academicJournals

Vol. 7(6), pp. 321-329, June 2015
DOI: 10.5897/IJBC2015.0855
Article Number: 186679B53938
ISSN 2141-243X

http://www.academicjournals.org/IJBC

International Journal of Biodiversity and Conservation

Full Length Research Paper

Assessment of plant diversity, regeneration status, biomass and carbon stock in a Central Himalayan cypress forest

Sumita Rana, Kiran Bargali and S. S. Bargali*

Department of Botany, DSB Campus, Nainital-263001, Uttarakhand, India.

Received 18 May, 2015; Accepted 19 June, 2015

The present study assessed population structure, biomass, carbon stock, phytosociociological and regeneration status of a Central Himalayan cypress forest of India. A total of 36 plant species (07 trees, 08 shrubs and 21 herbs) were recorded from the study site. Total tree density ranged from 460 to 600 tree ha^{-1} and total basal area ranged from 19.11 to 58.20 m^{2} ha^{-1}. The total biomass of trees across all the sites ranged between 178 and 431 t ha^{-1} while carbon stock ranged between 89.07 and 206 t ha^{-1}. *Cupressus torulosa* was the only tree species showing fair regeneration at all the sites while most of the species were represented by seedling and sapling indicating new regeneration.

Key words: Biomass, carbon stock, diversity, regeneration, vegetation structure.

INTRODUCTION

Cupressus torulosa D. Don, commonly known as Himalayan cypress is an evergreen conifer tree species distributed throughout the Himalayan region at elevations of 1800 to 2800 m (Shahni, 1990). It is an important species forming Himalayan moist temperate forest (12/E_1) in the western Himalayan region and occurs as open forest of scattered trees on steep rocky ground with xerophytic shrubs and little grass (Champion and Seth, 1968).

Cypress forest most frequently grows on limestone, which provides relatively dry soil conditions on limestone cliffs and shale, and occasionally on other rock types (Troup, 1921). This species generally occur in stands of varying extent, sometimes pure, sometimes associated with deodar (*Cedrus deodara*), spruce (*Picea smithiana*), silver fir (*Abies pindrow*), blue pine (*Pinus wallichiana*) or oaks (*Quercus* spp.). These forests are of immense significance from the environmental conser-vation and sustainable development view point as they provide a diverse range of resources; they store carbon, aid in regulating the planetary climate and purify water (Baduni and Sharma, 1996). Of the different types of forest vegetation, the coniferous forests have played an important role in human culture as they have been the subject of various uses including folklore and mythology.

In last four decades many studies (Singh and Singh, 1987; Rawat and Singh, 1988; Singh et al., 1994; Bargali et al., 2013, 2014, 2015) concentrated on the structure and function of major forests types and adjacent tree plantations of the region.

*Corresponding author. E-mail: surendrakiran@rediffmail.com.

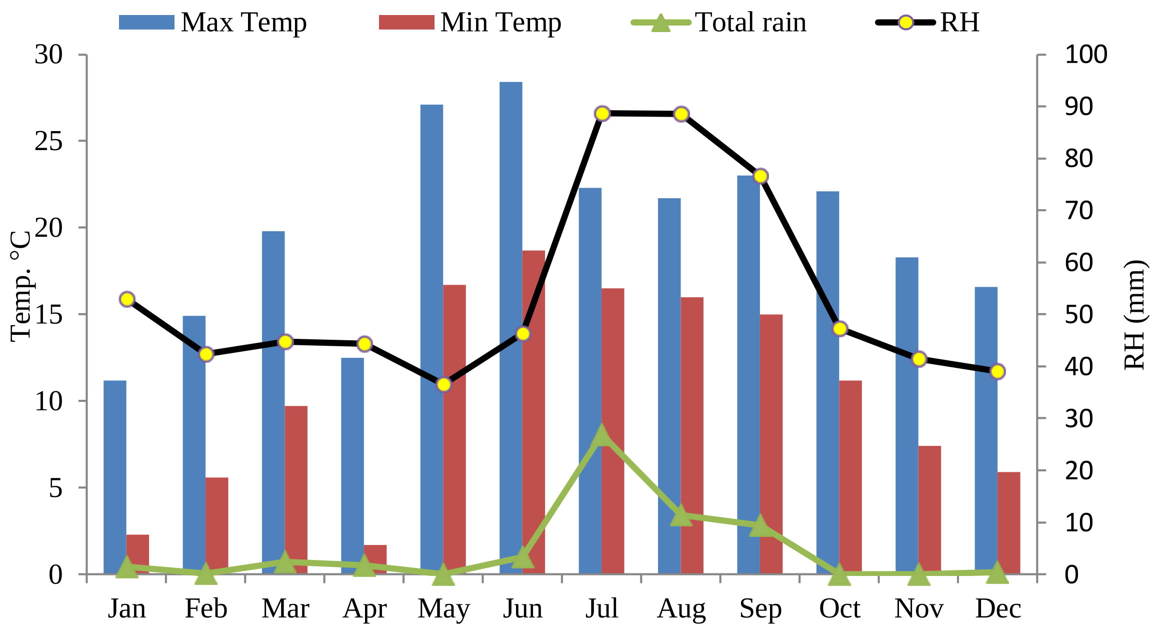

Figure 1. Monthly metrological observations of 2012 (source: GIC Nainital).

