Original Research Article

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

.

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 baselineinformation 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 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 m^2.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.

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. MATERIAL 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 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.

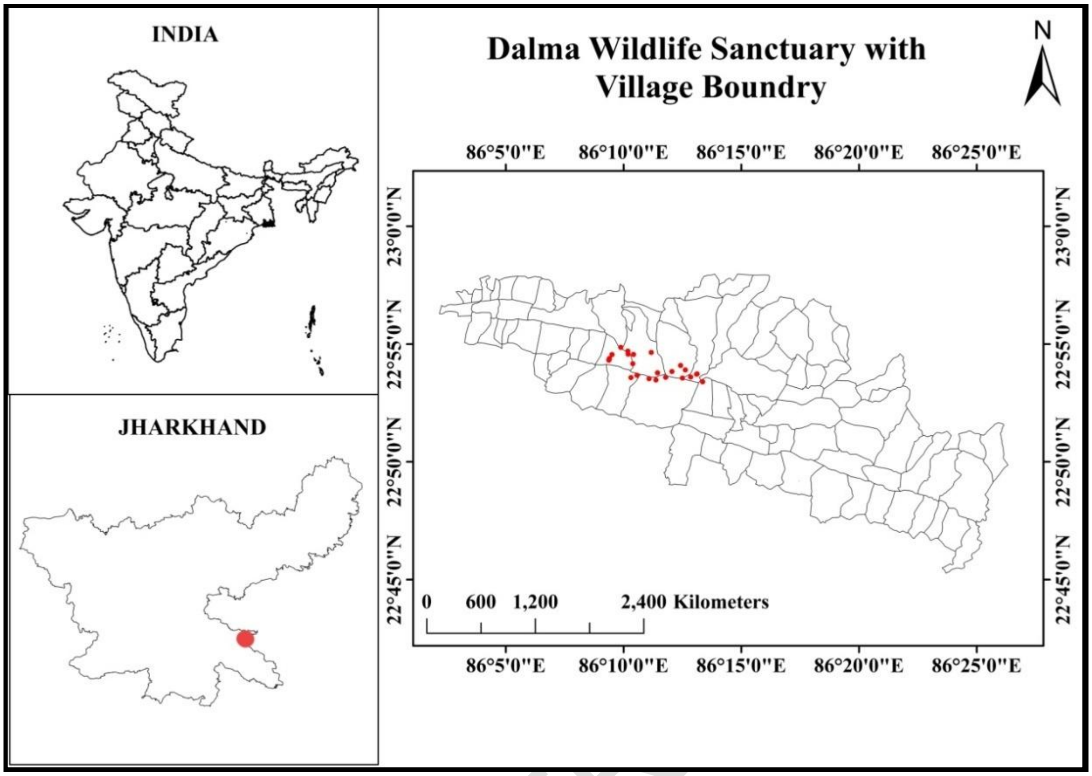

Fig.1. Location of study area and Sampling plots in the study area

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 [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-Wiener 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]. 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].

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.

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	$\frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$

Table. 2 : List of formulas for quantitative analysis of Floristic analysis

Diversity Indices	**Formulas**
Shannon-Wiener 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')	$(S-1)/\ln N$
Menhinick's Richness (MI)	$S/\sqrt{N}$

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* (177ind.) and *D. meanoxylon*(167ind.). The total basal area ranged between 0.086 sq. m for *A.salvifolium* to 193.138sq. m for *S. robusta.*

The highest IVI value was recorded for *S. robusta* (65.207) and higher IVI value was represented by *B. cochinchinensis*(22.451), *A. latifolia* (18.071) and *T. tomentosa* (15.604). 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.

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 the22 family 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.

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
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.

