* followed by *Cedrus deodara* (at almost 3 sites), *Betula utilis*, *Picea smithiana* and *Quercus semecarpifolia* showed satisfactory regeneration status in almost all sites (Table 4), showing their wide adaptability and tolerance to the changing climatic conditions. However *Acer caesium* was reported in non-recruiting phase in site 1 (Raithal) and site 4 (Harshil). Other species with similar trends were *Taxus baccata*, *Juglans regia*, *Acer acuminatum*, *Sorbus cuspidata*, *Aesculus indica* and *Ilex dipyrena*.

Table 3. Details of major tree species phytosociology in four different forests sites in ridge top areas.

Tree species	Family	Raithal				Dharali				Sukhee top				Harshil			
		F	D	TBC	IVI	F	D	TBC	IVI	F	D	TBC	IVI	F	D	TBC	IVI
Abies spectabilis	Pinaceae	40	50.0	10.3	38.3	14.3	270.0	39.5	92.7	37.5	145	14.2	52.8	50.0	242.5	25.7	95.9
Acer caesium	Aceraceae	5	2.0	0.01	2.5	14.3	15.7	1.0	10.8	58.3	50	4.1	31.1	12.5	5	0.6	8.4
Acer acuminatum	Aceraceae	-	-	-	-	-	-	-	-	12.5	6.7	0.7	5.8	-	-	-	-
Aesculus indica	Hippocastanaceae	-	-	-	-	3.6	1.4	0.1	2.2	-	-	-	-	-	-	-	-
Betula utilis	Betulaceae	20	68.0	4.7	26.4	28.6	24.3	4.2	22.9	45.8	76.7	12.7	41.6	50.0	157.5	22.4	79.6
Cedrus deodara	Pinaceae	-	-	-	-	46.4	112.9	29.3	73.3	16.7	25	4.6	14.6	31.3	162.5	14.9	60
Ilex dipyrena	Aquifoliaceae	-	-	-	-	-	-	-	-	20.8	10.0	2.1	10.7	-	-	-	-
Juglans regia	Juglandaceae	-	-	-	-	-	-	-	-	8.3	3.3	3.8	7.3	-	-	-	-
Lyonia ovalifolia	Ericaceae	-	-	-	-	-	-	-	-	16.7	35	4.2	15.9	-	-	-	-
Picea smithiana	Pinaceae	-	-	-	-	17.9	35.7	4.6	19.7	25.0	30.0	4.7	18.1	6.3	2.5	0.3	4.2
Pinus wallichiana	Pinaceae	-	-	-	-	60.7	170.0	13.3	72.2	62.5	160.0	37.7	89.1	31.3	140	11.3	52.0
Quercus semecarpifolia	Fagaceae	80	336.0	61.1	167.3	-	-	-	-	-	-	-	-	-	-	-	-
Rhododendron arboreum	Ericaceae	10	20.0	1.7	9.9	-	-	-	-	-	-	-	-	-	-	-	-
Pyrus pashia	Rosaceae	25	20.0	1.7	16.3	-	-	-	-	-	-	-	-	-	-	-	-
Sorbus cuspidata	Rosaceae	35	24.0	2.4	22.1	-	-	-	-	-	-	-	-	-	-	-	-
Taxus baccata	Pinaceae	20	32.0	2.4	17.2	10.7	4.3	0.1	6.2	-	-	-	-	-	-	-	-
Unknown	-	-	-	-	-	-	-	-	-	25.0	23.3	1.1	12.9	-	-	-	-

Note: F- Frequency; D- Density (stem h^{-1}); TBC- Total Basal Cover ($m^2 h^{-1}$); IVI- Importance Value Index.

Table 4. Regeneration status of the Ridge top species.