The plant diversity and regeneration status of a particular forest provide valuable information for the management and conservation of biodiversity. Therefore, in the present study species diversity, population structure, regeneration status, biomass and carbon stock of tree species in *C. torulosa* forest of Indian Central Himalaya were carried out.

MATERIALS AND METHODS

Study area

The study sites were selected between 2100 to 2400 m above mean sea level (at 29°19' to 29°28' N and 79°22' to 79°38' E) in Nainital, Central Himalaya in an area dominated by *C. torulosa* forest. As altitudinal gradients influence tree species diversity and distribution; the study site was therefore, divided into three sub sites, hill base (low altitude; 2,120 m), hill slope (mid altitude; 2,220 m) and hill top (high altitude 2,325 m).

Climate

Nainital has long cold and often snowy winter and short summer. The climate is determined by the monsoon rhythms and the year can be divided into three main seasons: winter, usually cold and relatively dry (mid-December to mid- February); summer, warm and dry (April to mid-June); and a rainy season, which is warm and wet (mid-June to mid- September). The period of transition occur between summer and winter and between winter and summer are autumn (October to November) and spring (February to March), respectively. The rainy season accounts for about three-fourths of the annual rainfall (Figure 1). Mean minimum monthly temperature ranges from 2.3°C (January) to 18°C (June) and mean maximum monthly temperature varies from 11.2°C (January) to 28.4°C (June). Mean annual rainfall is 2,195 mm. Average humidity fluctuates near the saturation point during the monsoon and is lower during summer, and ranging between 36.5% (May) to 88.7% (July). The study sites are located within the krol formation and Blaini formations (Valdiya, 1980). Soil is thin due to topography (mainly slope) and usually acid in nature. Soil moisture and water retention capacity ranged between 14.1 to 27.4% and 30.9 to 40.7%, respectively.

Vegetation analysis

For the phytosociological study, the quadrat method was used. The number and size of the quadrats were determined by the running mean method (Kershaw, 1973) and species area curve (Misra, 1968). Ten (10) plots of 10 × 10 m at each site were randomly established at hill base, hill slope and hill top for determination of species richness and other vegetation parameters. Trees and saplings were sampled in 10 × 10 m quadrats, shrubs in 5 × 5 m quadrats, and seedlings and herbs in 1 × 1 m quadrats within each plot (Curtis and McIntosh, 1950; Phillips, 1959). Circumference at breast height (CBH at 1.37 m from the ground) of individual tree and sapling was measured in each quadrat. Individual trees having ≥ 30 cm girth were considered as trees, 30 to 10 cm was considered as saplings and ≤10 cm at the base were considered as seedlings.

Density, frequency, abundance, basal area and Importance value index (IVI) were calculated following Cottam and Curtis (1956). Species richness (Margalef, 1958), Shannon - Wiener diversity Index (Shannon and Weaver, 1963), Simpson dominance Index (Simpson, 1949), and evenness (Pielou, 1966) were also computed based on phytosociological data. Dispersion pattern of individual plant species was calculated as an abundance/frequency (A/F) ratio. A/F ratio < 0.025 indicates regular distribution, between 0.025 and 0.05 indicates random distribution and >0.05 indicates contagious distribution (Cottam and Curtis, 1956).

Index of similarity (IS) between forests was calculated following (Muller–Dombois and Ellenberg 1974) using species richness in different forests as:

$$\text{Index of similarity (IS)} = \frac{2C}{A + B} \times 100$$

Where C is the number of common species shared between compared sites, and A and B are the number of species in each site.

Population structure and regeneration pattern

To describe population structure and to understand species regeneration, individuals were measured for CBH with a girthing tape at each site for each tree species. In addition to seedling and sapling classes (Good and Good, 1972), six or more classes based on CBH were arbitrarily established. The total number of individuals belonging to these size classes was calculated for each species at each site. Regeneration status of individual tree species was determined on the basis of the population size of seedlings, saplings and trees (Khumbongmayum et al., 2006). If the population size is seedlings > saplings > trees the regeneration status of tree species is "good". If the population size is of seedlings > or ≤ saplings ≤ trees, seedlings ≤ saplings > trees, seedlings ≤ saplings and the species had no adult trees, the regeneration status of tree species is "fair". If the species survives only at sapling stage, but not as seedlings (saplings may be <, > or = trees), the regeneration status of tree species is "poor". If a species is absent both in sapling and seedling stage, but present only as trees it is considered as "not regenerating". A species is considered as "new" if the species are found only either in seedling or sapling stage without any tree.

