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Research Article

Diversity patterns and community structure of Deulghata sacred forest, West Bengal, India

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ABSTRACT

Sacred groves are the patches of forest protected by local people through their cultural and religious beliefs. The objective of the present study is to analyze the vegetation structure and diversity of different strata (tree, shrub and herb) in Deulghata sacred forest of West Bengal. Vegetation data were obtained from five randomly oriented line transects during November 2017 to July 2018. Total 81 species including 25 trees, 7 shrubs, 46 herbs and 3 climbers were recorded. *Butea monosperma* was the dominant tree species (IVI - 97.23) here. Highest family importance value (FIV) was exhibited by Leguminosae (109.39). Anacardiaceae, Apocynaceae, Combretaceae and Sapotaceae were the least represented families each having single tree species with single individual. All but *Azadirachta indica* and *Bombax ceiba* had clumped distribution. Diversity was higher in herb layer than the other layers of vegetation. Diameter class 1 to 10 cm was the most preferred class showing the highest density of individuals while maximum basal area was covered by class 10.1 to 30cm. Tree layer occupied total basal area of 26.05 m^2/ha and achieved complexity index of 43.58. Lack of seedlings for majority of the tree species is a matter of concern as regeneration is essential for continued existence. Therefore management intervention is needed for proper conservation.

Key words: Basal area, Diameter class, Diversity, Family importance value, Sacred groves, Vegetation structure

INTRODUCTION

Sacred groves or sacred forests are a group of trees, or a patch of vegetation protected by the local people through their religious and cultural beliefs (Sukumaran *et al*., 2008). Sacred groves can support and conserve diverse flora and fauna (Khan & Tripathi, 2004; Sukumaran & Jeeva, 2008; Singh *et al*., 2010). Local communities contributed major role in maintaining health and growth of sacred groves (Devakumar *et al*., 2018). Sacred groves establish a connecting link between man and nature with their socio-cultural heritage, and religious and ethnic beliefs (Khan *et al.*, 2008; Rao & Sunitha, 2011; Basha *et al*., 2012). In terms of community-based nature conservation, the concept of sacred groves is highly acceptable (Singh *et al*., 2019) and the most relevant tools for the conservation are cultural and biological diversity (Ray & Ramachandra, 2010). Sacred groves not only preserve biological wealth of the ecosystem but also play an important role for conservation of soil and water (Singh *et al*., 2019). Therefore, sacred forests are considered as the epicenter of ecological conservation and management of forest at state and national levels (Ray & Ramachandra, 2010).

In India out of total forest cover, 38.2% is the dry tropical forests (MoEF, 1999). As per West Bengal State Forest Report (2011-12), the forest cover in West Bengal is only 13.38% of the total geographical area. Purulia is the south-western district of West Bengal which covers only 14% of the recorded forest area. These forests are classified as Northern Tropical Dry Deciduous forests (Champion & Seth, 1968). The forests of Purulia district mostly found in the uplands of Ayodhya–Baghmundi and Dalma. Besides this, some patches of forest also exist in the upper catchment areas of the Kangsabati, Silai and Dwarakeswar valley (Das *et al.,* 2016). The forests of this area are rarely virgin, but more often of secondary origin.

Concept of sacred groves is very ancient and widespread phenomenon in the old-world cultures (Agbogidi & Benson, 2014). Malhotra *et al*. (2007) and Hughes & Chandran (1998) reported sacred groves from different continents of the world such as Africa, Asia, Europe, Austro- pacific region and Americas. India has recognized and conserved this ancient wealth from the pre-Vedic age (Sharma & Kumar, 2021). Sacred groves (forests) are found all over the country. More than 50,000 sacred groves have been reported from different parts of India (Malhotra *et al*., 2001). Deb *et al.* (1997) reported over 670 sacred groves from Bankura, Birbhum, Midnapur, Purulia and Jalpaiguri district of West Bengal. Purulia, the westernmost district of West Bengal is the home of so many sacred groves. Das *et al*. (2016) surveyed 36 sacred groves, Imam *et al*. (2016) surveyed 53 sacred groves and Basu (2000) studied 18 sacred groves from Purulia district.

Forest studies conducted so far in Purulia district concentrated on angiospermic diversity and ethnobotanical aspects (Mandal & Mukherjee, 2016; Dey & De, 2011), Non timber forest product (Chanda & Mukherjee, 2013) and about the present status of sacred

