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Studies on Species Composition and Diversity in Natural Dry Temperate and Alpine Forest Ecosystem of the North Western Himalayas

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ABSTRACT

The present study was undertaken in natural dry temperate and alpine forest ecosystem of Kinnaur district of Himachal Pradesh situated at 77°45′00′′ and 79°00′35′′ E longitude and between 31°05′50′′ and 32°05′15′′ N latitude. After reconnaissance survey, we classified Himalayan dry temperate and alpine forest ecosystem into nine forest types (FT_1 to FT_9) based on dominance of forest species and their association with other forest species. These nine forest types (FT) were : FT_1-13C1-Dry broad-leaved and coniferous forests (*Quercus ilex –Pinus gerardiana*), FT_2-$13C_2$a- Neoza pine forest (*Pinus gerardiana*), FT_3-$13C_2$b- Dry deodar forest (*Cedrus deodara*), FT_4-13 C_3- West Himalayan high level dry blue pine forest (*Pinus wallichiana*), FT_5-$14C_1$a- West Himalayan sub- alpine birch forest, FT_6-$14C_1$b- West Himalayan sub-alpine fir forests, FT_7-$15C_1$- Birch-rhododendron scrub forest, FT_8-$15C_3$- Alpine pasture, FT_9-$16C_1$- Dry alpine scrub in dry temperate and alpine forest ecosystem. A total of 139 plant species (7 tree, 26 shrub and 106 herb) belonging to 102 genera and 44 families were recorded. The different indices i.e. Important value index, Shannon index of diversity, Simpson index of dominance and Margalef's index of richness revealed that values of species diversity, plant density and plants basal cover were lower in the study area in comparison to similar forests growing in other parts of Western Himalayas. These results imply that dry temperate and alpine forests need effective monitoring and conservation.

Keywords Important value index, Species diversity, Species richness, Dominance.

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INTRODUCTION

The Himalayan region is blessed with a wide variety of natural resource. The total geographical area of the Himalaya in India is 61.5 m ha, out of which 17.8 m ha area is covered with alpine pastures and occupy about 1.52% of the total land area in the

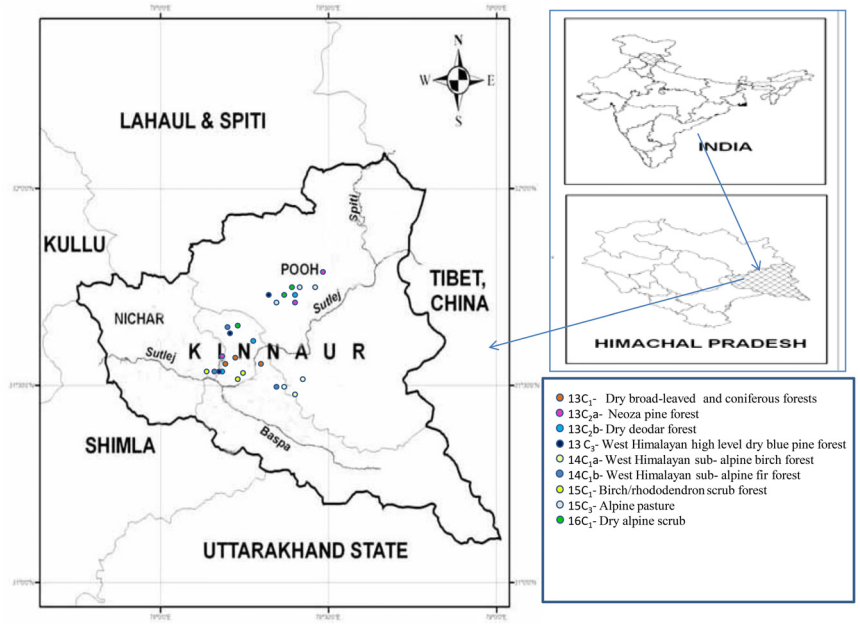

Fig. 1. Location of study area and forest type map of Kinnaur district (HP).

country with wide range of variations in terms of its size, climate and altitudinal ranges which have created environments that are unique and characteristic to this region only (Negi 2009). Further, the rapidly changing factors influence the species composition, structure and function of tree communities is not well known and remains a critical gap in developing conservation plans. So, it is of utmost importance to consider the habitat specific species pool when studying or planning conservation of diversity (Partel 2014) and this quantitative floristic sampling study provides the necessary context for planning and interpreting long term ecological research.