Biomass and carbon stock estimation

The biomass for each tree component was estimated using the regression equation of Rawat and Singh (1988) and Adhikari et al. (1998):

$$\ln Y = a + b \ln X$$

Where, ln = natural log, Y= dry weight of component (kg), X= CBH (cm), a = the y intercept and b = slope of regression.

The carbon stock was assumed to be half of the total estimated biomass of each tree species (Brown, 2002; Jhariya et al., 2014).

RESULTS AND DISCUSSION

Species composition and forest structure

A total of 36 plant species were recorded in the study area, of which 7 were trees, 8 were shrubs and 21 were herbs. At hill base, 26 species (5 trees, 6 shrubs and 15 herbs) were recorded; at hill slope 25 species (5 trees, 8 shrubs and 12 herbs) were recorded while at hill top 28 species (4 trees, 6 shrubs and 18 herbs were recorded. Among trees, *C. torulosa* was dominant (IVI 205 to 300) at all three sites (Table 1) whereas, *Cedrus deodara* was co-dominant. Highest tree density (360-600 tree ha^{-1}) was also reported for *C. torulosa* (Table 1). Total density of trees ranged from 460 to 600 trees ha^{-1} and within the range (420 to 1640 trees ha^{-1}) was reported for temperate forest of Kumaun Himalaya by Saxena and Singh (1982). Similar ranges for density were reported (Adhikari et al., 1998, Baduni and Sharma, 1996, Pande et al., 2014) for other cypress and cypress-mixed oak forests in the region. Tree density increased with increasing elevation from hill base to hilltop which could have been due to less anthropogenic disturbances at hill top compared to hill base. Total basal area of trees was higher at hill top (58.20 m^2 ha^{-1}) than at hill base (19.11 m^2 ha^{-1}) of which *C. torulosa* contributed from 70% (at hill base) to 100% (at hill top). Baduni and Sharma (1996) reported 19.83 to 56.46 m^2 ha^{-1} basal area for *C. torulosa* in forest of Garhwal Himalaya and Adhikari et al. (1998) reported 26.5-51.4 m^{2}ha^{-1} basal area for *C. torulosa* in forest of Kumaun Himalaya.

Sapling density ranged from 200 to 520 saplings ha^{-1} and it was maximum at hill top (Table 1). Baduni and Sharma (1996) reported maximum density of saplings at hill slope in a *C. torulosa* forest, possibly due to the suitable moisture conditions. Maximum density of saplings (80 to 400 ha^{-1}) was shared by *C. torulosa* at all the three sites. Seedling density ranged from 300 to 400 individuals ha^{-1} and it was greatest at hill base (Table 1). Adhikari et al. (1998) reported density of 90 to 420 seedlings ha^{-1} and 100 to 810 seedlings ha^{-1} for saplings in moist temperate cypress forest.

A total of 8 shrub species were reported from the study area and *Reinwardtia indica* was dominant at hill base and slope while *Colquehonia coccinea* was dominant at hill top. The density values of shrubs ranged from1303 ind ha^{-1} to 5380 ind. ha^{-1} (Table 1). For other cypress forest of the region a lower range of 1280 to 4170 ind ha^{-1} was reported by Adhikari et al. (1998). Numbers of herbs species ranged from 15 at hill base to 18 at hill top (Table 1). A higher number of herbs (22 to 25) were reported by Rawat and Singh (1988) for oak forest and by Pande et al. (2014) for mixed oak forests of the region.

Plant diversity

A higher Shannon diversity index (0.96) for tree species was recorded in hill base (Table 1). At hill top, only one species was present in tree layer so diversity indices were not calculated. In all the three sites, herb diversity was found to be higher than trees and shrubs. Devi and Yaddava (2006) reported that for Indian forests Shannon diversity Index (H') ranged from 0.83 to 4.1. The value of the Shannon diversity Index in the present study lies within the range reported for temperate forests (Singh et al., 1994, Bargali et al., 2013). The Simpson index (Cd) was 0.67 in hill slope and 0.64 in hill slope for tree species. The evenness index was maximum (1.07) in hill slope and minimum (0.88) in hill base.

For shrub species diversity was maximum (0.75) at hill slope and minimum (0.52) at hill base. The Simpson and evenness index were maximum at hill slope and minimum at hill top. Herb layer also followed the same pattern as recorded for shrub layer (Table 1).

