Vegetation structure and species diversity in Garhjungle sacred forest, West Bengal, India

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***Abstract*—** *Sacred forests are traditionally managed forest patches relevant for biodiversity conservation. Vegetation structure of different strata (tree, shrub and herb,) were analysed in Garhjungle sacred forest of lateritic zone in West Bengal. Total 738 woody individuals belonging to 14 species were recorded from random quadrats covering 0.25 ha area. The highest stem density and IVI was obtained by Shorea robusta. All the species had clumped distribution. The trees occupied a basal area of 20.39 m^2 ha^{-1}. Species richness and diversity of shrubs and herbs were greater than trees. Presence of various anthropogenic disturbances warrants immediate conservation efforts.*

Keywords*— *Lateritic zone, Sacred forest, Species diversity, Vegetation structure.

I. INTRODUCTION

Biodiversity is essential for human survival and economic well being and for the ecosystem function and stability (Singh, 2002). Sacred forests are patches of native vegetation traditionally managed as part of local cultural tradition and functionally link social life and forest management system of a region (Boraiah et al., 2003). The practice of sacred groves dates back to the nomadic hunter-gatherer age of human history (Gadgil and Vartak 2004). At certain places in India such traditional forest management has sustained over the years by native communities (Kushalappa et al., 2001). Sacred groves are believed as treasure house of medicinal and rare plants, as refugia for regional relic flora, and as centres of seed dispersal (Chandran et al., 1998) and are therefore relevant for *in-situ* biodiversity conservation (Upadhaya et al., 2003). Commonly it is believed that sacred forests are better protected and managed owing to their religious significance and harbour richer plant diversity than other forests. However, several sacred forests are experiencing failure of legal protection in guaranteeing their integrity and conservation (Rawat et al., 2011).

Description of forest vegetation by determining essential measurable properties, such as species richness and biomass, and documenting quantitative relationships among them is a desirable goal of plant ecology (Keddy, 2005). Many studies have documented the community structure, species diversity and regeneration of sacred forests in India. Rao et al. (2011) higher species richenss, diversity and density in sacred forest stands compared with reserve forests in the Eastern Ghats. Sunitha (2002) studied plant biodiversity in the 14 sacred groves of Andhra Pradesh. Higher number of medicinal plants as well as higher success of species regeneration compared to reserve forests has been reported Himachal Pradesh and Western Ghats, respectively (Singh et al., 1998; Boraiah et al., 2003).

The dry tropical forest accounts for 38.2% of the total forest cover of India (MoEF, 1999). Garhjungle forest forms an important part of the tropical dry deciduous forests of the lateritic zone. Lateritic zone in West Bengal comprising Purulia district and western portions of Birbhum, Burdwan, Midnapore and Bankura districts harbor floristically important Northern Tropical Dry Deciduous forests (Champion and Seth, 1968). Lateritic soils are characterized by acidic pH, low NPK content and high iron as reported by many studies (Raychaudhuri, 1980; Chakraborty et al., 2002). Many plants of this region are having immense importance due to their medicinal and dye yielding properties. The minor forest products of the region include lac, sal seeds and leaves, mohua flowers, fibres and flosses, grasses, barks, gums and resins (Mukherjee, 1995). Sacred forests of Garhjungle are very old natural forest and dedicated to goddess Durga.

Forest studies conducted so far in the entire lateritic zone concentrated on floristic and ethnobotanical aspects (Rahaman et al., 2000, 2008; Bhattacharya and Mukherjee, 2006; Bouri and Mukherjee, 2011). Reconstruction of modern vegetation changes using pollen analysis was attempted by Bhattacharya et al. (2003) while Gupta Joshi (2012) made a preliminary quantitative analysis of vegetation structure covering a few sites in the lateritic zone. Kushwaha and Nandy (2012) compared species diversity and community structure of sal forests under different rainfall regimes. Pandit (2011) documented about sacred groves of West Medinipur district. No reports are available on vegetation analysis of Garhjungle sacred forests.

The objective of the present study is to analyze the vegetation structure and species diversity pattern of a sacred forest from lateritic zone which in turn will help to control the forest structure by plantation and better management of the forest flora.

