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Regeneration status of tree composition in the sacred groves of Mercara, Central Western Ghats

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ABSTRACT

Sacred groves are pristine forest patches that are left untouched for centuries in the name of local deities, beliefs and taboos. They play an important role in conservation of biodiversity as they are abode of many endemic and threatened species. Tree species diversity, structure and their regeneration status was investigated in the eight sacred groves of Mercara, Central Western Ghats. A total of 170 tree species belonging to 110 genera and 49 families were recorded from them. Higher species richness was observed in the sacred groves which were bigger in size and moderately disturbed. Though, a good number of tree density, seedling and sapling density and basal area were observed in all the eight sacred groves, an inversely proportional relation was observed between degree of disturbances and tree density, seedling density, sapling density and basal area. Lesser similarity between adult and regenerating tree species and greater number of species with no regeneration status and reappearing status indicated a possible change in the tree species composition of these sacred groves in the near future. Hence it becomes crucial that efforts should be taken in a sustainable manner to protect these pristine forest patches for future generations.

Key words: Basal area, Biodiversity, Conservation, Disturbance, Quadrats, Regenerates.

INTRODUCTION

Prehistorically, social and cultural beliefs associated with nature and its conservation has been an integral part of human population. Unique and significant example of such nature is the existence of sacred groves across the world. They are the patches of native vegetation traditionally protected by local communities with the belief that local deities reside in them and any human activity is a taboo. They reflect the value system evolved and preserved through long years by the ancient communities. They are the priceless treasures of great ecological, biological, cultural and historical values. They are considered as an asylum for many endemic, threatened, vulnerable and endangered species. The prevalence of some of the Critically Endangered tree species of the Western Ghats such as, *Syzygium travancoricum* and *Vateria indica* in some of the small groves of Siddapur Taluk, Uttara Kannda, Karanataka [1]; occurrence of threatened species in the sacred groves of Manipur State of India [2] such as *Bombax ceiba, Anaphalis contorta, Bonnaya brachiata, Scutellaria discolor* and *Blumea hieracifolia* which fall under the rare and vulnerable categories, *Alnus nepalensis, Schima wallichii* and *Pasania polystachya* - threatened species, and *Aphanamixis polystachya* - an endangered species; and presence of *Semecarpus kathalekanesis* in the Kaans of Shimoga, Karnataka [17] - are the indications that they are the rich repository of nature's unique biodiversity and product of socio-ecological philosophy our ancestors have been cherishing since olden days.

Arboreal species are the major component of any forest community and hence study of their diversity, structure and regeneration status gives immense insight into its dynamics and successful management. An obvious approach to conserve plant biodiversity is to map distributional patterns and look for concentrations of diversity and endemism [3]. Studies on floristic composition and structure in forests are instrumental in the sustainability of forests [4]. Further, management of forest requires understanding of its composition, the effects of past impacts on the present status and the present relationship of the forest with surrounding land uses [3]. However, a fewer attempts have made in Kodagu district towards biodiversity survey and landscape study, plenty of sacred groves have remained unexplored. In view of this, the present investigation was undertaken to assess the tree species diversity, structure and regeneration status in view of degree of disturbance in the selected sacred groves of Mercara, Central Western Ghats.

MATERIALS AND METHODS

Study area

The study was undertaken in the eight sacred groves of Mercara Taluq, Kodagu District, Karnataka, India (Figure 1). Kodagu is one of the highly wooded Western Ghats regions of Karnataka with 80% of the land area under tree cover. The altitude ranges between 850 and 1745 m above MSL. The mean temperature varies from 14.2^{o} C (winter) to 28.6^{o} C (summer). The mean annual rainfall is 2,725.5 mm, received mainly from south-western monsoon concentrated during the months of June to September. As the study area receives heavy rainfall and the soils are of lateritic type. It is mainly composed of semi-evergreen to evergreen forests [5].