Tree species	Raithal				Dharali				Sukhee top				Harshil			
	T	SPL	SDL	RS	T	SPL	SDL	RS	T	SPL	SDL	RS	T	SPL	SDL	RS
Abies spectabilis	5.0	147	1150	Good	27.0	372	4479.0	Good	15.0	304	3625.0	Good	24.0	303	2281	Good
Acer caesium	0.2	0	0	No	1.6	2	0	Poor	5.0	12	41.7	Good	0.5	0	0	No
Acer acuminatum	-	-	-	-	-	-	-	-	0.7	0	0	NO	-	-	-	-
Aesculus indica	-	-	-	-	0.1	0	0	NO	-	-	-	-	-	-	-	-
Betula utilis	6.8	101	1175	Good	2.4	0	187.5	Fair	7.7	10	437.5	Good	16.0	23	250	Good
Cedrus deodara	-	-	-	-	11.0	290	4979.0	Good	2.5	36	333.3	Good	16.0	171	531	Good
Ilex dipyrena	-	-	-	-	-	-	-	-	1.0	0	0	NO	-	-	-	-
Juglans regia	-	-	-	-	-	-	-	-	0.3	0	0	NO	-	-	-	-
Lyonia ovalifolia	-	-	-	-	-	-	-	-	3.5	36	437.5	Good	-	-	-	-
Picea smithiana	-	-	-	-	3.6	46	125.0	Good	3.0	82	208.3	Good	0.3	80	188	Good
Pinus wallichiana	-	-	-	-	17.0	144	1458.0	Good	16.0	210	1708.0	Good	14.0	117	1031	Good
Quercus semecarpifolia	33.6	442	3700	Good	-	-	-	-	-	-	-	-	-	-	-	-
Rhododendron arboreum	2.0	27	500	Good	-	-	-	-	-	-	-	-	-	-	-	-
Pyrus pashia	2.0	59	300	Good	-	-	-	-	-	-	-	-	-	-	-	-
Sorbus cuspidata	2.4	0	0	No	-	-	-	-	-	-	-	-	-	-	-	-
Taxus baccata	3.2	0	0	No	0.4	12		Poor								
Unknown	-	-	-	-	-	-	-	-	2.3	0	0	NO	-	-	-	-

Note: T- Tree Density ($stem/100m^2$); SPL- Sapling Density ($sapling/100m^2$); SDL- Seedling Density ($seedling/100m^2$); RS- Regeneration Status

