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Assessment of diversity, population structure, regeneration and conservation status of tree species in a sacred grove of west Midnapore district, West Bengal, India

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Abstract
The present study was carried out for quantitative analysis of diversity, population structure, regeneration and conservation status of tree species in Joypur Joysini Matar Than (JJMT), a sacred grove of West Midnapore district. A total of 32 tree species belonging to 30 genera distributed in 23 families from 13 orders were recorded. *Ficus benghalensis*, family Moraceae showed the highest SIVI (34.58%) and FIVI 76.36 (25.45%) values respectively. Individuals were categorized into three groups, seedling, sapling and adult based on girth classes. Majority of tree species (40.62%) species exhibited good regeneration followed by poor regeneration (28.12%) and fair regeneration (15.63%) respectively. The overall population structure of tree species showed a good regeneration potential with a stable nature of the sacred grove. The study area being a sacred grove would be well protected by tribal communities due to their religious sanctity.

Keywords: conservation, diversity, importance value index, population, regeneration, sacred grove

1. Introduction
Biodiversity represents the variability of all ecosystems, species and genetic material, within and among them, but it is heterogeneous with respect to a number of parameters [1]. The number of species per unit area/volume is stated to determine diversity. A variety of indices are available to quantify the diversity of biological communities and information on species composition in a region provides good economic and regeneration potential. It is fact that India is very rich in biodiversity and ranks, eighth among seventeen mega diverse countries [2]. Patches of vegetation protected on the basis of religious faith are called sacred groves. The practice of assigning a patch of forest as the abode of Gods or Goddesses is not new. The societies of Africa, America, Asia, Australia and Europe had long been preserving sections of the natural environment as sacred groves to Gods and Goddesses [3-6]. In spite of a generally very high population ratio, sacred groves which are the relics of vegetation which have survived under a variety of ecological situations in India and they represent hot spots of biodiversity [7]. According to the National Environment Policy of India, ancient sacred groves should be treated as possessing “unique values”. Many valuable red listed threatened species, including medicinal plants and wild relatives of cultivated species, are present in the groves which may have a definite role to play in the future species enhancement programs [8-11]. Examination of the contribution of the sacred groves to biodiversity conservation offers perspective on the sacred groves as a model for environmental protection[12]. Thus the role of natural sacred sites, particularly sacred groves, is attracting increasing interest in conservation organizations such as UNESCO, the WWF and has significant relevance for the implementation of the Conservation of Biological Diversity which stresses more on the use of traditional wisdom and practices for conservation and sustainable use of biological diversity.
Assessment of quantitative information on composition, distribution, and abundance of woody species is of key significance to understand the form and structure of a forest community and also for planning and implementation of conservation strategy of the community [13-14]. Regeneration is also a key process for the existence of species in a community under varied environmental conditions [15]. Reliable data on regeneration trends are required for successful management and conservation of natural forests [16]. Therefore, the present study was carried out to assess the vegetation analysis with their ecological attributes and regeneration status in tribal dominated West Midnapore district of West Bengal, a state of India.

2. Materials and Methods
2.1 Study site
The study was conducted in an isolated sacred grove in outer edge of two tribal dominated villages (Joypur and Sinhajora in Lalgeria gram panchayet) under Pirakata police station in Salboni block (latitude 22º34'49.71"- 22º 34'51.69" N and longitude 87º11'03.51"- 87º11'05.32"E, average altitude 57 m asl) in the West Midnapore district of West Bengal. The grove is located about 32 km. north-west from district headquarters at Midnapore town, located in the southern part of West Bengal, India (Fig. 1).
West Midnapore district is located in the southern part of West Bengal, India. It is bounded by Bankura and Hooghly districts from the northern side, Howrah district from northeastern side and East Midnapore district from the southeastern side. The western boundary is merged with Jhargram district of West Bengal. The present population of

the district is 4776909; density 636/km^2 with 18.05 % schedule caste and 14.87 % schedule tribe population. Geographical area of the district is 6,307.76 sq. km. 86.28% of the total population were rural and only 13.72% were urban population [17].

West Midnapore district represents regional diversity in terms of physiographic, agro-climatic characteristics and social composition etc. Geo-morphologically, the district may be sub-divided into three parts, viz. Chhotonagpur flanks, mounds and rolling lands in the westernmost part, Rahr Plain with lateritic uplands in the middle part and Alluvial plain of the east with recent deposits. It is the abode of tribes and primitive tribes (*Bhumij*, *Kheria*, *Lodha*, *Mahali*, *Munda* and *Santal*) in the western blocks while most of the other areas are inhabited by all castes of the mass society. It represents cultural diversity across blocks.

The climate is tropical and the land surface of the district is characterized by hard rock uplands, lateritic areas, flat alluvial and deltaic plains. The soil is fairly fertile. Normal rainfall in the district is around 1400 - 1500 mm. Average temperature of the district varies widely across seasons, varying between maximum of 44° C and minimum 10° C. The climate is characterized by hot summer, cold winter, abundant rainfall and high humidity. Rainfall fluctuates widely throughout the year and concentrates over a few months of a year under monsoon. The soil is lateritic, sandy loam in texture and slightly acidic (pH 5.9). The soil organic carbon content varies between 0.87% - 1.2%.

