Plant biodiversity distribution pattern under pure and mixed chir-pine (*Pinus roxburghii* Sarg.) forests of central Himalaya, India

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Abstract: Pure chir pine and mixed chir pine-deodar are the primary forests distributed in the central Himalayan of India. The significance of this zone may be drawn considering the fact that major population and developmental pressures on this zone have increased manifold over the decayed. The present study was undertaken to assess the present status of species diversity and distribution trend in these two types of forests. Trees, shrubs and herbs species were collected and described on the basis of taxonomy, distribution, habitat and economic importance. Apart from chir pine and deodar trees, *Myrica nagi*, *Rhododendron arboreum* and *Quercus leucotricophora* have been observed in these forests. However, dominant tree species are *Pinus roxburghii* in pure chir pine forests, and *Cedrus deodara* and *Pinus roxburghii* in mixed forests. *Quercus leucotricophora* as a broad leaved tree species also showed satisfactory dominance in the mixed forests. Shrubs *viz*., *Eupatirium canabinum* and *Asparagus racemosus* in pure forests and *Berberis asiatica* and *Utrica dioica* in mixed forests are the dominant species. *Geranium nepalensis* is the most dominant herb species in pure forests, whereas, *Justica simplex* and *Heteropogon contortus* are dominant in mixed forests. Mixed forests have higher diversity index for all the categories *viz*., tree, shrubs and herbs. Tree density was higher in mixed forests, whereas, shrub and herb density were higher in pure chir pine forests. These observations reflected the plant biodiversity spectrum in the mid hills of central Himalayan chir pine and mixed forests. Considering the significance of these forests, conservation and regeneration (naturally as well as artificially) processes of all types of species present in these forests have to be taken care for a balanced carbon reserve.
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Introduction

The great Himalaya is globally recognized for its vast resources of biodiversity. A large variety of wild plants growing in this zone are used for food and to meet many substantial needs of the local communities (Sundriyal and Sundriyal 2003; Kala, 2004; Brown *et al*., 2011), such as medicine, edible fruits, fodder, fuel, timber and many other purposes. Thus, a very close relationship and dependence have been established between forest and inhabitants of the hill. This bonding has been also substantiated by various workers, that forest products constitute an important source of livelihood for millions of people from forest fringe communities across the world (Murphy *et al.,* 2005; Mamo *et al.*, 2007; Blay *et al.*, 2007; Negi *et al.,* 2011). The Himalayan vegetation ranges from sub-tropical deciduous to evergreen forests across the foothills to alpine meadows above the timberline (Singh and Singh, 1987). Trees of *Pinus roxburghii* along with other conifers and broad leaved tree species dominate from low to mid elevation sub temperate to dry temperate zones. Over the decayed, this zone is confronting different challenges. Large scale human interferences for timber and other raw materials and continued disturbance either by geological, anthropogenic or developmental have been viewed as major challenges. Occurrence of fires in chir-pine forests in varying intensities has become an unwarranted feature during the dry spells despite of utmost precautionary measures (Kumar and Thakur 2008), and is posing a great threat in the sustainability of this type of ecology in the Central Himalaya, especially for the sub-strata species. The climate change factors of the Himalayan region, as evident from the erratic and abnormal (both low and heavy) annual precipitation (rain and snow) trend and increasing hot days in the spring and summer is also affecting distribution of vegetation. As a whole, all these factors are severely threatening the Himalayan biological diversity, in terms of ecological diversity, genetic/species diversity, organism diversity and other conjoined. One of the foundations for conservation of biological diversity in forest landscape is understanding and managing the disturbances regimes of a landscape under vast natural and semi natural conditions. Considering the greater role of pine forest and its inner biodiversity spectrum of the central Himalaya. The present study was carried out to assess the present status of biodiversity in disturbed pure chir-pine and chir pine-deodar mixed forests. Plant biodiversity of this zone

was assessed by quantitative analysis of forest vegetation in different forests on the basis of different phyto-sociological parameters.