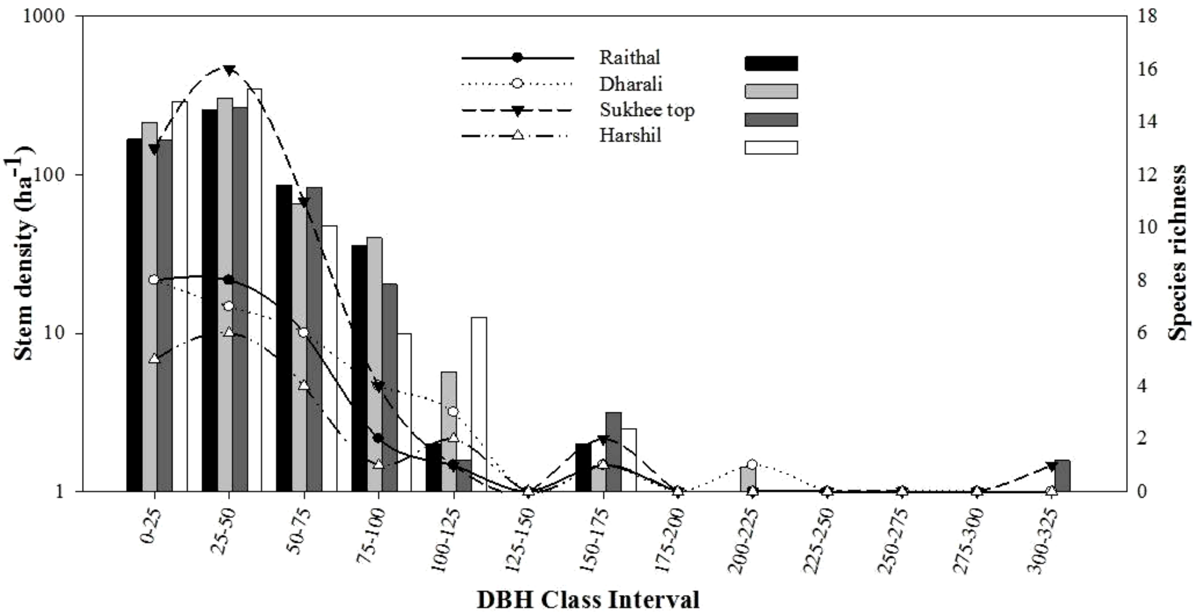

Figure 3. DBH (Diameter at breast height) class based distribution patterns of forest population attributes: Stem density and Species richness in studied ridges top.

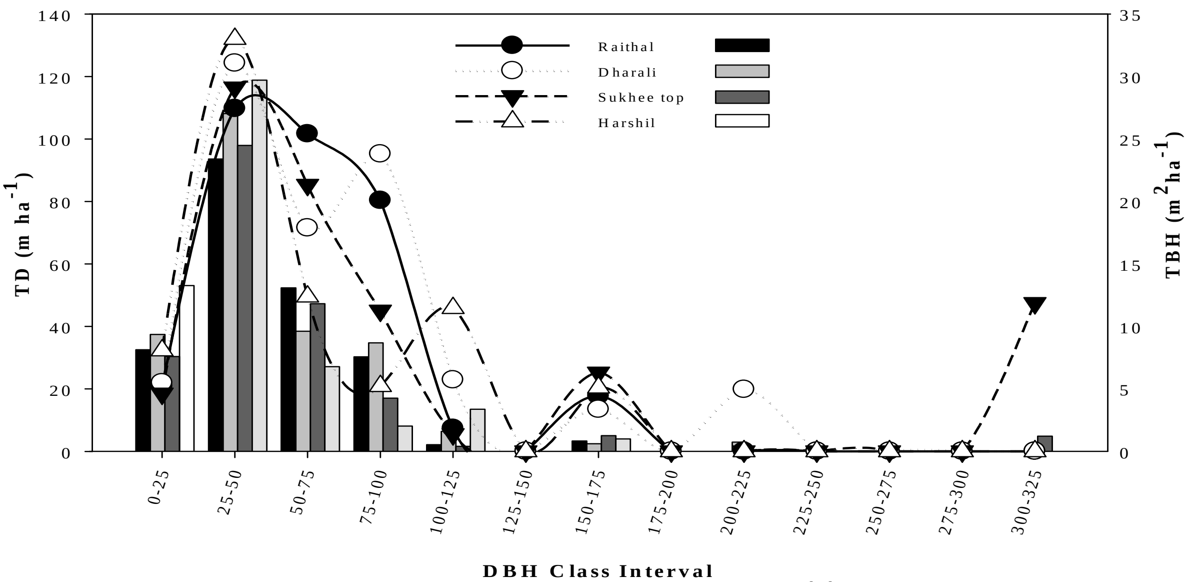

Figure 4. DBH (Diameter at breast height) class based distribution patterns of forest population attributes: Total diameter and Basal cover in studied ridge tops.

