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Phytosociology and Stand Structure of Tropical Dry Deciduous Forest of Dalma Wildlife Sanctuary, Jharkhand, Eastern India

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RN and SS did the conceptualization, author RN did the investigation, writing—original draft preparation, authors SS and YM did the review, editing, supervision. All authors read and approved the final manuscript.

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ABSTRACT

Assessing the composition and structure of ecosystems is of the utmost importance for the conservation of forests. Tree species diversity, distribution pattern and stand structure provide baseline information for conservation and management of the forest. The present study was conducted in the Dalma Wildlife Sanctuary to assess the diversity, composition, richness and stand structure. Standard sampling method was used for vegetation sampling and data collection. An

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aggregate of 2876 individuals belonging to 41 species, 34 genera and 22 families were identified from 2.5 ha sampling area. The sanctuary recorded tree density of 1151 ind./ha with a total basal area of 510.807 sq. m. Analysis of IVI value revealed that *S. robusta* (65.207), *B. cochinchinensis* (22.451), *A. latifolia* (18.071), *T. tomentosa* (15.604) and *D. melanoxylon* (12.449) were the dominant tree species in the sanctuary. The family Fabaceae was the most species-rich family with 9 species. Over 70% of tree species showed contiguous distribution pattern in the studied area. The sanctuary recorded diversity index (H') of 3.204, richness index (R') of 4.504 and evenness index (E) of 0.863. The stand structure indicates a natural satisfactory regeneration and healthy population in the studied forest areas. Density-girth class distribution showed that more than 75% of the total population was dominated by seedlings and saplings. The research findings suggests that the sanctuary is an ecolologically rich site with an expanding population. An efffective management and conservation strategy will ensure a sustained biodiversity and richness of this protected site.

Keywords: Species diversity; total basal area; importance value index; phytosociological studies; floristic analysis; distribution pattern; population structure.

1. INTRODUCTION

Tropical forests, occupy only 7% of the Earth's land surface [1], sustain almost two-thirds of the world's biodiversity [2] and offer significant ecological services both regionally and globally. Currently, the rate of disappearance of tropical forests ranges from 0.8 to 2.0% annually [3] due to various anthropogenic disturbances [4]. The gradual destruction of habitat in tropical forests is thought to be the cause of the extinction of 14–40,000 species every year [2]. Tree diversity is critical to the overall biodiversity of tropical forests since trees provide practically every other forest species with food and habitat [5,6]. It is certainly justified to say that plant diversity and phytosociological characteristics have a major role in the long-term viability of forest ecosystems. Any ecological and phytogeographical research as well as conservation management initiatives require an understanding of an area's floristic composition [7,8]. It is well-established that species diversity and composition in forested areas can serve as indicators of previous management strategies [9,10] and long-term monitoring help in assessing the changes in diversity and compositions of forest trees. Recent years have seen the adoption of small permanent plots for quantitative floristic analysis for assessment of the structure, composition, and diversity of the vegetation in different tropical forests [11,12,13,14]. These forest inventories provide details on the floristic composition and abundance of individual species, as well as particular structural features of the vegetation [15] and help in documenting the long-term dynamics of tropical forests.

The objective of the current study was to comprehend the ecological diversity and floristic composition of tropical forests of Dalma Wildlife Sanctuary, Jharkhand. The information identifies the species-rich communities, and contributes to both the formulation and execution of efforts aimed at conserving the biodiversity.

2. MATERIALS AND METHODS

2.1 Study Area

The study has been carried out in Dalma Wildlife Sanctuary, Jharkhand comprises of mainly northern tropical dry deciduous forests 5(B), particularly dry peninsular Sal and northern dry mixed deciduous forest. It lies between 22'46'30" to 22'57' N and 86'3' 15" to 86'26'30" E in Chotanagpur plateau of south Jharkhand, covering an area of about 193.22 sq.km of which 45.56 sq.km is under reserved forest & 147.44 sq.km is under protected forest.

2.2 Vegetation Sampling

2.2.1 Plot laying and enumeration

The vegetation survey was conducted from January 2022 to September 2022 using the standard quadrate method [16]. The phytosociological studies and floristic assessment was done by laying out twenty-five belt transects of 0.1 ha (100m X 10m) in different locations of the sanctuary (Fig.1). Each belt transect was then divided into 10 quadrates of 10 X 10 sq. m size. Likewise, similar belt transects of 0.1 ha size were drawn randomly at different locations.

