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Tree diversity, stand structure and community composition in tropical forest of Rajaji tiger reserve, Northern India

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Abstract
In present study, we present data on tree diversity, stand structures and community composition in six sites of tropical forest in Rajaji tiger reserve, Northern India. The enumeration of 72 plots results a total of 19,050 individuals, 47 species, 42 genera, 25 families in which *Holoptelia integrifolea, Dalbergia sissoo, Shorea robusta, Cassia fistula* and *Trewia nudiflora* were the species which showed higher importance value index (IVI) in the study area. The stand density of the six sites ranges from 149.99 - 397.91 hac-^{1} where as the total basal area of trees ranges from 3.612 - 46.813 m^{2}/hac-^{1}. The Shannon diversity index ranged from 1.35 to 2.51, Simpson index ranged from 0.097 - 0.446, Margalef index ranged 2.584 - 4.9, The Evenness index ranged from 0.551 - 0.852 in the study area. Further the studied area has showed ample evidences from indices in supporting the higher floristic diversity and stand structure after providing the present area as a status of tiger reserve.

Keywords: Density, Diversity, Tree species, Tropical forest, Tree species

INTRODUCTION

Tropical forests are regarded one of the most biological rich habitat on earth and have been recognized to harbour a significant proportion of world biodiversity (Myers *et al* 2000; Baraloto *et al*., 2013). These forests provide significant ecological services such as conservation of the habitats of plants and animals, prevention of soil erosion and species conservation as well (Armenteras *et al* 2009). Many factors like seedling survivorship, seed quality and recruitment are the important factors which are playing significant contribution in the maintaining the tree composition of tropical forests (Connell, 1971).

Tropical forest accounts for approximately 86% of the total forest cover in India (Singh and Singh, 1988) and the dry tropical forest accounts for approximately 38.2% of the forest cover but unfortunately the dry deciduous forests are being converted into dry savannah, scrub and dry grasslands (Champion and Seth, 1968; Singh and Singh, 1989). These forest are degrading at a rate of 3.5% (Puyravaud and Davidar, 2010). The main reason behind for the loss of tropical forest are invasive species, fragmentation, deforestation, over-exploitation as well as the climate change. (Gardner *et al*., 2009; Morris, 2010; Anonymous, 2013). The degradation of these tropical forest is likely to continue in the future (Bradshaw *et al*., 2009). So this condition is calls for in depth study of the demographic stability of the species in these tropical forest (Sagar and Singh, 2003). The tropical moist deciduous forests are found throughout India except in the north-western and western regions of the country. The tropical moist deciduous forests receive a range of rainfall between 100-200 cm. In the higher ranges of north-eastern India and the hilly areas of Uttarakhand, West Bengal, these forests mainly comprises of *S. robusta, D. sissoo, Tectona grandis, Emblica officinalis, Bombex ceiba, Schlifera oleosa* etc. Uttarakhand has about 34,359 hectares of total forest cover and approximately 63 % of total area of the state. This state is 358 km in length and 322 km in breadth. The Haridwar forest division cover 7304.60 hactare of forest cover in Uttarakhand state. Our objective is to study the stand structure,

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community composition and diversity of tree species in tropical forest of Rajjai tiger reserve.

MATERIALS AND METHODS

The study was conducted in six different forest sites of Haridwar-Pauri forest division of Rajaji tiger reserve. The tiger reserve is an essentials part of the terai landscape between Sharda and Yamuna river in Shivalik landscape (Akash *et al*., 2018a). The study area comes division under Chilla forest range. The sub tropical forest of tiger reserve comes under Shivalik hill. Rajai Tiger reserve is located in northern India at 29°51' N to 30°15' N, 077°52' E to 078°22' E at an elevations from 250–1,100 above mean sea level. It falls within the Gangetic Plains biogeographic zone and upper Gangetic Plains province (Rodgers *et al*. 2002). Shivalik hill is categorized as part of the Indo-Gangetic Plains and has great significance in India's biogeography due to intermingling of flora from the Indo Malayan and Palaearctic regions (Sivakumar *et al*. 2010). The Chilla range of the reserve is one of the great centre of attractions for tourists (Akash *et al*., 2018b)

Assessment of tree species composition, stand structure and distribution along the elevation gradient was done to cover the six sites of the study area. The six sites area given below along with elevation gradient and coordinates which are taken from the GPS Instruments (Table 1 and Fig. 1).