Status of dominant woody species composition, distribution and regeneration

Abies *spectabilis, Acer caesium, Betula utilis, Cedrus deodara, Picea smithiana* and *Pinus wallichiana* were reported as dominant species of the ridge tops in the present study (Fig. 5), which was similar with different parts of Himalaya (Kunwar & Sharma 2004, Ghimai *et al*. 2010). IVI of the dominant species at four sites was quite lower than Kunwar and Sharma (2004) from mid Nepal may be due to climatic effect. *Abies spectabilis* had highest value in Harshil (95.9) followed by Dharali (92.7) and lowest in Raithal (38.28). It occupied highest TBC values in Dharali (39.5 $m^2.ha^{-1}$) (Table 3). In all study area its regeneration pattern found in good regeneration categories. *Acer caesium* was dominant and widely distributed in Sukhee top followed by Dharali whereas in other two sites it had low occurrence. Regeneration of this species was good in Sukhee top whereas in other site its regeneration was subject of concern. *Betula utilis* showed satisfactory with wide distribution in almost all girth classes in study area. Dharali top was dominated by *Cedrus deodara* and *Picea smithiana*. *Cedrus deodara* was absent in Raithal top whereas at other three sites it was reported with good regeneration. *Picea smithiana* showed healthy regeneration in all sites whereas it was totally absent in Raithal. *Pinus* *wallichiana* was widely distributed in three study sites with good regeneration state. Sustainable regeneration of *Pinus wallichiana* already reported from different parts of Himalaya (Kimmins 1987, Shimano 2000).

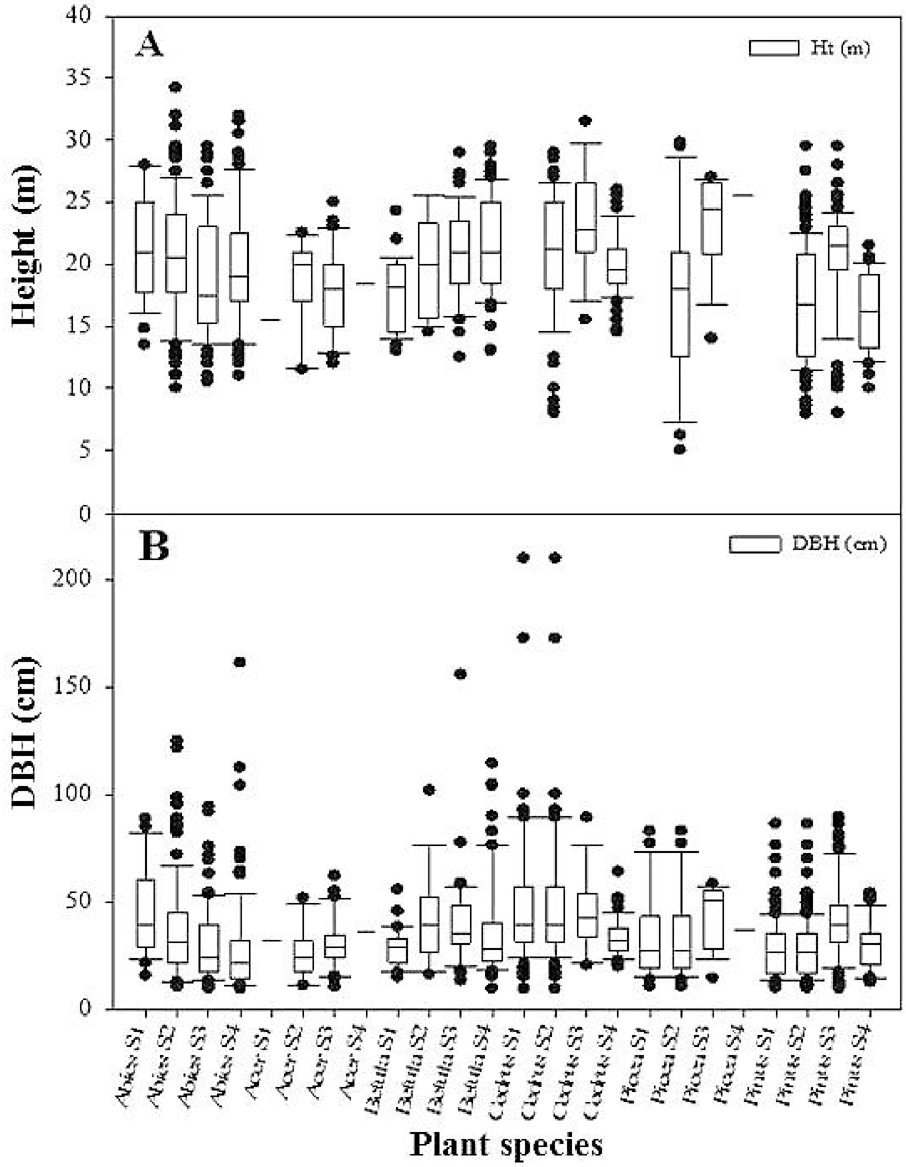

Figure 5. Distribution of the dominant plant species of the studied ridge tops: **A**, Height (Ht); **B**, Diameter at breast height (DBH).