2.1.1 The sacred grove

The present sacred grove popularly known as JJMT (named after its presiding goddess *Joysini*), is situated in the Midnapore Sadar sub division of West Midnapore district. The grove is spread over an area of 1.174 hectare in a public land along the outskirt of the said villages on the south-eastern bank of the perennial *Parang* rivulet. It represents a 200-250-year-old relict forest patch consisting of evergreen, deciduous and semi-deciduous plants. After the day of annual *Paus Sankranti* (a ritual celebrated on the last day of the Bengali Month *Paus* or middle of January) local people, both tribal and non-tribal of Joypur and adjoining Sinhajora villages, visit the grove and worship the deity. Since the grove is an abode of deity, the entire area along with plants and other life forms is considered sacred. Owing to this socio-cultural tag on the grove, local people do not cut or disturb the grove flora, thus strictly adhering to the taboos and ethics.

2.2 Phytosociological studies

The Phytosociological inventory was made by conducting frequent field visits at the study site, during three different seasons (summer, rainy and winter) for a period of five years (2013-2017) to investigate the botanical and biological circumstances. It presented a prospect to compose plant compilation and field interpretation throughout the flowering and fruiting of the maximum quantity of species. Phytosociological data were collected by laying 10m x 10m quadrates for tree species. These were systematically surveyed all trees having a girth at breast height (GBH) of ≥ 10 cm. Species Importance Value Index (SIVI) and Family Importance Value Index (FIVI) were determined and are given bellow [18]. A brief floristic survey was carried out through “spot identification” basis. From unknown plants, samples of plants with flowers or fruits were collected. After collection, the specimens were processed, preserved, poisoned and mounted on herbarium sheets following the standard and modern herbarium techniques [19]. Photographs were taken for some of the common, locally rare, endemic and valuable plant species in the sacred grove. Abbreviations of authors’ names of plant species strictly followed Brummitt and Powell [20]. The herbarium sheets were identified by matching with correctly annotated materials available at the Vidyasagar University Herbarium. For identification purpose, different relevant catalogue [21], regional floras [22-27], monographs [28-31], revision works [32] and other literature [33-34] were consulted.

2.2.1 Importance Value Index (IVI)

2.2.1.1 Species Importance Value Index (SIVI)

A measure often used to describe and compare the species dominance of the plots is the Importance Value Index [18]. The SIVI for a species is calculated as the sum of its relative dominance, its relative frequency and its relative density.

$$\text{Relative Dominance (RDo)} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all species}} \text{ X } 100$$

$$\text{Relative Density (RD)} = \frac{\text{Number of individuals of the species}}{\text{Number of occurrence of all the species}} \text{ x } 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \text{ x } 100$$

SIVI = Relative Dominance (RDo) + Relative Density (RD) + Relative Frequency (RF)

2.2.1.2 *Family Importance Value Index (FIVI)*

Family Importance Value Index (FIVI) may be calculated as follows:

$$\text{Relative Diversity (RDi)} = \frac{\text{Number of species in a family in the quadrats}}{\text{Total no. of species in a quadrats}} \text{ x } 100$$

FIVI = Relative Dominance (RDo)+ Relative Density (RD)+ Relative Diversity (RDi)

The total basal area was calculated from the sum of the total diameter of immerging stems. In trees, poles and saplings, the basal area was measured at breast height (1.37m) and by using the formula πr^2.

2.3 Biodiversity measures

Computed Diversity indices were Shannon-Weaver diversity index, Simpson index, Dominance, Evenness, Brillouin Index, Menhinick’s index, Margalef's index, Equitability, Fisher's alpha and Berger-parker index.

2.3.1 Shannon-Weaver (1963) index of diversity

The formula for calculating the Shannon diversity index is $H' = -\sum p_i \ln p_i$. Where, H' = Shannon index of diversity; p_i = the proportion of the important value of the ith species ($p_i = n_i / N$, n_i is the important value index of ith species and N is the important value index of all the species) [35].

2.3.2 Simpson (1949) index of Dominance
The equation used to calculate Simpson's index is D = ∑ (*p*i)^2. Where, D = Simpson index of dominance; *p*i = the proportion of important value of the ith species (*p*i = *n*i / N, *n*i is the important value index of ith species and N is the important value index of all the species). As D increases, diversity decreases and Simpson's index is therefore usually expressed as 1 – D or 1/ D[36].
Dominance = 1-Simpson index. Ranges from 0 (all taxa are equally present) to 1 (one taxon dominates the community completely).

$$D = \sum_i \left(\frac{n_i}{n}\right)^2$$

where n_i is number of individuals of taxon *i*.

2.3.3 Evenness
Comparing the actual diversity, value of the maximum possible diversity by using a measure is called evenness. The evenness of the sample is obtained from the formula: Evenness = H'/Hmax = H'/lnS by definition, evenness is constrained between 0 and 1.0. As with H', evenness assumes that all species are represented within the sample.

2.3.4 *Brillouin Index (1956)*
The Brillouin index (HB) [37], is calculated using:]

$$HB = \frac{\ln N! - \sum \ln n_i!}{N}$$

Where N is the total number of individuals in the sample, n_i is the number of individuals belonging to the ith species and s the species number. The Brillouin index measures the diversity of a collection, as opposed to the Shannon index which measures a sample. The value obtained rarely exceeds 4.5 and both the Brillouin and Shannon indices tend to give similar comparative measures. This information measure should be used in favor of the Shannon index when the species differ in their capture rates.