Sampling and data analysis: The six sites were studied to cover the stand structure, diversity and distribution of the species in the studied area. At each site, 12 Quadrates (a total of 72 Quadrates) of 20*20 m^2 were randomly laid down to observe the tree species of the area. To determine the population structure of the forest, trees were measured for cbh with a girthing tape. The representative taxa were collected and after that identified with the help of regional floras (Raizada and Saxena, 1978; Gaur, 1999; Duthie, 1903-29) and prepared into herbarium**.** The voucher specimens were submitted in the Department of Botany and Microbiology, Gurukul Kangri University, India.

Data analysis: The individuals recorded in the discrete plot samples, vegetation data were analyzed quantitatively for relative density, relative frequency, relative dominance and basal area. The importance value index (IVI) of tree species was calculated as the summation of relative frequency, relative density, and relative dominance (Curtis and McIntosh 1950**).** After that structural composition was analyzed by comparing the distribution of tree diameter classes. The data were also used to interpret community indices like species diversity (H') of different tree species and was calculated by using the Shannon-Weiner Index (Shannon and Weiner 1963)

The Shannon weaver index, Simpson index, Species richness, (Margalef index) and evenness (Whittaker index) were calculated for each community. These all diversity indices were calculated with the help of following formulas:

$H' = - \Sigma\ pi \ln p_i$ (Shannon and Wiever, 1963)..**Eq.1**

Where, pi = ni/N, which denotes the importance probability of each species in a population; ni = importance value for species "i", N = total of importance values.

$Cd = \Sigma\ p_i^2$ (Simpson, 1949)..... **Eq.2**

Where Cd = Concentration of dominance

$R = S\text{-}1/\ln (N)$ (Margalef, 1968).....**Eq.3**

Where S = Number of species, N = Total number of Individuals

Statistical analysis: The correlation analysis was used to determine the relation between various phytoscociological attributes (Prasad, 2011) as mentioned in Tables 2-6, Table 8 and Figs.2-3

RESULTS

Floristic structure and Species composition: A total of 19,050 individuals of trees belonging to the 47 species among 42 genera and 25 families from 72 quadrates of 20×20 m^2 were enumerated in tropical forest of Northern India.

Stand density and diversity: Trees stand density ranged between 4775 ind/ hac of GS to 1825 ind/ hac in KS. The other sites showed moderate density of tree in the study area. In LS the density of trees was 3275 ind/ hac, 2225 ind/hac in KR whereas in KB- 6-8 it was 3825 ind/hac and 3125 ind/hac in SF. The total basal area was highest recorded in KB- 6-8 (46.81 m^2hac^{-1}) whereas the

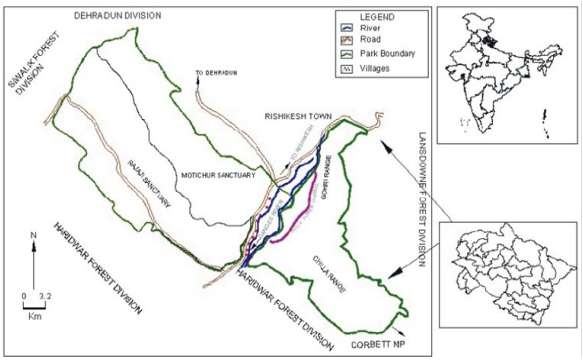

Fig. 1. *Map of the Rajaji tiger reserve (Modified from (Rasily, 2008).*

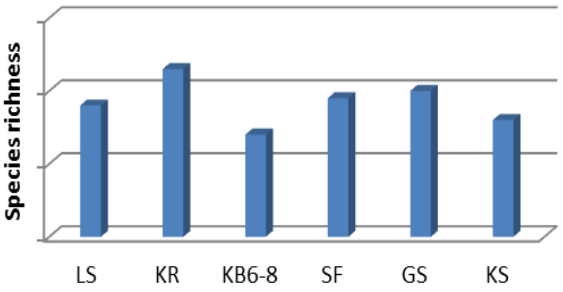

Fig. 2. *Species richness in different studied sites (LS = Lalsroth, KR= Kodiya ridge, KB= Kodiyabelt 6-8, SF= Sofuti, GS= Ghasiram, KS=Kharasroth).*

Table 1. Coordinates analysis of the study sites.