II. MATERIALS AND METHODS

2.1 Area description

The study was conducted in Garhjungle forest located in Burdwan district of West Bengal, India extending between 23°40'54.4"N latitude and 87°40'20.2"E longitude. The altitude ranges from 65 to 68 meters above the sea level. This is a very old natural forest considered sacred among local people. This area is also known as the Dharma Garh of Raja Surath. It is believed to be one of the oldest places where Raja Surath was defeated by the Bhils and the Koals. But in the modern days, it was Jogiraj Bhahmananda Giri of the Dasami cult, who revived the place and once again started the Durga Puja during which thousands of devotees visit from nearby area (Wikitravel, 2015). Despite being a sacred forest with traditional restrictions, Garhjungle experience various levels of anthropogenic disturbances such as extraction of fuel wood, collection of non timber forest produce, cattle grazing, and frequent human-caused fire particularly in areas near Durga temple.

The climate of the study area is tropical. The temperature ranges from 34˚C to 45˚C in the summer and 8˚C to 15˚C in the winter. This area shows three distinct seasons - winter, summer and rainy throughout the year. Annual rainfall ranges from 120 to 150 cm. Soil is red lateritic which is known for high level of iron content and poor in nutrient status.

2.2 Vegetation sampling

The vegetation was sampled randomly by laying 25 quadrats of 10m x 10m each, covering 0.25 ha area, during February 2013 to March 2014 covering all the seasons (Fig. 1). In each quadrat all the trees (dbh>1cm) were identified and their number and diameter at breast height (dbh) were recorded with the help of a slide caliper. Where dbh measurement was not possible, girth at breast height (gbh) was measured using a meter tape. The shrubs, climbers and tree saplings (< 1cm dbh, height >30 cm) were sampled in two 5m x 5m quadrats, and herbs including tree seedlings (< 1cm dbh, height <30 cm) were sampled by lying four 1m x 1m quadrats nested within each 10m x 10m quadrat. Plant specimens were collected and identification of the unknown species was done by consulting regional flora (Sanyal, 1994; Guha Bakshi, 1990).

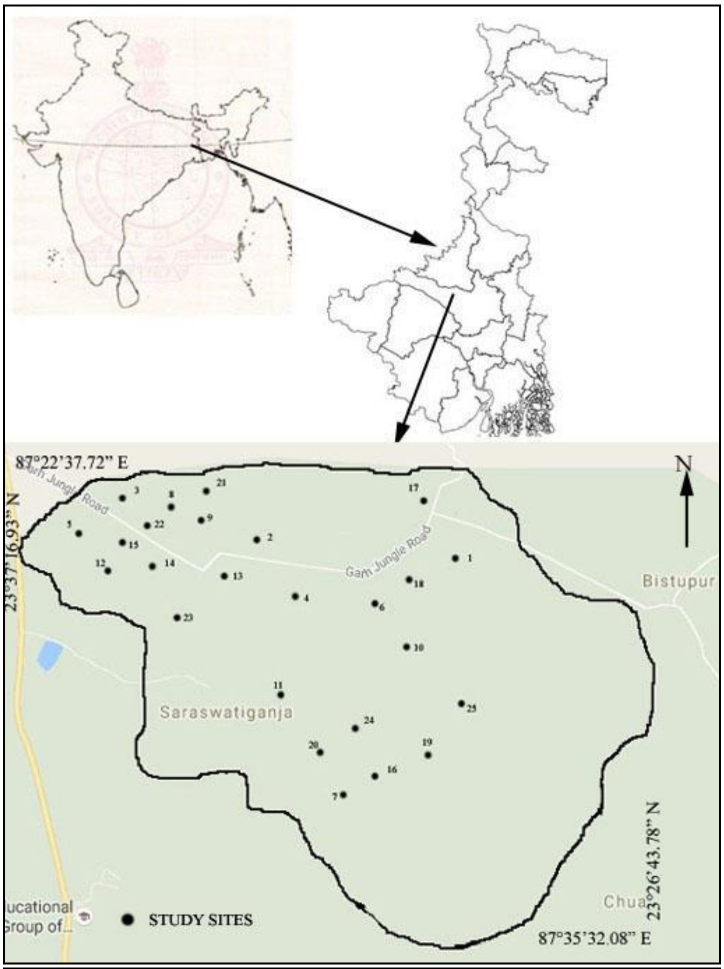

FIGURE 1: LOCATION GARHJUNGLE SACRED FOREST SHOWING STUDY SITES

2.3 Data Analysis

Phytosociological characters like frequency, density, basal area and importance value index (IVI) were calculated for each tree species according to Misra (1968). Family importance value (FIV) was estimated as the sum of relative density, relative diversity and relative dominance of a family (Ganesh et. al., 1996). Dispersion of species was calculated as ratio of abundance to frequency (A/F) (Curtis and Cottam, 1956).