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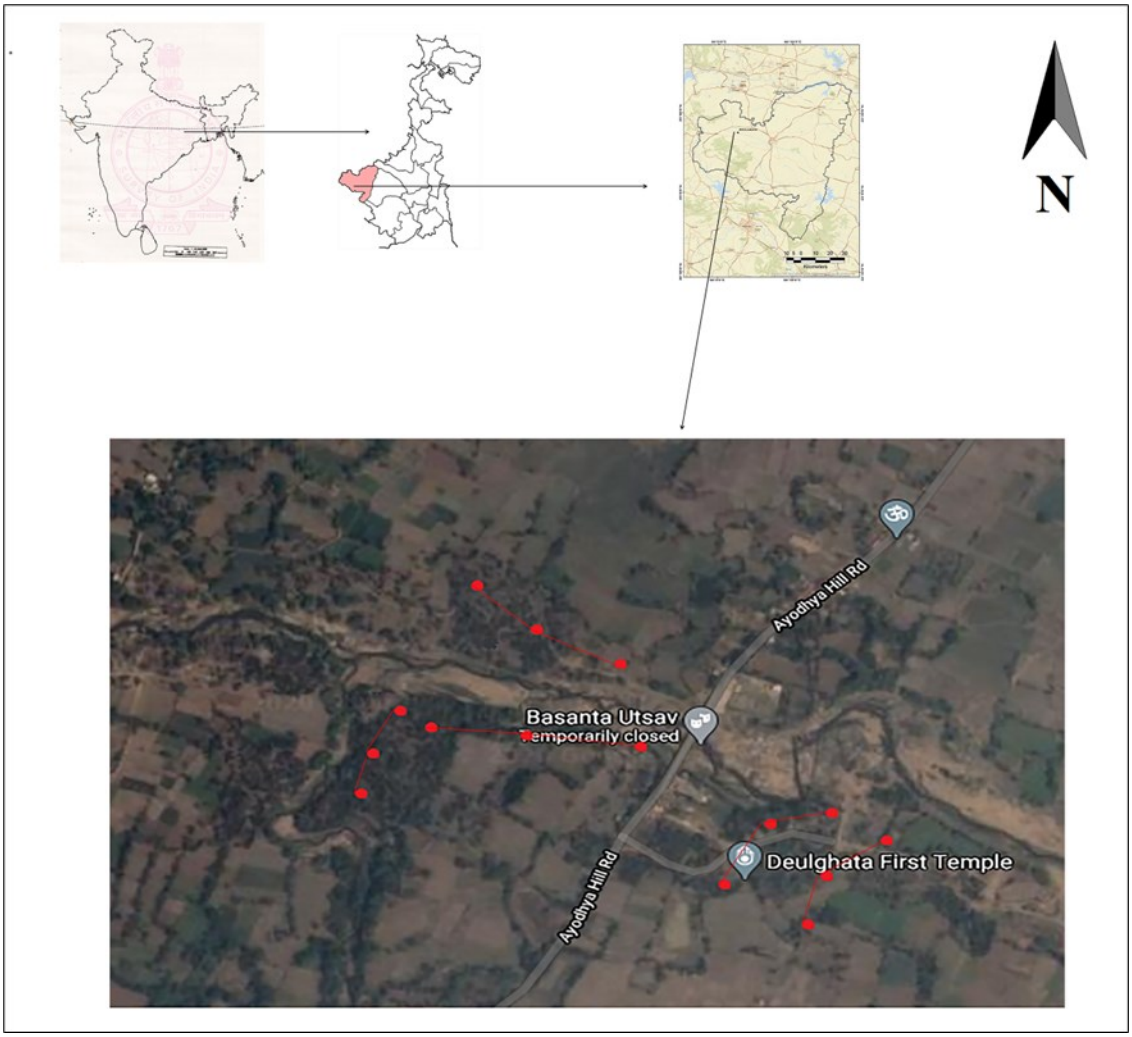

Figure 1. Map of the study area showing location of sampled plots.

groves in Purulia (Imam *et al.,* 2016; Das *et al.,* 2016, Konar, 2010; Basu, 2000). Despite having diverse type of forests as well as being rich in forest dependent tribal communities, published information on quantitative analysis of vegetation structure of these extracted forests are unavailable.

The objective of the present study is to explore the pattern of diversity, structure and composition of a sacred forest of Purulia district, West Bengal.

MATERIALS AND METHODS

Study area

The study was conducted in Deulghata sacred forest located in Purulia district of West Bengal, extending between 23˚22′ N latitude and 86˚07′ E longitude (Figure 1). It is a temple grove, situated beside the Kangsabati River near the Boram village. Literal meaning of Deulghata is 'The land of Temples'. It is considered as one of the rich heritage site of Purulia district as it bears the marks of ancient history especially Jainism (Dutta, 2012). The climate of this area is sub-tropical monsoon type with distinctly separated winter, summer and rainy seasons. Average annual rainfall is 1320 mm and temperature ranges from 3˚C (minimum) to 45˚C (maximum). Relative humidity is highest during July to September.

Vegetation sampling

Five random sites were selected, and at each site a 200m long randomly oriented line transect, with three circular plots of 10m radius at start, middle and end, was established for sampling tree species. The shrub layer was sampled in 5m radius circular plot and herb layer by laying four 1m x 1m quadrats, nested within 10m radius plot for trees. Thus total fifteen circular plots of 10 m radius were laid during November 2017 to July 2018 for collecting vegetation data. Geographical coordinates (Lat- Long Values) were recorded for each plot. All the trees (dbh≥1cm) were identified and their numbers counted in each quadrat. Diameter at breast height (dbh) or girth at breast height (gbh) of all the tree species was recorded. Tree height was recorded by tangent method (Larjavaara & Muller-Landau, 2013). Tangent method involves the measurement of horizontal distance from the technician to the tree and angles from horizontal to the top of the tree. The recommended angle should be smaller than 45° (Goodwind, 2004). The reason behind this recommendation is that the tangent of an angle increases rapidly for larger angles, and thus, the precision of the height measurement declines disproportionately. To obtain the recommended angle, the technician has to stand at a distance equal to the tree height or more. Horizontal distance was measured by measuring tape and angle was measured by clinometer.