Dry temperate and alpine forests, life form a diverse plant community; have invited the attention of researchers over several decades in order to understand their complex structure, function, phytosociology and ecology. Quantitative inventory of species diversity of any forest ecosystem is an important tool for forest assessment, forest management and biodiversity conservation.

The baseline data of forest ecosystem is used to understand the forest ecology including plant diversity and community organization, biodiversity conservation and effective management of these fragile ecosystems. Inadequacy of information on quantitative data on species diversity, composition, characteristics and its population structure is the reason behind the present study aiming to fill the gaps on data of dry temperate and alpine forests in particular.

MATERIALS AND METHODS

Study area

The present study area fall in Kinnaur district of Himachal Pradesh situated at 77°45′00′′ and 79°00′35′′ E longitude and between 31°05′50′′ and 32°05′15′′N latitude (Fig. 1). The district of Kinnaur adjoins part of western Tibet with which it shares its eastern boundary by following a well defined ridge generally along the Zanskar Mountains. Its southern boundary adjoins the Uttra-Kashi district of Uttrakhand and Rohru Tehsil of Shimla district. Its western

Table 1. Forest types under dry temperate and alpine region of Kinnaur district of Himachal Pradesh.

FT	Forest type (Champion and Seth 1968)	Altitude range (m)	Important value index of dominant plant species
FT_1	$13C_1$- Dry broad-leaved and coniferous forests	2000-2450	Tree =*Quercus ilex* (175.87), *Pinus gerardiana* (124.13). Shrubs=*Plectranthus rugosus* (92.59), *Lonicera quienquelo cularis* (72.28), *Desmodium tiliaefolium* (31.67). Herbs =*Stipa sibrica* (51.94), *Piptatherum* spp. (26.70), *Artemisia parviflora* (25.91).
FT_2	$13C_{2a}$ - Neoza pine forest	2300-2750	Tree= *Pinus gerardiana* (199.48), *Cedrus deodara* (82.24) *Pinus wallichiana* (18.27). Shrubs= *Lonicera hypoleuca* (75.49), *Ephedra gerardiana* (34.51), *Lonicera quinquelo cularis* (33.57). Herbs = *Artemisia brevifolian* (63.54), *Sopubia trifida* (25.75), *Verbascum thapsus* (19.92)
FT_3	$13C_{2b}$ - Dry deodar forest	2450-2950	Tree= *Cedrus deodara* (270.61), *Pinus gerardiana* (18.75), *Pinus wallichiana* (10.64). Shrubs = *Plectranthus rugosus* (51.87), *Indigofera gerardiana* (39.07), *Indigo feragerardiana* (31.83). Herbs =*Agropyron longearistatum* (41.52) *Alopecurus arundi naceus* (22.38), *Impatiens sulcata* (20.59)
FT_4	13 C_3- West Himalayan high level dry blue Pine forest	3000-3450	Tree = *Pinus wallichiana* (213.06), *Cedrus ceodera* (65.73), *Abies spectabilis* (21.21). Shrubs = *Salix hastata* (110.05), *Berberis erythrolada* (80.99), *Indigo fera gerardiana* (37.28). Herbs= *Salvia nubicola* (44.55), *Chrysopogon gryllus* (25.25), *Setaria viridis* (24.60)
FT_5	$14C_{1a}$ - West Himalayan sub-alpine birch forest	3100-3550	Tree = *Betula utilis* (204.15), *Abie spindrow* (66.09), *Pnus wali chiana* (29.76). Shrubs = *Berberis vulgaris* (161.48) *Rosa macrophylla* (75.78), *Cotoneaster bacillaris* (46.70). (75.78), *Cotoneaster bacillaris* (46.70). Herbs =*Danthoni aschneideri* (71.42), *Chenopodium opulifolium* (46.61), *Impatiens sulcata* (36.67)
FT_6	$14C_{1b}$ - West Himalayan sub-alpine fir forest	3150-3550	Tree= *Abies pindrow* (152.92), *Abies spectabilis* (77.31), *Pinus wallichiana* (61.08), *Betulautilis* (8.66). Shrubs = *Rosa macrophylla* (93.25), *Berberis erythroclada* (66.91) *Salix hastata* (60.69) (75.78), *Cotoneaster bacillaris* (46.70). Herbs = *Impatiens sulcata* (43.10), *Stachys melissifolia* (36.93), *Ligularia fischeri* (34.48).
FT_7	$15C_1$- Birch-rhododendron scrub forest	3300-3600	Tree= *Betula utilis* (285.11), *Abies pindrow* (14.89). Shrubs =*Rhododendron campanulatum* (273.63), *Salix hastata* (16.45), *Rhododendron anthopogon* (9.93). Herbs = *Dryopteris barbigera* (82.89), *Bistorta affinis* (60.75), *Aconogonum alpinum* (50.22).
FT_8	$15C_3$- Alpine pasture	2900-3350	Herbs =*Agropyron semicostatum* (63.26), *Agrostiscanina* (47.61), *Alopecurus arundinaceus* (30.14),
FT_9	$16C_1$- Dry alpine scrub	3300-3750	Shrubs = *Juniperus communis* (191.23), *Juniperus indica* (62.21) *Ribes orientale* (46.56). Herbs = *Danthonia schneideri* (67.63), *Agropyron semicostatum* (43.13), *Echinops cornigerus* (38.81).