3.2 Diversity, Richness and Evenness Indices

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

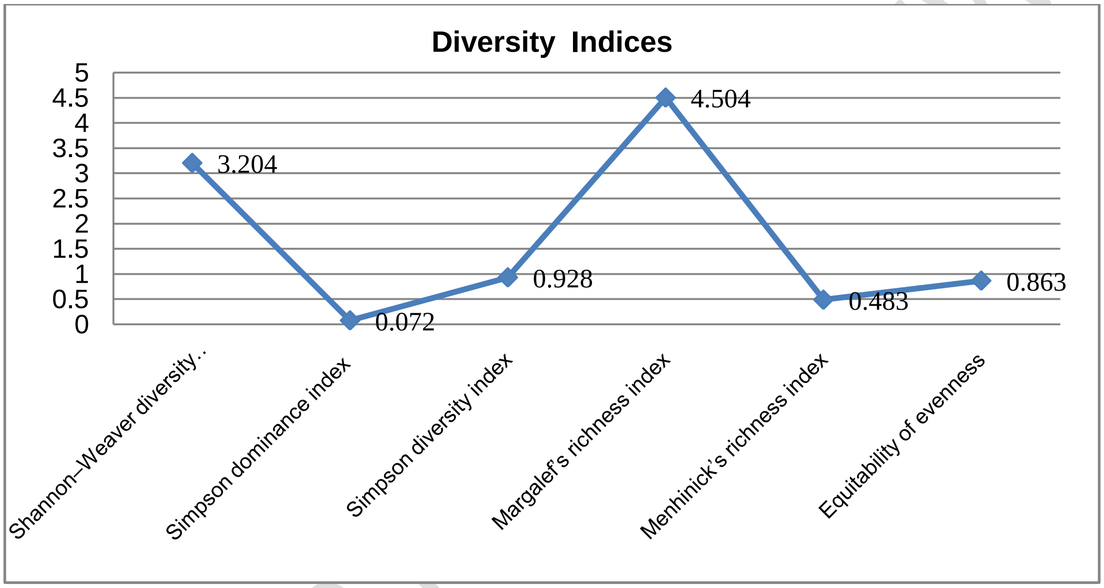

Fig.2: Different diversity indices of the forest vegetation of Dalma WLS

3.3 Stand Structure :

The depiction of the stand structure of the sanctuary has been accomplished by calculating the density of seedlings, saplings, and adults (Fig.3). High accumulation of seedlings and then a sharp decrease towards the sapling stage and the decrease continues towards the higher girth classes was the characteristics of the sanctuary. 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 was 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].

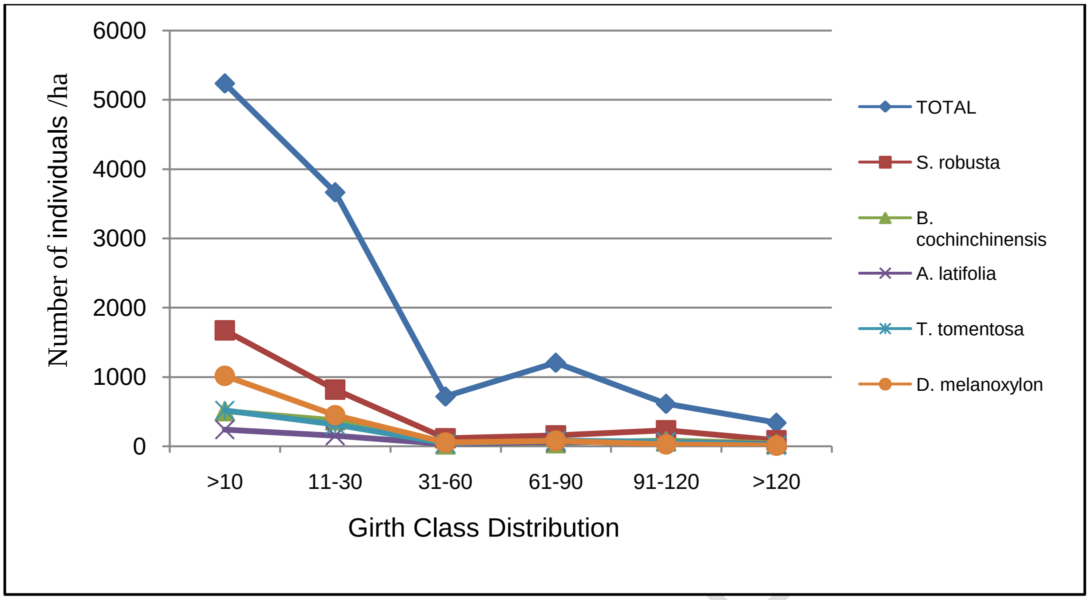

Fig.3 : Population structure of Dalma WLS and its dominant species

3.1 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 (R2 Linear: 0.863, $p < 0.001$) in the IVI value of the species found in the studied forest (Fig. 4).