DBH of shrub species were also recorded. Regional floras were consulted for species identification of the collected plant specimens (GuhaBakshi, 1990; Sanyal, 1994). Families were arranged according to "Flora of Bilaspur" by Panigrahi & Murti (1989) and the scientific names of plants were enlisted by following "The Plant List" (www.theplantlist.org)

Data analysis

Different phytosociological characters like frequency, density, abundance, basal area, distribution pattern and importance value index (IVI) were calculated for each tree species following Misra (1968). Relative frequency, relative density and relative dominance (basal area) were summed up to calculate IVI. IVI of herbaceous species was calculated by summing relative density and relative frequency only (Lopez *et al*., 2008). To estimate family importance value (FIV), the relative values of diversity, density and dominance of a family were summed up (Ganesh *et al.,* 1996). Species dispersion pattern was estimated from the ratio of abundance to frequency (A/F) (Curtis & Cottom, 1956). Number of individuals was arranged in six diameter classes to study population structure of tree species, starting from 1–10 cm to 120-150 cm diameter classes. Complexity index (I_c) for tree layer was estimated according to Pool *et al.* (1977) as:

I_c = Number of species x stand density x stand basal area x stand height x 10^{-5}

Five indices of species diversity were estimated - Shannon-Wiener's Heterogeneity (H′) (Shannon & Weaver, 1949), concentration of dominance (Cd), known as Simpson's index (Simpson, 1949), Margalef's index of species richness (M) (Margalef, 1968), evenness (E) (Pielou, 1966) and within habitat beta diversity (β), known as habitat heterogeneity (Whittaker, 1972).

$$H' = \sum_{i=1}^{s} pi \ln pi$$

$$Cd = \sum (pi)^2$$

$$E = H'/H^{max}; H^{max} = \ln(s) \text{ (Krebs, 1978)}$$

$$M = (s - 1)/\ln N$$

$$\beta = Sc/S$$

Where,

s = total no of species,

pi= ni/N, ni= total no of individual of "i^{th}" species,

N= total no of individual of all species,

ln= natural log

Sc = total number of species

S = average number of species per sample

RESULTS

Species composition and dominance

25 tree species under 15 families having 587 individuals (Table 1), seven shrub species under 5 families having 213 individuals (Table 2), 46 species of herb and grasses of 22 families with 1937 individuals (Table 3), were recorded. Three species of climbers (*Capparis zeylanica, Cayratia trifolia* and *Dioscorea esculenta*) each with single individual were also recorded from the sacred forest. The minimum number of individual was 1 for all the strata of vegetation and maximum numbers of individuals for various species of trees, shrubs and herbs were 270, 85 and 331 respectively (Tables 1-3). Percentage cover of herb, shrub and trees including saplings and seedlings in terms of species and individuals are shown in figure 2. Herbs had the maximum cover while shrubs had the minimum.

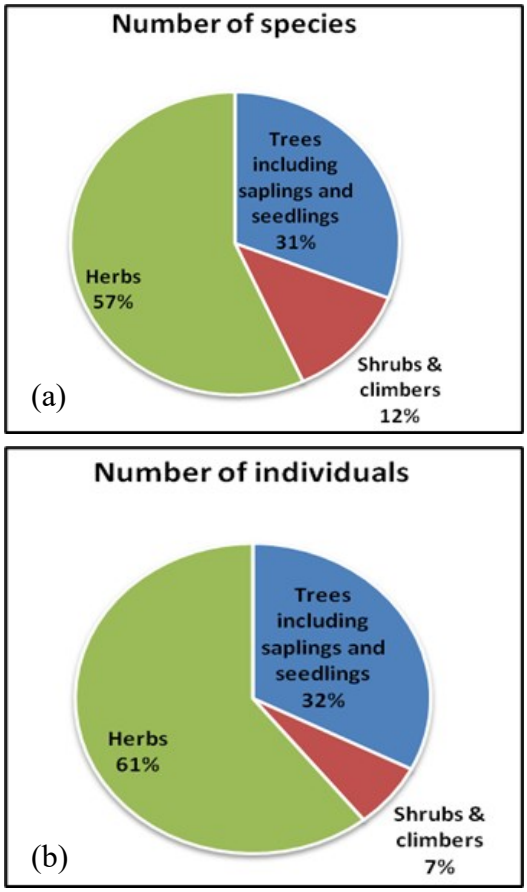

Figure 2. Percentage cover of herb, shrub and tree in terms of number of species (a) and number of individuals (b).

Butea monosperma exhibited the highest IVI value (97.21) and was the dominant tree species whereas *Dalbergia sissoo, Gardenia latifolia* and *Psidium guajava* showed the lowest value of IVI (1.67). *Alangium salviifolium* although possessed maximum number of individuals (270), was the codominant tree species (IVI 74.94). *Dalbergia sissoo, Ficus hispida, Gardenia latifolia, Holarrhena pubescens, Lannea coromandelica, Madhuca longifolia var. latifolia, Psidium guajava* and *Terminalia arjuna* were the tree species represented by single individual each (Table 1). Single species having single individual represented the family Anacardiaceae, Apocynaceae, Combretaceae and Sapotaceae. Highest number of individuals (270) were of family Cornaceae followed by Leguminosae (224). Highest and lowest family importance values (FIV) were exhibited by Leguminosae (109.39) and Combretaceae (4.34) respectively (Table 4).