The similarity index value was maximum for herb layer

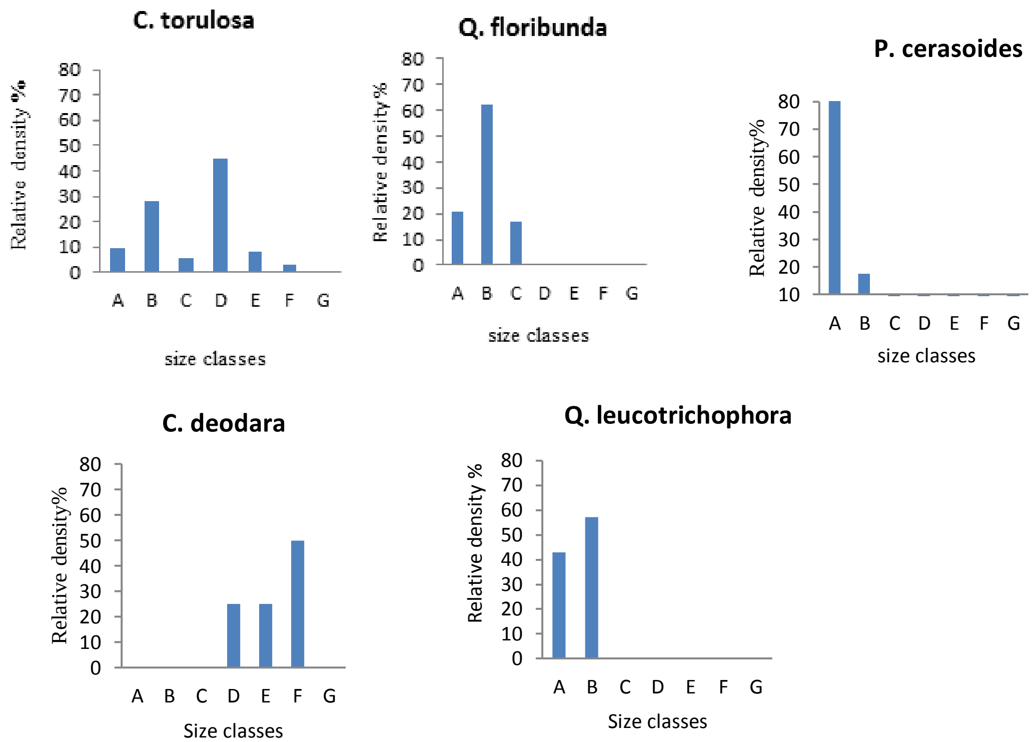

Figure 2A. Population structure of tree species at hill base of Central Himalayan cypress forest. A= seedlings, B= sampling, trees: C= 31-60 cm, D=61-90 cm, E=91-120 cm, F= 121-150 cm and G=>150 cm CBH.

(48.8) and minimum for tree and sapling layer (33.3) indicating that the species were more common in the herb layer as compared to other layers (Table 1). *β*-diversity was maximum (1.91) for seedling layer and minimum (1.20) for shrub layer (Table 1).

Population structure and regeneration pattern

According to the criteria given by Saxena and Singh (1984), four types of population structure were reported at hill base (Figure 2A). The dominant species, *C. torulosa* showed higher number of population in the middle size class than lower and higher size classes. This indicates that seedlings were not sufficient to replace trees. Benton and Werner (1976) suggested that such type of population could become extinct if such tendency continues. In *Q. floribunda* more individuals were recorded in the middle size class (saplings), indicating a poor generation. In *C. deodara* most trees belonged to higher girth classes while populations of lower girth classes including seedlings and saplings were completely absent. This indicates that this species did not reproduce well in the past and seedlings were not establishing. In *P. cerasoides* and *Q. leucotrichophora,* individuals belonged to lower size classes (seedlings and saplings) while higher girth classes were completely absent, indicating that these species were new to the area and on maturity they could reproduce well and expand their populations. At this site the maximum tree species (60%) were included in the category of “Fair” regeneration while 20% were included in “new” and 20% in “not regenerating” category.

At hill slope, *C. torulosa* indicated good regeneration followed by a phase of poor regeneration. Fewer established seedlings compared to saplings indicated poor regeneration. It reproduced well in the immediate past and continued to do so at present but at a lower rate. Occurrence of only seedlings and saplings in *Q. floribunda* and *P. cerasoides* indicated that these species has recently invaded the area and might become canopy (upper most strata in the forest) or sub canopy species later on. Absence of established seedlings of *C. deodara* indicated that this species reproduced well at first but at present its regeneration has been stopped. *Q. leucotrichophora* was represented by saplings only and reflect that this species was new to the area. At this site, 60% species showed “fair” regeneration, 20% showed “poor” regeneration and 20% were included in “new” (Figure 2B)

At hill top, *C. torulosa* had high density in intermediate size classes and decreasing number toward higher and lower size classes. According to Saxena and Singh (1984) and Kittur et al. (2014), the population is on the way to extinction if such a trend continues. Knight (1975) referred to the species showing such population