Materials and Methods

The present study was carried out in mid hills of Uttarakhand (India). This district Almora is geographically situated between 29^0 29' to 29^0 58' 40" North latitude and 79^0 2' 40" to 80^0 59' 55" East latitude, covering an area of 370 sq km. The altitude of the district ranges from 525 m (Gajmalla, salt block) to 2412 m (Binsar, Takula block) amsl. The district Almora is bordered by four districts *viz.*, Bageshwar, Pithoragarh, Nainital and Champawat of Kumaun region and two districts, Pauri and Chamoli of Garhwal region.

The climate is wet sub temperate to temperate. Cold season (winter) begins from mid November and lasts up to mid February. Spring season is from last week of March to April, summer season is during May to June. Onset of rain occurs during first week of June (pre-monsoon), June-July-August (Monsoon) and September (post-monsoon). There is occasional rainfall during fall (October-November). Winter season experiences light to medium rain fall with snow. Late winter and early spring season also experience low temperature, when there is light-medium rainfall with hail storm. Occurrence of dry spell during mid spring to mid summer seasons has become regular feature in this zone. The heaviest precipitation occurs in the month of August–mid September and heavy losses in terms of soil erosion as well as landslides in the forest and cultivated areas have become regular feature. Annual rainfall ranges from 4-275 mm. Temperature during winter (average range 5-17 ^{0}C) may fall to sub zero degrees and in other season temperature may go as high as 34 ^{0}C with a minimum temperature of 13-16 ^{0}C.

Methodology

Study materials in the pure chir-pine and mixed chir pine-deodar forest were defined as trees, shrubs and herbs, and all the three strata of forest vegetation were analyzed.

Various species present in the study areas were collected, identified and described as per previous descriptions (Gupta 1969; Collett 1971; Bhatnagar and Moitra 1996; Gangwar *et al.,* 2010; Negi *et al*., 2011; Kumari *et al*,. 2011) on the basis of their taxonomy, distribution and habitat in the central Himalaya. Three forests sites in each type of forest (pure and mixed) were randomly selected across the altitudinal range of 1550-1800m msl for carrying out the present study. Tree analysis was done by sampling methods and data generated from all the three selected forest sites in each forest type (pure and mixed) were pooled for further quantitative analysis. Ten samples from each site were taken for data collection. The size and number of samples were determined according to Saxena and Singh (1982). Observations on trees (>30 cbh), seedling (having <10 cm cbh.) and sapling (having 10-31 cm cbh.) were recorded by randomly marking 10 x 10 m, 1 x 1 m and 5 x 5 m quadrates, respectively. The trees were sampled for cbh. at 1.37 m height from the ground level. Shrub layer was analyzed by placing 5 x 5 m quadrats and herbs by 1 x 1m quadrats randomly from each site. Individual shrub crown cover was estimated on 25 m^2 circular plot by measuring crown length at the largest axis and width at the largest axis perpendicular to the length, and radius (r) was calculated from the {(avg. of length and width in each case)/2}. Area of circular was calculated by the formula 'πr^{2}' and this was actually crown cover of a single unit shrub. Total crown cover of shrub in each plot was determined by summing all the values of crown cover of individual shrubs (Wagner *et al*., 2007). Herbs cover was determined by placing a transect of 1 x 1 m on the ground (Mishra 1968).

Formula used for measurement of different phyto-sociological parameters is given as below:
The vegetation data was analyzed (Curtis and McIntosh 1950).

Density = Total number of individuals of a single species in all the samples/ Total number of samples studied

Frequency = (Total number of samples in which a single species occurred) x 100/Total number of samples studied)

Abundance = Total number of individuals of a single species in all samples/Total number of samples in which species occurred

Abundance/Frequency ratio was measured as an indicative of distribution pattern of different plant species in a forest.