Among the shrubs, *Clerodendrum infortunatum* (IVI 85.09) and *Lantana camara* (IVI 81.47) were the dominant and co dominant species respectively (Table 2). *Leonotis leonurus* was the only shrub represented with single individual. Family Lamiaceae exhibited the highest family importance value (FIV 112.33) whereas it was lowest for Euphorbiaceae (26.31) (Table 5).

Evolvulus nummularius exhibited the highest IVI value (27.56) among the herbaceous species and

Table 1. Phytosociological characteristics of tree species.

Tree species	Family	Total number	Fre-quency	Density (N/ha)	Abun-dance	Basal area (m^2/ ha)	IVI
Aegle marmelos (L.) Corrêa	Rutaceae	3	13.33	6.37	1.5	0.4	4.87
Alangium salviifolium (L.f.) Wangerin	Cornaceae	270	100	573.25	18	2.04	74.96
Albizia lebbeck (L.) Benth.	Leguminosae	2	13.33	4.25	1	1.46	8.76
Annona squamosa L.	Annonaceae	2	6.67	4.25	2	0.02	1.82
Azadirachta indica A.Juss.	Meliaceae	6	40	12.74	1	0.36	10.85
Bombax ceiba L.	Malvaceae	7	33.33	14.86	1.4	3.78	22.76
Butea monosperma (Lam.) Taub.	Leguminosae	213	86.67	452.23	16.38	11.1	97.23
Cassia fistula L.	Leguminosae	5	13.33	10.62	2.5	0.02	3.74
Dalbergia sissoo DC.	Leguminosae	1	6.67	2.12	1	0.02	1.67
Ficus hispida L.f.	Moraceae	1	6.67	2.12	1	0.25	2.55
Ficus religiosa L.	Moraceae	2	13.33	4.25	1	0.83	6.34
Flacourtia jangomas (Lour.) Raeusch.	Salicaceae	4	6.67	8.49	4	0.19	2.83
Gardenia latifolia Aiton	Rubiaceae	1	6.67	2.12	1	0.02	1.67
Haldina cordifolia (Roxb.) Ridsdale	Rubiaceae	2	13.33	4.25	1	0.23	4.03
Holarrhena pubescens Wall. ex G.Don	Apocynaceae	1	6.67	2.12	1	0.11	2.01
Lannea coromandelica (Houtt.) Merr.	Anacardiace-ae	1	6.67	2.12	1	0.89	5.01
Madhuca longifolia var. *latifolia* (Rox b.) A.Chev.	Sapotaceae	1	6.67	2.12	1	0.36	2.97
Mallotus philippensis (Lam.) Müll.Arg.	Euphorbia-ceae	2	6.67	4.25	2	0.28	2.82
Miliusa tomentosa (Roxb.) J.Sinclair	Annonaceae	8	13.33	16.99	4	0.28	5.25
Mitragyna parvifolia (Roxb.) Korth.	Rubiaceae	2	6.67	4.25	2	0.28	2.82
Pongamia pinnata (L.) Pierre	Leguminosae	3	13.33	6.37	1.5	0.74	6.17
Psidium guajava L.	Myrtaceae	1	6.67	2.12	1	0.02	1.67
Streblus asper Lour.	Moraceae	45	33.33	95.54	9	1.25	19.5
Syzygium cumini (L.) Skeels	Myrtaceae)	3	6.67	6.37	3	1.06	5.99
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Combreta-ceae	1	6.67	2.12	1	0.04	1.74

Table 2. Phytosociological characteristics of shrub species.

Shrub species	Family	Total number	Fre-quency	Density (N/ha)	Abun-dance	Basal area (m^2/ha)	IVI
Clerodendrum infortunatum L.	Lamiaceae	85	46.67	180.47	12.14	0.02	85.1
Chromolaena odorata (L.) R.M.King & H.Rob.	Asteraceae	68	46.67	144.37	9.71	0.023	79.47
Jatropha gossypiifolia L.	Euphorbia-ceae	7	6.67	14.86	7	0.011	16.28
Lantana camara L.	Verbenaceae	35	40	74.31	5.83	0.05	81.41
Leonotis leonurus (L.) R.Br.	Lamiaceae	1	6.67	2.12	1	0.002	6.26
Solanum sisymbriifolium Lam.	Solanaceae	9	6.67	19.11	9	0.01	16.4
Vitex negundo L.	Lamiaceae	8	6.67	16.99	8	0.009	15.1

Table 3. Phytosociological characteristics of herbs and grasses.