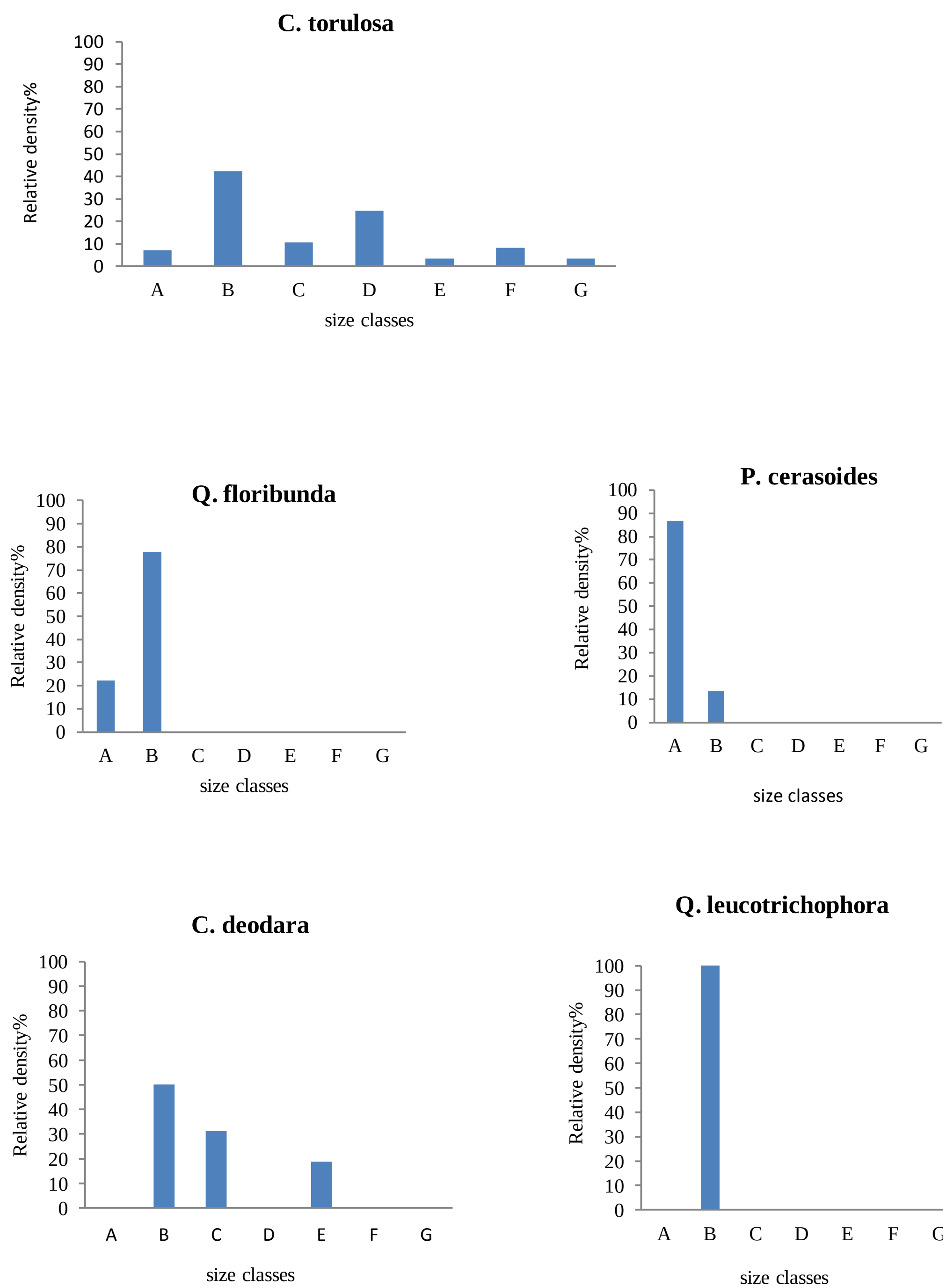

Figure 2B. Population structure of tree species at hill slope of Central Himalayan cypress forest. A= seedlings, B= sampling, trees: C= 31-60 cm, D=61-90 cm, E=91-120 cm, F= 121-150 cm and G=>150 cm CBH.

structure as infrequent reproducer. *P. cerasoides, F. numoralis* and *R. purpurea*, were represented by seedlings and saplings only indicating that these species were new to area and may become established in due course of time to become canopy and sub- canopy species. At this site all the species showed fair regeneration (Figure 2C).

Biomass and carbon stock

The total biomass of trees across all three sites ranged from 178.1 t ha^{-1} at hill base to 431 t ha^{-1} at hill top. Above-ground biomass contributed from 68 to 85%. Among the tree components, bole contributed maximum biomass of 36% at hill base and 54% at hill top. Leaves