Sites	Elevation	Latitude(N)	Longitute(E)
1-Lalsroath	378.6 m	30° 00' 35.9'' N	78° 16' 21.8 E
2-Kodiya ridge	350 m	30° 0' 35.8'' N	78° 15' 45.7 E
3-Kodiyabelt 6-8	458.1 m	29°59' 41.0'' N	78° 17' 41.1 E
4-Sofuti	482.7 m	29°59'28.8'' N	78° 17' 44.2 E
5-Ghasiram sroath	304 m	29°57' 44.92''N	78° 11' 33.81 E
6- Kharasroath	318 m	29°56' 51.9'' N	78° 10' 46.17 E

Tabel 2. List of tree species encountered in Lalsroth with their family names, densities(hac-^{1}), basal area (m^2 hac-^{1}), Relative values and importance value Index.

Species	Family	Density/hac	Basal area	RF	RD	RDo	IVI
Holopotelia integrifolea	Ulmaceae	160.4	14.08	25.532	61.105	70.239	156.87
Cedrella toona	Meliaceae	2.082	0.662	2.128	0.795	3.306	6.229
Alstonia scholaris	Apocynaceae	2.082	0.134	2.128	0.795	0.67	3.593
Naringi crenulata	Rutaceae	6.25	0.1194	4.255	2.386	0.596	7.237
Cassia fistula	Fabaceae	8.35	0.209	6.383	3.179	1.046	10.608
Mallotus phillipensis	Euphorbiaceae	31.25	0.521	17.022	11.932	2.602	31.556
Ehretia laevis	Ehertiaceae	10.4	0.261	6.383	3.971	1.305	11.659
Oroxylum indicum	Bignoniaceae	4.165	0.059	4.255	1.59	0.297	6.142
Listea chinensis	Lauraceae	10.25	0.15	6.383	3.914	0.748	11.045
Terminalia bellerica	Combretaceae	4.165	0.855	2.128	1.59	4.264	7.982
Ziziphus oenoplia	Rhamnaceae	2.082	0.0169	2.128	0.795	0.085	3.008
Aegle marmelos	Rutaceae	2.082	0.026	2.128	0.795	0.132	3.055
Crateva relegiosa	Capparaceae	8.32	0.114	8.511	3.179	0.569	12.259
Syzygium cumini	Myrtaceae	2.08	0.02	2.128	0.795	0.132	3.055
Ficus religiose	Moraceae	2.08	0.106	2.128	0.795	0.529	3.452
Adina cordifolia	Rubiaceae	2.08	2.652	2.128	0.795	13.277	16.2
Morus alba	Moraceae	2.08	0.02	2.128	0.795	0.1	3.023
Celtis australis	Cannabaceae	2.08	0.033	2.128	0.795	0.0167	2.939
Total		261.91	20.05	100	100	99.99	299.91

Tabel 3. List of tree species encountered in Kodiya ridge with their family names, densities (hac-^{1}), basal area (m^2 hac-^{1}), Relative values and importance value Index.

Species	Family	Density/ hac	Basal area	RF	RD	Rdo	IVI
Dalbergia sissoo	Fabaceae	87.5	1.18	24.001	47.193	32.678	103.872
Trewia nudiflora	Euphorbiaceae	10.41	0.2545	8	5.618	7.048	20.666
Ehertia leavis	Ehertiaceae	10.41	0.32	8	5.618	8.882	22.5
Ziziphus oenoplia	Rhamnaceae	6.25	0.161	2	3.371	4.476	9.847
Chordia dichotoma	Boraginaceae	2.08	0.069	2	1.124	0.47	3.594
Emblica officinalis	Fabaceae	10.41	0.151	6	5.618	4.204	15.822
Mallotus phillipensis	Euphorbiaceae	14.5	0.187	10	7.865	5.18	23.04
Holoptelia integrifolia	Ulmaceae	2.08	0.018	2	1.124	0.5	3.624
Butea monosperma	Fabaceae	2.08	0.035	2	1.124	0.972	4.096
Psidium gujava	Myrtaceae	2.08	0.037	2	1.124	1.025	4.149
Ficus glomerata	Moraceae	2.08	0.0597	2	1.124	1.653	4.777
Cedella toona	Meliaceae	2.08	0.0175	2	1.124	0.485	3.609
Legerestroemia indica	Lythraceae	8.33	0.209	6	4.494	5.811	16.305
Cassia fistula	Fabaceae	2.08	0.0597	2	1.124	1.653	4.777
Ficus religiose	Moraceae	2.08	0.0812	2	1.124	2.25	5.374
Acacia spp	Fabaceae	2.08	0.0335	2	1.124	0.93	4.054
Melia azadirachta	Meliaceae	2.08	0.0335	2	1.124	0.93	4.054
Acacia catatue	Fabaceae	2.08	0.01833	4	1.124	0.507	5.631
Pterospermum acirifolium	Malvaceae	2.08	0.02031	2	1.124	0.562	3.686
Caliandra haematocephala	Fabaceae	2.08	0.0265	2	1.124	0.734	3.858
Bombex ceiba	Bombecaceae	6.25	0.1825	4	3.37	5.052	12.422
Bahunia variegata	Fabaceae	2.08	0.0812	2	1.124	2.25	5.374
Adina cordifolia	Rubiaceae	2.08	0.424	2	1.124	11.752	14.876
Total		**185.4**	**3.612**	**100**	**100**	**100**	**300**