Name of Herbs	Family	Total number	Frequency	Density (N/m^2)	Abundance	IVI
Ageratum conyzoides (L.) L.	Asteraceae	1	1.67	0.02	1	0.41
Alternanthera sessilis (L.) R.Br. ex DC.	Amaranthaceae	8	3.33	0.13	4	1.1
Amaranthus viridis L.	Amaranthaceae	1	1.67	0.02	1	0.41
Arisaema dracontium (L.) Schott	Araceae	3	1.67	0.05	3	0.5
Blumea lacera (Burm.f.) DC.	Asteraceae	47	20	0.78	3.92	6.62
Boerhavia diffusa L.	Nyctaginaceae)	4	3.33	0.07	2	0.92
Brachiaria mutica (Forssk.) Stapf	Poaceae	41	10	0.68	6.83	4.21
Chrysopogon aciculatus (Retz.) Trin.	Poaceae	153	16.67	2.55	15.3	11.4
Cleome viscosa L.	Cleomaceae	8	5	0.13	2.67	1.45
Commelina benghalensis L.	Commelinaceae	7	3.33	0.12	3.5	1.07
Corchorus aestuans L.	Malvaceae	1	1.67	0.02	1	0.41
Croton bonplandianus Baill.	Euphorbiaceae	2	1.67	0.03	2	0.44
Cyanthillium cinereum (L.) H.Rob.	Asteraceae	10	6.67	0.17	2.5	1.93
Cynodon dactylon (L.) Pers.	Poaceae	215	28.33	3.58	12.65	17.03
Cyperus involucratus Rottb.	Cyperaceae	1	1.67	0.02	1	0.41
Cyperus rotundus L.	Cyperaceae	26	13.33	0.43	3.25	4.13
Dactyloctenium aegyptium (L.) Willd.	Poaceae	13	6.67	0.22	3.25	2.08
Desmodium gangeticum (L.) DC.	Leguminosae	1	1.67	0.02	1	0.41
Desmodium triflorum (L.) DC.	Leguminosae	331	43.33	5.52	12.73	26.19
Echinochloa colona (L.) Link	Poaceae	22	6.67	0.37	5.5	2.55
Elephantopus scaber L.	Asteraceae	10	3.33	0.17	5	1.23
Evolvulus nummularius (L.) L.	Convolvulaceae	263	66.67	4.38	6.58	27.56
Hybanthus enneaspermus (L.) F.Muell.	Violaceae	6	5	0.1	2	1.36
Indigofera linifolia (L.f.) Retz.	Leguminosae	6	3.33	0.1	3	1.01
Kyllinga bulbosa P.Beauv.	Cyperaceae	28	5	0.47	9.33	2.51
Kyllinga nemoralis (J.R.Forst. & G.Forst.) Dandy ex Hutch. & Dalziel	Cyperaceae	29	8.33	0.48	5.8	3.24
Leucas aspera (Willd.) Link	Lamiaceae	12	8.33	0.2	2.4	2.37
Lindernia ciliata (Colsm.) Pennell	Linderniaceae	18	5	0.3	6	1.98
Lindernia crustacea (L.) F.Muell.	Linderniaceae	7	3.33	0.12	3.5	1.07
Mollugo stricta L.	Molluginaceae	1	1.67	0.02	1	0.41
Murdannia nudiflora (L.) Brenan	Commelinaceae	17	6.67	0.28	4.25	2.27
Oldenlandia corymbosa L.	Rubiaceae	8	6.67	0.13	2	1.8
Oplismenus compositus (L.) P.Beauv.	Poaceae	124	21.67	2.07	9.54	10.96
Paspalidium flavidum (Retz.) A.Camus	Poaceae	4	1.67	0.07	4	0.57
Peperomia pellucida (L.) Kunth	Piperaceae	14	3.33	0.23	7	1.41
Phyllanthus niruri L.	Phyllanthaceae	40	13.33	0.67	5	4.88
Rungia pectinata (L.) Nees	Acanthaceae	221	53.33	3.68	6.91	22.59
Scoparia dulcis L.	Plantaginaceae	2	1.67	0.03	2	0.44
Sesamum indicum L.	Pedaliaceae	5	5	0.08	1.67	1.3
Sida acuta Burm.f.	Malvaceae	4	3.33	0.07	2	0.92
Sida cordata (Burm.f.) Borss.Waalk.	Malvaceae	88	35	1.47	4.19	11.89
Sida rhombifolia L.	Malvaceae	1	1.67	0.02	1	0.41
Spermacoce alata Aubl.	Rubiaceae	21	8.33	0.35	4.2	2.83
Sporobolus diandrus (Retz.) P.Beauv.	Poaceae	97	16.67	1.62	9.7	8.52
Tridax procumbens (L.) L.	Asteraceae	7	5	0.12	2.33	1.42
Zornia gibbosa Span.	Leguminosae	9	5	0.15	3	1.51

Table 4. Family importance value (FIV) of tree species.

Family	Individuals	No of sp.	Rdi	RD	Rdo	FIV
Anacardiaceae	1	1	4	0.18	3.42	7.6
Annonaceae	10	2	8	1.68	1.16	10.84
Apocynaceae	1	1	4	0.18	0.42	4.6
Combretaceae	1	1	4	0.18	0.15	4.33
Cornaceae	270	1	4	45.99	7.84	57.83
Euphorbiaceae	2	1	4	0.33	1.08	5.41
Leguminosae	224	5	20	38.14	51.25	109.39
Malvaceae	7	1	4	1.2	14.52	19.72
Meliaceae	6	1	4	1.02	1.38	6.4
Moraceae	48	3	12	8.17	8.95	29.12
Myrtaceae	4	2	8	0.69	4.15	12.84
Rubiaceae	5	3	12	0.84	2.04	14.88
Rutaceae	3	1	4	0.51	1.54	6.05
Salicaceae	4	1	4	0.69	0.73	5.42
Sapotaceae	1	1	4	0.18	1.38	5.56

Table 5: Family importance value (FIV) of shrub species.