Population structure of tree species was studied by determining the number of individuals in different diameter classes starting from 1–5cm to 50-55cm. Species diversity was calculated separately for various vegetation strata – trees, shrubs and herbs. Various diversity measures were estimated like Shannon - Wiener index (H′), Simpson's index (Cd), evenness (E) and Margalef's index of species richness (M) (Shannon and Weaver, 1949; Simpson, 1949; Pielou, 1966; Margalef, 1968).

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

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

$$E = H'/H^{max}; \quad H^{max} = \ln(S)$$

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

Where, s=total no of species, pi= ni/N, ni= total no of individual of "i" species, N= total no of individual of all species, ln= natural log.

III. RESULTS

3.1 Species Composition and Vegetation Structure

A total of 738 woody individuals (≥1cm dbh) of 14 species from 12 families were recorded in the study area (Table 1). The number of individuals of various species varied from 1 to 468. The family dipterocarpaceae had the greatest number of individuals (468) of single species. The family ebenaceae was represented by single species having single individual. The number of species ranged from 2 to 5 per quadrat and individuals from 8 to 72 per quadrat. Total stem density in the area studied was 2952 N ha^{-1}. However the total density of stems with dbh ≥ 10 cm was 744 N ha^{-1} (Table 2). Mean stem density per quadrat was 29.52 and 11 out of 25 quadrats had stem density more than the mean value.

TABLE 1
PHYTOSOCIOLOGICAL CHARACTERISTICS OF TREE SPECIES IN GARHJUNGLE SACRED FOREST

Species	Family	Total No.	Density ± sd (N ha^{-1})	Frequency (%)	Basal area (m^2 ha^{-1})	IVI
Shorea robusta Gaertn. F.	Dipterocarpaceae	468	1872 ± 1095.51	84	11.72	145.90
Madhuca indica Gmelin	Sapotaceae	76	304 ± 180.69	68	1.63	38.51
Acacia nilotica (L.) Willd. Ex Del.	Mimosaceae	9	36 ± 264.58	12	0.033	4.95
Buchanania lanzan Spreng.	Anacardiaceae	109	436 ± 583.57	72	1.37	42.89
Semecarpus anacardium L.f.	Anacardiaceae	7	28 ± 70.71	8	0.016	3.41
Tectona grandis L.f.	Verbenaceae	21	84 ± 275.38	16	0.88	11.91
Haldina cordifolia (Roxb.) Ridsdale	Rubiaceae	7	28 ± 57.74	12	1.05	9.67
Pterocarpus marsupium Roxb.	Fabaceae	8	32 ± 54.77	20	0.48	9.39
Schleichera oleosa (Lour.) Oken	Sapindaceae	10	40 ± 321.46	12	0.41	6.93
Spondias pinnata (L.f.) Kurz	Anacardiaceae	13	52 ± 577.35	12	2.12	15.75
Alangium lamarckii Thw.	Alangiaceae	3	12 ± 70.71	8	0.009	2.83
Bombax ceiba L.	Bombacaceae	2	8	4	0.60	4.42
Diospyros melanoxylon Roxb.	Ebenaceae	1	4	4	0.003	1.34
Aegle marmelos (L.) Corr.	Rutaceae	4	16	4	0.07	2.09

TABLE 2
THE PROPORTION OF TREE SPECIES, STEM DENSITY AND BASAL AREA IN DIFFERENT DIAMETER CLASSES

S. No.	dbh class (cm)	Species	Stems ha⁻¹	% of stems	Basal area (m²)	% of basal area
1	1 to 5	3	1264	42.82	0.028	0.14
2	>5 to 10	2	944	31.98	0.11	0.52
3	>10 to 15	0	452	15.31	0	0
4	>15 to 20	1	172	5.83	1.63	7.97
5	>20 to 25	2	80	2.71	1.29	6.30
6	>25 to 30	3	24	0.81	13.56	66.54
7	>30 to 35	1	8	0.27	0.60	2.96
8	>35 to 40	0	0	0	0	0
9	>40 to 45	0	0	0	0	0
10	>45 to 50	2	8	0.27	3.17	15.57
11	>50 to 55	0	0	0	0	0
	total	14	2952	100	20.39	100

Based on their density, species were categorized into five classes:

Predominant species (≥ 200 individuals): *Shorea robusta* with highest density (1872 N ha^{-1}) contributing 63.41 % of the total density.

Dominant species (100 to 199 individuals): *Buchanania lanzan* with 109 individuals contributing 14.76% of total density belong to this group.

