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A Community Analysis of Woody Species in a Tropical Forest of Rajaji Tiger Reserve

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Abstract The structure, function as well as the ecosystem services of tropical forest highly depend on its species diversity, regeneration pattern, richness and variation in the assemblages of the tree species population over time. The long-term data from permanent vegetation plots generally have yielded a wealth of data on the species diversity as well as the dynamics of tree populations but these types of studies only rarely been undertaken in the tropical landscape which favor large human population. Thus the drivers of anthropogenic pressures and their effects on community composition and species diversity are not well known. To investigate tree, sapling, seedling and their diversity pattern as well as the status of woody species, random plots of 20×20 m^2 was randomly laid out by Nested quadrate sampling method in tropical forest of Rajaji tiger reserve. Higher Shannon weaver index was recorded for tree (2.059) whereas lowest value of Simpson index (0.161) was observed for seedling layer. On the other hand, tree layer was recorded with highest Margalef index (3.496) and evenness index (0.852). Low value of Simpson index, higher value of Margalef index and Shannon weaver index revels the maximum diversity in tree layer in the study area. Further this area has faced various forms of anthropogenic pressures in past but regeneration potentials has got strengthen due to fencing of the reserve and by reduction of anthropogenic pressures.

Keywords Community analysis, Woody species, Tropical forest, Rajaji tiger reserve.

Introduction

Tropical forests are regarded as one of the most diverse ecosystems in the world (Sanders 2006) and account 52% of the total forest. The dry tropical woodlands and subtropical once covered once half of the world tropics but now has decreased during last decennia. The immense biodiversity of tropical forest and the different variety of natural resources which sustain the local community's livehood but huge areas of the tropical forest are under great under anthropogenic pressure. Deforestation, fragmentation and climatic changes are the responsible factors for tropical biodiversity losses (Gardner et al. 2009, Morris 2010, Anonymous 2013). The losses of biodiversity in tropical forest is likely to continue in the future causing extinction of species (Bradshaw et al. 2009). Over exploitation has resulted in the rapid looses of these forest and is recognized to be one of the biggest environmental and economic problems around the world (Mani and Parthasarathy 2006). These forests are disappearing from the earth at an alarming rates reducing annually by 1–4% by their current area. The relatively increased anthropogenic pressures have led to agricultural expansion as well as overgrazing of livestock (Anitha et al. 2010). Due to looping, heavy grazing and industrialization these tropical forest are under immense pressure. The fragmented land and reduced populations resulted from

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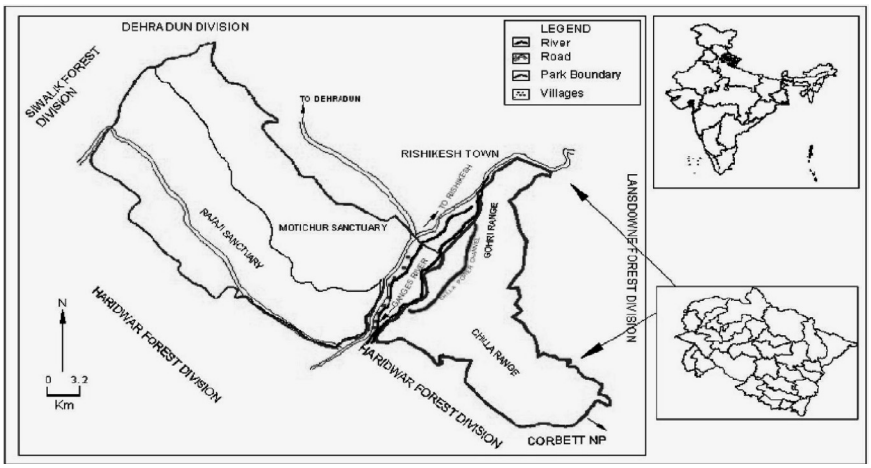

Fig. 1. Map showing study sites.

anthropogenic pressures are the issues of growing importance in evolutionary as well as conservational biology. So this condition is calls for in depth study of the demographic stability of the species in these tropical forest.