2.3.5 Menhinick's index
Menhinick's index Dmn [38], is calculated using:

$$Dmn = \frac{S}{\sqrt{N}}$$

Where, N is the total number of individuals in the sample and S the species number.

2.3.6 Margalef's richness index, D (1968)
Margalef's D [39] has been considered as a favorite index for many years. It is calculated as the species number (S) minus 1 divided by the logarithm of the total number of individuals (N). This equation uses the natural logarithm:

$$D = \frac{(S-1)}{\ln N}$$

The species richness (total number of species in each sample), and Margalef index, considering either the absolute number of individuals or the density, are calculated. The percentage variation is calculated as the ratio of Margalef index determined by the density matrix divided by the Margalef index determined by the absolute numbers matrix.

2.3.7 Equitability
Shannon diversity divided by the logarithm of the number of taxa. This measures the evenness with which individuals are divided among the taxa present.

2.3.8 Fisher's alpha
This is a parametric index of diversity that assumes that the abundance of species follows the log series distribution, defined implicitly by the formula S=a X ln(1+n/a) where S is number of taxa, *n* is a number of individuals and a is the Fisher's alpha.

$$ax, \frac{ax^2}{2}, \frac{ax^3}{3}, \ldots\ldots \frac{ax^n}{n}$$

Where each term gives the number of species predicted to have 1, 2, 3....n individuals in the sample. The index is the alpha parameter.

2.3.9 Berger-parker index (d)
Berger-parker index (d) is an intuitively simple dominance measure (Berger and Parker, 1970). It has also the virtue of being extremely easy to calculate. The Berger-Parker index expresses the proportional abundance of the most abundant species:
d = N_{max} / N. Where, N_{max} = the number of individuals in the most abundant species.

2.4 Regeneration diversity measures
The status of regeneration of tree species was assessed in following categories as per Uma [40]. For this study trees were categorized in three categories, i.e. seedlings (< 10 cm in gbh), saplings (10-31 cm gbh) and adults having girth size more than 31 cm. a) Good (if seedling>sapling>adults). b) Fair (if seedling > sapling ≤ adults). c) Poor if a species survive in only the sapling stage, but not as seedlings. d) None when a species have no seedlings or sapling.
A method of measuring diversity consists of two component species richness and its relative abundance. Diversity is measured by recording the number of species and their relative abundance[41]. In this study Shannon diversity index (*H*') is the main index to be used to measure the regeneration diversity of the area, as it takes in to account regeneration diversity of the area, as it takes in to account regeneration abundance and richness of the forests. Eventually Shannon evenness (E) and Simpson indexes are being used, as evenness and composition of species are also important as complementary measurements.

3. Results and Discussions
3.1 Species composition
In the present study, a total of 32 tree species belonging to 30 genera distributed in 23 families from 13 orders were recorded

from the JJMT sacred grove. Major contribution of orders in terms of descending species number were from Rosales (5 species, 15.62%), Sapindales (5 species, 15.62%), Gentianales (4 species, 12.5%), Malpighiales (4 species, 12.5%), Myrtales (4 species, 12.5%), Arecales (2 species, 6.25%) and Malvales (2 species, 6.25%). Another six orders contained single species each (Table 1; Fig. 2). Gnanasekaran *et al*. [42]and Karthik *et al*. [43] showed the similar study on angiosperms of Cuddalore district, Tamil Nadu, India. Similar types of contribution of orders were highlighted by Mygatt and Medeiros [44], Perez-Luque *et al*. [45] and Sen [46].

The six well represented families in terms of species (≥2 species) quantity were Combretaceae 3 (13.04%), Moraceae 3 (13.04%), Anacardiaceae, Arecaceae, Phyllanthaceae and Rubiaceae contain 2 (8.70%) species each. Another 17 families each carried only a single species (Table 2; Fig. 3). Same type dominant families of sacred groves in India were observed by Mitra *et al*. [47]; Rajasri *et al*. [48].

The six dominant plant families encompassed more than 40% genera with descending numbers (≥ 2 species) were Moraceae 3 (10%), Anacardiaceae 2 (6.67%), Arecaceae 2 (6.67%), Combretaceae 2 (6.67%), Phyllanthaceae 2 (6.67%) and Rubiaceae 2 (6.67%). Another 17 families each carried only a single genus. Such type of dominant plant families in sacred grove was observed by Bhakat and Sen [49] (Table 1).