CONCLUSIONS

High altitude Himalayan forest is facing significant/drastic change owing to changing climatic conditions. Quantification of the current forest composition and regeneration dynamics of the ridge tops is crucial in order to assess the role of climate change in predicting effect on future species coexistence and species shift in Himalayan range. *Abies spectabilis, Betula utilis, Cedrus deodara, Pinus wallichiana, Acer caesium* and *Quercus semecarpifolia* were observed as the dominant species of the ridge tops with good regeneration potential whereas *Taxus baccata*, *Acer acuminatum*, *Aesculus indica*, *Juglans regia*, *Ilex dipyrena* and *Sorbus cuspidata* were poorly distributed with poor regeneration status. It can thus be concluded that the species with poor and non-recruiting regeneration status and rare distribution may be affected by the warming temperatures on ridge tops whereas dominant species with good regeneration potential may adapt and shift in opinionated microclimate. In the current scenario the species with poor regeneration status are required to be earmarked so that proper measures could be adopted for their conservation as they are susceptible to the changing climatic conditions which may result in their complete extermination and hence lead to change of the future composition of the ridge tops. This study may be constructive to assess biological impacts of climate change which have focused on species abundance and distribution in search of the predicted systematic shifts in both upwards and downwards direction.

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REFERENCES

Adler PB & Lambers JHR (2008) The influence of climate and species composition on the population dynamics of ten prairie forbs. *Ecology* 89: 3049–3060.

Bajpai O, Kumar A, Mishra AK, Sahu N, Pandey J, Behera SK & Chaudhary LB (2012) Recongregation of tree species of Katerniaghat wildlife sanctuary, Uttar Pradesh, India. *Journal of Biodiversity and Environmental Sciences* 2(12): 24–40.

Breckle JW (2002) *Walter's Vegetation of the Earth*. Springer Verlag, Berlin, 4 (527), pp. 300.

Brown JH (1988) Species diversity. In: Myers AA & Giller PS (eds) *Analytical biogeography: An integrated approach to the study of animal and plant distribution*. Chapman and Hall, New York, pp. 57–89.

Cannone N, Sgorbati S & Guglielmin M (2007) Unexpected impacts of climate change on alpine vegetation. *Frontiers in Ecology and the Environment* 5: 360–364.

Gairola S, Sharma CM, Suyal S & Ghildiyal SK (2011) Composition and diversity of five major forest types in moist temperate climate of the western Himalayas. *Forest Study China* 13(2): 139–153.

Getachew T, Demel T, Masresha F & Erwin B (2010) Regeneration of seven indigenous tree species in a dry Afromontane forest, Southern Ethiopia. *Flora* 205: 135–143.

Ghimire B, Mainali KP, Lekhak HD, Chaudhary RP & Ghimeray AK (2010) Regeneration of *Pinus wallichiana* AB Jackson in a trans-Himalayan dry valley of north-central Nepal. *Himalayan Journal of Sciences* 6(8): 19–26.

Ghimire B & Lekhak HD (2007) Regeneration of *Abies spectabilis* (D. Don) Mirb. in sub-alpine forest of Upper Manang, north-central Nepal. In: Chaudhary RP, Aase TH, Vetaas OR, Subedi BP (eds) *Local Effects of Global Changes in the Himalayas: Manang, Nepal*. Tribhuvan University, Kathmandu and University of Bergen, Norway, pp. 139–149.

Henle K, Lindenmayer DB, Margules CR, Saunders DA & Wissel C (2004) Species survival in fragmented landscapes: where are we now? *Biodiversity and Conservation* 13: 1–8.