Uttarakhand is situated in Northern India and has about 34,651 km 2 of forests. The protected forests constitute about 28.52% of the total forested area (Forest Survey of India 2011). The tropical moist deciduous forests are more common in the Uttarakhand which receive a range of rainfall between 100–200 cm. These forests are found in the North-Eastern states of the country along with the foothills of Himalayas and succeeded by the wet temperate type of forests between altitudes of 1,000–2,000 m. In the higher ranges of North-Eastern India and the hilly areas of Uttarakhand, West Bengal these forests mainly comprises of *Dalbergia sissoo, Emblica officinalis, Bombex ceiba, Sclechera oleracea, Tectona grandis, Shorea robusta.*

Study site

Rajaji tiger reserve (Earlier named as Rajaji National park) was established in 1983 with the aim of maintaining a viable population of the Asian elephants and is designated as protected area for 'Project Elephant' by the Ministry of Environment, Forest and Climate Change, Government of India. It spread in an area of 820.42 sq km. The tiger reserve is an essentials part of the Terai landscape between Sharda and Yamuna river in Shivalik landscape (Akash et al. 2018). The natural vegetation of the region has a broad sense of sub tropical moist deciduous types. The river Ganga flows through the Rajaji tiger reserve for a distance of 24 km. Winter start from November to February when the days are pleasant (20–25^{o}C) and nights are generally cold but humidity is low. Temperature rises rapidly to 40–45^{o}C in the summer season (March to June) and rainfall increases with the occasional thunderstorm. The level of humidity is high in the rainy season (July to October). Annual rainfall ranges from 1200–1500 mm. Soils are generally poor and infertile, with accumulation of humus in only at few places. About 84% area of the tiger reserve is forested. Although, the study region comes under the protected area network but undergoing rapid changes in vegetation and faunal wealth due to the large scale anthropogenic forcing in the form of grazing, lopping and hydro-power project. Besides sporadic tree felling, widespread scraping, trampling and extraction of non timber resources has been noticed. In some areas, the forest cover is continuously decreasing but due to its large area and some strict laws and provision of wildlife, the forest has maintained its diversity.

The present study was carried out in Chilla range of Rajaji tiger reserve (29^{o}15′ top 30^{o}31′ N, 77^{o}52′ to 78^{o}22′ E, altitude 250–1100 m) in Shivalik Hills of outer Himalayas (Fig. 1). The study area comes

under Northern Sub tropical moist deciduous forest. The Chilla range of the reserve is one of the great center of attractions for tourists (Akash et al. 2018). The dominant plant species are *Shorea robusta*, *Mallotus phillipinensis*, *Acacia catatue*, *Dalbergia sissoo*, *Terminalia bellerica*, *Cassia fistula*, *Listea chinensis*, *Adina cordifolia*, *Ficus benghalensis* in lower elevation of the reserve but high altitudinal area is dominated with *Pinus roxburghii*, *Celtris australis*, *Mallotus phillipinensis*.

Data analysis

At each site, 12 quadrates of 20*20 m^2 were randomly laid down to observe the tree species of the area. In order 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 and prepared into herbarium. The voucher specimens were submitted in the Department of Botany and Microbiology, Gurukul Kangri University, India.

The individuals recorded in the discrete plot samples, vegetation data were analyzed quantitatively for relative density, relative frequency, relative dominance and basal area. Further the importance value index (IVI) of tree, sapling and seedling was calculated as the summation of relative frequency, relative density and relative dominance. 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. 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:

$$H' = - \sum pi \ln pi$$

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.

$$Cd = \sum pi^2$$

Where, Cd = Concentration of dominance.

$$R = S-1/\ln (N)$$

Where, S = Number of species, N = Total number of individuals.

In addition to tree, sapling and seedling classes, six more classes for trees species based on cbh (circumference at breast height i.e. 1.37 m) were established which are as follows:

Catagories	Size classes	Cbh (Diameter classes)
Seedling	A	< 10.5 cm
Sapling	B	< 31.5 cm
Young tree	C	31.5–60.0 cm
Middle aged tree	D	61.0–90.0 cm
Older tree	E	91.0–120.0 cm
	F	121.0–150.0 cm
	G	151.0–180.0 cm
	H	> 181.0 cm

The regeneration status of tree species was determined based on population size of seedling and sapling. (i) Good regeneration, if seedlings > saplings > adults, (ii) Fair regeneration, if seedlings > or < saplings < adults, (iii) Poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be <, > or = adults, (iv) Nil regeneration, if a species is present only in adult form, (v) New regeneration, if the species has no adults but only seedlings or saplings.