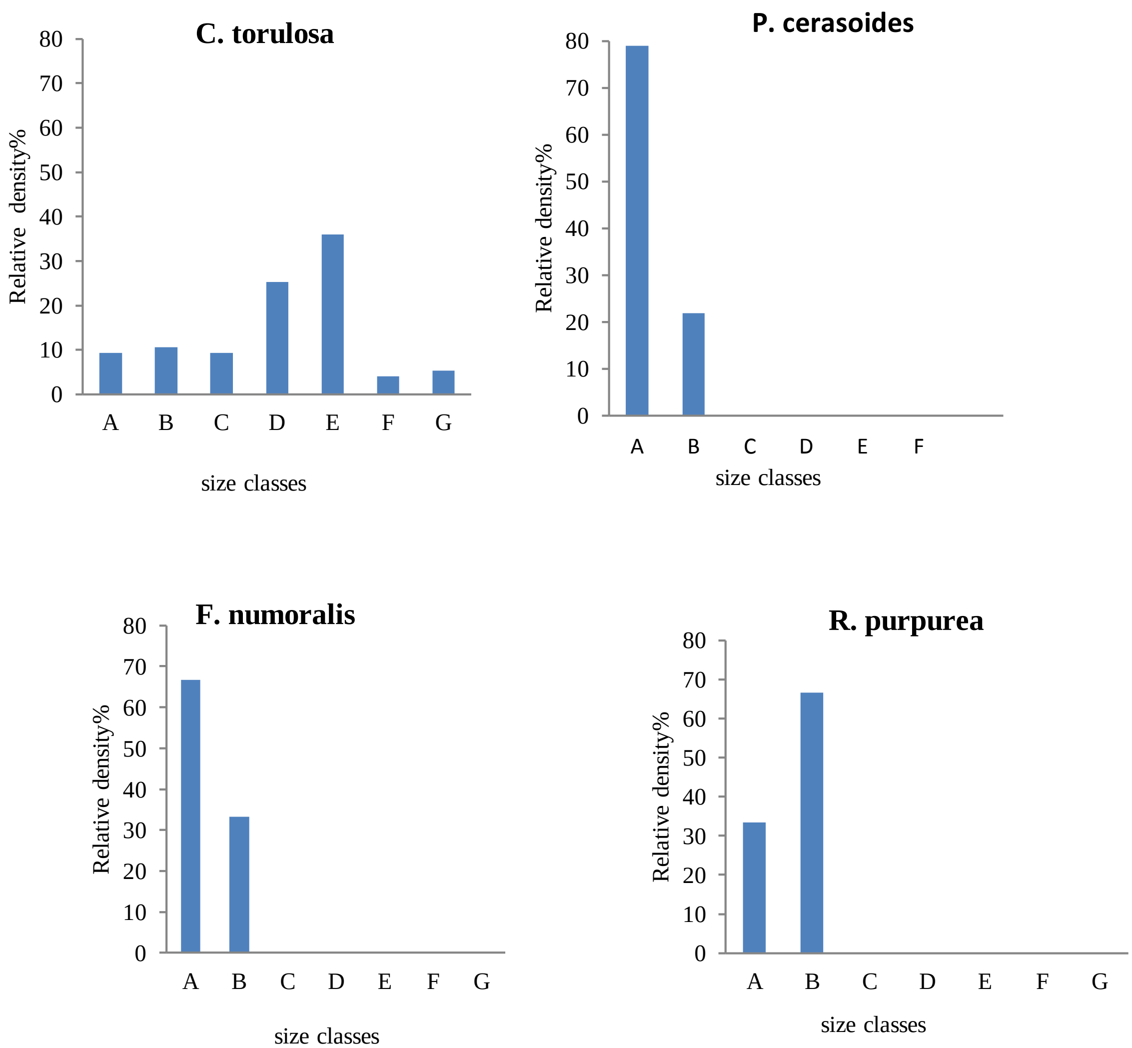

Figure 2C. Population structure of tree species at hill top of Central Himalayan cypress forest. A= seedlings, B= sampling, trees: C= 31-60 cm, D=61-90 cm, E=91-120 cm, F= 121-150 cm and G=>150 cm CBH.

contributed about 4-6%. Fine root contributed the minimum value (1.1 to 1.5%) of biomass (Table 2).

The contribution of the foliage to total above ground biomass was 4.9 to 7.5% and was similar to that reported for *P. roxburghii forest* (Chaturvedi and Singh, 1987), oak forest (Rawat and Singh, 1988) and *P. patula* forest (Bargali and Singh, 1997) of the region. Total root biomass ranged from 34.3 to 65. 6 t ha^{-1}. These value are comparable to the value (47.6 to 95.9 t ha^{-1}) reported for oak forest (Rawat and Singh, 1988). Root biomass contributed 15-32% of total biomass. The carbon stock in *C. torulosa* forest ranged from 89.07 to 206.14 t ha^{-1} (Table 3). Rana et al. (1989) reported a higher range of carbon stock values (166.8 tree ha^{-1} C for *P. roxburghii* mixed broad leaf forest to 440.1 tree ha^{-1} C for *Quercus floribunda* dominated mixed oak forest). The total carbon storage of *C. torulosa* forest was comparable with that of *P. roxburghii* forest.

Conclusions

Phytosociological analysis of the present study indicate the dominance of *C. torulosa* at all three sites. However, co-dominant species and composition varied from the base to the top of the hill. These results probably indicate a wide ecological amplitude and tolerance of *C. torulosa*. Most species showed random or contagious distribution patterns.