Common species (25 to 99 individuals): *Madhuca indica* represented this group accounting for 10.29% of total density (76 individuals).

Rare species (5 to 24 individuals): seven species contributing 10.16% of total density (75 individuals) formed this group – *Acacia nilotica*, *Semecarpus anacardium*, *Tectona grandis*, *Haldina cordifolia*, *Pterocarpus marsupium*, *Schleichera oleosa*, *Spondias pinnata*.

Very rare species (< 5 individuals): four species with total 10 individuals (1.35% of total density) belonged to this category. These four species were *Alangium lamarckii* (3 individuals), *Bombax ceiba* (2 individuals), *Diospyros melanoxylon* (single individual) and *Aegle marmelos* (4 individuals).

The total basal area occupied by the tree species was 20.39 m² ha^{-1}. However considering the stems with dbh ≥ 10 cm, total basal area was 20.25 m² ha^{-1}. Species-wise basal area ranged from 0.0003 m² ha^{-1} to 11.719 m² ha^{-1}. Largest basal area was occupied by *Shorea robusta* (11.719 m² ha^{-1}) followed by *Spondias pinnata* (2.1239 m^2 ha^{-1}). Dipterocarpaceae was the dominant family based on basal area. Quadrat wise basal area varied from 0.09 to 0.42 m² with a mean of 0.203 m²; in 10 quadrats the basal area exceeded the mean value.

The highest IVI was exhibited by *Shorea robusta* (145.904) followed by *Buchanania lanzan* (42.89). *Diospyros melanoxylon* had the lowest IVI (1.34). Based on family importance value (FIV), dipterocarpaceae ranked highest among all families followed by anacardiaceae (Table 3).

TABLE 3
FAMILY IMPORTANCE VALUE (FIV) BASED ON NUMBER OF SPECIES, DENSITY AND BASAL AREA UNDER DIFFERENT FAMILIES

Family	Species	Trees	Basal area (m² ha⁻¹)	Relative Density	Relative Diversity	Relative Dominance	FIV
Anacardiaceae	3	129	3.51	17.48	21.43	17.19	56.10
Alangiaceae	1	3	0.01	0.41	7.14	0.05	7.59
Bombacaceae	1	2	0.60	0.27	7.14	2.96	10.38
Dipterocarpaceae	1	468	11.72	63.42	7.14	57.49	128.05
Ebenaceae	1	1	0.003	0.14	7.14	0.02	7.29
Fabaceae	1	8	0.48	1.08	7.14	2.36	10.58
Mimosaceae	1	9	0.03	1.22	7.14	0.16	8.52
Rubiaceae	1	7	1.05	0.95	7.14	5.15	13.24
Rutaceae	1	4	0.07	0.54	7.14	0.35	8.04
Sapindaceae	1	10	0.41	1.36	7.14	2.00	10.50
Sapotaceae	1	76	1.63	10.30	7.14	7.97	25.42
Verbenaceae	1	21	0.88	2.85	7.14	4.30	14.29
Total 12	14	738	20.39	100	100	100	300