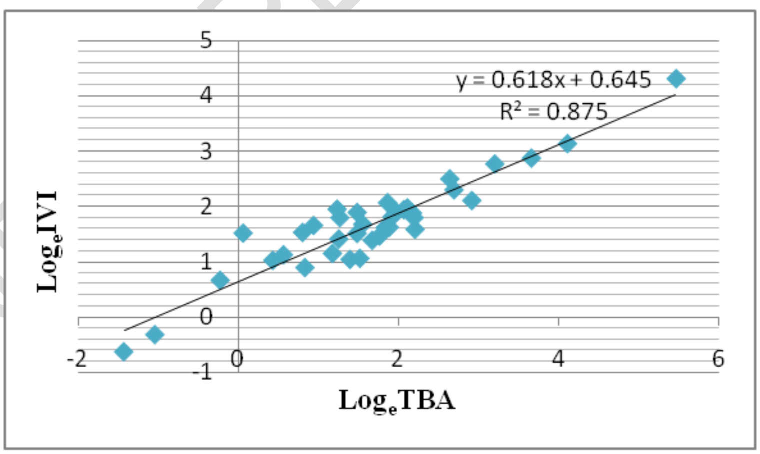

Fig.4. : Linear regression between Log_eIVI and Log_eTBA of all tree species under different sites

Table 4 : Correlation between phytosocilogical 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)

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 structure of the sanctuary shows that timber-producing trees like *S. robusta*, *A. latifolia*, and *T. tomentosa* predominate. 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 contagious 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.

REFERENCES

1. Wilson EO. The current state of biological diversity. Biodiversity 1988;521(1):3-18.
2. Hughes JB, Daily GC, Ehrlich PR. Population diversity: its extent and extinction. Science 1997;278(5338):689-92.
3. May RM, Stumpf MP. Species-area relations in tropical forests. Science 2000; 290(5499):2084-6.
4. Chaturvedi RK, Raghubanshi AS, Singh JS. Carbon density and accumulation in woody species of tropical dry forest in India. Forest Ecology and Management 2011;262(8):1576-88.

5. Huston MA. Biological diversity: the coexistence of species. Cambridge University Press; 1994.
6. Whitmore TC. An introduction to tropical rain forests. Clarendon Press; 1990.
7. Jafari SM, Akhani H. Plants of jahannama protected area, Golestan province, N. Iran. Pakistan journal of botany 2008;40(4):1533-54.
8. Tavankar F. Woody species diversity and stand types in relict of Hyrcanian lowland forests, north of Iran. Plant Sci Feed 2013;3(7):83-7.
9. Hunter ML, editor. Maintaining biodiversity in forest ecosystems. Cambridge university press; 1999:10.
10. Kneeshaw DD, Leduc A, Drapeau P, Gauthier S, Pare D, Carigan R, Doucet R, Bouthillier L, Messier C.. Development of integrated ecological standards of sustainable forest management at an operational scale. Forestry Chronicle 2000;76(3):481–93.
11. Parthasarathy N. Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. Current science 2001;389-93.
12. Sagar R, Raghubanshi AS, Singh JS. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. Forest ecology and Management 2003;186(1-3):61-71.
13. Dar JA, Sundarapandian S. Patterns of plant diversity in seven temperate forest types of Western Himalaya, India. Journal of Asia-Pacific Biodiversity 2016;9(3):280-92.
14. Sharma CM, Tiwari OP, Rana YS, Krishan R, Mishra AK. Elevational behaviour on dominance–diversity, regeneration, biomass and carbon storage in ridge forests of Garhwal Himalaya, India. Forest ecology and management 2018;424:105-20.
15. Linares-Palomino R, Ponce-Alvarez SI. Structural patterns and floristics of a seasonally dry forest in ReservaEcológicaChaparri, Lambayeque, Peru. Tropical Ecology 2009;50(2):305.
16. Curtis JT, Mcintosh RP. The interrelations of certain analytic and synthetic phytosociological characters. Ecology 1950;31(3):434-55.
17. Knight DH. A distance method for constructing forest profile diagrams and obtaining structural data. Tropical Ecology 1963;4:89-94.
18. Phillips EA. Methods of vegetation study.1959.
19. Curtis JT. The vegetation of Wisconsin: an ordination of plant communities. University of Wisconsin Pres; 1959.
20. Shanon CE, Weaver W. The mathematical theory of communication. University of Illinois Press; 1963.
21. Simpson EH. Measurement of diversity. Nature 1949;163: 688.
22. Ludwig JA, Reynolds JF. Statistical ecology: a primer in methods and computing. John Wiley & Sons; 1988.
23. Whittaker RH. Evolution of species diversity in land communities. Evolutionary biology 1977;10:1-67.
24. Pielou EC. Ecological Diversity, Wiley, New York. 1975.
25. Whitford PB. Distribution of woodland plants in relation to succession and clonal growth. Ecology 1949;30(2):199-208.
26. Curtis JT. Plant ecology workbook. A laboratory, field and reference manual. Burges Publishing Co., Minnesota. 1956; 193.
27. Kumari A, Kumar S, Kumar J. An assessment of Floral Diversity of Makulakocha and Pindrabera area of Dalma Wildlife Sanctuary, Jharkhand. The Biobrio 2017;1(1):262-8.