lowest in KR (3.61 m^2hac^{-1}). The other sites showed moderate range of basal area.

Diversity of tree species in the studied plots of the area was calculated by using the Shannon-Weiner diversity index (H'). The Shannon-Weiner diversity index showed that the highest diversity was in KR (2.161) and the lowest diversity was in KB (1.350), with dominance of Simpson's value ranging from

Tabel 4. List of tree species encountered in Kodiyabelt 6-8 with their family names, densities(hac-^{1}), basal area (m^2 hac-^{1}), Relative values and importance value Index.

Species	Family	Density/hac	Basal area	RF	RD	Rdo	IVI
Shorea robusta	Dipterocarpaceae	208.25	43.649	20.692	65.424	93.241	179.357
Mallotus phillipensis	Euphorbiaceae	41.65	0.606	20.692	13.085	1.295	35.072
Aegle marmelos	Rutaceae	6.25	0.1037	12.069	1.964	0.222	14.255
Listea chinensis	Lauraceae	10.25	0.119	10.346	3.222	0.254	13.82
Naringi crenulata	Rutaceae	10.25	0.18	8.62	3.22	0.386	12.226
Cassia fistula	Fabaceae	6.25	0.267	5.173	1.964	0.571	7.708
Legestroemia parviflora	Lythraceae	2.083	0.016	1.724	0.654	0.036	2.416
Ficus religiose	Moraceae	6.25	0.902	3.444	1.964	1.928	7.339
Holoptelia integrifolea	Ulmaceae	2.08	0.134	1.724	0.654	0.287	2.665
Erythrina indica	Fabaceae	2.08	0. 1 86	3.447	0.654	0.398	4.499
Crateva relegiosa	Capparaceae	2.08	0.0414	1.724	0.654	0.088	2.466
Schlifera oleosa	Sapindaceae	2.08	0.0595	1.724	0.654	0.127	2.505
Miliusa velutina	Annonaceae	2.08	0.0699	3.447	0.654	0.149	4.25
Ehretia laevis	Ehertiaceae	16.66	0.476	5.173	5.234	1.018	11.425
Total		**318.308**	**46.813**	**100**	**99.999**	**100**	**299.99**

Tabel 5. List of tree species encountered in Sofuti with their family names, densities(hac-^{1}) basal area (m^2 hac-^{1}), Relative values and importance value Index.