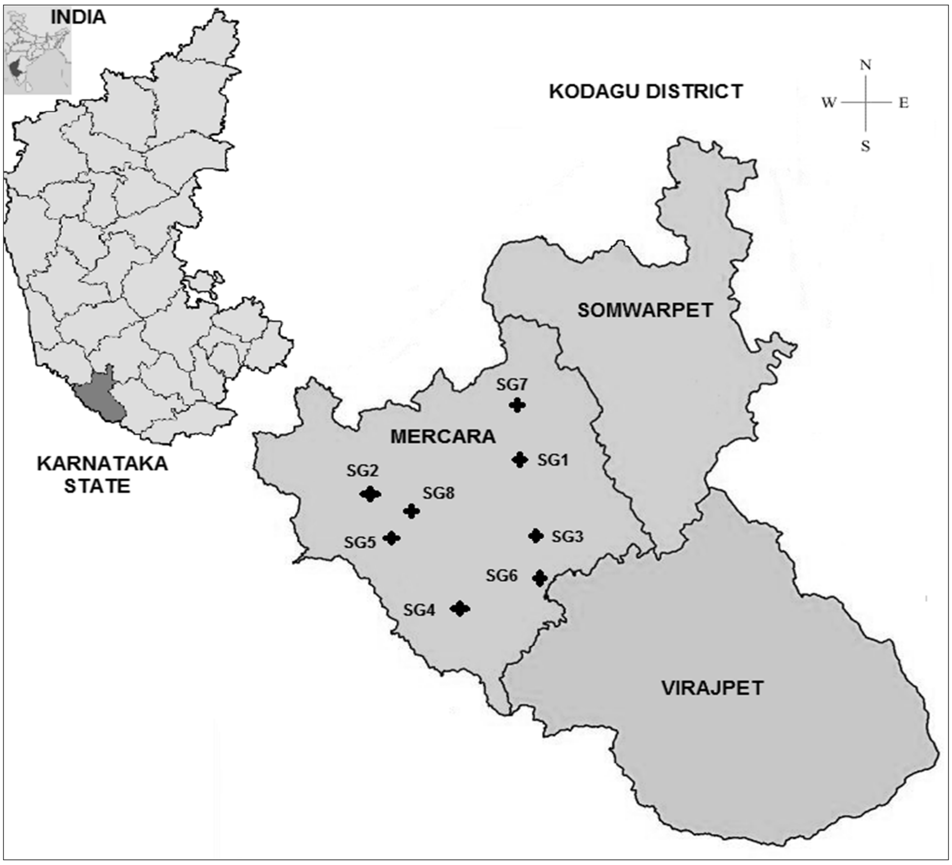

Figure 1: Map of study area, Mercara, Central Western Ghats

Kodagu district has 1,214 sacred groves covering an area of 2,550 ha. Mercara Taluk has 306 sacred groves covering an area of 534.23 ha. Considering the number and density, diversity of deities and communities, and forms of worship and management, Kodagu can be called 'hotspot of sacred groves' in the world [6]. A preliminary reconnaissance survey was carried out in the forest ranges to identify the sacred groves, their size, location and degree of disturbance. Based on this, eight sacred groves (SG1 to SG8) (Figure 1) were selected for detailed study (Table 1). Of the eight sacred groves studied, temple worship was observed in SG5, SG7 and SG8, whereas remaining groves still enjoy nature worship. The deities in the groves are worshipped once a year in the month of March/April.

Table 1: Geographical details of eight sacred groves, Mercara, Central Western Ghats

Study sites	Residing Deity	Area in acres	Location	Elevation
SG1	Sree Poda	6.88	N12° 28.286' E75° 41.604'	1140 m
SG2	Ayyappa	8.23	N12° 22.979' E75° 31.539'	907 m
SG3	Ayyappa	8.24	N12° 23.425' E75° 45.712'	962 m
SG4	Ayyappa	10.42	N12° 16.108' E75° 38.582'	913 m
SG5	Ayyappa	14.77	N12° 21.854' E75° 35.303'	918 m
SG6	Ayyappa	21.62	N12° 19.598' E75° 48.356'	930 m
SG7	Ayyappa	49.16	N12° 31.193' E75° 42.280'	1008 m
SG8	Subraya	59.34	N12° 21.959' E75° 32.643'	1046 m

Data collection and analysis

Field exploration was undertaken to record the tree species composition of the sacred groves. Quadrats of 20 m x 20 m dimension were laid randomly to enumerate the mature trees covering 5% of total area. Stems having GBH (Girth at Breast Level – 1.34 m height) ≥ 30 cm were counted as adults/trees. Identification of species was made using authentic floras [5, 7, 8, 9, 10, 11] and voucher specimens have been deposited in Biodiversity Conservation Laboratory, DOS in Environmental Science, University of Mysore, Mysore, India. Regeneration studies were carried out by laying down plots of 2 m x 2 m size randomly. In each plot, all tree species ≤ 30 cm GBH were considered as regenerates and enumerated separately into seedlings (< 40 cm height) and saplings (> 40 cm height and <30 cm GBH). Regeneration status of each tree species was evaluated considering the number of seedlings and saplings based on [12], with modifications:

1. Good regeneration, if seedlings > saplings > adults;
2. Fair regeneration, if seedlings > or < saplings > or < adults;
3. Poor regeneration, if the species survives only at sapling stage or only seedlings stage (seedlings and saplings may be less or more or equal to adults);
4. No regeneration, if a species is present only in adult form;
5. Reappearing, if the species has no adults but only seedlings or saplings.