All the trees above 10 cm GBH (girth at breast height) were measured within each quadrate and noted down [17]. Observations like GBH, number of species, number of individuals, number of coppices/seedlings, latitude, longitude and altitude were recorded. Species identification and vernacular names were carried out by a local field guide and the information was rectified by taxonomic experts.

2.2.2 Tree diversity, phytosociology, floristic richness and stand structure

Tree diversity and phytosociology of the studied forests was analyzed by frequency, relative frequency, density, relative density, abundance and relative dominance (Table 1) [18]. Relative frequency, relative density, and relative dominance were added to determine the IVI value [19]. Floristic richness was analyzed by various diversity indices viz. Shannon-Weaver diversity index (H') [20], Simpson's diversity index (D) [21], Simpson's dominance index (Cd) [21], Margalef Richness index (R') [22], Menhinick's Richness (MI) [23] and Evenness index [24] (Table 2). Distribution pattern of the tree species was assessed by a/f ratio [25] which categorizes as regular (<0.025), random (0.025 – 0.05), and contiguous (>0.05) distributions [26].

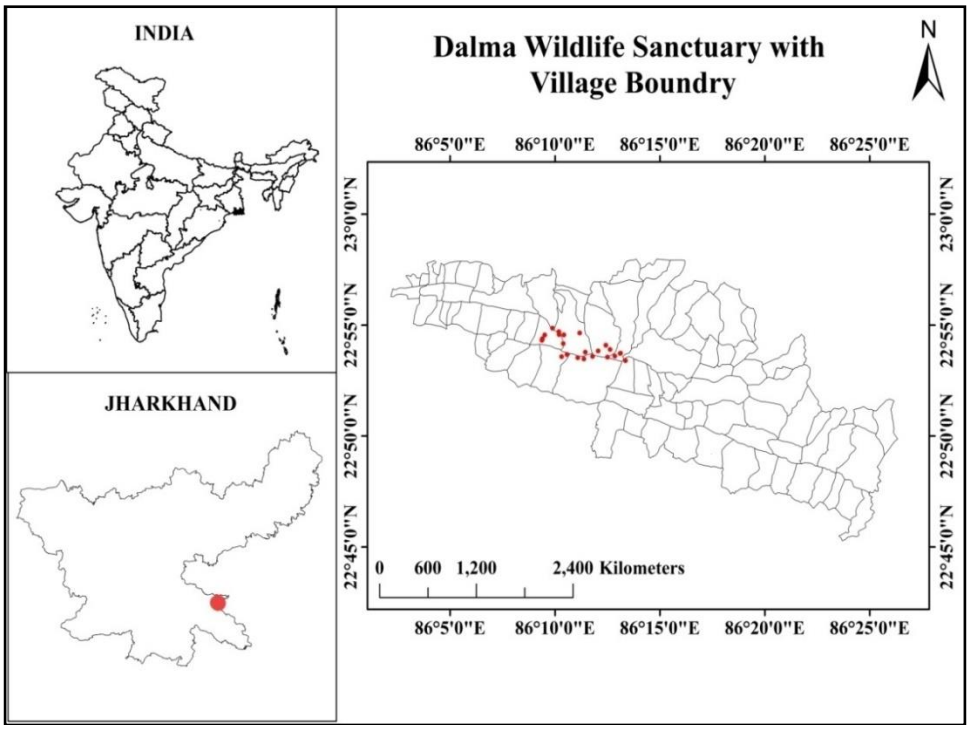

Fig.1. Location of study area and Sampling plots in the study area

Table 1. List of formulas for quantitative analysis of Phytosociology

Phytosociological attributes	*Formulas*
Frequency	$\frac{\text{Number of quadrates in which the species occurred}}{\text{Total number of quadrates studied}} \times 100$
Density	$\frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates studied}}$
Abundance	$\frac{\text{Total number of individuals of a species in all quadrates}}{\text{Total number of quadrates in which the species occurred}}$
Relative frequency	$\frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$
Relative density	$\frac{\text{Number of individual of the species}}{\text{Number of individual of all the species}} \times 100$
Relative dominance	$\frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$

Table2. List of formulas for quantitative analysis of floristic diversity and richness

Diversity Indices	Formulas
Shannon-Weaver diversity index (H')	$-\sum pi \ln pi$
Simpson's dominance index (Cd)	$\sum (p_i)^2$
Simpson's diversity index (D)	1 - Cd
Evenness index (E)	H'/log S
Margalef Richness index (R')	(S-1)/ In N
Menhinick's Richness (MI)	S/ √N

Stand structure was obtained from the density-girth class distribution curve. The curve was drawn among the 6 girth classes viz., >10 cm, 11–30, 31–60, 61- 90, 91 –120, and > 120 cm to depict the stand structure of the studied forest areas. The total number of individuals belonging to an individual girth class was calculated for each species. The population structure of dominant tree species in the forest was depicted similarly.