Mean and total basal area of a plant was measured as:

Mean basal area of tree = (Average circumference of the plant)^2/4π, or, $C^2/4\pi$ or = πr^2,

Total basal area of an individual species = Average basal area of the species x Density of the species

The relative parameter and IVI (Importance value index) for different forest strata were determined following Curtis (1959) and calculated as:

Relative density = (Density of a species) x 100/ Total density of all species

Relative frequency = (Frequency of a species) x 100/Total frequency of all species

Relative dominance = (Total basal area or cover of a single species) x 100/ Total basal area of all species
I V I (Importance Value Index) = (Relative density + Relative frequency + Relative dominance).
Species diversity: Diversity is measured as the number of species occurring within an area of a given size (Huston, 1994). It, therefore, measures the richness of a potentially interactive assemblage of species. The diversity index was computed by using Shannon Weiner information index (Shannon and Weiner 1963) as

H= - Σ (ni/n) log2 (ni/n)

where, ni = total number of individuals of a species, n = total number of individuals of all species.

Results

Specific analysis in the pure chir pine forest

Tree layer

In the pure chir pine forest, three tree species (Table 1a&b) *viz*., *Pinus roxburghii, Myrica nagi* and *Rhododendron arboreum* were present with a total density of 5.3 trees/100 m^2 or 530 trees/ha. It was maximum (4.5 trees/100 m^2 or 450 trees/ha.) for *Pinus roxburghii* and minimum (0.3 trees/100 m^2 or 30 trees/ha.) for *Rhododendron arboreum*. The maximum frequency (100%) was observed for *Pinus roxburghii* and minimum (10%) for *Rhododendron arboreum* with a total frequency value of 140% in this type of forests. Abundance varied from 0.03 trees/100 m^2 or 3 trees/ha. (*Rhododendron arboreum*) to 4.5 trees/100 m^2 or 450 trees/ha. (*Pinus roxburghii*). A/F ratio varied from 0.03 to 0.06. Total basal area of each tree species ranged from 38.6 cm^2/100 m^2 or 38.6 m^2/ha. (*Rhododendron arboreum*) to 82.9 cm^2/100 m^2 or 82.9 m^2/ha. (*Pinus roxburghii*) with overall total basal area of 163.6 cm^2/100 m^2 or 163.6 m^2/ha. for all the tree species in this forests. The highest scores for relative density (86.5%), relative frequency (71.4%) and relative dominance (95.9%) were recorded in case of *Pinus roxburghii,* whereas, the lowest scores were recorded in *Rhododendron arboreum* with respective values of 1.9%, 7.1% and 1.4%. Accordingly, *Pinus roxburghii* recorded the maximum value (253.8) and *Rhododendron arboreum* recorded the minimum (10.4) for IVI. Total tree diversity in terms of Shannon Weiner index was 0.73.

Table 1a. Phyto-sociological parameters for tree layer in pure chir pine and mixed chir pine-deodar forest.

Species	Density (Trees/100m^2)	Frequency (%)	Abundance (Trees/100m^2)	A/F ratio	Total basal area (cm^2/100m^2)	Diversity index
Pure Chir pine forest						
Pinus roxburghii	4.5 (450)	100	4.5 (450)	0.05	82.9 (82.9)	0.20
Myrica nagi	0.5 (50)	30	1.7 (170)	0.06	42.1 (42.1)	0.36
Rhododendron arboreum	0.3 (30)	10	0.03 (3)	0.03	38.6 (38.6)	0.17
Total value	5.3 (530)	140	6.23 (623)	0.14	163.6 (163.6)	0.73
Mean value	1.8 (176.6)	46.7	2.1 (207.6)	0.05	54.5 (54.5)	0.24
Mixed chir pine-deodar forest						
Cedrus deodara	4 (400)	100	4 (400)	0.04	121.0 (121)	0.52
Pinus roxburghii	3.6 (360)	100	3.6 (360)	0.36	128.7 (128.7)	0.53
Quercus leucotricophora	1.4 (140)	70	2.0 (200)	0.03	66.6 (66.6)	0.42
Total value	9 (900)	270	9.6 (960)	0.43	316.3 (316.3)	1.47
Mean value	3 (300)	90	3.2 (320)	0.14	105.4 (105.4)	1.19

Digits in parenthesis are quantification per hectare (density and abundance (trees/ha; total basal area (m^2/ha)

Table 1b. Relative density, relative frequency, relative dominance and Importance value index of tree layer in pure chir pine and mixed chir pine-deodar forest.