Floristic diversity was measured using Simpson Index of Diversity [13] and Shannon and Wiener's Index of Diversity [14]. Importance Value Index (IVI) of each tree species was determined [15] calculating frequency, density and basal area. Sorenson's similarity index [16] was used to assess the similarity between adult and regenerating tree species.

Degree of disturbance was assessed in terms of 14 parameters such as cut stumps, grazing, fire, weeds, roads, footpath, domestic animal dung, wild animal dung, collection of firewood, canopy opening, encroachment, conversion, sanskritization and impacts of pilgrim's activities. Four levels of disturbance were given to each parameter namely absent (0), low (1), medium (2) and high (3). For each sacred grove, the degree of disturbance is expressed in-terms of all the fourteen parameters as percentage of Combined Disturbance Index (CDI) [17]. CDI values were compared with basal area, number of species, tree density, seedling density and sapling density of each sacred grove for possible correlation.

RESULTS AND DISCUSSION

Tree species diversity and richness

A total of 170 tree species belonging to 110 genera and 49 families were recorded from eight sacred groves. A highest number of 93 tree species from SG8 and lowest number of 25 tree species from SG2 was recorded (Table 2). Of the 49 families recorded, maximum species were from Lauraceae (17), followed by Euphorbaceae (14), Moraceae (13) and Myrtaceae (10). Twenty three families were represented by single species.

Table 2: Diversity, basal area, densities and indices of tree species recorded from the eight sacred groves of Mercara, Central Western Ghats

Study sites/ Sacred groves	Taxa	Genus	Family	Basal Area/ha	Tree Density /ha	Seedling Density /100 m2	Sapling Density/ 100 m2	Shannon's index	Simpson's index
SG1	46	40	25	62.72	591.66	354.54	361.36	3.155	0.94
SG2	25	24	19	57.71	750	312.5	493.75	2.643	0.88
SG3	47	40	26	100.42	508.33	222.91	1058.33	2.148	0.74
SG4	47	38	26	77.29	512.5	519.79	507.29	2.756	0.88
SG5	54	47	29	52.33	566.66	504.16	380.55	3.275	0.94
SG6	77	64	35	73.41	379.54	235.79	604.54	2.934	0.89
SG7	87	60	33	42.92	460	137.02	385.12	2.993	0.88
SG8	93	70	37	49.38	605	319.15	353.24	3.466	0.93

On an average, Shannon's diversity index was 2.91 and Simpson's evenness index was 0.88. The highest values for Shannon's index and Simpson's index were scored by SG8 (3.46) and SG1 (0.94) respectively, whereas, SG3 (2.14 and 0.74) scored the lowest value for both the indices.

A good number of tree species were recorded in the studied sacred groves of Mercara, Central Western Ghats. Species richness ranged from 25 to 93 tree species among the sacred groves. As the total area of sacred groves increased species richness also increased, hence the large variation between the species richness of eight sacred groves.

Shannon's and Simpson's indices have also shown a similar trend. Diversity and evenness showed an increasing tendency with increased areas of the studies sacred groves. Similar values were recorded for Shannon's and Simpson's indices from various researchers across the Western Ghats. A Shannon index value of 3.11 was recorded for the Kaan forests of Shimoga, Karnataka; 4.04 for Myristica swamps of Uttara Kannada, Karnataka; 4.90 for Charmady reserve forests, Karnataka; 2.46 for Swamp forests of Southern Kerala; 3.2 for Chandoli National Park, Maharastra. A Simpson's index value of 0.75 was recorded for Swamp forests of Southern Kerala; 0.90 for Charmady reserve forests, Karnataka; 0.93 for Myristica swamps of Uttara Kannada, Karnataka [17, 18, 19, 20, 21]. Species richness of any community is a function of severity, variability and predictability of the environment in which it develops [22]. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable [23]. The present study areas, being a part of one of the biodiversity hotspots in the world and having enjoyed hundreds of year's protection from the local people in the name of different local deities, greater species richness and diversity become obvious.