Results and Discussion

Floristic structure and species composition

The primary aim of our study was to understand the community structure, diversity and regeneration pattern of woody species in tropical forest of Rajaji tiger reserve in Northern India. Large plots were implemented to enumerate the tree, sapling and seedling. A total of 8725 individuals of trees, sapling and seedling belonging to the 25 species among 23 genera and 16 families were enumerated from 12 quadrates of 20×20 m^2 in tropical forest of Northern India. There were 16 well represented families of the tree species in the study area in which Fabaceae has maximum number of species (5 species) followed by Moraceae

Table 1. Status of tree, seedling and sapling in different diameter classes of a tropical forest of Rajaji tiger reserve, Northern India.

Site 6	Family	A	B	C	D	E	F	G	H	Total
Holoptelea integrifolea	Ulmceae	63	46	19	9	9	–	–	–	146
Schleichera oleosa	Sapindaceae	3	2		–	1	–	–	1	6
Mallotus phillipensis	Euphorbiaceae	10	4	13	2	–	–	–	–	29
Putranjiva roxburghii	Euphorbiaceae	3	–	–	–	–	–	–	–	3
Thevetia peruviana	Apocynaceae		–	2	–	–	–	–	–	2
Ficus palmata	Moraceae	4	–	2		–	–	–	–	6
Delonix regia	Fabaceae		–		1	–	–	–	–	1
Cassia fistula	Fabaceae	3	1		1	–	–	–	–	5
Grewia asiatica	Tilliaceae		–	3	–	–	–	–	–	3
Crateva relegiosa	Capparaceae	5	4	2	–			–	–	11
Aegle marmelos	Rutaceae		4		–	–	–	–	–	4
Adina cordifolia	Rubiaceae				–	1	–	–	2	3
Ehretia leavis	Boraginaceae	9	7	3	–	–	–	–	–	19
Cedrella toona	Meliaceae				1	–	–	–	–	1
Acacia catatue		19	6	2	–	–	–	–	–	27
Melia azadirachta	Meliaceae	9	7	3	–	–	–	–	–	19
Naringi crenulata	Rutaceae	14	2		–	–	–	–	–	16
Ziziphus oenophilla	Rhamnaceae	9	7	3	–	–	–	–	–	19
Bahunia varigata	Fabaceae	–	4	–	–	–	–	–	–	4
Holorehaena pubescence	Apocynaceae	–	5	–	–	–	–	–	–	5
Mangifera indica	Anacardiaceae	5		–	–	–	–	–	–	5
Syzium cumini	Myrtaceae	3		–	–	–	–	–	–	3
Zizipus oenophilla	Rhamnaceae	28		–	–	–	–	–	–	28
Butea monosperma	Fabaceae	10		–	–	–	–	–	–	10
Bahunia racemosa	Fabaceae	1		–	–	–	–	–	–	1

Table 2. list of tree species encountered with their family names, density (hec^{-1}), basal area ($m^2\ hac^{-1}$), abundance frequency ratio and relative values and importance value index.

Species	Family	Density/ hac	Basal area	A/F	IVI
Holoptelea integrifolia	Ulmaceae	60.416	1.4511	0.034	93.644
Schlifera oleosa	Sapindaceae	4.1667	0.8492	0.059	23.872
Mallotus phillipensis	Euphorbiaceae	31.25	0.65	0.05	48.757
Putranjiva roxburghii	Euphorbiaceae	4.1667	0.162	0.059	11.07
Thevetia peruviana	Apocynaceae	4.1667	0.0372	0.24	6.103
Ficus palmata	Moraceae	2.0832	0.02	0.059	7.031
Delonix regia	Fabaceae	2.0832	0.0933	0.12	5.759
Cassia fistula	Fabaceae	2.0832	0.02798	0.12	9.237
Grewia asatica	Tiliaceae	6.25	0.0731	0.36	8.161
Acacia catatue	Fabaceae	4.166	0.0466	0.24	6.279
Listea chinensis	Lauraceae	8.333	0.0835	0.3	17.64
Adina cordifolia	Lauraceae	2.083	1.209	0.12	26.559
Ehretia leavis	Ehretiaceae	6.25	0.0633	0.04	13.242
Cederall toona	Meliaceae	2.083	0.1061	0.12	5.999
Cratavea religiosa	Capparaceae	8.333	0.0722	0.48	9.534
Melia azadirachta	Meliaceae	2.083	0.16585	0.12	7.112
Total		149.997	5.3645		299.99

Table 3. List of sapling species encountered with their family names, density (hac^{-1}), basal area (m^{2}hac^{-1}), abundance frequency ratio and relative values and importance value index.