2.3 Data Analysis

The effect of species basal area on species dominance (IVI) was determined by a linear regression analysis using Log_e IVI and Log_e total basal area (TBA). The study used two-tailed Carl-Pearson's correlation to identify the trajectory and magnitude of the association between species richness indices (Margalef's and Menhinick index), diversity indices (Shannon-Weaver index, Simpson's concentration of dominance, and Pielou's evenness index) and phytosociological parameters (frequency, density, and total basal area). IBM Corp.'s SPSS program, version 25.0, was used to do regression and correlation analysis.

3. RESULTS AND DISCUSSION

3.1 Species Richness, Diversity and Phytosociology

During the study Dalma Wildlife Sanctuary was recorded with 41 tree species belonging to 34 genera and 22 families (Table 3). The study concurs with previous study in the sanctuary that recorded 30 spp. [27] but lesser than 66 spp. [28]. The study also aligns with tropical dry deciduous forest in Bhadra WLS (46 spp.) [29] ,Chalsa forest range, West Bengal (43 spp.) [30]. Tree density was found 2876 ind./ha whereas the density of *S. robusta* was 587 ind./ha in the studied forests. It is challenging to evaluate species richness in sal forests across India as floristic inventories were highly influenced by differences in quadrate size, sampled area, and minimum stem diameter measurement standards.

The phytosociological characteristics primarily density and total basal cover, provide the major research basis across all vegetation types and are used for evaluating the extent of changes in forest ecosystems [31]. During the study, *S. robusta* was found to be the most dominant species with highest frequency (100%), density (5.87) and total basal area (193.138sq. m). After *S. robusta*, most frequently found species were *B. cochinchinensis* (61.2%), *T. tomentosa* (60.8%)**,** *A. latifolia* (59.2%), *L. parviflora* (58.8%) and *D. mealoxylon* (56.4%). In terms of density, *S. robusta* was followed by *T. tomentosa* (197 ind.), *B. cochinchinensis*(189 ind.), *A. latifolia* (17**7**ind.) and *D. meanoxylon*(167ind.). The total basal area ranged between 0.086 sq. m for *A.salvifolium* to 193.138 sq. m for *S. robusta.*

The highest IVI value was recorded for *S. robusta* (65.207) in the sanctuary. Subsequently, higher IVI value was also represented by its associate species namely*, B. cochinchinensis* (22.451), *A. latifolia* (18.071) and *T. tomentosa* (15.604) and *D.melanoxylon* (12.449). Least IVI value was found for *A.Salvifolium* (0.268),*Spondias* sp. (0.382)**,** *D. Montana* (0.686**)** and *A. procera*(1.466).

Sal is one of the dominant trees in the forests of South Asia [32]. The dominance of *S. robusta* was also evident from the previous studies in the Dalma wildlife sanctuary [27-28]; sal forests of Ranchi [33]; sal forests of Jharkhand [34]; tropical deciduous forests of Chhotanagpur plateau, Bokaro, Jharkhand [35]. Sal dominance is influenced by a number of factors, including age, species association, disturbance regime, successional shifts, water buildup, and anthropogenic activity for wood and other purposes.