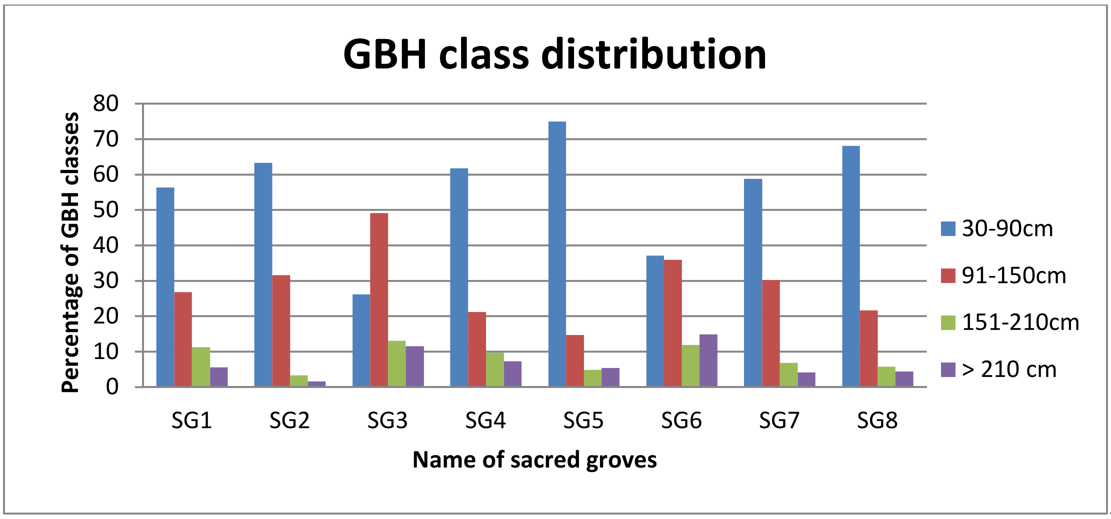

Figure 2: Percentage distribution of four GBH classes in the sacred groves of Mercara, Central Western Ghats

Table 3: Tree species with top ten IVI values and their regeneration status in the eight sacred groves of Mercara, Central Western Ghats (IVI=Importance index value; RS=Regeneration status)