part boundary adjoins the Rampur tehsil of Shimla district. The northern boundary of Kinnaur adjoins Spiti sub-division of Lahaul-Spiti district by following mostly the ridge of Spiti and Satluj river basin. The area is characterized by long winters from October to April and short summers from June to August. Heavy rain fall in monsoon is found in outer Himalayas to the arid Tibetan type with a winter

Table 2. Inventory of trees, shrubs and herbs in different forest types in dry temperate and alpine forest ecosystem of Kinnaur district of Himachal Pradesh.

	Forest types (FT)									
Category	FT_1-Dry broad-leaved and coniferous forests	FT_2-Neoza pine forest	FT_3-Dry deodar forest	FT_4-Dry blue pine forest	FT_5-Sub alpine birch forest	FT_6-Sub alpine fir forest	FT_7-Birch rhodo-den-dron scrub forest	FT_8-Alpine pas-ture	FT_9-Dry alpine scrub	Total repre-san-tion in forest type
Trees	3	3	3	3	3	4	2	0	0	21
Shrubs	9	9	12	6	4	5	3	0	3	51
Herbs	22	20	25	24	15	23	11	23	12	175
Total	34	32	40	33	22	32	16	23	15	247

snowfall and practically nosummer rain. In winter season, whole of the Kinnaur district experiences heavy snowfall. Type with a winter snowfall and practically no summer rain. In winter season, whole of the Kinnaur district experiences heavy snowfall. Parent material consists of gneiss, schist, phyllites, quartzite and granites. Among the member of the schistose series micaceous-schists, talcose rocks, phyllites and gneisses are commonest and support good forest of Deodar, Kail and Fir. The soil profiles are well developed under dense forest. On ridges and southern slopes the soil is shallow. On the other hand it is moderately deep on the cooler aspects and on gentle slopes.