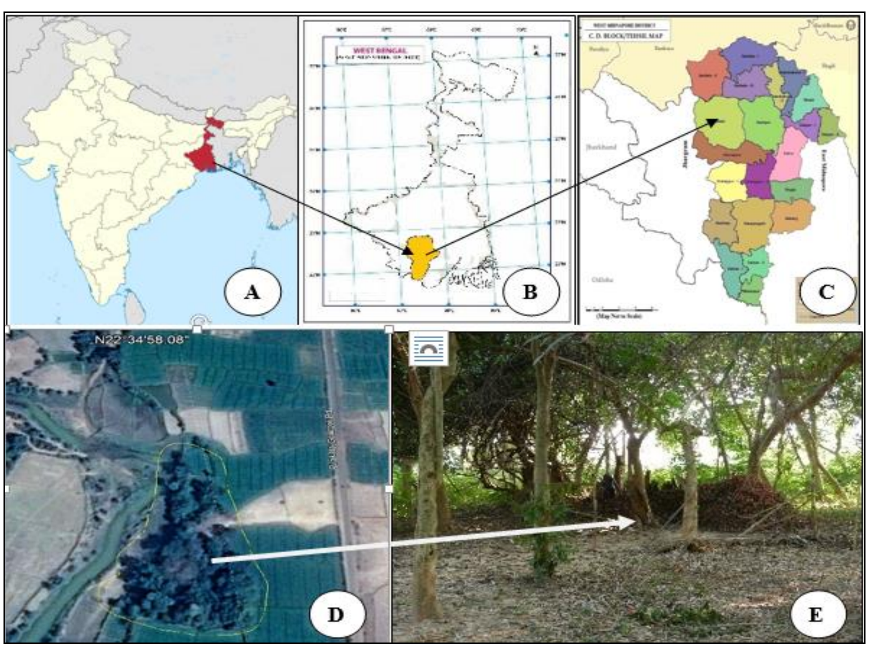
Two well represented genera containing two species were *Ficus* and *Terminalia*. Another 30 species contain single genus respectively (Table 1).

3.2 Density, frequency and dominance of the stand

The mean tree density of the JJMT was 0.034. The highest density 5.13 of 154 individuals was showed by *Streblus asper*, while the lowest density (0.03, 1 individuals) was found in *Catunaregam spinosa*, *Cleistanthus collinus*, *Schleichera oleosa* and *Semecarpus anacardium*. The mean tree frequency of the JJMT was 1.101. The highest frequency 100 of 154 individuals was showed by *Streblus asper*, while the lowest frequency (3.33, 1 individuals) distributed in five species; these were *Anogeissus latifolia*, *Catunaregam spinosa*, *Cleistanthus collinus*, *Schleichera oleosa* and *Semecarpus anacardium*. The mean dominance was 2.794. Major contributions of dominance (≥5) in terms of descending number were from *Ficus benghalensis* (26.48), *Syzygium cumini* (13.78), *Madhuca longifolia* var. *latifolia* (12.20), *Bombax ceiba* (9.19) and *Terminalia arjuna* (6.32) respectively (Table 1; Fig. 4). The density and abundance of seedling, sapling and mature tree indicate soil nutrient availability and vegetation heredity of the forest [50-51].

3.3 Species importance value index

The SIVI results revealed that *Ficus benghalensis* had the highest SIVI value (34.58) followed by *Streblus asper* (32.33), *Syzygium cumini* (29.60%), *Holarrhena pubescens* (23.77), *Alangium salviifolium* (22.34) and *Madhuca longifolia* var. *latifolia* (20.03) respectively, while the lowest SIVI value was for *Semecarpus anacardium* (0.52). The data further revealed that *Streblus asper* had the highest values for relative density (19.56%), relative frequency (11.54%). *Ficus benghalensis* contained the maximum value (29.61%) of relative dominance. The minimum values for relative density (0.13%), relative frequency (0.38%) and relative dominance (0.008%) were recorded for *Semecarpus anacardium*, while *Catunaregam spinosa*, *Cleistanthus collinus*, *Schleichera oleosa* also had a minimum value of 0.13% for relative density and *Anogeissus latifolia*, *Catunaregam spinosa*, *Cleistanthus collinus*, *Schleichera oleosa* showed minimum value (0.38%) for relative frequency (Table 1; Fig. 5). SIVI is a measure of how dominant a species was in a forested area (sacred grove). So, it is a standard tool to inventory a sacred grove. Such type of study was carried by Chandrashekara and Sankar [52]; Mgumia and Oba [53] and Ramanujam and Cyril [54].



Fi. 1: Location of the study area (A: India, B: West Bengal with West Midnapore district, C: West Midnapore district with Salboni block, D: Google Earth image showing JJMT sacred grove, E: Joysini Matar Than inside the grove)

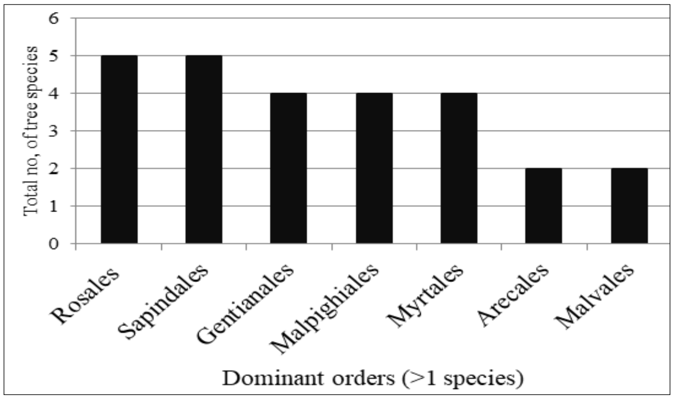


Fig 2: Dominant orders (> 1 species) in JJMT sacred grove.