Sl no	Botanical name	SG2		SG8		SG4		SG7		SG3		SG1		SG5		SG6	
		IVI	RS	IVI	RS	IVI	RS	IVI	RS	IVI	RS	IVI	RS	IVI	RS	IVI	RS
1	*Glochidion ellipticum* Wight	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.39	Poor
2	*Stereospermum colais* (Dillw.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.08	Poor
3	*Palaquium ellipticum* (Dalz.)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.93	Fair
4	*Dimocarpus longan* Lour.	49.92	Fair	51.24	Good	56.59	Good	69.17	Good	-	-	40.14	Fair	31.53	Good	11.48	Fair
5	*Schleichera oleosa* (Lour.) Oken	-	-	-	-		-	-	-	-	-	-	-	-	-	14.94	Good
6	*Herpullia arborea* (Blanco) Radlk.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	16.90	Poor
7	*Caanrium strictum* Roxb.	-	-	-	-	28.63	Fair	-	-	39.36	None	-	-	18.10	None	20.34	Good
8	*Holigarna grahamii* (Wight) Kurz.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	27.29	Fair
9	*Aphananthe cuspidate* (Bl.) Planch.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41.91	Fair
10	*Caryota urens* L.	18.81	Poor	-	-	12.49	Fair	-	-	-	-	-	-	11.42	Fair	48.28	Fair
11	*Dysoxylum malabaricum* Bedd. ex Heirn	-	-	-	-	-	-	-	-	-	-	-	-	11.05	Poor	-	-
12	*Nothopegia racemosa* (Dalz.) Ramam	-	-	11.65	Good	-	-	24.54	Good	-	-	-	-	11.89	Good	-	-
13	*Litsea floribunda* (Bl.) Gamble	-	-	14.80	Fair	-	-	12.04	Poor	10.79	Fair	-	-	12.25	Fair	-	-
14	*Excoecaria crenulata* Wight	-	-	16.70	Fair	9.10	Fair	-	-	-	-	-	-	14.15	Poor	-	-
15	*Tabernaemontana heyneana* Wall.	19.81	None	-	-	-	-	-	-	-	-	-	-	16.02	Poor	-	-
16	*Litsea oleoides* (Meissn.) Hook. f.	-	-	-	-	-	-	-	-	-	-	-	-	16.52	Good	-	-
17	*Vernonia arborea* Ham.	-	-	-	-	14.31	Good	-	-	-	-	-	-	17.71	Fair	-	-
18	*Olea dioica* Roxb.	-	-	11.72	Fair	-	-	-	-	-	-	8.75	Poor	-	-	-	-
19	*Antidesma montanum* Blume.	-	-	-	-	14.12	Fair	-	-	11.92	None	10.01	Poor	-	-	-	-
20	*Mangifera indica* L.	-	-	10.57	Fair	-	-	-	-	-	-	14.15	Good	-	-	-	-
21	*Mimusops elengi* L.	-	-	-	-	-	-	-	-	-	-	15.16	None	-	-	-	-
22	*Euonymous indicus* Heyne ex Wall.	-	-	-	-	27.97	Poor	-	-	12.82	None	16.00	Poor	-	-	-	-
23	*Memecylon malabaricum* (C.B Clarke) Cogn.	-	-	-	-	-	-	-	-	-	-	16.35	Good	-	-	-	-
24	*Chrysophyllum roxburghii* G.Don	-	-	-	-	-	-	-	-	20.40	None	18.90	Poor	-	-	-	-
25	*Artocarpus heterophyllus* Lam.	22.7	Poor	7.65	Fair	-	-	-	-	20.56	Poor	23.24	None	-	-	-	-
26	*Myristica dactyloides* Gaertn	-	-	-	-	-	-	16.22	Fair	90.19	Poor	28.99	Poor	-	-	-	-
27	*Artocarpus hirsutus* Lam.	-	-	-	-	-	-	-	-	7.94	None	-	-	-	-	-	-
28	*Garcinia gummi-gutta* (L.) Robs.	-	-	-	-	-	-	-	-	11.10	Poor	-	-	-	-	-	-
29	*Holigarna nigra* Bourd.	-	-	-	-	-	-	7.62	Poor	12.09	Good	-	-	-	-	-	-
30	*Xanthophyllum arnottianum* Wt.	-	-	-	-	9.56	Poor	-	-	-	-	-	-	-	-	-	-
31	*Margaritaria indica* (Dalz.) A. Shaw	-	-	-	-	11.79	None	-	-	-	-	-	-	-	-	-	-
32	*Homalium zeylanicum* (Gardner) Benth	-	-	-	-	28.08	None	-	-	-	-	-	-	-	-	-	-
33	*Elaeocarpus tuberculatus* Roxb.	-	-	-	-	-	-	6.95	Poor	-	-	-	-	-	-	-	-
34	*Archidendron monadelphum* (Roxb.) Nielson	-	-	-	-	-	-	9.54	Fair	-	-	-	-	-	-	-	-
35	*Persea macrantha* (Nees) Kosterm	-	-	-	-	-	-	10.88	Poor	-	-	-	-	-	-	-	-
36	*Syzygium laetum* (Ham.) Gandhi	-	-	-	-	-	-	15.87	Good	-	-	-	-	-	-	-	-
37	*Mesua ferrea* L.	-	-	-	-	-	-	17.37	None	-	-	-	-	-	-	-	-
38	*Actinodaphne malabarica* Balak.	-	-	6.90	Fair	-	-	-	-	-	-	-	-	-	-	-	-
39	*Elaceocarpus serratus* L.	-	-	9.10	Poor	-	-	-	-	-	-	-	-	-	-	-	-
40	*Olea paniculata* Wall.	-	-	11.47	None	-	-	-	-	-	-	-	-	-	-	-	-
41	*Syzigium mundagam* (Bourd.)	11.89	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	*Cinnamomum malabatrum* (Burm.f.) Blume	15.43	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-
43	*Chionanthus malabarica* (Wall. ex G.Don) Bedd.	15.45	Poor	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	*Elaeocarpus variabilis* Zmartzy.	20.05	Poor	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	*Antidesma menasu* Miq. ex Tul.	21.52	Fair	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	*Syzigium cumini* (L.) Skeels	23.19	None	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Density, basal area and IVI values

Among the sacred groves, basal area ranged from 42.92 to 100.42 m^2/ha area. Highest and lowest basal area were recorded from SG3 (100.42 m^2/ha) and SG7 (460 m^2/ha) respectively. Tree density per hectare varied greatly among the study sites; recording the highest value for SG2 (750 stems/ha) and lowest for SG6 (379.54 stems/ha). Reverse J-shaped curves were recorded for four GBH classes in terms of density (Figure 2) except for SG3.