The present study was conducted in dry temperate and alpine forest ecosystem of Kinnaur district of Himachal Pradesh. Different forest types noticed in the study area are $13C_1$-Dry broad-leaved and coniferous forests (*Quercus ilex –Pinus gerardiana*), $13C_{2a}$- Neoza pine forest (*Pinus gerardiana*), $13C_{2b}$- Dry deodar forest (*Cedrus deodara*), 13 C_3-West Himalayan high level dry blue pine forest (Pinuswallichiana), $14C_{1a}$- West Himalayan sub- alpine birch forest, $14C_{1b}$- West Himalayan sub- alpine fir forest, $15C_1$- Birch-rhododendron scrub forest, $15C_3$-Alpine pasture, $16C_1$-Dry alpine scrub (Champion and Seth 1968).

Sampling and data analysis

After reconnaissance survey, we classified Himalayan dry temperate and alpine forest ecosystem into nine forest types (FT_1 to FT_9) based on dominance of forest species and their association with other forest species. Community analysis was carried out during rainy season when majority of the plants were at the peak of their growth. In each nine forest type, 9 quadrates of size 20 m × 20 m for trees were laid out randomly across the slope distributed along the elevation gradient (lower, medium and high). Within each quadrate (20 m × 20 m), three sub-quadrates of size of 5 m × 5 m for shrubs and 1 m × 1 m for herbs were laid out. Density of trees was calculated by counting trees in each sample plot. Physiographic factors i.e., altitude and aspect across different forest types were measured by GPS (Garmin, Rino-130). Diameter of each tree in the sample plot was determined by tree calliper or tap. Diameter at breast height (dbh) was taken for the determination of tree basal cover and was calculated as πr^2 or $\pi rd^2/_4$, where r is radius and d is diameter. The data were quantitatively analyzed from stem density, frequency and abundance following Curtis and Mclntosh (1950). Density of shrubs was calculated by counted plants of different species in each sub-plot. The diameter of shrub was calculated by using digital calliper. While in case of herbaceous vegetation, each quadrate was segregated species wise and identified with the help of herbarium at Dr YS Parmar University of Horticulture and Forestery experts, FRI Dehradun scientists, Journals and research books.

Diversity of a community can be assessed using several nonparametric measures such as diversity indices and these measures have gradually gained cred-

ibility (Magurran 1988). The Important Value Index (IVI) (Misra 1968), Shannon-Wiener diversity index (Shannon and Weaver 1963), Simpson concentration of dominance (Simpson 1949), Simpson diversity index (Simpson 1949) and Margalef index of species richness (Margalef 1958) were calculated for each forest type with the following formulae :

Basal area ($m^2 ha^{-1}$)

Basal area = $\pi d2/4$

Where:d = Diameter

Density (No. ha^{-1})

$$\text{Density (D)} = \frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates studied}}$$

Importance value index (IVI)

IVI = Relative Basal Area (RBA) + Relative Density (RD) + Relative Frequency (RF)

Margalef's index of richness' (Dmg) (Magurran 19***88)***

Dmg =(S-1) / InN

Where,

S = Total number of species.
N = Total number of individual per hectare.

Shannon-Wiener Index of diversity (H) (Shannon –Wiener 1963)

The formula for calculating the Shannon-weaver Index of diversity is

$H = -\sum pi \text{ In } pi$

Where

H = Shannon Index of diversity

pi = The proportion of important value of the i^{th} species (pi = ni/N, ni is the important value index of ithspecies and N is the important value index of all the species).

Simpson's concentration of dominance index (Simpson 1949)

The equation is used to calculate Simpson's index was $D = \sum (pi)\ 2$

Where,

D = Simpson index of dominance.

Pi = The proportion of important value of the ith species (pi = ni/N, ni is the important value index of i^{th} species and N is the important value index of all the species).

RESULTS AND DISCUSSION

Plant vegetation study under different forest communities of natural dry temperate and alpine forest ecosystem comprised of 139 species, out of which 7 tree species, 26 shrub species and 106 herbs species were recorded that belongs to 102 genera and 44 families. The number of plant species (Tree + shrub + herb) as counted under different types were recorded maximum in FT_3 (40) followed by FT_1 (34), FT_4 (33), FT_2 and FT_6 (32), FT_8 (23), FT_5 (22), FT_7 (16) and FT_9 (15) (Table 2).