Species	Relative Density (%)	Relative Frequency (%)	Relative dominance (%)	Important Value index
Pure Chir pine forest				
Pinus roxburghii	86.5	71.4	95.9	253.8
Myrica nagi	9.6	21.4	2.7	33.7
Rhododendron arboreum	1.9	7.14	1.4	10.4
Total value	98	99.9	100	298
Mixed chir pine-deodar forest				
Cedrus deodara	44.4	37.0	47.1	128.5
Pinus roxburghii	40.0	37.0	47.0	124.0
Quercus leucotricophora	15.6	25.9	4.90	46.4
Total value	100	99.9	99	298.9

Shrub Layer

A total of five shrubs were collected from this pure pine forest (Table 2a&b). Total density of shrub species was 35.2 shrubs/25 m^2 or 14080 shrubs/ha. Individual density ranged between 3.5 shrubs/25 m^2 or 1400 shrubs/ha. (*Berberis asiatica* and *Desmodium elegans*) to 15.5 shrubs/25 m^2 or 6200 shrubs/ha. (*Eupatorium cannabinum*). Frequency (50%) and abundance (31 shrubs/25 m^2 or 12400 shrubs/ha.) were also maximum in case of *Eupatorium cannabinum*. The total crown coverage of each shrub species ranged between 3.4 m^2/25 m^2 (1360 m^2/ha.) to 12 m^2/25 m^2 (4800 m^2/ha.). It was maximum for *Eupatorium cannabinum* and minimum for *Berberis asiatica.* The highest values for relative density (44.4%), relative frequency (31.3%) and relative dominance (33.9%) were recorded in case of *Eupatorium cannabinum*. Whereas, *Berberis asiatica* scored the lowest values for relative density and relative frequency, and *Desmodium elegans* recorded the lowest value for relative dominance. Accordingly, *Eupatorium cannabinum* resulted in the highest IVI (109.6). Over all shrub diversity index in these forests was 2.19.

Table 2a. Phyto-sociological parameters for shrub layer in pure chir pine and mixed chir pine-deodar forest.

Species	Density (shrub/25m^2)	Frequency (%)	Abundance (shrub/25m^2)	A/F ratio	Total basal area (m^2/25m^2)	Diversity index
Pure Chir pine forest						
Eupatorium cannabinumi	15.5 (6200)	50	31.0 (12400)	0.6	12 (4800)	0.53
Asparagus racemosus	8.3 (3320)	30	27.7 (11080)	0.4	6.5 (2600)	0.47
Rubus ellipticus	4.4 (1760)	30	14.7 (5880)	0.5	6.6 (2640)	0.43
Berberis asiatica	3.5 (1400)	20	15.0 (6000)	0.8	3.4 (1360)	0.34
Desmodium elegans	3.5 (1400)	30	11.6 (4640)	0.4	6.9 (2760)	0.42
Total value	35.2 (14080)	160	100 (40000)	2.7	35.4 (14160)	2.19
Mean value	7.0 (2816)	32	20 (8000)	0.5	5.0 (2831)	0.44
Mixed chir pine-deodar forest						
Berberis asiatica	4.5 (1800)	40	11.3 (4520)	0.28	4.5 (1800)	0.46
Utrica dioica	3.8 (1520)	30	12.6 (5040)	0.42	6.3 (2520)	0.45
Rubus ellipticus	3.7 (1480)	30	12.3 (4920)	0.41	8.2 (3280)	0.46
Myrsine africana	3.1 (1240)	40	7.75 (3100)	0.19	7.9 (3160)	0.47
Randia tetrasperma	2.7 (1080)	20	13.5 (5400)	0.67	3.1 (1240)	0.36
Asparagus racemosus	1.1 (440)	20	5.5 (2200)	0.013	4.9 (1960)	0.34
Total value	18.9 (7560)	180	62.95 (25180)	1.983	34.9 (13960)	2.54
Mean value	3.2 (1260)	66.7	10.5 (4196.7)	0.33	5.8 (2326.7)	0.42

Digits in parenthesis are quantification per hectare (density and abundance (shrubs/ha; total basal area (m^2/ha)

Table 2b. Relative density, relative frequency, relative dominance and Importance value index shrub layer in pure chir pine and mixed chir pine-deodar forest.