Dimocarpus longan showed highest basal area and density in SG1, SG7 and SG8 with a value of 14.83 m^2 from 83.33 stems/ha, 12.85 m^2 with 133.75 stems/ha and 11.12 m^2 with 127.5 stems/ha respectively. In SG2, *Syzygium cumini* have shown the highest basal area of 10.43 m^2/ha with 12.5 stems/ha while *Dimocarpus longan* recorded the highest density (212.5 stems/ha) with a basal area of 8.37 m^2/ha. *Myristica dactyloides* showed a highest basal area and density in SG3 with a value of 31.41 m^2/ha with 250 stems/ha. In SG4, *Schleichera oleosa* showed the highest density (141.66 stems and 15.0 m^2 basal area per hactare) while *Homalium zeylanicum* showed the highest basal area (19.2 m^2 with 8.33 stems/ha). *Canarium strictum* has shown a highest value for basal area of 7.36 m^2 with 8.33 stems/ha in SG5 and *Dimocarpus longan* showed highest density of 83.33 stems/ha with a basal area of 5.66 m^2/ha. In SG6, *Aphananthe cuspidata* had highest basal area (17.65 m^2 with 31.81 stems/ha) and *Caryota urens* had highest density (104.54 stems/ha with 7.47 m^2 of basal area).

Dimocarpus longan scored highest IVI values in the six sacred groves of the eight sacred groves studied (Table 3). In the remaining two groves, *Myristica dactyloides* (SG3) and *Caryota urens* (SG6) have shown highest IVI values. A large difference between the first and second highest IVI values among the tree species was observed in **SG2, SG3, SG4, SG7 and SG8.**

In SG1, *Dimocarpus carpus* scored highest IVI value (40.14) followed by *Myristica dactyloides* (28.99) and *Artocarpus heterophyllus* (23.24). In SG2, highest IVI value was recorded for *Dimocarpus longan* (49.92) followed by *Syzygium cumini* (23.19) and *Artocarpus heterophyllus* (22.77). *Myristica dactyloides* (90.19) recorded the highest IVI value in SG3 followed by *Canarium strictum* (39.36) and *Artocarpus heterophyllus* (20.56). In SG4, IVI value of *Dimocarpus longan* was 56.59 followed by *Canarium strictum* (28.63) and *Homalium zeylanicum* (28.08). *Dimocarpus longan* (31.53) scored highest IVI value in SG5 followed by *Canarium strictum* (18.10) and *Vernonia arborea* (17.71). The IVI value of *Dimocarpus longan* in SG6 was 48.28 followed by *Aphananthe cuspidata* (41.91) and *Holigarna grahamii* (27.29). In SG7, IVI value of *Dimocarpus longan* was 69.17 followed by *Nothopegia racemosa* (24.54) and *Mesua ferrea* (17.37). SG8 showed a highest IVI value for *Dimocarpus longan* (51.24) followed by *Exocoecaria crenulata* (16.70) and *Litsea floribunda* (14.80).

Results of the present study revealed that density (379.54-750 individuals/ha) and basal area (42.92-100.42 m2 basal area /ha) were well within the reported range of various workers. Rao *et al*., [24] reported a density of 999 stems/ha and 31.7 m^2 of basal area/ha for sacred forests of Chittoor, Andhra Pradesh; Gunaga *et al*., [17] reported 387 stems per ha and 23.62 m^2/ha in the Kaan forests of Shimoga; Muthukumar *et al*., [25] reported a range of 384-566 stems/ha of area and 46.3 to 99.7 m^2/ha basal area for Valparai, Annamalai hills, Tamil Nadu.

All seven sacred groves showed reverse J-shaped curve for four GBH classes except SG3. The tendency of decreasing density with increasing GBH resulting in a reverse J-shaped curve is a typical characteristic of tropical forests and an indication of sustainable regeneration. Similar curves have been reported for evergreen forests of Annamalai hills, Western Ghats [25], dry deciduous forests of Chittoor, Andhra Pradesh [24] and Swer sacred grove, Meghalaya [26].