The data obtained from the survey of nine different forest types was analyzed using rescaled distance cluster analysis (Fig. 2). Cluster analysis divided forest types of dry temperate and alpine forest into two major groups based on similarities of species in them. Group -1 consists of FT_8, FT_9, FT_5, FT_4 and FT_6 whereas, group -2 is comprised of FT_2 and FT_3. Group-1 was further divided into sub-groups in which sub- group -1 consists of FT_8 and FT_9 which were very close to each other than sub alpine birch forest interims of similar species. Sub-group-2 consists of FT_4 and FT_6. FT_1 and FT_7 showed non significant relation with other forest types of dry temperate and alpine forest. Hence, they were not forming any distance cluster.

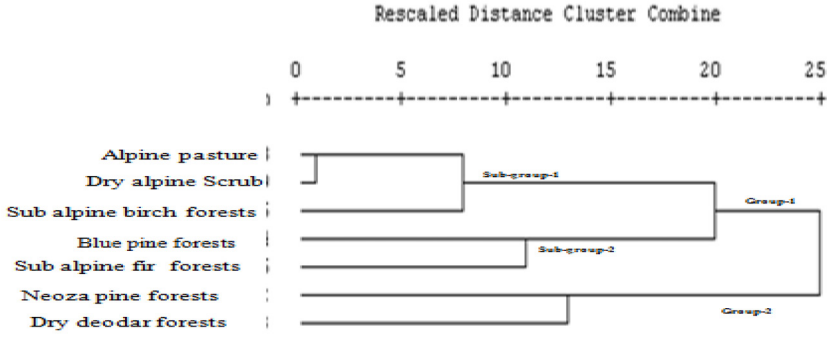

Fig. 2. Cluster dendrogram of different forest types (trees + shrubs + herbs) of Kinnaur, Himachal Pradesh.

Rescaled distance cluster analysis shows that similar climate and habitat condition result in common plant species grown there. The presence of any species in any area is determined by the prevailing environmental conditions and its tolerance and adaptation by it. The range of niches available and occupied by these species in turn suggests their long biotic range.

The values of phyto-sociological and diversity indices in different forest types are demonstrated in Table 3. The highest level of Species richness (Tree+Shrub+Herbs) were recorded in FT_3 (4011) followed by FT_2 (3.31), FT_1 (3.12), FT_4 (3.07), FT_6 (3.06), FT_5 (2.04), FT_8 (1.77), FT_7 (1.35) and FT_9 (1.33). Maximum species diversity was recorded in FT_3 (5.79) followed by FT_4 (5.64), FT_2 (5.53), FT_6 (5.45), FT_1 (5.36), FT_5 (4.28), FT_9 (3.16), FT_8 (2.67) and FT_7 (2.65) wheras, species dominance follow the trend : FT_7 (1.91) > FT_5 > (1.02) >FT_3 (0.98) >FT_4 (0.87) >FT_2 and FT_1 (0.78) > FT_6 (0.68) >FT_9 (0.58) >FT_8 (0.10). It is clear from the data that maximum tree density (275 N ha^{-1}) was recorded in FT_1 which, remain statistically different to FT_4. The density in different forest types follows the trend:F T_1>FT_4> FT_6 > FT_5 > FT_3 > FT_2 > FT_7>FT_8=FT_9. While, in basal area significantly maximum value was recorded in dry deodar forest type (39.94 m^2 ha^{-1}). The basal area recorded in FT_4, FT_2, FT_1, FT_6 and FT_5 remain statistically identical to one another.