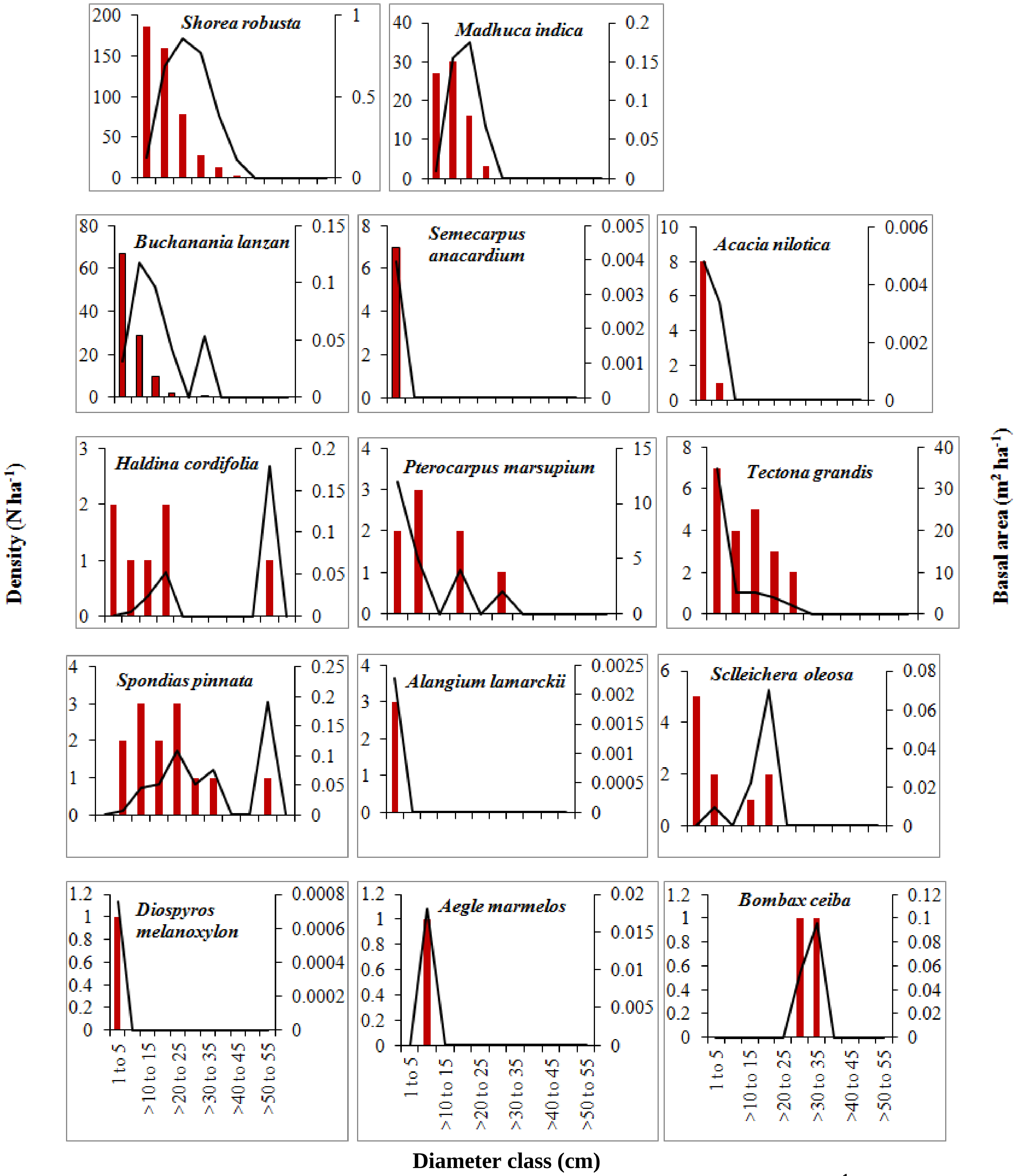

FIGURE 2: DIAMETER CLASS DISTRIBUTION OF TREE SPECIES BASED ON DENSITY (N ha^{-1}) (COLUMN) AND BASAL AREA (m^2 ha^{-1}) (LINE)

The maximum diameter recorded was 49.31cm (for *Spondias pinnata*). The most preferred diameter class was 1-5 cm with density ranging from 4 to 748 stems ha^{-1}. However based on basal area, the 10-15 cm dbh class had the highest basal area of 5.04 m² ha^{-1}. Figure 2 shows the diameter density distribution of tree species. Almost all the species exhibited a reverse ‘J’ pattern with stems restricted below 40cm dbh, except *Spondias pnnata* and *Haldina cordifolia*.

The shrub layer had 608 individuals belonging to 17 species including 5 climbers and a creeper species having 278 individuals. The highest frequency is exhibited by *Erycibe paniculata.* 30 herbs with 1639 individuals composed the ground flora.

Distribution pattern for all the species in the area studied was of clumped type (>0.5).

3.2 Species Diversity

For tree species Shannon-Wiener Index or heterogeneity (H´) was 1.88 (Table 4). Evenness was low resulting in higher concentration of dominance. Species richness was high leading to high heterogeneity value. Shrub layer had higher species richness and evenness than trees leading to heterogeneity value of 3.42. Species richness and heterogeneity were highest in the herb layer and evenness was highest in the shrub layer.