Hill MO (1973) Diversity and evenness: a unifying notation and its consequences. *Ecology* 54: 427–432.

Holzinger, Hulber K, Camenisch M & Grabherr G (2008) Changes in plant species richness over the last century in the eastern Swiss Alps: Elevational gradient, bedrock effects and migration rates. *Plant Ecology* 195: 179–196.

Kammer PA & Mohl A (2002) Factors controlling species richness in alpine plant communities: an assessment of the importance of stress and disturbance. *Arctic, Antarctic and Alpine Research* 34: 398–407.

Kammer PM, Christian S & Philippe C (2007) Increasing species richness on mountain summits: upward migration due to anthropogenic Climate change or recollection? *Journal of Vegetation Science* 18: 301–306.

Kharkwal G, Mehrotra P, Rawat YS & Pangtey YPS (2005) Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kumaun) region of India. *Current Science* 89(5): 873–878.

Kimmins JP (1987) *Forest ecology*. New York: Macmillan Publishing Company. pp. 531.

Korner C (2003) *Alpine plant life. Functional plant ecology of high mountain ecosystems*. Springer, Berlin.

Kunwar RM & Sharma SP (2004) Quantitative analysis of tree species in two community forests of Dolpa district, mid-west Nepal. *Himalayan Journal of Sciences* 2 (3): 23–28.

Lalfakawma (2010) Disturb and perish, conserve and flourish regenerating forests: a review *Science vision* 10: 3–7.

Lemoine N, Schaefer HC & Bohning-Gaese K (2007) Species richness of migratory birds is influenced by global climate change. *Global Ecology Biogeography* 16: 55–64.

Lesica P & McCune B (2004) Decline of arctic-alpine plants at the southern margin of their range following a decade of climatic warming. *Journal of Vegetation Science* 15: 679–690.

Mishra A, Sharma CM, Sharma SD & Baduni NP (2000) Effect of aspect on the structure of vegetation community of moist bhabar and tarai Shorea robusta forest in Central Himalaya. *Indian Forester* 126(6): 634–642.

Mishra AK, Behera SK, Singh K, Chaudhary LB, Mishra RM, Singh B (2013a) Influence of abiotic factors on community structure of understory vegetation in moist deciduous forests of north India. *Forest Science and Practice* 15(4): 261–273.

Mishra AK, Bajpai O, Sahu N, Kumar A, Behera SK, Mishra RM & Chaudhary LB (2013b) Study of plant regeneration potential in tropical moist deciduous forest in northern India. *International Journal of Environment* 2(1): 153–163.

Misra R (1968) *Ecology work book*. Oxford and IBH publishing company, Calcutta.

Mueller-Dombois D & Ellenberg H (1974) *Aims and methods of vegetation ecology*. John Wiley & Sons, New York.

Negi CS & Nautiyal S (2005) Phytosociological studies of a traditional reserve forest- Thal Ke Dhar, Pithoragarh, Central Himalayas (India). *Indian Forester* 131: 519–534.

Pande PK (2001) Quantitative vegetation analysis as per aspect and altitude, and regeneration behavior of tree species in Garhwal Himalayan forest. *Annuls of Forest* 9(1): 39–52.

Pauli H, Gottfried M, Reiter K, Klettner C & Grabherr G (2007) Signals of range expansions and contractions of vascular plants in the high Alps: observations (1994-2004) at the GLORIA master site Schrankogel, Tyrol, Austria. *Global Change Biology* 13: 147–156.

Pokhriyal P, Uniyal P, Chauhan DS & Todaria NP (2010) Regeneration status of tree species in forest of Phakot and Pathri Rao watersheds in Garhwal Himalaya. *Current Science* 98: 171–174.

Pusalkar PK & Singh DK (2012) *Flora of Gangotri National Park, Western Himalaya, India*. Botanical Survey of India, Kolkata.