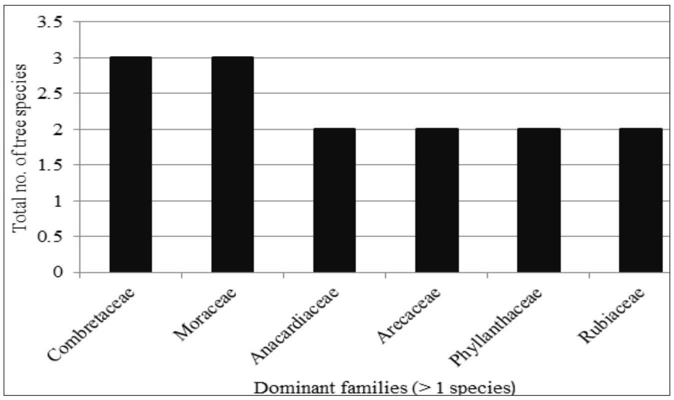


Fig 3: Dominant families (> 1 species) in JJMT sacred grove.

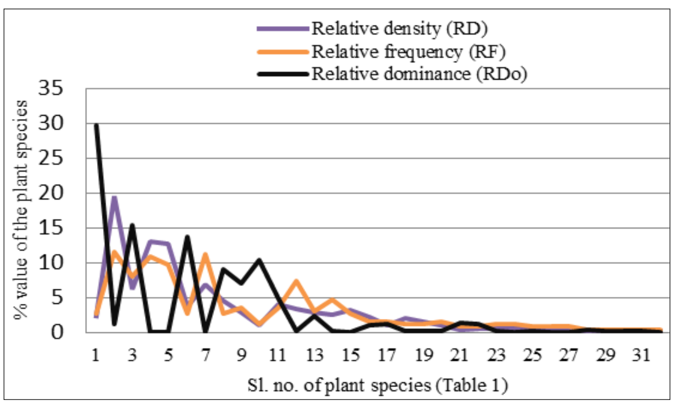


Fig 4: Relation between RD, RF and RDo in JJMT sacred grove.

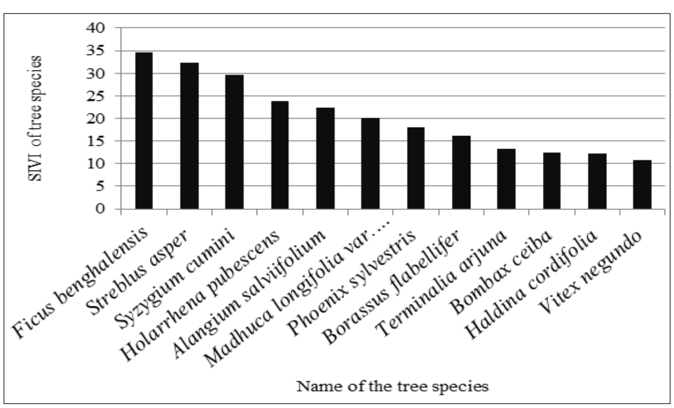


Fig 5: Dominant SIVI (≥10%) of twelve tree species.

3.4 Family importance value index

The maximum FIVI was observed for Moraceae 76.36 (25.45%) followed by Arecaceae 31.67 (10.56%), Myrtaceae 27.61 (9.20%), Apocynaceae 25.94 (8.65%), Cornaceae 25.43 (8.48%), Sapotaceae 21.01 (7%), Combretaceae 14.75 (4.92%), Rubiaceae 13.31(4.44%) and Malvaceae 12.32 (4.11%). The remaining 14 families had FIVI values <10. The top nine families accounted for 248.40 (82.80%) of the overall FIVI (Table 2; Fig. 6). The lowest value of FIVI, 0.37 (0.12%) scored by Sapindaceae. Such type of FIVI were observed by Reddy *et al*. [55], Panda *et al*. [56] and Pradhan *et al*. [57].

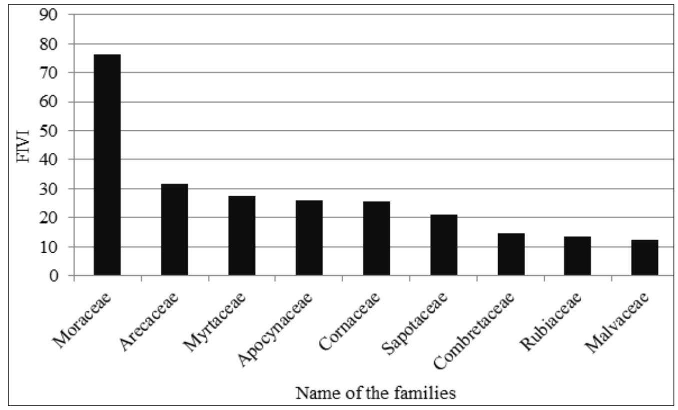


Fig 6: Dominant FIVI (≥10%) in JJMT sacred grove

3.5 Diversity, richness, dominance and evenness for species composition

The Shanon-weaver diversity index (H'), Brillouin index, Menhinick's index, Margalef's richness index, Fisher's alpha and Equitability index were 2.779, 2.698, 1.141, 4.649, 6.703 and 1.802 respectively. In case of dominance, Simpson index and Berger Parker index (d) were 0.909 and 0.196 respectively. Species evenness 0.503 had recorded from the tree species in the grove. Shannon's Index varied from 1.85-2.05 which were within the reported range (0.83 to 4.1) for the forests of Indian sub-continent [58-59]. Diversity indices provide important information about the rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure.