Table 3. Phytosociological analysis of tree species found in Dalma Wildlife Sanctuary

Species name	Family	Frequency	Abundance	Density	TBA	IVI	a/f ratio
Aegle marmelos	Rutaceae	19.2	1.17	0.22	3.711	2.848	0.061
Alangiumsalvifolium	Cornaceae	2.4	1.00	0.02	0.086	0.268	0.417
Albizia procera	Fabaceae	11.6	1.03	0.12	1.211	1.466	0.089
Albizia lebbeck	Fabaceae	30.4	1.57	0.48	6.262	5.007	0.052
Anogeissus latifolia	Combretaceae	59.2	2.99	1.77	39.689	18.071	0.051
Anthocephalus cadamba	Rubiaceae	16.8	1.02	0.17	1.456	2.058	0.061
Bauhinia pupurea	Fabaceae	21.2	1.15	0.24	1.148	2.556	0.054
Bauhinia variegata	Fabaceae	34.8	1.86	0.65	4.731	5.613	0.054
Boswellia serrata	Burseraceae	26.4	1.35	0.36	9.077	4.861	0.051
Buchnaniacochinchinensis	Anacardiaceae	61.2	3.09	1.89	59.218	22.451	0.051
Butea monosperma	Fabaceae	42.4	2.21	0.94	6.448	7.482	0.052
Butea superba	Fabaceae	16.4	1.07	0.18	0.665	1.889	0.065
Cassia fistula	Fabaceae	42.4	1.17	0.50	5.274	5.722	0.028
Clistanthuscollinum	Phyllanthaceae	43.6	1.26	0.55	2.916	5.525	0.029
Dilleniapentagyna	Dilleniaceae	23.2	1.19	0.28	3.189	3.206	0.051
Diospyros melanoxylon	Ebenaceae	56.4	2.96	1.67	13.748	12.449	0.053
Diospyros montana	Ebenaceae	6	1.00	0.06	0.296	0.686	0.167
Erythrina variegata	Fabaceae	50	1.29	0.64	4.419	6.601	0.026
Glochidionlanceolarium	Phyllanthaceae	26	1.37	0.36	5.325	4.099	0.053
Gmelina arborea	Lamiaceae	26.8	1.36	0.36	3.512	3.827	0.051
Holarrhenaantidysentrica	Apocynaceae	42.4	1.37	0.58	2.565	5.484	0.032
Lagerstroemia parviflora	Lythraceae	58.8	1.79	1.05	18.225	11.338	0.030
Lanneacoromandelica	Anacardiaceae	48.8	1.25	0.61	8.218	7.149	0.026
Madhuca longifolia	Sapotaceae	41.2	2.10	0.86	27.440	11.257	0.051
Mallotusphilippensis	Euphorbiaceae	45.2	1.16	0.52	6.563	6.268	0.026
Mimusopselengi	Sapotaceae	24.4	1.25	0.30	1.788	3.113	0.051
Mitragynaparvifolia	Rubiaceae	37.6	1.07	0.40	6.019	5.213	0.029
Phyllanthus emblica	Phyllanthaceae	51.2	1.59	0.81	3.438	7.077	0.031
Pterocarpus marsupium	Fabaceae	36.4	1.85	0.67	9.246	6.692	0.051
Schleicheraoleosa	Sapindaceae	31.6	1.09	0.34	5.835	4.548	0.034
Semecarpus anacardium	Anacardiaceae	51.2	1.32	0.68	8.249	7.546	0.026
Shorea robusta	Dipterocarpaceae	100	5.87	5.87	193.138	65.207	0.059

Species name	Family	Frequency	Abundance	Density	TBA	IVI	a/f ratio
Soymidafebrifuga	Meliaceae	31.2	1.58	0.49	4.412	4.756	0.051
Spondiassp	Anacardiaceae	3.2	1.13	0.04	0.167	0.382	0.352
Syzygiumcumini	Myrtaceae	20.4	1.08	0.22	2.351	2.652	0.053
Terminalia arjuna	Combretaceae	14.8	1.00	0.15	3.018	2.140	0.068
Terminalia bellirica	Combretaceae	25.6	1.30	0.33	4.924	3.908	0.051
Terminalia chebula	Combretaceae	28.4	1.46	0.42	6.967	4.796	0.052
Terminalia tomentosa	Combretaceae	60.8	3.24	1.97	22.962	15.604	0.053
Wrightia tinctoria	Apocynaceae	29.6	1.57	0.46	1.077	3.894	0.053
Ziziphus mauritiana	Rhamnaceae	30.8	1.66	0.51	1.823	4.291	0.054

TBA= total basal area (in sq. m), IVI= important value index

Table 4. Correlation between phytosociological parameters and diversity and richness indices