Of the eight sacred groves, *Dimocarpus longan* was found to show the highest basal area in SG1, SG7 and SG8 among the other tree species. This species also has shown the highest density in SG1, SG2, SG5, SG7 and SG8. The highest IVI values were shown by *Dimocarpus longan* in the six sacred groves except SG3 and SG6. Significantly lesser timber and non-timber forest uses of this species could be attributed to its dominance in these study areas.

Regeneration status

Distribution of four regeneration classes among the eight sacred groves varied greatly (Figure 3). SG1, SG2, SG4 and SG8 showed a reverse J-shaped curve for the regeneration classes. In SG5, 66.51% of total regenerates was of Class I regenerates and percentage of Class II regenerates were less than Class III and IV. In case of SG3, SG6 and SG7, an almost J-shaped curve was observed. Sorenson's similarity between the mature tree species and regenerating tree species in each sacred grove was calculated. SG3 showed the lowest similarity (35.08%) while

SG5 recorded the highest similarity (65%). Similarity within the other groves was recorded as: SG1 - 57.57%, SG2 - 55.55%, SG4 - 62.68%, SG6 - 55.04%, SG7 - 51.96% and SG8 - 54.54%.

Among the eight sacred groves, on an average, 37.93% of tree species showed regeneration, 30.6% showed no regeneration and 31.45 % were considered as reappearing as the mature individuals were absent in the sampled area (Figure 4). The average seedling and sapling density among the study sites were found to be 325.73 regenerates /100m^2 and 518.02 regenerates /100m^2 respectively.

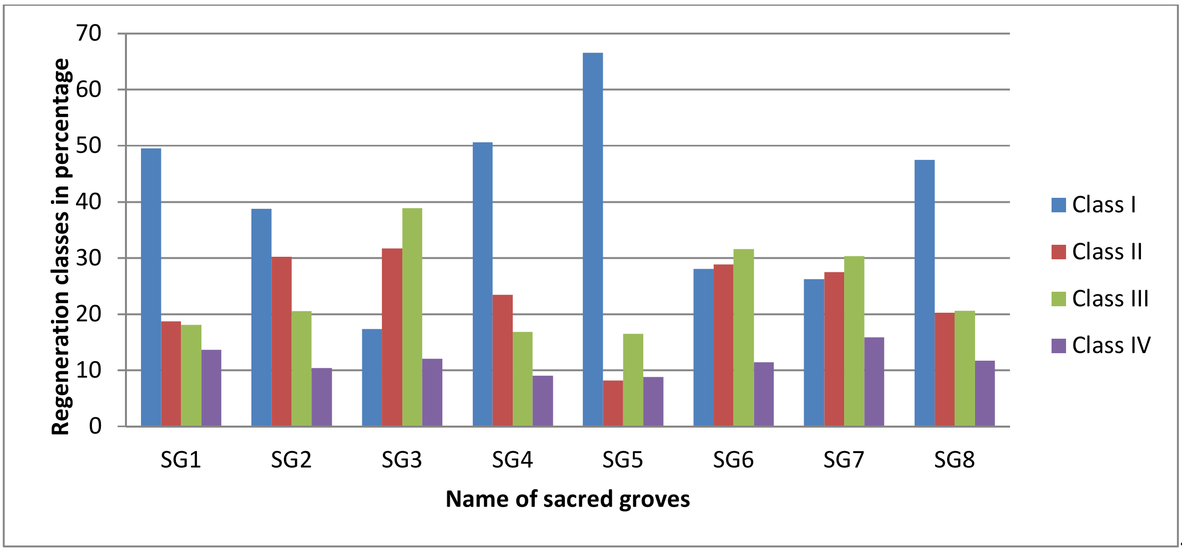

Figure 3: Distribution of regeneration classes among the eight sacred groves, Mercara, Central Western Ghats