TABLE 4
DIVERSITY VALUES OF TREE, SHRUB AND HERB LAYER IN GARHJUNGLE SCARED FOREST

Vegetation stratum	H'	E	Cd	M
Tree	1.88	0.71	0.44	1.97
Shrub	3.42	1.21	0.12	2.50
Herb	3.62	1.06	0.13	3.92

IV. DISCUSSION

No two forest communities could be closely identical with respect to vegetation composition and structure (Murphy and Lugo, 1986). The presence of 738 woody individuals belonging to 14 species in 0.25 ha area of Garhjungle sacred dry deciduous forest is relatively a good number. Among these, only *Aegle mermelos* is evergreen to semi deciduous. Higher number of species including medicinal plants has been reported from other conserved as well as disturbed sacred groves involving areas ranging from 1 ha to 50 ha - 146-156 in Karnataka (Boriah et al., 2003), 239 in Uttarakhand (Rawat et al., 2011), 158 tree species in southern Eastern Ghats (Rao et al., 2011), 83 tree species form 14 sacred groves in Kurnool district of Andhra Pradesh (Sunitha, 2002), and139 species form 25 sacred groves in West Medinipur, West Bengal (Pandit, 2011).

Mean stem density in this study ranged from 4 to 1872 N ha^{-1}, with mean 210.85 N ha^{-1}, and only one species representing 63.41% of the total tree population. Density range of 929-1018 N ha^{-1} has been reported from sacred dry deciduous forest stands in Eastern Ghats (Rao et al., 2011). Reported values of mean stem density from other deciduous forests of India are 35 – 419 ha^{-1} (Sagar and Singh, 2006), 591 ha^{-1} (Sahu et al., 2007) & 315-494 ha^{-1} (Pandey and Shukla, 2001). Mean tree density of 276 - 980 stems ha^{-1} has been reported in some other tropical dry forests with preferred diameter classes ranging from 20-50 cm (Bhadra et al., 2010; Krishnamurthy *et al*., 2010; Kumar et al., 2010).

The highest stem density and IVI was obtained by *Shorea robusta*, which showed similarity with the previous study in similar adjacent forests showing dominance of *Shorea robusta* (Gupta Joshi, 2012). The total basal area occupied by the tree species of sampled plot (0.25 ha) was 20.39 m^2 ha^{-1} which showed almost similar range when compared to the earlier studies including 1.31 to 13.78 m^2 ha^{-1} (Sagar and Singh, 2006); 7 - 23 m^2 ha^{-1} from certain dry forest communities in India (Jha and Singh, 1990), 10.79 - 20.44 m^2 ha^{-1} for a tropical dry evergreen forest of southern India (Parthasarathy and Sethi, 1997). However comparatively higher range of basal area (16.6 m^2 ha^{-1} to 31.7 m^2 ha^{-1}) is reported from sacred forest sites (Rao et al., 2011).

Almost all the species exhibited reverse J shaped diameter density distribution suggesting a young or regenerating population. Only two species exceeded 40cm diameter class – *Spondias pinnata* and *Haldina cordifolia*. In the present study all the species showed clumped distribution which is very common in nature (Odum, 1971) due to patchy distribution and coppice forming (Roy and Singh, 1994), insufficient mode of seed dispersal or gap formation encouraging recruitment and growth of numerous saplings (Richards, 1996) or vegetative reproduction by suckers (Lieberman, 1979).

The values of Shannon-Wiener diversity index (1.88) and Simpson's dominance index (0.43) in the present study are within the reported range for tropical forests. Diversity (H’) range of 0.83 - 4.1 has been reported by earlier workers for Sal forests (Rasingam and Parthasarathy, 2009; Shukla, 2009; Tripathi and Singh, 2009; Krishnamurthy et al., 2010; Sahu et al., 2012) and the concentration of dominance (Cd) ranged 0.10-1 for tropical dry forests by other workers (Visalakshi, 1995; Kumar et al., 2010; Sahu et al., 2012). However, the Shannon’s diversity value of 1.8 is much lower when compared with Shannon’s diversity index value of 3.34 reported from a scared tropical dry deciduous forest (Rao et al. 2011). The species diversity as well as richness (H′ and M) increased as we moved from the trees to the herbs. Concentration of dominance was highest for trees indicating dominance by a few species. Increased diversity of shrubs and herbs also indicate an open canopy forest and presence of disturbance.

V. CONCLUSION

The results of present study indicated a young or regenerating population of tree species. Future work will compare the vegetation structure of this sacred forest with adjacent forests under different management regimes. It is generally believed and supported by published reports that sacred forests are better protected and managed owing to their religious significance and harbour richer plant diversity than other forests. However, comparison with results from other sacred forests indicated lower species richness, diversity as well as basal area in the Garhjungle sacred forests. The health of Garhjungle sacred forests is deteriorating due to various anthropogenic disturbances such as grazing, extraction of fuel wood, collection of various NTFP, etc. apart from the periodic man made fires. Therefore further conservation efforts are immediately needed to curb the anthropogenic disturbances.

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