Family	Individuals	No of sp.	Rdi	RD	Rdo	FIV
Asteraceae	68	1	14.29	31.9	18.05	64.24
Euphorbiaceae	7	1	14.29	3.31	8.71	26.31
Lamiaceae	94	3	42.86	44.15	25.32	112.33
Solanaceae	9	1	14.29	4.23	7.87	26.39
Verbenaceae	35	1	14.29	16.41	40.06	70.76

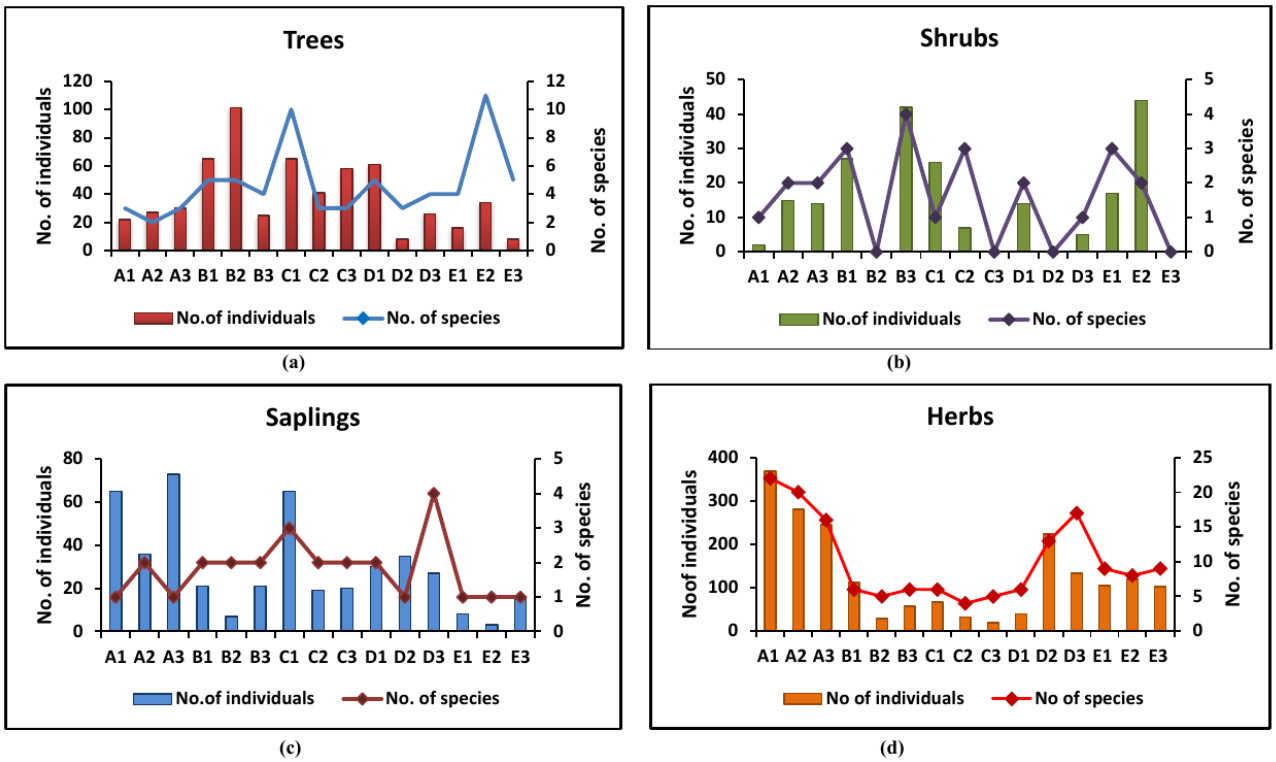

Figure 3. Plot wise distribution of species and individuals- (a) Trees, (b) Shrubs, (c) Saplings and (d) Herbs.

was dominant herb. *Desmodium triflorum* possessed maximum number of individuals (331) and was the co dominant herb (IVI 26.19) (Table 3). Among 46 herbaceous species *Ageratum conyzoides, Amaranthus viridis, Corchorus aestuans, Cyperus involucratus, Desmodium gangeticum, Mollugo stricta* and *Sida rhombifolia* were represented by single individual each. Molluginaceae was the only family for herbaceous species represented by single species having single individual.

Figure 3 (a-d) represents the plot wise distribution of species and individuals of herb, shrub, sapling and tree. Highest number of herbaceous species and individuals were recorded from plot A1. Maximum number of shrub species and individuals were found in plot B3 and E2 respectively. Number of tree species was highest in plot E2, whereas number of individuals of trees was highest in plot B2. Maximum individuals for tree saplings were recorded in plot A3. An important observation is that the highest tree density in B2 coincides with absence of shrubs and low densities of herbs and saplings. In many plots higher number of individuals coincided with the lower number of species and *vice-versa*, indicating dominance by few species.

Azadirachta indica and *Bombax ceiba* had random dispersion pattern. Rest of the species showed clumped distribution or dispersion (A/F >0.5). According to Odum (1971) clumped dispersion is the most common dispersion pattern in nature.

Out of 25 tree species only 5 species *(Aegle marmelos*, *Alangium salviifolium*, *Butea monosperma, Cassia fistula* and *Streblus asper)* were found in sapling stage also. *Azadirachta indica* and *Bombax ceiba* were the only species possessing seedling stage.