Species	Relative Density (%)	Relative Frequency (%)	Relative dominance (%)	Important Value index
Pure Chir pine forest				
Eupatorium cannabinumi	44.4	31.3	33.9	109.6
Asparagus racemosus	23.8	18.8	28.4	61.0
Rubus ellipticus	12.6	18.6	18.6	49.8
Berberis asiatica	9.2	12.5	13.7	35.4
Desmodium elegans	10.0	18.8	9.5	38.3
Total value	100	100	94.1	294.1
Mixed chir pine-deodar forest				
Berberis asiatica	23.8	22.2	12.9	58.9
Utrica dioica	20.1	16.7	18.1	54.9
Rubus ellipticus	19.6	16.7	23.5	59.8
Myrsine africana	16.4	22.2	22.6	61.2
Randia tetrasperma	14.3	11.1	8.8	34.2
Asparagus racemosus	5.8	11.1	1.4	30.9
Total value	100	100	99.9	299.9

Herbs Layer

Five types of herbs were observed in the sites studied (Table 3a&b). Total density and total ground cover of all the herb species were 16.9 herbs/m^2 (169000 herbs/ha.) and 4.4 cm^2/m^2 (440 m^2/ha.), respectively. Individual species density ranged between 0.4 herbs/m^2 or 4000 herbs/ha. (*Plectranthus japonicus*) to 12 herbs/m^2 or 120000 herbs/ha. (*Geranium nepalense*). Total ground cover of different herb species ranged between 0.5 cm^2/m^2 or 50 m^2/ha. (*Heteropogon contortus*) to 1.8 cm^2/m^2 or 180 m^2/ha. (*Geranium nepalense*). The highest values for relative density (71.0%) and relative dominance (40.9%) were for *Geranium nepalense*, whereas, *Rumex hastatus* scored the highest relative frequency (27.3%). However, the highest IVI value was recorded for *Geranium nepalense* (134.6) and the lowest was for *Plectranthus japonicus* (25.4). Total herb diversity index in the pure chir pine forests was found to be 2.07.

Table 3a. Phyto-sociological parameters for herb layer in pure chir pine and mixed chir pine-deodar forest.

Species	Density (herb/m^2)	Frequency (%)	Abundance (herb/m^2)	A/F ratio	Total basal area (cm^2/m^2)	Diversity index
Pure Chir pine forest						
Geranium nepalense	12.0 (120000)	50	24.0 (240000)	0.5	12 (4800)	0.52
Rumex hastatus	2.1 (21000)	60	3.5 (35000)	0.6	6.5 (2600)	0.46
Fragaria indica	1.4 (14000)	50	2.8 (28000)	0.6	6.6 (2640)	0.41
Heteropogon contortus	1.0 (10000)	40	2.5 (25000)	0.06	3.4 (1360)	0.36
Plectranthus japonicus	0.4 (4000)	20	2.0 (20000)	0.1	6.9 (2760)	0.32
Total value	16.9 (169000)	220	34.8 (348000)	1.86	35.4 (14160)	2.07
Mean value	3.4 (33800)	44.0	7.0 (69600)	0.4	5.0 (2831)	0.41
Mixed chir pine-deodar forest						
Justicia simplex	6.0 (60000)	50	12.0 (120000)	0.24	4.5 (1800)	0.52
Heteropogon contortus	4.2 (42000)	30	14.0 (140000)	0.47	6.3 (2520)	0.45
Anaphalis contorta	2.8 (28000)	30	9.3 (93000)	0.31	8.2 (3280)	0.42
Carex nubigena	1.9 (19000)	40	4.7 (47000)	0.01	7.9 (3160)	0.44
Fragaria indica	0.8 (8000)	50	1.6 (16000)	0.03	3.1 (1240)	0.44
Total value	15.7 (157000)	200	41.6 (416000)	1.06	34.9 (13960)	2.27
Mean value	3.1 (31400)	40.0	8.3 (83200)	0.21	5.8 (2326.7)	0.45

Digits in parenthesis are quantification per hectare (density and abundance (herb/ha; total basal area (m^2/ha)

Table 3b. Relative density, relative frequency, relative dominance and Importance value index herb layer in pure chir pine and mixed chir pine-deodar forest.