The population structure of a tree species reflects its biological and ecological characteristics and it describes the distribution of individuals by size class. In the present study, *C. torulosa* was the only tree species showing fair regeneration at all three sites. The variation among the population size of seedlings, saplings and adults at the three study stands might be due to the variation in climatic as well as edaphic factors required by the species for growth and survival. Seedling and saplings of

Table 1. Ecological indices of tree, shrub and herb in cypress forest of Central Himalaya.

Stage	Site	Species richness	No. of genera	Shannon index (H')	Simpson index (Cd)	Evenness (e)	Density (ind.ha^{-1})	Basal area (m^2 ha^{-1})	Similarity index	β-diversity
	HB	03	03	0.96	0.64	0.88	460	19.11		
Tree	HS	02	02	0.74	0.67	1.07	520	24.35	33.33	1.50
	HT	01	01	-	-	-	600	58.20		
	HB	03	03	0.86	0.69	0.98	500	1.65		
Sapling	HS	05	04	1.60	3.31	1.00	520	1.40	33.33	1.75
	HT	04	04	1.80	1.31	1.29	200	0.54		
	HB	04	03	1.62	0.38	1.18	440	-		
Seedling	HS	03	03	1.51	0.36	1.37	300	-	36.00	1.91
	HT	04	04	1.88	0.42	1.35	300	-		
	HB	06	06	0.52	0.42	0.05	5380	-		
Shrub	HS	08	08	0.75	0.99	0.09	3046	-	40.00	1.20
	HT	06	06	0.65	0.26	0.09	1303	-		
	HB	15	15	1.24	0.40	0.12	5110	-		
Herb	HS	12	12	2.17	0.34	0.23	10320	-	48.8	1.40
	HT	18	18	1.22	0.44	0.13	15480	-		

Table 2. Component – wise biomass (t ha^{-1}) of tree layer in a Central Himalayan cypress forest

Species	Bole	Bark	Branch	Twig	Foliage	Stump Root	Lateral root	Fine root	Total (t ha^{-1})
Hill base									
C. torulosa	43.51	2.38	26.1	8.53	7.63	12.34	8.84	1.90	111.23
C. deodara	9.16	0.49	2.13	0.79	0.55	1.61	0.67	0.08	15.46
Q. floribunda	16.77	1.47	7.63	1.73	1.65	29.36	4.90	0.83	64.31
Total									**191.00**
Hill slope									
C. torulosa	70.20	3.57	36.44	10.56	9.67	17.55	10.62	2.42	161.03
C. deodara	7.28	0.42	2.96	1.57	1.12	2.28	1.29	0.17	17.09
Hill top									
C. torulosa	233.43	9.08	85.97	18.80	18.23	43.36	17.62	4.59	431.08

C. deodara were absent both at hill base and hill slope, indicating that this species reproduced well in the immediate past but its regeneration hadd stopped. Most of the species, viz. *Q. floribunda*, *Q. leucotrichophora, P. cerasoides, F. numoralis* and *R. purpurea* were represented by only seedlings and/ or saplings. These species could be recent invadders.

Conflict of interest

The authors did not declare any conflict of interest.

ACKNOWLEDGEMENT

We are thankful to Professor N. Pande, Head,

Table 3. Carbon stock (t ha^{-1}) of different component of tree species in *C. torulosa* forest

Species	Bole	Bark	Branch	Twig	Foliage	Stump Root	Lateral root	Fine root	Total (t ha^{-1})
Hill Base									
C. torulosa	21.75	1.19	13.05	4.26	3.81	6.17	4.42	0.95	55.60
C. deodara	4.58	0.24	1.06	0.39	0.27	0.80	0.33	0.04	7.71
Q. floribunda	8.38	0.73	3.81	0.86	0.82	14.68	2.45	0.41	32.14
Total									**95.45**
Hill Slope									
C. torulosa	35.10	1.78	18.22	5.28	4.83	8.77	5.31	1.21	80.05
C. deodara	3.64	0.21	1.48	0.78	0.56	1.14	0.64	0.08	8.53
Total									**88.58**
Hill Top									
C, torulosa	116.71	4.54	42.98	9.40	9.11	21.68	8.81	2.29	**215.52**

Department of Botany, DSB Campus, Nainital for providing necessary lab facilities.

REFERENCES

Adhikari BS, Dhaila S, Rawat YS (1998). Structure of Himalayan moist temperate cypress forest at and around Nainital, Kumaun Himalayas. Oecologia Montana 7:21-31.

Baduni NP, Sharma CM (1996). Effect of aspect on the structure of some natural stands of *Cupressus torulosa* in Himalayan moist temperate forest. Proceedings of Indian National Science Academy, B62 (5):345-352.

Bargali K, Bisht P, Khan A, Rawat YS (2013). Diversity and regeneration status of tree species at Nainital catchment, Uttarakhand, India. International J. Biol. Conserv. 5(5):270-280.

Bargali K, Joshi B, Bargali SS, Singh SP (2014). Diversity within Oaks. International Oaks 25:57-70.