Site 6	Family	TBA	D/Hac	A/F	IVI
Holoptelea integrifolea	Ulmceae	0.2846	95.833	0.045	129.674
Bahunini varigata	Fabaceae	0.00437	4.1666	0.24	5.634
Mallotus phillipensis	Euphorbiaceae	0.01917	8.333	0.12	13.072
Ficus palmata	Moraceae	0.0094	4.1666	0.06	9.144
Thevetia peruviana	Apocyncaeae	0.02508	4.1666	0.06	11.922
Cassia fistula	Fabaceae	0.01494	2.0832	0.12	6.377
Cretavea religiosa	Capparidaceae	0.01167	8.333	0.12	11.774
Listea chinensis	Lauraceae	0.09316	16.666	0.06	35.637
Naringi crenulata	Rutaceae	0.00438	4.1667	0.24	5.635
Ehretia leavis	Boraginaceae	0.03529	14.583	0.0933	21.827
Aegle marmelos	Rutaceae	0.03825	8.333	0.0533	19.079
Holorrhaena pubescence	Apocynaceae	0.0228	10.41	0.066	17.488
Mangifera indica	Anacardiaceae	0.01093	10.41	0.15	12.73

(2), Meliaceae (2), Euphorbiaceae (2), Rutaceae (2), Apocynaceae (2). The other 10 families Tilliaceae, Ulmaceae, Lauraceae, Rubaceae, Capparaceae, Boraginaceae, Sapindaceae, Myrtaceae, Anacardiaceae, Rhamnaceae.

Stand density and diversity

In tree layer, the individual density ranged from 2.08 hac^{-1} –60.41 hac^{-1}, whereas in sapling layer individuals density ranged from 2.08 hac^{-1} – 95.833 hac^{-1} and on the other hand seedling density for individuals species ranged from 2.08 hac^{-1} –131.25 hac^{-1}. The overall density (hac^{-1}) of tree species was 149.99 hac^{-1}, for sapling it was 191.65 hac^{-1} and for seedling it was 589.02 hac^{-1}. The total basal area tree was 5.36, for sapling it was 0.01 and for seedling it was 589.02. Low individual density of tree species in a forest describes that the forest faced anthropogenic pressure in form of looping, trampling, scraping. Although the study area have ample number of seedling, sapling due to its conservation status but in past it has faced severe pressures from vthe locals

Table 4. List of seedling species encountered with their family names, density (hac^{-1}), basal area (m^{2}hac^{-1}), abundance frequency ratio and relative values and importance value index.

Site 6	Family	TBA	D/hac	A/F	IVI
Holoptelea integrifolea	Ulmaceae	74.291	131.25	0.093	63.833
Schliechera oliosa	Sapindaceae	22.116	6.25	0.09	9.158
Mallotus phillipensis	Euphorbiaceae	50.1664	20.8332	0.033	25.273
Syzium cumini	Myrtaceae	17.914	6.25	0.09	8.444
Putranjiva roxburghii	Euphorbiaceae	79.837	25	0.36	23.85
Cassia fistula	Fabaceae	5.52844	6.25	0.36	4.456
Cretavea religiosa	Cappaeaceae	11.9741	10.416	0.15	8.523
Listea chinensis	Lauraceae	43.124	20.8332	0.0332	24.078
Mangifera indica	Anacardicaeae	6.7176	4.16675	0.24	4.115
Naringi crenulata	Rutaceae	42.65	29.166	0.186	20.51
Zizipus oenophilla	Rhamnaceae	88.455	56.25	0.066	42.9
Ehretia leavis	Boraginaceae	66.3412	18.75	0.067	23.701
Butea monosperma	Fabaceae	29.249	20.833	0.1333	16.061
Bahunia racemosa	Fabaceae	4.1456	2.083	0.12	3.134
Melia azadirachta	Fabaceae	46.497	25	0.09	21.963
Total		589.002	383.331		299.99