28. Lal HS, Ganguly S, Pramanik K, Prasanna PV, Ranjan V. Plant diversity and vegetation structure in Sal (Shorea robusta Gaertn.) dominated forest of Dalma Wildlife Sanctuary, Jharkhand, India. Indian Journal of Forestry 2019;42(1):83-90.
29. Prakasha HM, Nanda A, Krishnamurthy YL. Stand structure of a tropical dry deciduous forest in Bhadra wildlife sanctuary, Karnataka southern India. Bulletin of the national Institute of Ecology 2008;19:1-7.
30. Sarkar AK, Dey M, Mazumder M. A comparative study of tree species composition of Panjhora forest beat and Sipchu forest beat of Chalsa forest range, West Bengal, India. Journal of Applied Biology and Biotechnology 2017;5(2):045-52.
31. Mishra BP, Tripathi RS, Tripathi OP, Pandey HN. Effect of disturbance on the regeneration of four dominant and economically important woody species in a broad-leaved subtropical humid forest of Meghalaya, northeast India. Current Science 2003;84(10):1449-53.
32. Troup RS. The silviculture of Indian trees. 1. Dilleniaceae to Leguminosae (Papilionaceae). Clarendon Press; 1921.
33. Kumar R, Saikia P. Floristic analysis and dominance pattern of sal (Shorea robusta) forests in Ranchi, Jharkhand, eastern India. Journal of forestry research 2020;31(2):415-27.
34. Divakara BN. Floristic analysis, phytosociological studies and regeneration status of tree species in sal forests of Jharkhand, India. Researchgate publication 2016.
35. Narayan CA, Anshumali J. Diversity indices and importance values of a tropical deciduous forest of Chhotanagpur plateau, India. J Biodiv Environ Sci 2015;7:358-67.
36. Odum EP, Barrett GW. Fundamentals of ecology. Philadelphia: Saunders. 1971.
37. Hubbell SP. Tree Dispersion, Abundance, and Diversity in a Tropical Dry Forest: That tropical trees are clumped, not spaced, alters conceptions of the organization and dynamics. Science 1979;203(4387):1299-309.
38. Ayyappan N, Parthasarathy N. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. Biodiversity & Conservation 1999;8:1533-54.
39. Sudhakar Reddy C, Babar S, Amarnath G, Pattanaik C. Structure and floristic composition of tree stand in tropical forest in the Eastern Ghats of northern Andhra Pradesh, India. Journal of forestry research 2011;22:491-500.
40. Panda PC, Mahapatra AK, Acharya PK, Debata AK. Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. Int J BiodiversConserv 2013;5(10):625-39.
41. Chauhan PS, Negi JD, Singh LO, Manhas RK. Regeneration status of Sal forests of Doon Valley. Annals of Forestry 2008;16(2):178-82.
42. Parthasarathy N, Karthikeyan R. Population structure of Grewia pandaica, a rare and endemic tree species in south-west India. International Journal of Ecology and Environmental Sciences 1997;23:85-90.
43. Joshi HG. Vegetation structure, floristic composition and soil nutrient status in three sites of tropical dry deciduous forest of West Bengal, India. Indian journal of fundamental and applied Life Sciences 2012;2(2):355-64.
44. Gairola S, Rawal RS, Todaria NP, Bhatt A. Population structure and regeneration patterns of tree species in climate-sensitive subalpine forests of Indian western Himalaya. Journal of Forestry Research 2014;25(2):343-9.