	Frequency	Density	TBA	IVI	H’	Cd	E	R’	MI
Frequency	1								
Density	0.768**	1							
TBA	0.654**	0.961**	1						
IVI	0.759**	0.989**	0.986**	1					
H’	-0.915**	-0.944**	-0.883**	-0.942**	1				
Cd	0.562**	0.935**	0.980**	0.955**	-0.803**	1			
E	-0.946**	-0.890**	-0.825**	-0.895**	0.990**	- 0.730**	1		
R’	-0.781**	-0.480**	-0.351*	-0.459**	0.652**	-0.281	0.717**	1	
MI	-0.785**	-0.469**	-0.338*	-0.448**	0.647**	-0.266	0.715**	0.999*	1

***Correlation is significant at the 0.01 level (2-tailed)*
**Correlation is significant at the 0.05 level (2-tailed)*

The most prevalent distribution pattern in nature is contiguous distribution [36]. In our study contiguous distribution also proved to be prevalent with 30 species. This type of distribution is a result of mode of seed dispersal in tropical forests [37]. Random distribution is the second prevalent distribution pattern in nature which requires an uniform environment [36]. During the study 11 species showed random distribution pattern. No species showed regular distribution pattern.

Among the 22 families were recorded Fabaceae was the most diverse with 9 species followed by Combretaceae (5), Anacardiaceae (4), Phyllanthaceae (3). *Terminalia* was the most species-rich genus with four species followed by *Bauhinia*, *Butea* and *Diospyros* with two species each and the other entire genus was represented by single species.

3.2 Diversity, Richness and Evenness Indices

The Dalma wildlife sanctuary was found to be diverse and homogeneous in species distribution with the Shannon-Weaver diversity index (H') of 3.204, Simpsons index of diversity (D) of 0.928 and evenness index (E) of 0.863 (Fig 2). In the studied forests area species richness was high with Margalef richness index (R') of 4.504 and Menhinick's Richness (M) of 0.483.

For Indian forests the value of Shannon-Weaver diversity index ranged between 0.83-5.18 [38-40]. The present study falls within the limits of the index. The high value of the evenness index reflects that much of the value of diversity which is attributed to the relatively rare species [28].

3.3 Stand Structure

The depiction of the stand structure of the sanctuary had been accomplished by calculating the density of seedlings, saplings, and adults (Fig. 3). Plant population density of the sanctuary was distinguished by a significant accumulation of seedlings, followed by a sharp decline to the sapling stage, and then a further decrease to the trees with greater girth classes. The density of seedlings was 5239 ind./ha representing 44.467% and the sapling population was 3667 ind./ha representing 31.123% of the total adult tree population. Among the higher girth class, 61-90 cm girth class was the most dominant with 10.236% followed by 31-60 (6.094%), 91-120 (5.203%) and >120 (2.877%) girth class. The dominant species were also depicted as an analogous population structure.

The sanctuary was dominated by small girth trees and exhibited reverse J-shaped density-girth class distribution. This reflects the young state of the forests and is believed to be the ideal condition for regeneration [41]. Several researchers documented similar trends in stand structure [42-44].

3.4 Statistical Analysis

The linear regression model indicates that TBA accounts for the high rate of variance in the species dominance value. According to the model, TBA explains 87.5% of the variation (R^2 Linear: 0.863, $p < 0.001$) in the IVI value of the species found in the studied forest (Fig. 4).