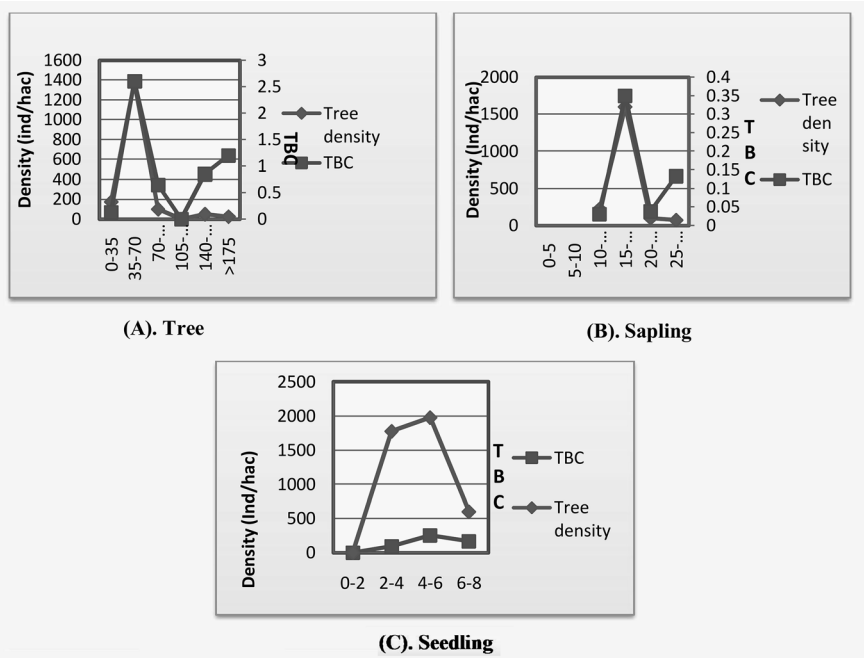

Fig. 2. (A-C). Density (ind/hac) and Basal area (m^2/hac) in different Girth Class (Basal area of seedling is given in (Cm^2/hac).

communities. Higher species diversity and richness of sapling as well as seedling inside forest predicts that in future, the vegetation of forest will be more diverse and heterogeneous if effective management is practiced. On the other hand, moderate basal area and higher density of tree species indicates the abundance of higher number of tree species with lower girth (Tables 1–4).

Regeneration pattern

Natural regeneration is a continuing process in which a species exist in a community. The ability of species to initiate new seedlings, their survival and growth are the three major components of successful regeneration. In present studied area <10 cm diameter class has been recorded with highest (198) individuals and whereas lowest was in that of > 181 cm diameter class which have only 3 individuals. The studied area represented with 16% Good, 28% Fair, 16% No and 40% New regeneration of tree, seedling and sapling. High number of new regeneration percentage resulting from the short period of exclosure. Presence of adequate seedlings in this area also proves that the earlier degraded forest could be rich in tree species if continuous protection measures would be applied in future. This will not only increase the level of biodiversity but would also show positive affect for livelihood of forest dependent people. Highly degraded forest can be recover their species composition and structure just in that way of natural forest if that forest are being protected from anthropogenic pressures which are impeding the natural regeneration of species.

Table 5. Diversity indices of species.

	Shannon weaver index	Simpson index	Margalef richness index	Jaccard index (evenness)
Tree	2.059	0.203	3.496	0.852
Sapling	1.862	0.268	2.653	0.725
Seedling	2.199	0.161	2.684	0.812

Diversity of woody species was calculated from by using Shannon-Weiner diversity index (H'). The

Shannon-Weiner diversity index for tree was 2.05, for sapling it was 1.86 and for seedling it was 2.19 (Fig. 2 A-C). The Simpson diversity index for tree was 0.20 for sapling 0.26 and for seedling it was 0.16. On the other hand, the Margalef richness index for tree was 3.49, for sapling 2.65 and for seedling it was 2.64. The evenness index (Jaccard index) for tree was 0.85, for sapling it was 0.72 and for seedling it was 0.81. Value of Shannon diversity index was comparable with those of earlier workers from Western Himalaya (2.43–3.33) and (0.95–3.30) (Gairola et al. 2011) (Table 5).

According to the concentration of dominance (Simpson index)is always affected by the first three relatively important value of a species in a community. Our result are almost comparable to the study of Raturi (2012) in subtropical forest of Garhwal Himalaya whose result ranged from 0.09–0.63 and Uniyal et al. (2010) as 0.47–0.83 form tropical forest of Garhwal Himalayas. Margalef values of our study also comparable with the earlier observation of Malik and Bhatt(2015) whose values ranges from 2.37–4.63 for trees. On the other hand similar results was also reported from Uttarakhand Himalaya by Uniyal et al. (2010) whose value ranges 2.21–7.00 for trees and Gairola et al. (2011) whose value ranged from 1.36–2.17 for trees.