Bargali K, Joshi B, Bargali SS, Singh SP (2015). Oaks and the Biodiversity They Sustain. International Oaks 26:65-76.

Bargali SS, Singh RP (1997). *Pinus patula* plantations in Kumaun Himalaya. I. Dry matter dynamics. J. Trop. For. Sci. 9(4):526-535.

Benton AH, Werner WE (1976). Field Biology and Ecology (New York) McGraw-Hill, Inc. 564pp.

Brown S (2002). Measuring, monitoring and verification of carbon benefits for forest-based projects. Phil. Trans. R. Soc. Lond. A360:1669-1684.

Champion HG, Seth SK (1968). A Revised Survey of the Forest Types of India, Manager of Publications, Government of India, New Delhi. 404 p.

Chaturvedi OP, Singh JS (1987).The structure and function of pine forest in Central Himalaya. I. Dry matter dynamics. Annals of Botany 60:237-252.

Cottam G, Curtis JT (1956). The use of distance measures in phytosociological sampling. Ecol. 35:451-460.

Curtis JT, McIntosh RP (1950). The interrelations of certain analytic and synthetic phytosociological characters. Ecol. 31:434-455.

Devi LS, Yadava PS (2006).Floristic diversity assessment and vegetation analysis of tropical semievergreen forest of Manipur, north east India. Trop. Ecol. 47: 89-98.

Good NF, Good RE (1972). Population Dynamics of Tree Seedlings and Saplings in Mature Eastern hardwood Forest. Bulletin of Torrey Botanical Club 99:23-34.

Jhariya MK, Bargali SS, Swamy SL, Kittur B, Bargali K, Pawar GV (2014). Impact of forest fire on biomass and Carbon storage pattern of Tropical Deciduous Forests in Bhoramdeo Wildlife Sanctuary, Chhattisgarh. Intl. J. Ecol. Enviro. Sci. 40(1):57-74.

Kershaw KA (1973). Quantitative and dynamic plant ecology. Edward Arnold Ltd. London. pp 308.

Kittur B, Swamy SL, Bargali SS, Jhariya MK (2014). Wildland Fires and Moist Deciduous Forests of Chhattisgarh, India: Divergent Component Assessment. J. Forestry Res. 25(4):857-866.

Khumbongmayum ADD, Khan ML, Tripathi RS (2006). Biodiversity conservation in sacred groves of Manipur north east India: population structure and regeneration ststus of woody species. Biodiv. Conserv. 15:2439-2456.

Knight DH (1975). A phytosociological analysis of species-rich tropical forest on Barro Coloraddo Island, Panama. Ecol. Monographs 45:259-284.

Margalef DR (1958). Information theory in ecology. General Systems Yearbook 3:36-71.

Misra R (1968). Ecology Work Book.Oxford Publishing Company, Calcutta.

Mueller-Dombois D, Ellenburg H (1974). Aims and methods of vegetation Ecology. Jhon Wiley and Sons.Inc.

Pande R, Bargali K, Pande N (2014). Impacts of Disturbance on the Population Structure and Regeneration Status of Tree Species in a Central Himalayan Mixed-Oak Forest, India. Taiwan J. Forest Sci. 29(3):179-192.

Phillips EA (1959). Methods of vegetation study. Henry Hill & Co. Inc., U.S.A.

Pielou EC (1966). The measurement of diversity in different types of biological collections. J. Theoret. Biol. 13:131-144.

Rana BS, Singh RP, Singh SP (1989). Carbon and energy dynamics of seven Central Himalayan forests. Trop. Ecol. 30:253-269.

Rawat YS, Singh JS (1988). Structure and function of Oak forest in central Himalaya. I. dry matter Dynamics. Annals of Botany 62:397-341.

Saxena AK, Singh JS (1982). A phytosociological analysis of woody species in forest communities of a part of Kumaoun Himalaya. Vegetatio 50(1):03-22.

Saxena AK, Singh JS (1984). Tree population structure of certain Himalayan forest associations and implications concerning their future composition. Vegetatio 58: 61-69.

Shahni KC (1990). Gymnosperms of India and addjacent countries. Bishan Singh and Mahendra Pal Singh Dehradun, India.

Shannon CE, Weaver W (1963). The Mathematical Theory of Communication. Urbana, USA: University of Illinois Press.

Simpson EH (1949). Measurment of diversity. Nature 163: 688.

Singh JS, Singh SP (1987). Forest Vegetation of the Himalaya. Botanical Rev. 53(1): 80-192.

Singh SP, Adhikari BS, Zobel DB (1994). Biomass, productivity, leaf

longevity and forest structure in the central Himalaya. Ecological Monographs, 64(4):401-421.
Troup RS (1921). The Silviculture of Indian trees Vol. 1-111. Clarendon Press, Oxford.1195.
Valdiya KS (1980). Geology of Kumaun Lesser Himalaya. Wadia Institute of Himalayan Geology, Dehradun.