Species	Family	Density/hac	Basal area	RF	RD	Rdo	IVI
Mallotus phillipensis	Euphorbiaceae	41.666	1.036	12.069	16	12.057	40.126
Listea chinensis	Lauraceae	10.414	0.084	5.173	4	0.987	10.16
Naringi crenulata	Rutaceae	39.583	0.083	10.345	15.2	9.654	35.199
Holoptelia integrifolea	Ulmaceae	20.833	0.605	3.448	8	7.039	18.487
Ehertia leavis	Ehertiaceae	4.166	0.04	3.448	1.6	0.47	5.518
Cassia fistula	Fabaceae	47.016	0.983	13.792	18.4	11.441	43.633
Schlifera oleosa	Sapindaceae	6.25	0.531	3.448	2.4	6.179	12.027
Anogeissus latifolia	Combretaceae	2.083	0.0812	1.724	0.8	0.945	3.469
Shorea robusta	Dipterocarpaceae	2.083	0.1666	1.724	0.8	1.938	4.462
Erythrina suberosa	Fabaceae	6.25	0.756	5.173	2.4	8.802	16.375
Aegle marmelos	Rutaceae	16.666	0.228	8.621	6.4	2.657	17.678
Adina cordifolia	Rubiaceae	8.333	2.516	6.897	3.2	29.269	39.366
Emblica officinalis	Fabaceae	2.083	0.02	1.724	0.8	0.236	2.76
Butea monosperma	Fabaceae	6.25	0.0731	1.724	2.4	0.851	4.975
Gewia asiatica	Tiliaceae	8.33	0.0996	5.173	3.2	1.158	9.531
Erythrina indica	Fabaceae	10.41	0.142	3.448	4	1.654	9.102
Mitrgyana parviflora	Rubiaceae	6.25	0.1375	3.448	2.4	1.532	7.38
Bauhinia purpurea	Fabaceae	8.333	0.1366	5.173	3.2	1.589	9.531
Chordia dichotoma	Boraginaceae	12.5	0.132	3.448	4.8	1.541	9.789
Total		260.41	8.598	100	100	99.99	299.57

Tabel 6. List of tree species encountered in Ghasiram sroath with their family names, densities(hac-^{1}) basal area (m^2 hac-^{1}), Relative values and importance value Index.

Species	Family	Density/hac	Basal area	RF	RD	Rdo	IVI
Trewia nudiflora	Euphorbiaceae	260.416	9.598	25.532	65.446	50.788	141.766
Naringi crenulata	Rutaceae	2.083	0.018	2.128	0.523	0.096	2.747
Listea chinensis	Lauraceae	25	0.0432	6.383	6.283	0.229	12.895
Ficus benghalensis	Moraceae	2.083	0.7313	2.128	0.523	3.87	6.521
Mallotus phillipensis	Euphorbiaceae	31.25	0.557	10.639	7.853	2.95	21.442
Azadirachta indica	Meliaceae	2.083	0.02031	2.128	0.523	0.107	2.758
Ziziphus mauritiana	Rhamnaceae	2.083	1.2089	2.128	0.523	6.397	9.048
Crateva religiosa	Capparaceae	4.1667	0.0339	4.255	1.047	0.18	5.482
Mitragyna parviflora	Rubiaceae	2.083	0.4245	2.128	0.523	2.246	4.897
Careya arborea	Lecythidaceae	4.1667	1.074	4.255	1.047	5.687	10.989
Ficus auriculata	Moraceae	2.083	0.5799	2.128	0.523	3.069	5.72
Bahunia variegata	Fabaceae	12.5	0.6237	8.511	3.141	3.3	14.952
Syzium cumini	Myrtaceae	18.75	0.4335	6.383	4.712	2.294	13.389
Holoptelia integrifoea	Ulmaceae	14.583	0.753	6.383	3.665	3.988	14.036
Albizia lebbek	Fabaceae	2.083	0.0414	2.128	0.523	0.219	2.87
Adina cordifolia	Rubiaceae	2.083	0.2388	2.128	0.523	1.264	3.915
Cassia fistula	Fabaceae	2.083	0.018	2.128	0.523	0.096	2.747
Acacia catatue	Fabaceae	2.083	0.1239	2.128	0.523	0.656	3.307
Putranjiva roxburghii	Euphorbiaceae	2.083	0.7594	2.128	0.523	4.018	6.669
Melia azadirachta	Meliaceae	4.1667	1.625	4.255	1.047	8.598	13.9
Total		**397.9123**	**18.9**	**100**	**99.99**	**100**	**300**

Tabel 7. List of tree species encountered in Kharsroath with their family names, densities(hac-^{1}) basal area (m^{2} hac-^{1}), Relative values and importance value Index.