There was an apparent variation in species richness and diversity of angiosperms across the approx two 1-ha subplot of sacred groves. This revealed the existence of some degree of internal site heterogeneity. The variation in diversity indices depends on the number of species and the frequency of individuals. An increase in species number and even distribution of their frequency would increase the diversity index, whereas an uneven frequency distribution of individuals would lower the diversity index values.

3.6 Regeneration status

Analysis of the regenerating status of 32 tree species revealed that 13 (40.62%) species exhibited good regeneration, 5 (15.63%) species exhibited fairly, 9 (28.12%) species exhibited poor regenerating status. In the sacred grove 5 (15.63%) species didn't show any status of regeneration as their seedlings were absent in the forest floor (Table 1; Fig. 7).

The abundance of seedling and sapling than mature tree indicate healthy regeneration with well regeneration potential. Similar observation was also reported from the sacred groves [60-61].

In northern Eastern Ghat, a small part of south West Bengal, the density of adult plants was disproportionately low compared to seedlings and saplings. In case of *Shorea robusta*, the predominant forest species of the region, density (stems/ha) of mature individuals was low but number of seedlings and saplings was proportionally high in number [56]. Among 32 tree species for which regeneration data could be collected, the seedlings and saplings population 19 species were high for *Aegle marmelos*, *Alangium salviifolium*, *Annona reticulata*, *Bombax ceiba*, *Borassus flabellifer*, *Bridelia retusa*, *Ficus benghalensis*, *Haldina cordifolia*, *Holarrhena pubescens*, *Holoptelea integrifolia*, *Madhuca longifolia* var. *latifolia*, *Phoenix sylvestris*, *Putranjiva roxburghii*, *Shorea robusta*, *Streblus asper*, *Strychnos nux-vomica*, *Syzygium cumini*, *Terminalia arjuna* and *Vitex negundo*. In 9 species, population were found to be less than that of seedlings and saplings; a reverse trend was noticed in the case of species as *Artocarpus lacucha*, *Bambusa bambos*, *Cassia fistula*, *Catunaregam spinosa*, *Cleistanthus collinus*, *Mangifera indica*, *Schleichera oleosa* and *Semecarpus anacardium*. Interestingly, seedlings and saplings ratio was in balance for 5 species including *Anogeissus latifolia*, *Azadirachta indica*, *Euphorbia antiquorum*, *Ficus racemosa* and *Terminalia alata* (Table 1).

In the present study the mean stem density showed the dominance of seedling (<10 cm gbh) than sapling (10-31 cm gbh) and mature trees (>31 cm gbh) (Table 3; Fig. 8) which reflected the stable nature of the sacred grove [10]. The density, abundance and distribution of individual species were measurable indicators of plant diversity [62]. The species richness of 32 tree species over 2 ha (approx.) sampled area reflected a moderate diversity status in forests of Chhotonagpur pleatu. The result of the study was compared well with other large-scale inventories conducted in tropical forests both in India [56, 57]. The tree density in semi-deciduous forests on south West Bengal reported in the present work was modest compared to other tropical forest zones. Species diversity was generated by species interaction such as competition and niche diversification [63], which was both greatly manifested in the tropics due to high humidity and temperature [64]. Similarly, tree density depended on efficacy of seed dispersal, survival and establishment and also on the levels of resource extraction by humans [65]. The intermediate level of tree density and species richness observed in the present work might be attributed to the combination of all these factors.

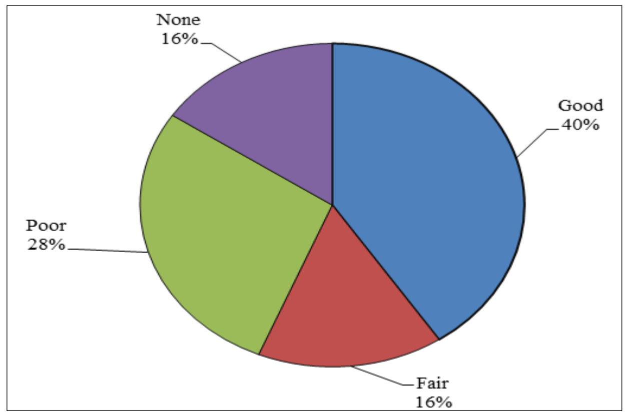


Fig 7: Regeneration status of tree species in JJMT sacred grove.

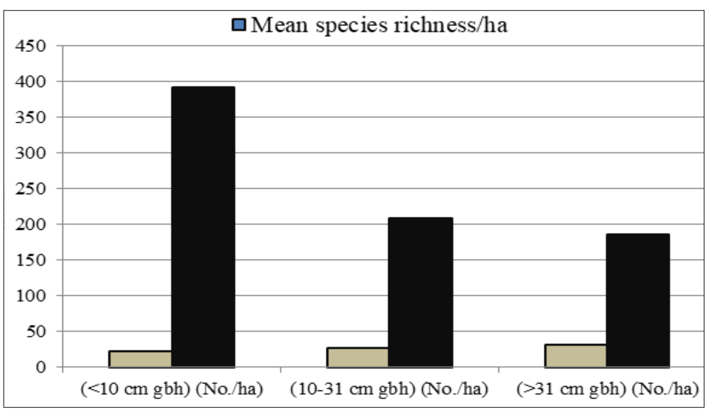


Fig 8: Relationship between mean species richness with mean stem density.