In case of shrubs, maximum value of shrubs density was recorded in FT_1 (592 N ha^{-1}), which was found statistical identical to shrubs density recorded in FT_3, FT_7 and FT_4. In respect of basal area huge variation was observed. Among shrub species, basal area ranged from 0.00-7.74 m^2 ha^{-1} which was attained by FT_7 (7.74) m^2 ha^{-1} followed by FT_9 (2.05 m^2 ha^{-1}), FT_3 (0.39 m^2 ha^{-1}), FT_4 (0.37 m^2 ha^{-1}), FT_1 (0.36 m^2 ha^{-1}), FT_2 (0.36 m^2 ha^{-1}), FT_5 (0.27 m^2 ha^{-1}), FT_6 (0.22 m^2 ha^{-1}) and FT_8 (0.00 m^2 ha^{-1}) in descending order, respectively. The density values for herbs also displayed a marked variation. Herbs density ranged from 99259-258890 N ha^{-1} attaining maximum values in FT_8 (258890 N ha^{-1}) followed by FT_1 (245185 N ha^{-1}), dry blue pine forest (210772 N ha^{-1}), FT_6 (207778 N ha^{-1}), FT_3 (194444 N ha^{-1}), FT_5 (179259 N ha^{-1}), FT_2 (152223N ha^{-1}), FT_7 (143333 N ha^{-1}) and FT_9 (99259 N ha^{-1}) in descending order, respectively. The basal area of herbaceous vegetation ranged from 1.25-6.82 m^2 ha^{-1} with maximum values in FT_8 (6.82 m^2 ha^{-1}) followed by FT_1 (5.50 m^2 ha^{-1}), FT_4 (5.53 N ha^{-1}), FT_6 (5.69 m^2 ha^{-1}), FT_3 (3.65 m^2 ha^{-1}), FT_5 (6.41 m^2 ha^{-1}), FT_2 (3.45 m^2 ha^{-1}), FT_7 (3.46 m^2 ha^{-1}) and FT_9 (1.25 m^2 ha^{-1}) in descending order respectively.

The study reveals that the number of plants-found in this part of Himalayas exhibit varying patterns of distribution along different altitudinal and climatic gradients. These finding are comparable with the results of other workers on the vegetation of Himalayas (Verma and Kapoor 2013, Deshmukh and Jain 2016, Kumar *et al.* 2016). While, some workers have also reported more number of genera (159-427), plant species (231-832) and families (69-128)

Table 3. Phytosociological and diversity attributes of nine forest types of dry temperate and alpine forest types.

Parameter		FT-1	FT-2	FT-3	FT-4	FT-5	FT-6	FT-7	FT-8	FT-9
No of plots	Trees	9	9	9	9	9	9	9	9	9
	Shrubs	27	27	27	27	27	27	27	27	27
	Herbs	27	27	27	27	27	27	27	27	27
Geners	Trees	2	2	2	3	2	3	2	0	0
	Shrubs	8	6	9	6	4	5	2	0	2
	Herbs	19	16	22	23	14	23	11	21	12
Families	Trees	2	1	1	1	2	2	2	0	0
	Shrubs	7	7	9	6	3	3	2	0	2
	Herbs	6	13	11	15	11	14	8	12	9
Species richness (SR)	Trees	0.18	0.38	0.38	0.37	0.37	0.56	0.19	0.00	0.00
	Shrubs	1.25	1.34	1.76	0.82	0.51	0.70	0.32	0.00	0.37
	Herbs	1.69	1.59	1.97	1.88	1.16	1.80	0.84	1.77	0.96
Shannon Index of diversity (H)	Trees	0.68	0.81	0.39	0.78	0.83	1.12	0.20	0.00	0.00
	Shrubs	1.90	1.95	2.36	1.95	1.13	1.55	0.37	0.00	0.89
	Herbs	2.78	2.77	3.04	2.91	2.32	2.78	2.08	2.67	2.27
Simpson index of dominance (Cd)	Trees	0.51	0.52	0.82	0.56	0.52	0.37	0.91	0.00	0.00
	Shrubs	0.19	0.17	0.10	0.24	0.38	0.23	0.84	0.00	0.47
	Herbs	0.08	0.09	0.06	0.07	0.12	0.08	0.16	0.10	0.12
Density (stem/ha) (N ha^{-1})	Trees	275	189	197	233	211	222	178	0.00	0.00
	Shrubs	592	385	518	459	355	296	489	0.00	222
	Herbs	245185	152223	194444	210772	179259	207778	143333	258890	99259
Basal area (m^2 ha^{-1})	Trees	17.03	18.45	34.94	19.80	13.93	21.07	6.66	0.00	0.00
	Shrubs	0.36	0.36	0.39	0.37	0.27	0.22	7.74	0.00	2.05
	Herbs	5.50	3.45	3.65	5.53	6.41	5.69	3.46	6.82	1.25