Species	Family	Density/hac	Basal area	RF	RD	Rdo	IVI
Holoptelia integrifolea	Ulmaceae	60.416	1.4511	26.316	40.278	27.05	93.644
Schlifera oleosa	Sapindaceae	4.1667	0.8492	5.263	2.778	15.831	23.872
Mallotus phillipensis	Euphorbiaceae	31.25	0.65	15.79	20.834	12.133	48.757
Putranjiva roxburghii	Euphorbiaceae	4.1667	0.162	5.263	2.778	3.029	11.07
Thevetia peruviana	Apocynaceae	4.1667	0.0372	2.631	2.778	0.694	6.103
Ficus palmata	Moraceae	2.0832	0.02	5.263	1.389	0.379	7.031
Delonix regia	Fabaceae	2.0832	0.0933	2.631	1.389	1.739	5.759
Cassia fistula	Fabaceae	2.0832	0.02798	2.631	1.389	5.217	9.237
Grewia asiatica	Tiliaceae	6.25	0.0731	2.631	4.167	1.363	8.161
Acacia catatue	Fabaceae	4.166	0.0466	2.631	2.778	0.87	6.279
Listea chinensis	Lauraceae	8.333	0.0835	10.526	5.556	1.558	17.64
Adina cordifolia	Lauraceae	2.083	1.209	2.631	1.389	22.539	26.559
Ehertia leavis	Ehertiaceae	6.25	0.0633	7.895	4.167	1.18	13.242
Cedrella toona	Meliaceae	2.083	0.1061	2.631	1.389	1.979	5.999
Crateva relegiosa	Capparaceae	8.333	0.0722	2.631	5.556	1.347	9.534
Melia azadirachta	Meliaceae	2.083	0.16585	2.631	1.389	3.092	7.112
Total		149.997	5.3645	99.99	100	100	299.99

Table 8. Floristic richness, density (hac-1), total basal cover (m^{2}/hac^{-}) and diversity indices of six sites in tropical forest Rajaji tiger reserve, Northern India.

Variables	LS	KR	KB 6-8	SF	GS	KS
No. of Genera	18	21	14	19	19	16
No. of Family	16	13	12	12	12	11
No. of Species	18	23	14	19	20	16
Density/hac	261.91	185.4	318.308	260.41	397.912	149.997
Total basal area(m^{2}/hac^{-1})	20.05	3.6121	46.813	8.598	18.9	5.3645
Shannon Index	1.593	2.161	1.35	2.51	1.459	2.059
Simpson index	0.389	0.235	0.446	0.097	0.44	0.203
Margalef index	3.51	4.9	2.584	3.728	3.617	3.496
Eveness	0.551	0.689	0.511	0.689	0.511	0.852

LS = Lalsroth, KR= Kodiya ridge, KB= Kodiyabelt 6-8, SF= Sofuti, GS= Ghasiram, KS=Kharasroth

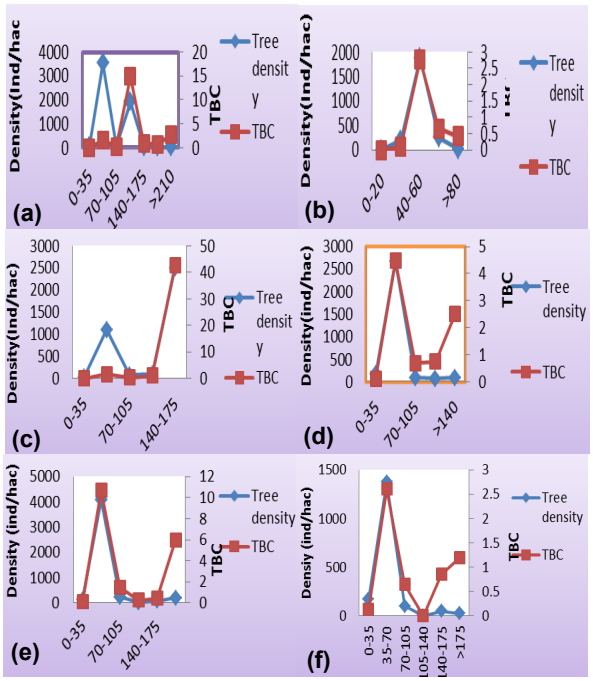

Fig.3 (a-f). *Contribution of tree Stand density and total basal cover based in different girth class (in Cm) of all the sites (a). - Lalsroath, (b).- Kodiya ridge, (c).- Kodiyabelt 6-8, (d).-Sofuti, (e). Ghasiram sroath (f). Kharasroath.*