3.7 IUCN categories

Among these 32 plants, 28 plants have not been evaluated still now. There are 1 Least Concerned (LC), 1 Vulnerable (VU), 1 Lower Risk/ Least Concerned (LR/LC) and 1 Data Deficient (DD) species. *Cleistanthus collinus* is the vulnerable tree species according to the IUCN [66]. In view of the above community analysis with ecological information about IUCN Red Listed plants reveals that the plants are still present and regenerate in the sacred grove but locally vanishing in nearby forests. This study would highlight the status and distribution of the species in the study area, the ecological characteristics necessary for its survival and the threats faced by some of the species designated by following the criteria devised by IUCN [66]. Various factors caused the increase in numbers of vulnerable species in the area. Overgrazing was a major cause which led to the destruction of seedlings. In contrast, restricted population and low natural reproduction were determined to be the factors most effective on the vulnerability of *Cleistanthus collinus*. The most important factor that caused the deterioration of this species was human activity, such as overexploitation of the plant and land use change.

Table 1: List of tree species with their Order, Family, Phytosociological attributes (SIVI), Regeneration status and IUCN categories in JJMT sacred grove.

S. No	Name of the plant species	Order/Family	Phytosociological attributes					Girth Class			Regene-ration status	IUCN categories
			N= (Total no of population)	Relative density (RD)	Relative frequency (RF)	Relative dominance (RDo)	SIVI	Seedling (<10 cm gbh) (No./ha)	Saplings (10-31 cm gbh) (No./ha)	Adults (>31 cm gbh) (No./ha) Status		
1.	*Ficus benghalensis* L.	Rosales (Moraceae)	18	2.28	2.69	29.610	34.58	10	4	4	F	NA
2.	*Streblus asper* Lour.	Rosales (Moraceae)	154	19.56	11.54	1.234	32.33	99	28	27	G	NA
3.	*Syzygium cumini* (L.) Skeels	Myrtales (Myrtaceae)	48	6.10	8.08	15.417	29.60	23	18	7	G	NA
4.	*Holarrhena pubescens* Wall. ex G.Don	Gentianales (Apocynaceae)	102	12.95	10.77	0.045	23.77	45	32	25	G	LC
5.	*Alangium salviifolium* (L.f.) Wangerin	Cornales (Cornaceae)	100	12.70	9.62	0.015	22.34	55	23	22	G	NA
6.	*Madhuca longifolia* var. *latifolia* (Roxb.) A.Chev.	Ericales (Sapotaceae)	29	3.69	2.69	13.649	20.03	22	3	4	F	NA
7.	*Phoenix sylvestris* (L.) Roxb.	Arecales (Arecaceae)	54	6.86	11.15	0.048	18.06	26	15	13	G	NA
8.	*Borassus flabellifer* L.	Arecales (Arecaceae)	35	4.45	2.69	8.999	16.14	14	11	10	G	NA
9.	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Myrtales (Combretaceae)	22	2.80	3.46	7.066	13.33	12	7	3	G	NA
10.	*Bombax ceiba* L.	Malvales (Malvaceae)	8	1.02	1.15	10.278	12.45	2	3	3	P	NA
11.	*Haldina cordifolia* (Roxb.) Ridsdale	Gentianales (Rubiaceae)	32	4.07	3.46	4.812	12.34	13	11	8	G	NA
12.	*Vitex negundo* L.	Lamiales (Lamiaceae)	26	3.30	7.31	0.093	10.70	12	8	6	G	NA
13.	*Strychnos nux-vomica* L.	Gentianales (Loganiaceae)	22	2.80	3.08	2.369	8.25	11	7	4	G	NA
14.	*Bridelia retusa* (L.) A.Juss.	Malpighiales (Phyllanthaceae)	20	2.54	4.62	0.160	7.32	8	6	6	F	NA
15.	*Annona reticulata* L.	Magnoliales (Annonaceae)	25	3.18	2.69	0.022	5.89	13	7	5	G	NA
16.	*Aegle marmelos* (L.) Corrêa	Sapindales (Rutaceae)	17	2.16	1.54	1.008	4.71	9	5	3	G	NA
17.	*Holoptelea integrifolia* Planch.	Rosales (Ulmaceae)	8	1.02	1.54	1.202	3.76	4	2	2	F	NA
18.	*Euphorbia antiquorum* L.	Malpighiales (Euphorbiaceae)	16	2.03	1.15	0.129	3.31	3	5	8	P	NA
19.	*Shorea robusta* Gaertn.	Malvales (Dipterocarpaceae)	12	1.52	1.15	0.096	2.77	7	3	2	G	LR/LC
20.	*Cassia fistula* L.	Fabales (Fabaceae)	8	1.02	1.54	0.114	2.67	0	2	6	P	NA
21.	*Mangifera indica* L.	Sapindales (Anacardiaceae)	3	0.38	0.77	1.292	2.44	0	1	2	P	DD
22.	*Putranjiva roxburghii* Wall.	Malpighiales (Putranjivaceae)	4	0.51	0.77	1.153	2.43	2	1	1	F	NA
23.	*Azadirachta indica* A.Juss.	Sapindales (Meliaceae)	4	0.51	1.15	0.228	1.89	1	1	2	P	NA
24.	*Ficus racemosa* L.	Rosales (Moraceae)	4	0.51	1.15	0.032	1.69	0	2	2	P	NA
25.	*Terminalia alata* Roth	Myrtales (Combretaceae)	4	0.51	0.77	0.228	1.51	0	2	2	P	NA
26.	*Artocarpus lacucha* Buch.-Ham.	Rosales (Moraceae)	3	0.38	0.77	0.011	1.16	0	1	2	P	NA
27.	*Bambusa bambos* (L.) Voss	Poales (Poaceae)	3	0.38	0.77	0.011	1.16	0	1	2	P	NA
28.	*Anogeissus latifolia* (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Myrtales (Combretaceae)	2	0.25	0.38	0.349	0.98	1	0	1	N	NA
29.	*Catunaregam spinosa* (Thunb.) Tirveng.	Gentianales (Rubiaceae)	1	0.13	0.38	0.107	0.62	0	0	1	N	NA
30.	*Cleistanthus collinus* (Roxb.) Benth. ex Hook.f.	Malpighiales (Phyllanthaceae)	1	0.13	0.38	0.107	0.62	0	0	1	N	VU
31.	*Schleichera oleosa* (Lour.) Merr.	Sapindales (Sapindaceae)	1	0.13	0.38	0.107	0.62	0	0	1	N	NA
32.	*Semecarpus anacardium* L.f.	Sapindales (Anacardiaceae)	1	0.13	0.38	0.008	0.52	0	0	1	N	NA
	Total		787	100	99.98	100	299.8	392	209	186		