Diameter class

Diameter class 1 to 10 cm was the most preferred class showing the highest density of individuals followed by diameter class 10.1 to 30 cm (Table 6). Out of twenty five species, *Annona squamosa*, *Cassia fistula* and *Gardenia latifolia* were restricted to 1 to 10 cm diameter class and five species, *Azadirachta indica, Dalbergia sissoo, Holarrhena pubescens, Psidium guajava* and *Terminalia arjuna* were restricted to 10.1 to 30 cm diameter class. Single individual each of *Ficus hispida*, *Madhuca longifolia* var. *latifolia* and *Lannea coromandelica* exhibited the diameter of 38.28 cm, 45.86 cm and 72.93 cm respectively. Diameter classes of *Flacourtia jangomas* and *Miliusa tomentosa* ranged from 1 to 30 cm whereas it ranged from 1 to 60 cm for *Alangium salviifolium*, *Butea monosperma*, *Streblus asper* and Syzygium cumini. *Aegle marmelos*, *Haldina cordifolia, Mallotus philippensis, Mitragyna parvifolia* and *Pongamia pinnata* exhibited the diameter class from 10.1 to 60 cm and *Albizia lebbeck* from 30.1 to 90 cm. *Ficus religiosa* exceeded the diameter class 90 cm and only one species *Bombax ceiba* exceeded the diameter class 120 cm. It was the highest diameter (123.88 cm) recorded from the forest. In spite of having highest density of individuals (745 individuals/ha) in diameter class 1to 10 cm, number of species was much lower than the diameter class 10.1 to 30 cm and 30.1 to 60 cm (Figure 4, Table 6). It indicates the stable forest.

Table 6. Diameter class distribution of tree species.

Tree Species	Diameter class (cm)						Total individuals
	1--10	10.1 - 30	30.1- 60	60.1- 90	90.1 - 120	120.1- 150	
Aegle marmelos		2	1				3
Alangium salviifolium	240	28	2				270
Albizia lebbeck			1	1			2
Annona squamosa	2						2
Azadirachta indica		6					6
Bombax ceiba		3	2	1		1	7
Butea monosperma	63	139	11				213
Cassia fistula	5						5
Dalbergia sissoo		1					1
Ficus hispida			1				1
Ficus religiosa		1			1		2
Flacourtia jangomas	1	3					4
Gardenia latifolia	1						1
Haldina cordifolia		1	1				2
Holarrhena pubescens		1					1
Lannea coromandelica				1			1
Madhuca longifolia var. *latifolia*			1				1
Mallotus philippensis		1	1				2
Miliusa tomentosa	2	6					8
Mitragyna parvifolia		1	1				2
Pongamia pinnata		1	2				3
Psidium guajava		1					1
Streblus asper	36	6	3				45
Syzygium cumini	1		2				3
Terminalia arjuna		1					1
Total number of species = 25	9	17	13	3	1	1	587

Table 7. Diversity values of tree, shrub and herb layers.

Vegetation stratum	Shannon Index (H')	Pielous Evenness Index (E)	Margalef's Index of species richness (M)	Simpson's Index (Cd)	Beta diversity(as habitat heterogeneity) (β)
Tree	2.08	0.65	3.76	0.35	5.29
Shrubs	1.19	0.61	1.12	0.03	4.38
Herbs	4.04	1.05	5.95	0.09	10

Basal area

In the sampled plot (0.471 ha) the tree species occupied total basal area of 26.05 m^2/ha. Highest basal area was occupied by *Butea monosperma* (11.1 m^2/ha) followed by *Bombax ceiba* (3.78 m^2/ha). Diameter class 10.1 to 30 cm occupied maximum basal area followed by 30.1 to 60 cm class (Figure 4).

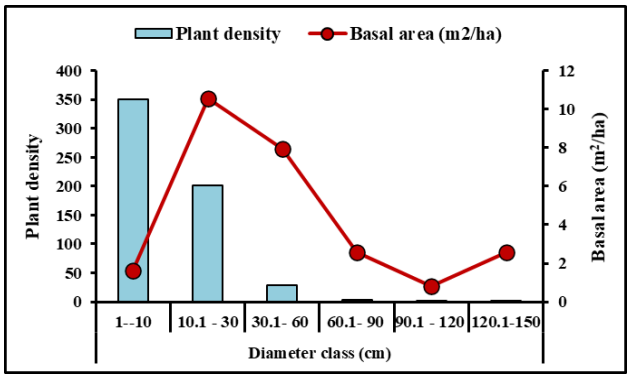

Figure 4. Diameter class distribution of tree species based on plant density and basal area.

Diversity and complexity

Values of various diversity indices for trees, shrubs and herbs are shown in Table 7. Shannon-Wiener Index (H´) showed variation among different vegetation strata. Diversity was higher in herb layer than in the other layers of vegetation. High evenness and species richness values of herbs resulted in lower concentration of dominance. Lower value of Simpson's index for herbs and shrubs indicate that the area was not dominated by a single or few species whereas Simpson's index of trees (0.35) was much higher than that of herbs and shrubs; it clearly indicates the dominance of single or few tree species. Within habitat beta diversity was highest for herbs followed by trees and shrubs.

25 tree species with mean stand height 5.37 m occupied a total basal area of 26.05 m^2/ha. The total density was 1246.29 N/ha. So the complexity index (I_c) value of the tree layer was 43.58.