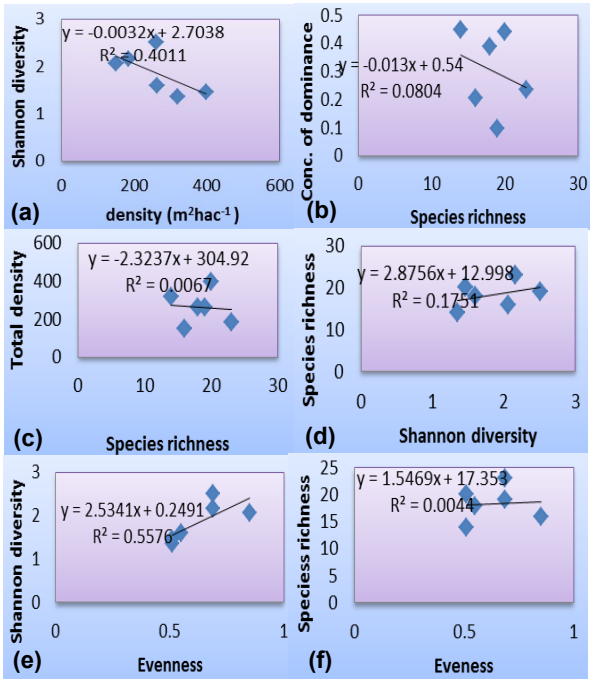

Fig. 4 (a-f): *Correlation among various phytosocio-logical attributes.*

0.097(SF)- 0.440 (GS). The Margalef species richness index was highest recorded in KR (4.90) and lowest was recorded in KB (2.584).The evenness index was highest recorded in KS (0.852) and lowest was in GS, KB which was 0.511(Table 8).

The sites represented different dominant and co-dominant species. In LS, *Holoptelia integrifolea* (IVI= 156.876) was the most dominant species followed by other co-dominant species *Mallotus phillipensis* (IVI= 31.556) and *Crateva relegiosa (*IVI= 12.259) and so on (Table 7)**.** On the other hand, in KR, *Dalbergia sissoo* (103.872) was the most dominant followed by other co-dominant species like *Trewia nudiflora* (IVI=20.666), *Legerestroemia indica* (IVI= 16.305) and others (Table 8). In KB 6-8, *Shorea robusta* (IVI= 179.357) was the most dominant species followed by the co-dominant species like *Mallotus phillipensis* (IVI= 35.072), *Naringi crenulata* (IVI=13.82) and others (Table 9). In SF, *Cassia fistula* (IVI= 43.633) was the most dominant species followed by species *Mallotus phillipensis* (IVI= 40.126) and other whereas in GS, *Trewia nudiflora* (IVI=141.766) was most dominant species followed by *Mallotus phillipensis* (IVI =21.442) and other but in GS, *Holoptelia integrifolea* (IVI= 93.644) was most dominant tree species followed by *Mallotus phillipensis* (IVI= 48.757), *Adina cordifolia* (IVI =2126.559) and others (Tables 2- 7).

Correlation analysis: The correlation between different phytosociological parameter are given in Fig. 4 (a-f). The density (hac^{-1}) was negatively correlated with the Shannon diversity (r= -0.633) and species richness (-0.081). The Shannon diversity was positively correlated with species richness (r= 0.418) whereas the species richness was negatively correlated with concentration of dominance (r= -0.28) and but positively correlated with Evenness (r= 0.066). On the other hand Evenness was positively correlated with the Shannon diversity (r= 0.746).

DISCUSSION

Tropical forests are rich in floral species density and diversity (Richards 1952; Paijmans 1970) but many factors affect their diversity (Janzen 1970; Connell 1971; Hubbell 1979; Parthasarathy 1999). The overall structural pattern of the forest community revealed the habitat is dominated by *Shorea robusta, Holoptelia integrifolea, Dalbergia sissoo, Mallotus phillipensis, Cassia fistula* and *co-dominated* with *Ziziphus oenophlia, Z. mauritiana, Ehretia laevis, Naringi crenulata etc.* These dominant species in stand sometimes restrict the light availability to other species of main canopy and ground flora in the undisturbed and mildly disturbed stands.

The absolute total stand density (hac^{-1}) of the six sites ranged from 149.99 / hac^{-1}- 397.91 hac^{-1}, in which highest density was recorded in GS and lowest was in KR. The recorded density values of our study did not vary considerably from values reported by other authors of Garhwal Himalaya (Singhal and Soni 1989 form Mussoorie forest division, Adhikari and Tiwari, 1991) but the total basal area in our study was more or less similar to the study of other workers in different tropical forest of Northern India. The total basal area (m^2/ hac) of trees ranged from 3.612 (KR) - 46.813 m^2/ ha (KB 6-8). These values are comparable to the value reported by Raturi, 2012 as 3.18- 43.62 m^2/ hac from Rudraprayagh forest division, Lata and Bisht 1991 as 13.60-71.25 m^2/hac from moist temperate forest of Pauri, Bhat, 2012 as 2.91-37.96 m^2/hac form Kedarnath Wildlife Santuary in Northern India.