Abbreviation: In G: Good; F: Fair; P: Poor; N: None

In IUCN Status: DD-Data Deficient, LC- Least Concern, LR/LC-Lower Risk/ Least Concerned, NE -Not Evaluated, VU-Vulnerable

Table 2: Family Importance Value Index (FIVI) of different families.

Sl. No.	Family	Genus/Genera	Tree species	Total individuals	RD	RDo	RDI	FIVI
1.	Moraceae	3	4	179	22.73	30.887	22.74	76.36
2.	Arecaceae	2	2	89	11.31	9.047	11.31	31.67
3.	Myrtaceae	1	1	48	6.10	15.417	6.10	27.62
4.	Apocynaceae	1	1	102	12.95	0.045	12.96	25.96
5.	Cornaceae	1	1	100	12.70	0.015	12.71	25.43
6.	Sapotaceae	1	1	29	3.69	13.649	3.68	21.02
7.	Combretaceae	2	3	28	3.56	7.643	3.56	14.76
8.	Rubiaceae	2	2	33	4.2	4.919	4.19	13.31
9.	Malvaceae	1	1	8	1.02	10.278	1.02	12.32
10.	Loganiaceae	1	1	22	2.80	2.369	2.80	7.97
11.	Lamiaceae	1	1	26	3.30	0.093	3.30	6.69
12.	Annonaceae	1	1	25	3.18	0.022	3.18	6.38
13.	Phyllanthaceae	2	2	21	2.67	0.267	2.67	5.61
14.	Rutaceae	1	1	17	2.16	1.008	2.16	5.33
15.	Euphorbiaceae	1	1	16	2.03	0.129	2.03	4.19
16.	Ulmaceae	1	1	8	1.02	1.202	1.02	3.24
17.	Dipterocarpaceae	1	1	12	1.52	0.096	1.52	3.14
18.	Anacardiaceae	2	2	4	0.51	1.30	0.51	2.32
19.	Putranjivaceae	1	1	4	0.51	1.153	0.51	2.17
20.	Fabaceae	1	1	8	1.02	0.114	1.02	2.15
21.	Meliaceae	1	1	4	0.51	0.228	0.51	1.25
22.	Poaceae	1	1	3	0.38	0.011	0.38	0.77
23.	Sapindaceae	1	1	1	0.13	0.107	0.13	0.37
Total		30	32	787	100	100	100	300

Table 3: Mean tree species richness. Density and occurrence rate in JJMT sacred grove.

Sl. No.	Girth class	Mean species richness/ha	Mean stem density/ha	Species occurrence rate (species richness/stem density)
1.	(<10 cm gbh) (No./ha)	22	392	0.06
2.	(10-31 cm gbh) (No./ha)	27	209	0.13
3.	(>31 cm gbh) (No./ha)	32	186	0.17

4. Conclusion

Quantitative analysis of tree species diversity, richness, importance value of JJMT will be useful in sacred grove management and conservation. The overall population structure of tree species in the sacred grove reveals that contribution of seedlings to the total population was highest followed by saplings and adult trees. It shows regeneration of tree species in the forest was 'good' and the future communities may be sustained unless there is any major biotic or abiotic stress. However, considering the increasing anthropogenic pressure, there may be spatial and temporal threat to the seedling establishment and growth of tree species in the grove. The growth, survival and reproductive potential of the tree species will be at risk in near future if the present trend of anthropogenic activities continues. Thus, a systematic management plan is badly required for the conservation of flora and sustainable use of available resources. The present study may provide baseline information for formulating conservation and management strategies of the present sacred forest. The information contained in this paper will provide a sound base for forest department to prioritize management actions for conserving the biodiversity in sacred groves of West Midnapore district, West Bengal, India.

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