Higher value of Shannon diversity index for seedling revels that in past this area has faced high pressures and now it is in the recovery stage. Secondly, the area comes under a protected forest that is why there are restrictions to some extent on human activities like grazing, collection of fuel wood, litter and tree felling. In addition to these factors, favorable climatic conditions and moderate temperature favors the luxuriant growth supporting the status of tree seedling in the study area.

Every species play important role and there is a definite quantitative relationship between abundant and rare species in an area. High importance value of species indicates that the dominance, ecological success as well as the regeneration of species in an area. In tree layer *Holoptelea integrifolea* (IVI=93.64) was the dominant tree species followed by *Mallotus phillipensis* (IVI=48.75), *Adina cordifolia* (IVI=26.55), *Schlifera oleosa* (IVI=23.87), *Listea chinensis* (IVI=17.64) and rest of the species have moderate importance value index. In sapling layer, again *Holoptelea integrifolea* (IVI=129.67) has been recorded with highest importance value followed by *Listea chinensis* (IVI=35.63), *Ehretia leavis* (IVI=21.82), *Aegle marmelos* (IVI=19.07), *Holorrhaena pubescence* (IVI=17.48) and rest of the species have moderate importance value. In seedling layer, *Holoptelea integrifolea* (IVI=63.833) was recorded with highest inportance value followed by *Mallotus phillipensis* (IVI=25.27), *Ehretia leavis* (IVI=23.70), *Listea chinensis* (IVI=24.07) and rest of the species have lower importance value. Dominancy of each species in a forest always reveals that each source is highly being utilized by that species in a community. A large number of the forest cover is occupies by *Holoptelea integrifolea* in Chilla forest range. Similar dominancy has been observed by Akash et al. (2018) for *Holoptelea integrifolea* (IVI=117.291) in a sub tropical forest of Rajaji tiger reserve.

Abundance- Frequency ratio (A/F)

The abundance frequency ratio (A/F) of tree, sapling and seedling layer in study site has showed maximum of the species with contagious or clumped pattern of distribution.In tree layer, *Holoptelea integrifolea*, *Mallotus phillipensis* and *Ehretia leavis* has showed random pattern whereas rest of the species have showed contagious pattern. In sapling layer *Holoptelea integrifolea* was the only species which has showed random pattern and rest have showed contagious pattern. On the other hand, in seedling layer, *Mallotus phillipensis*, *Listea chinensis* has showed random pattern where rest has been recorded with contagious pattern. No species have been recorded with regular pattern in the studied area. In tree layer, 18.75% species have random pattern, 81.25% species have contagious pattern whereas in sapling, 7.69% species have random pattern, 92.30% have contagious pattern. On the other hand, in seedling 13.33% species have random pattern and 86.66% have contagious pattern. It has been argued that contagious pattern of species is the characteristics pattern of nature. It may also be due to the different environmental condition in an area. From our study we also concluded that

the woody community has multitudinal condition of environmental. Similar observation was given by various workers in Garhwal Himalaya.

Conclusion

The tropical forest of Rajaji tiger reserve maintaining the diversity of woody species and providing the significant contribution in Northern India. Although, the studied area comes under a protected area network but there are so many pastoralist communities in the tiger reserve which sometime severely affect the biodiversity. The local restrict the moment of the animals in their corridor because they also live near or nearby areas of the corridor and also lopped important food or fodder plants. Recently, due to the exploration it has shown to have significant positive effects on the rehabilitation of the degraded forest and enhancement of their various services. Recently, due to the rehabilitation of the some pastoralist community from the dense area of the forest and short period of exclosure establishment as well as the results of the present study further provides empirical evidence on the increment of tree species, their diversity, richness, frequency, density, dominance and importance value index as well. Crucial efforts have enhanced the population structure and regeneration pattern of the tree species in the study area. Therefore, the results demonstrated that rehabilitation program of the pastoralist community, establishment of exclosure may be best and convenient strategies for management and to rehabilitate the degraded area. Further study is recommended focusing on the herbaceous diversity, richness, density, biomass of soil, plant and carbon pool as well as the content of soil. The results also illustrates that the enclosed area is in an initial stage of recovery since it had been an open grazing area for the cattle of the pastoralists community prior to the establishment of the exclosure. Despite of the short time of exclosure, results from present study provide ample evidence in increasing of tree diversity, species richness, evenness, frequency and important value index (IVI) as well as the population structure.

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