Species	Relative Density (%)	Relative Frequency (%)	Relative dominance (%)	Important Value index
Pure Chir pine forest				
Geranium nepalense	71.0	22.7	40.9	134.6
Rumex hastatus	12.4	27.3	18.2	57.9
Fragaria indica	8.3	22.7	13.6	44.6
Heteropogon contortus	5.9	18.2	11.4	35.5
Plectranthus japonicus	2.4	7.1	15.9	25.4
Total value	100	98	100	298
Mixed chir pine-deodar forest				
Justicia simplex	38.2	25	28.6	91.8
Heteropogon contortus	26.7	15	14.3	56.0
Anaphalis contorta	17.8	15	14.3	47.1
Carex nubigena	12.1	20	19.0	51.1
Fragaria indica	5.1	25	23.8	53.9
Total value	99.9	100	100	299.9

Specific analysis in the chir pine-deodar mixed forest

Tree layer

In this type of mixed forests, three tree species were present (Table 1a&b). Tree species *viz.*, *Cedrus deodara, Pinus roxburghii* and *Quercus leucotricophora* were found to have 9 trees/100 m^2 or

900 tree/ha total density for all these tree species. The range of individual species density was 1.4 trees/100 m^2 or 140 trees/ha. (*Quercus leucotricophora*) to 4 trees/100 m^2 or 400 tree/ha (*Cedrus deodara*). The frequencies for *Cedrus deodara*, *Pinus roxburghii* and *Quercus leucotricophora* were 100%, 100% 70%, respectively. Abundance of *Cedrus deodara* was 4 trees/100 m^2 (400 trees/ha.), *Pinus roxburghii* was 3.6 trees/100 m^2 (360 trees/ha.), and *Quercus leucotricophora* was 2.0 trees/100 m^2 (200 trees/ha.). A/F ratio ranged from 0.03-0.36. Total basal area of *Cedrus deodara* was found to be 121.0 cm^2/100 m^2 or 121 m^2/ha. and for *Pinus roxburghii* it was 128.7 cm^2/100 m^2 or 128.7 m^2/ha., whereas, *Quercus leucotricophora* recorded 66.6 cm^2/100 m^2 or 66.6 m^2/ha. Over all total basal area was 316.3 cm^2/100 m^2 (316.3 m^2/ha.). The highest scores for relative density (44.4%), relative frequency (37.03%) and relative dominance (47.1%) were recorded in case of *Cedrus deodara*, closely followed by *Pinus roxburghii*. IVI was maximum for *Cedrus deodara* (128.5) and minimum for Quercus *leucotricophora* (46.4%). Total diversity index of trees species in these type of mixed forests was 1.47.

Shrub Layer

A total of six shrubs species were present in the mixed forests studied (Table 2a&b. Over all total density and total crown cover of the entire shrub species were found to be 18.9 shrubs/25 m^2 or 7560 shrubs/ha. and 34.9 m^2/25 m^2 or 13960 m^2/ha, respectively. The range of density was 1.1 shrubs/25 m^2 or 440 shrubs/ha (*Asparagus racemosus*) to 4.5 shrubs/25 m^2 or 1800 shrubs/ha (*Berberis asiatica*), and total crown cover of individual shrub species was in range of 3.1 m^2/25 m^2 or 1240 m^2/ha. (*Randia tetrasperma*) to 8.2 m^2/25m^2 or 3280 m^2/ha. (*Rubus ellipticus*). Abundance was maximum for *Randia tetrasperma* (13.5 shrubs/25 m^2 or 5400 shrubs/ha.), closely followed by *Utrica dioica* (12.6 shrubs/25 m^2 or 5040 shrubs/ha.) and *Rubus ellipticus* (12.3 shrubs/25 m^2 or 4920 shrubs/ha.). A/F ratio was ranged between 0.013 to 0.67. The highest scores for relative density (23.8%) was for *Berberis asiatica* , relative frequency (22.2%) for *Berberis asiatica* and *Myrsine Africana*, whereas, the highest relative dominance (23.5%) was recorded for *Rubus ellipticus*. IVI was maximum for *Myrsine Africana* (61.2) and minimum for *Asparagus racemosus* (30.9). Total diversity index of shrubs in these type of mixed forests was 2.54.