in Himalayan vegetation in their studies (Rai *et al* 2012, Shaheen *et al.* 2012, Sharma *et al.* 2014, Dar and Sundarapandian 2016). The lower number of plant species recorded in study area may be attributed to harshness of the climatic and edaphic conditions and high biotic interference. The data pertaining to species richness for trees ranged from 3.31-1.33. The maximum species richness was observed in Dry deodar forest type (FT_3) and minimum in Dry alpine scrub (FT_9). Kharkwal *et al.* (2009), Pandey *et al*. (2010), also, contended that species richness changes with amount of rainfall and temperature owing to secondary succession when environmental and edaphic conditions are favorable with low fluctuations. Similar changes along the altitude on species richness have also been reported by Kharkwal *et al*. (2009). Maximum species diversity (5.79) was observed in dry deodar forest, whereas minimum (2.65) was in birch-rhododendron scrub forest.

The slow rate of evolution and community stabilization along with relatively drier climatic conditions could be the reason for the low diversity valuess of alpine pasture and dry alpine scrub as compared to other forest types. The recorded index values in the present study showed almost similar ranges as reported Sharma *et al.* (2009) for forests in central Himalayan region. In the presents study density ranged from 0.00–275 N ha^{-1} and basal area ranged from 0.00-34.94 m^2 ha^{-1} under different forest types of dry temperate and alpine forest of Kinnaur district of Himachal Pradesh. In several temperate forest, the values of total density and basal area ranged from 179–892.51 N ha^{-1} and 42.40–69.16 m^2 ha^{-1}, respectively (Sharma *et al*. 2010, Verma and Kapoor 2013, Kumar and Sharma 2014, Kumar 2014, Kumar and Sharma 2016). Among shrub species, shrubs basal area was recorded maximum in FT_7 (7.74 m^2 ha^{-1}), which was found significantly higher than all forest types under investigation. The basal area in treatments : FT_1, FT_2, FT_3, FT_4, FT_5, FT_6 remain statistically identical. The values of total density and basal area of shrubs in different temperate Himalayan forests-ranged from 330–2286 N ha^{-1} and 0-0. 15-m^2 ha^{-1},

respectively as reported by Kumar (2012), Sharma *et al.* (2014), Deshmukh and Jain (2016).

Maximum herbage density was recorded in FT_8 (2,58, 890 N ha^{-1}), whereas, minimum was found in FT_9 (99, 259 N $ha^{-1)}$. Herbage basal area also displayed a marked variation. The maximum density for herbage was recorded in FT_8 (6.82 m^2 ha^{-1}) which remains statistically at par with FT_5, FT_1, FT_4 and FT_6, whereas lowest value for basal area was recorded in FT_9 (1.25 m^2 ha^{-1}). The herbs density recorded in the present study falls in the range of 1982.43–614500 N ha^{-1}. Similarly, herb density range have also been reported by other workers for other ecosystems of Himalaya (Kumar 2012, Verma and Kapoor 2013, Verma 2014, Sharma *et al.* 2014).

CONCLUSION

The present study highlights the poor status of species richness, diversity, dominance and densityof plant species in dry temperate and alpine forests of Western Himalayas. Lower and comparatively warmer elevations revealed higher species richness and diversity than the cold and higher elevation cover types, which implies that dry temperate and alpine forests need effective monitoring and conservation. The quantitative inventory of species diversity will be a valuable tool for forest assessment, forest management and biodiversity conservation.

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