Rahman MH, Khan ASA, Roy B & Fardusi MJ (2011) Assessment of natural regeneration status and diversity of tree species in the biodiversity conservation areas of Northeastern Bangladesh. *Journal of Forestry Research* 22: 551–559.

Rawat VS & Chandra J (2014) Vegetational Diversity Analysis across Different Habitats in Garhwal Himalaya. *Journal of Botany* 2014: 1–5.

Rosenzweig C, Casassa CG, Karoly DJ, Imeson A, Liu C, Menzel A, Rawlins S, Root TL, Seguin B & Tryjanowski P (2007) Assessment of observed changes and responses in natural and managed systems. In: Parry ML, Canziani OF, Palutikof JP, van der Linden PJ & Hanson CE (eds) *Climate Change 2007: Impacts, adaptation and vulnerability*. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK, pp. 79–131.

Saxena AK, Pandey U & Singh JS (1979) On the ecology of Oak forest in Naini Tal hills, Kumaun Himalaya. In: Singh JS & Gopal B (eds) Glimpses *of ecology*. International Scientific Publishers, Jaipur, pp. 167–180.

Saxena AK & Singh JS (1984) Tree population structure of certain Himalayan forest assodations and implications concerning their future composition. *Vegetation* 58: 61–69.

Shannon CE & Wiener W (1963) *The mathematical theory of communication, 1st Editions*. University of Illinois Press, Urbana, IL.

Shimano K (2000) A power function for forest structure and regeneration pattern of pioneer and climax species in patch mosaic forests. *Plant Ecology* 146: 207–220.

Shrestha BB, Ghimire B, Lekhak HD & Jha PK (2007) Regeneration of treeline birch (Betula utilis D. Don) forest in trans-Himalayan dry valley in Central Nepal. Mountain Research and Development 27: 259–267.

Simpson EH (1949) Measurement of diversity. *Nature* 163: 688–688.

Singh CP, Panigrahy S, Thapliyal A, Kimothi MM, Soni P & Parihar JS (2012) Monitoring the alpine tree line shift in parts of Indian Himalayas using remote sensing. *Current Science* 102: 559–562.

Stevens GC (1992) The elevational gradient in altitudinal range: an extension of Rapoport's latitudinal rule to altitude. *American Naturalist* 140: 893–911.

Suyal S, Sharma CM, Gairola S, Ghildiyal SK, Rana CS & Butola DS (2010) Phytodiversity (Angiosperms and Gymnosperms) in Chaurangikhal Forest of Garhwal Himalaya, Uttrakhand, India. *Indian Journal of Science and Technology* 3(3): 267–275.

Theurillat JP & Guisan A (2001) Potential impact of climate change on vegetation in the European Alps: a review. *Climate Change* 50: 77–109.

Tiwari JC & Singh SP (1985) Analysis of woody vegetation in a mixed oak forest of Kumaun Himalaya. *Proceedings' in Indian Natural Science Academy* 51(B): 232–247.

Uma Shankar (2001) A case of high tree diversity in a Sal (*Shorea robusta*) - dominated low land forest of eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science* 81(7): 776–786.

Valdiya KS (1980) Stratigraphic scheme of the sedimentary units of the Kumaon lesser Himalaya. In: Valdiya KS & Bhatiya SB (eds) *Stratigraphy and correlations of the lesser Himalayan formations.* Hindustan Publication Corporation, Delhi, India, pp. 7–48.

Walther GR, Berger S & Sykes MT (2005) An ecological 'footprint' of climate change. *Proceedings of the Royal Society: Biological Science* 72: 1427–1432.

Ward JS, Worthley TE, Smallidge PJ & Bennett KP (2006) *North-east forest regeneration handbook: A guide for forest owners, harvesting practitioners, and public officials*. USDA Forest Service, Newton Square, PA.

Woodward FI & Kelly CK (2008) Responses of global plant diversity capacity to changes in carbon dioxide concentration and climate. *Ecological Letters* 11: 1229–1237.