Herbs Layer

Five different types of herbs were collected in the study area (Table 3a&b). Over all total density and total ground cover of all the species were 15.7 herbs/m^2 or 157000 herbs/ ha. and 2.1 cm^2/m^2 or 210 m^2/ha., respectively, with respective ranges of 0.8 herbs/m^2 or 8000 herbs/ha (*Fragaria indica*) to 6.0 herbs/m^2 or 60000 herbs/ha. (*Justicia simplex*) herbs/m^2, and 0.3 cm^2/m^2 or 30 m^2/ha. (*Heteropogon contortus* and *Anaphalis contorta*) to 0.6 cm^2/m^2 or 60 m^2/ha. (*Justicia simplex*). Frequency ranged between 30% (*Heteropogon contortus* and *Anaphalis contorta*) to 50% (*Justicia simplex* and *Fragaria indica).* Abundance ranged from 1.6 herbs/m^2 or 16000 herbs/ha. (*Fragaria indica*) to 14.0 herbs/m^2 or 140000 herbs/ha. (*Heteropogon contortus*). The highest values for relative density was 38.2% (*Justicia simplex*), relative frequency was 25% (*Justicia simplex and Fragaria indica*), and relative dominance was highest for *Justicia simplex* (28.6%). Accordingly, IVI was maximum in case of *Justicia simplex*. Total diversity index of herbs in these type of mixed forests was 2.27.

Discussion

The observations from all the phyto-sociological attributes examined *viz*., density, frequency, abundance, total basal area, relative density, relative frequency, relative dominance and IVI, (Table 1a&b) revealed that *Pinus roxburghii* (450 trees/ha. density) was the most dominating tree species in pure chir pine forests along with the presence of *Myrica nagi* (50 trees/ha. density) and *Rhododendron arboretum* (30 tree/ha. density) at limited scale. Whereas in the mixed type forests, *Cedrous deodara* (400 trees/ha. density) was the dominating tree species, closely followed by *Pinus roxburghii* (360 trees/ha. density). The density of *Quercus leucotricophora* (140 trees/ha. density) was also high. These observations may be further substantiated from their respective IVI values also (Table 1b). The most dominating shrub species in the pure chir pine forests was observed (Table 2a&b) to be *Eupatorium cannabinum* (6200 shrubs/ha. density and 109.6 IVI), closely followed by *Asparagus racemosus*. Whereas, other shrubs *viz*., *Berberis asiatica*, *Desmodium elegans* and *Rubus ellipticus* were also present along with these two dominating shrubs at different densities. The distribution pattern of shrubs in mixed forests were different form pure chir pine forests as indicated in data expressed in different phyto-sociological attributes *viz*., densities, frequencies, abundance as well as other parameters. *Berberis asiatica* (1800 shrubs/ha density and 58.9 IVI) was the most dominating shrubs in these type of mixed forests, closely followed by *Utrica dioica*, *Rubus ellipticus* and *Myrsine africana*. *Randia tetrasperma* and *Asparagus racemosus* were observed at limited scale along with these three shrubs. Similarly, dominance of species under herbs (Table 3a&b) in pure chir pine forests varied from mixed forests in the study sites. *Geranium nepalense* (120000 herbs/ha. density and 134.6 IVI) was the