DISCUSSION

Vegetation analysis of Deulghata sacred forest revealed relatively lower species richness as compared to the sacred forests of Western Ghats (Devakumar *et al.,* 2018), Garwal Himalaya (Pala *et al.,* 2016) and western Odisha (Pradhan *et al*., 2018). Species richness of the present study is comparatively higher than a previous report from West Bengal (Ganguli *et al*., 2016a); however Pandit (2011) has reported 139 species from 25 sacred groves in West Medinipur of West Bengal. Variation in species richness might be due to the different climatological pattern, geographical location and habitat disturbances.

Plant density in the present study showed similarity with the values reported earlier from the sacred forests of Meghalaya (Suchiang *et al.,* 2020), Western Odisha (Pradhan *et al.,* 2018) and Garwal Himalaya (Pala *et al*., 2016). The basal area in this sacred forest (26.05 m^2/ha) is relatively higher than the values observed by Ganguli *et al.* (2016a) in Garhjungal sacred forest of West Bengal and Pradhan *et al*. (2018) in five sacred forests of Western Odisha; although the value is much lower than the range of other sacred forests (24.5 to 84.34 m^2/ha) from Western Ghats (Devakumar *et al.,* 2018), Eastern Ghats (Rao *et al*., 2011), Garwal Himalaya (Pala *et al.,* 2016) and Meghalaya (Suchiang *et al.,* 2020; Bdoor, 2016). Lower value of basal area is an indication of regenerating forest.

Diversity among the species is represented by the species diversity indices. Higher is the value of index, the higher is the species diversity and abundance (Adekunle *et al.,* 2013). The Shannon diversity index for tree species in this sacred forest is 2.08, which is within the range of values (1.88- 4.28) reported by several researchers (Suchiang *et al.,* 2020; Pradhan *et al.,* 2018; Devakumar *et al.,* 2018; Pala *et al.,* 2016; Ganguli *et al.,* 2016a; Bdoor, 2016) from different sacred forests of India. Increased diversity of herbs and shrubs in present study also indicate an open canopy forest and presence of disturbance; while higher concentration of dominance for trees indicate dominance by fewer species. Importance value of tree species also reveals dominance by relatively few species with four species comprising 71.5% of the importance values.

Complexity index combines the floral characteristics, density, basal area and height to give a quantitative description of structural complexity of vegetation. A report by Murphy and Lugo (1986) represents the range of complexity index for sub-tropical dry forest (I_c = 5 - 45) and sub-tropical wet and rain forest (I_c = 180 - 405). Another study from Santa Rosa by Kalacska *et al.* (2004) in a dry tropical forest observed I_c values 28 - 159 in different successional stages. Kiruba-sankar *et al.* (2017) reported I_c values ranging from 196.84 – 507.48 in tropical mangrove forest of Andaman; while Gupta (Joshi) & Ghose (2014) reported I_c value of 4.1 to 73.3 for Sundarbans mangroves. Complexity index in the present study is very much similar to the earlier report from dry tropical forests.

Sacred groves possess a great heritage of diverse gene pool of many forest species with concentration of rare, endemic and endangered species (Khan *et al.,* 2008). Pradhan *et al.,* 2018 reported 17 tree species as high priority conservation species (Biswal and Nair, 2008; IUCN 2018) from five sacred forests of Western Odisha with six species without any regeneration. Sen (2019) also reported a vulnerable tree species, *Cleistanthus collinus* from a sacred grove of West Midnapore of West Bengal as per IUCN (2017) but with no regeneration. Singh *et al.* (2019) reported few rare and

threatened animal species from sacred groves of Western Himalaya. Ganguli and Gupta (Joshi) (2020) have reported poor regeneration of dominant species *Shorea robusta* in the Garhjungle sacred forest of West Bengal. In the present study, *Aegle marmelos* belonged to the vulnerable category as per ENVIS report (envis.frlht.org). This species showed regeneration in form of saplings.

Despite of being storehouse of diverse species, providing enormous ecosystem services and having socio-cultural significance, the condition of sacred groves is deteriorating. Sacred groves have altered their ecosystems and decreased the social and cultural values due to the gradual increase of human interference (Sharma & Kumar, 2021). Sacred groves are also vanishing day by day due to the impact of modernization (Singh *et al*., 2017). Deteriorating belief and faith of the present generation towards such natural sacred places is another reason (Singh *et al.,* 2019). Therefore, conservation and documentation of biodiversity of sacred groves are required (Rampilla & Mahammad 2015; Savithramma et al. 2015; Rajesh 2016). External intervention by conservationists, government and non- government organizations taking local people into confidence, and covering important sacred groves under 'Protected Area Network' have been emphasized for proper conservation (Pradhan *et al*., 2018; Singh *et al*., 2019). Alternate conservation strategies like eco-development and eco-restoration (Vipat & Bharucha, 2014) and educating surrounding village communities (Kandari *et al*., 2014) have also been suggested.

CONCLUSION

The species richness, density and basal area of Deulghata sacred forest were comparable to other sacred forests of India. Presence of large number of individuals (339, 57.75%) of few (3) tree species in lower diameter class (1-10cm) indicated dominance by few tree species as well as their good regeneration status. At the same time lack of seedlings and saplings of majority of the tree species indicated less regenerative potential of those species. It also gives an indication of presence of anthropogenic disturbances that might lead to gradual reduction of species richness. Therefore conservation efforts are needed to stop overexploitation of this sacred forest. Care must be given for the species represented by a few individuals.

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