The Shannon weaver diversity index of the tree species in present study area varies from 1.35 (KB, 6-8) to 2.51 (SF). These values are comparable with those reported by Ghidiyal *et al*., 1998 as 1.86-2.73 from Garhwal forest division, Raturi *et al*., 2012 as 0.78-3.45 from Rudraprayagh forest division, Singh *et al*., 2014 as 0.66-2.69 from Gorakhal forest of Nainital, Pant and Samant, 2012 as 0.74-2.66 from Khokan Wildlife Santuary, Uniyal *et al*., 2010 as 0.70-3.08 from Devalgarh forest division in the Uttarakhand Himalaya. The dominance of forest sometimes increased with an increase in the elevation. Simpson's index value (con. of dominance) was 0.097 in SF (482.7 m) which was highest at the elevation gradient. This situation might be due to tolerance-based dominance of only few of the tree species under severe environmental conditions. According to Baduni and Sharma (1999), the concentration of dominance is always affected by the first three relatively important species in a community. The concentration of dominance (Cd) in our study ranged from 0.097(SF) -0.446 (KB 6-8). These result are almost similar to the study carried out by Raturi, (2012) in subtropical forest of Rudraprayagh district in Garhwal Himalaya whose results value ranged from 0.09 - 0.63. All the results on vegetation composition and phytosociological were in accordance with the earlier findings in tropical forests of Bhagirathi basin in Garhwal region (Sharma *et al*. 2009, 2014, 2015)

Every species play significant role and there is a definite quantitative relationship between abundant and rare species (Bhandari *et al*., 1999). High importance value index ((IVI)) indicates that all the available resources are being utilized by that species and left over being trapped by other competitors and associated species. In present study area, high importance value was observed for *H. integrifolea* (in LS- 156.876), *D. sissoo* (in KR- 103.872), *S. robusta* (in- KB6-8- 179.357), *C. fistula* (in SF- 43.633), *T. nudifolra* (in GS-

141.766), *H. integrifolea* (in KR- 93.644). Similar results were also observed by Raturi (2012) in Rudraprayagh forest of Garhwal Himalaya for *Quarcus lecuotrichophora* as the dominant species and by Kukshal.*et al*., 2009 for *Callipedium parviflorum* in Badiyargarh forerst of Garhwal Himalaya.

Rajji tiger reserve is characterize by sub tropical climate, varied topography with rich alluvial soil and fragile ecosystem which makes it one of the most diverse area of Northern India. These factors have evolved new association of forest community inside the reserve. In present study, high value of *H. integrifloea, S. robusta, D. sissoo, C.fistula* and *T. nudiflora* revels that all the source being utilized by these species in each community as compared to the other associated species. High importance value and basal cover of these species reveals that dominancy over other species in a community. The dominancy of these species also reveals that these species in each community are highly utilizing the entire sources.

Highest basal area of in KB 6-8 and highest diversity in SF inside the tiger reserve reveals that it is providing conservation to major forest of *S. robusta* and various mixed forest communities in Northern India.

Conclusion

Rajaji tiger reserve cover the huge part of northern India and providing many goods and ecosystem services which are essential for improving and maintaining the livelihoods of humans, animals and plants in addition to performing various ecological functions. The five relative highest ecological importance (IVI) species in the six sites of study area were *H. integrifolea, D. sissoo, S. robusta, C. fistula* and *T. nudiflora.* The results also revealed more than twenty species showed the unstable population hence hampered regeneration but diversity and stand structure increases significantly due to the its conservation status and strict provision for community in past years. Further study suggests that the studied area is still in a recovery stage. Since it had faced severe anthropogenic pressure prior to the establishment of the exclosure with the fence plants, sociological characters such as frequency, density, abundance as well as the basal area were being influenced by anthropogenic as well as natural stress in past, but now various protection strategies like restriction to Gujjar community, fire line, eradication of harmful weed, Gujjar rehabilitation programme further support species regeneration inside the tiger reserve.

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