most dominating herb, whereas, other herb species *viz*., *Rumex hastatus*, *Fragaria indica*, *Heteropogon contortus* and *Plectranthus japonicas* were present at lesser densities. *Justicia simplex* (60000 herbs/ha. density and 91.8 IVI) was the most dominating species in mixed forests, closely followed by *Heteropogon contortus*. Other herbs such as *Anaphalis contorta*, *Carex nubigena* and *Frageria indica* were also present at different densities in these type of forests. In total perspective, it has been observed that mixed type of forests scored higher values (Table 1a&b) for density, frequency, abundance, A/F ratio and tree basal area for tree species in comparison to pure pine forests. However, in case of shrubs total density, abundance were higher in pure pine forests (Table 2a&b), though, frequency (%) was higher in mixed forests. Herb density, frequency and ground area coverage were higher in pure pine forests, whereas, abundance was higher in mixed forests (Table 3a&b). Individually all the species under tree, shrub and herb showed greater variation in relative values of density. Frequency, dominance and IVI . Diversity in terms of Shannon and Weiner index showed that mixed chir pine-deodar forests has greater values for all the three categories (trees, shrubs and herbs) in comparison to pure chir pine forests.

The present observations represent an over all species diversity in the Central Himalayan mid hill forests, where, chir pine is the main tree species along with other conifers and broad leaved tree species, shrubs and herbs. Mixed forests showed greater diversity in terms of occurrence of species in all the strata. Higher tree density in the mixed forests comprising conifers and broad leaved species (*Quercus leucotricophora*) favoured greater shrubs and herbs diversity. Similar observations were also reported by Gurarni *et al,*. 2010), where, mixed (pine-oak) forests always comprised more species diversity. Rathore (1993) also reported higher species richness and diversity in the *P. roxburghii* mixed broadleaf forests. Greater amount of diversity of shrubs and herbs in coniferous broad leaved mixed forests was also reported by Saxena and Singh (1982) and Semwal *et al.,* (2008). *Pinus roxburghaii* and *Quercus leucotricophora* with higher IVI were the determinant of dominance in the temperate forests in central Himalaya in the present study. Dependence on these plant species for different kinds of socio-economic benefits including medicinal uses in the central Himalaya mid hill zone have been also well documented by various workers (Anonymous, 1986; Gangwar and Joshi; 2008, Negi, *et al*. 2011; Kumari *et al*., 2011). These observations also revealed that variation in occurrence of different species as well as their dominance patterns in terms of different phyto-socialogical attributes under tree, shrub and herb in both type of forests is the indicative of variation in microclimate, soil conditions and mainly because of ecological selectivity or adaptive nature of species in these two types of forests ecosystems. Shrestha *et al.,* (1998) and Spies and Turner (1999) also reported that species density and richness are dependent on associated species, human activities, soil types, environmental stability and habitat heterogeneity. Shannon-Weiner index range was 0.73-2.54 in the present study, which was slightly lower than the earlier reports (1.16-3.4) in the Indian temperate forests (Saxena and Singh 1982). This might be due to the fact that human interferences in terms of fuel wood, felling, cattle grazing, and collection of fallen dry leaves which resulted in reduced diversity in the lower strata over the years.

Conclusion

Phyto-sociological parameters as analyzed for tree, shrub, and herb layers of the forests of the sites *viz*., pure chir pine and mixed chir pine-deodar forests showed greater differences is different analytical characteristics. Considering the principal components of any biodiversity set up, which refers to the sum of all the different species of flora and fauna in a particular ecological zone that facilitates the ecosystem to function properly, such a study on the total species diversity of these forests, holds significance. It is true as the biodiversity is in serious danger; it is shrinking at an alarming rate. The impact may be viewed in terms of gradual warming of Himalayan climate, insufficient winter precipitation, low snow fall, water shortage, rise in temperature, fluctuating winter chilling temperature *etc*. All these are affecting distribution and diversity pattern of shrubs and herbs in these forests. Pure chir pines as well as mixed chir pine-deodar type of forests are the barrier between hot sub-tropical North Indian zone and wet temperate higher altitudes zones in the central Himalaya. There is every apprehension that any drift or change in the basic set up in this zone may extend the hot sub-tropical zone to the mid hill zones affecting the sub temperate areas. This change may affect the forest ecology as well as agricultural and horticultural cropping systems, which are the primary source of livelihood in the Hills. Therefore, the pure as well as mixed chir pine-deodar forests may be considered very vital natural carbon reserves, which, are to be conserved, protected and regenerated.

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