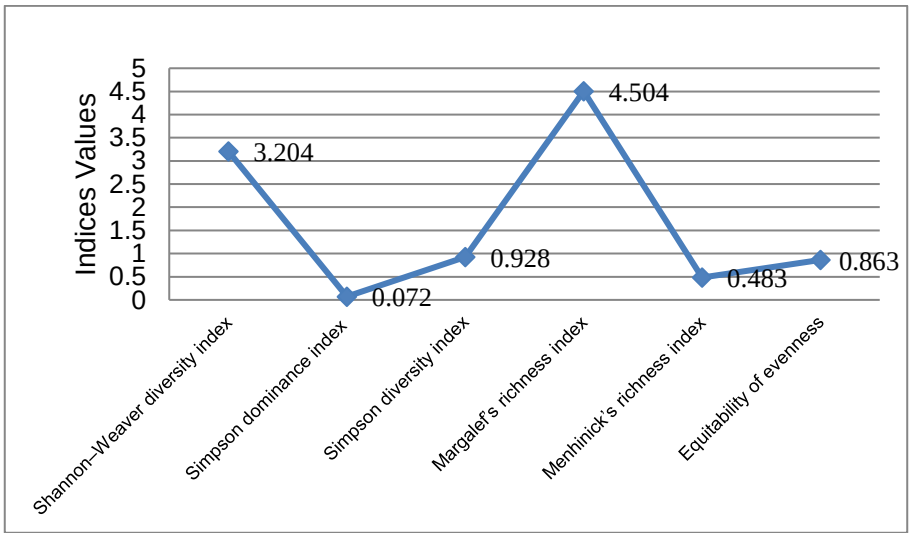

Fig.2. Different diversity indices of the forest vegetation of Dalma WLS

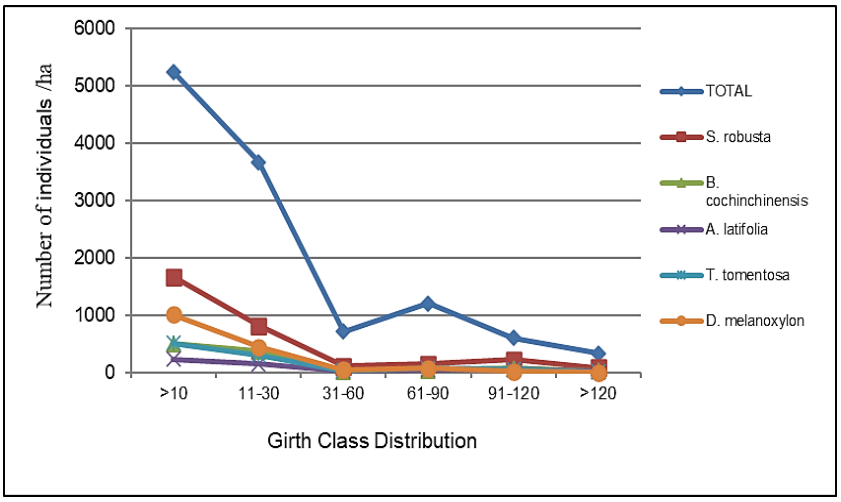

Fig. 3. Population structure of Dalma WLS and its dominant species

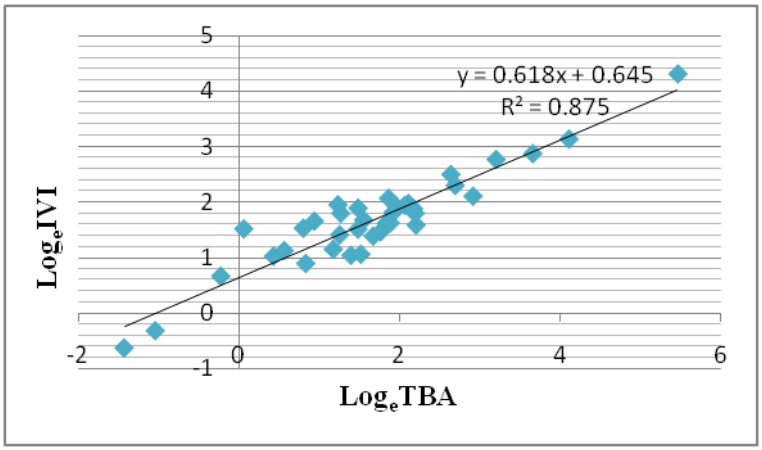

Fig.4. Linear regression between Log$_e$IVI and Log$_e$TBA of all tree species under different sites

Tree density and frequency have a significant strong correlation with species richness and diversity (Table 4). The strong correlation between species diversity and richness indices reflects that the high-diversity sites also have high species richness. Absence of significant correlation between the concentration of dominance with species richness reflects that sites having dominant species have less species diversity.

4. CONCLUSIONS

The forests of Dalma Wildlife Sanctuary are home to a variety of tree species representing high species richness and diversity. The forest composition of the sanctuary shows that timber-producing trees like *S. robusta*, *A. latifolia*, and *T. tomentosa* predominate the sanctuary. Understanding the ecological relevance of the species in the studied forest has been comprehended by the IVI value. The strong correlation found between TBA and IVI suggests that large-diameter trees have a major role in controlling species dominance in these ecosystems. Presence of frequent contiguous dispersion of individuals indicate non-uniform occurrence of these individuals. The study depicted a young and expanding population of trees with stand density decreasing sharply with the increase in girth class. Further monitoring of the sanctuary will be required to understand its vegetation dynamics with the climate change.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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