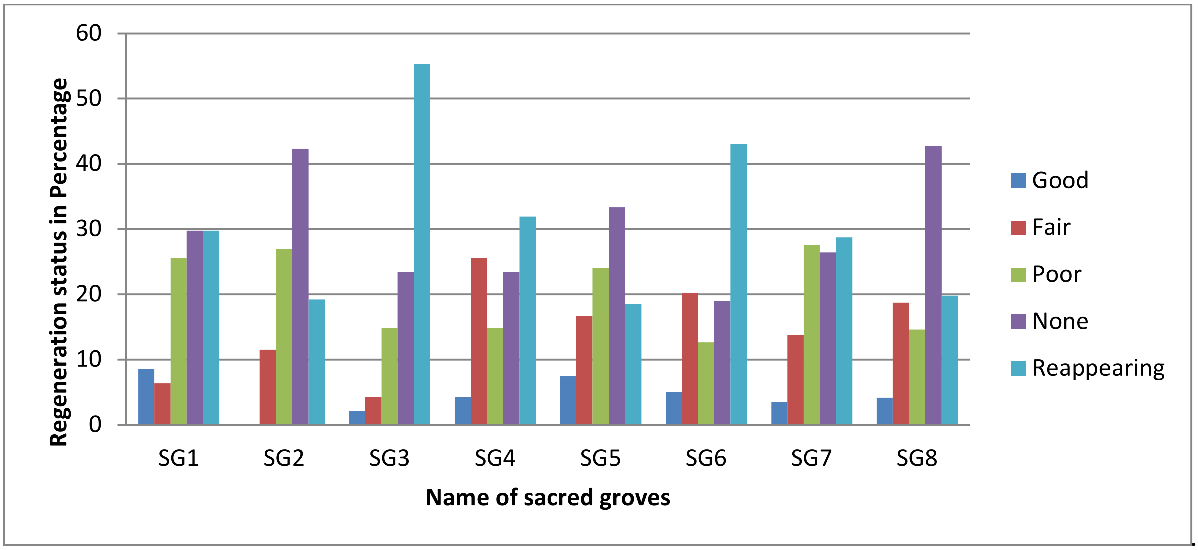

Figure 4: Percentage of regeneration status of tree species among the eight sacred groves, Mercara, Central Western Ghats

In SG1, only four species; *Microtropis stocksii*, *Mangifera indica*, *Schleichera oleosa* and *Memecylon malabaricum* showed good regeneration. *Nothopegia racemosa*, *Litsea floribunda* and *Dimocarpus longan* showed a fair regeneration (6.38%) while 25.53% of species showed poor regeneration. No regeneration was observed in 14 species and 14 species reappearing in the area have been recorded. Although *Myristica dactyloides* scored second highest IVI value, poor regeneration was observed without any saplings found in the area. *Artocarpus heterophyllus* having third highest IVI value, showed no regeneration. The seedling density was found to be 354.54 regenerates

/100m2 and sapling density was found to be 361.36 regenerates /100m^2. Highest seedling and sapling density was recorded by *Dimocarpus longan* with a value of 68.18 seedlings /100m^2 and 81.81 sapling /100m^2. *Memecylon malabaricum* had second highest seedling (86.36/100m^2) and sapling (18.18/100m^2) density.

In SG2, no species showed good regeneration. 11.53% of species had fair regeneration and 26.92% of species had poor regeneration. A highest of 42.31% of species had no regeneration and 19.23% species were recorded only in regenerating stage. Seedling and sapling density were recorded to be 312.75 regenerates /100m^2 and 493.75 regenerates /100m^2 respectively. *Dimocarpus longan* recorded highest seedling (234.37 regenerates) and sapling (321.87 regenerates) densities per 100m^2. *Memecylon malabaricum* recorded the second highest seedling and sapling density with a value of 62.5 regenerates /100m^2 and 90.62 regenerates /100m^2 respectively.

In SG3, only *Holigarna nigra* showed good regeneration; *Litsea floribunda* and *Eudia lunu-ankenda* showed fair regeneration. 14.89% of species had poor regeneration. A total of 26 species were found only in seedling and sapling stage. Eleven species had no regeneration. Though *Canarium strictum* recorded second highest IVI values, it had no saplings or seedlings in the area. Seedling and sapling density were recorded to be 222.91 regenerates/ 100m^2 and 1058.33 regenerates/ 100m^2 respectively. Highest seedling and sapling density was recorded by *Dimocarpus longan* with a value of 120.83 seedlings/ 100m^2 and 404.16 sapling /100m^2. The second highest seedling and sapling density was recorded in *Goniothalamus cardiopetalus* with a value of 10.41 seedlings /100m^2 and 214.58 saplings /100m^2.

A total of 44.67% of species found in SG4 showed regeneration, of which 25.53% had fair regeneration, *Dimocarpus longan* and *Vernonia arborea* showed good regeneration. Eleven species had no regeneration and fifteen species were reappearing in the area. Seedling density was 519.79 regenerates /100m^2 and sapling density was 507.29 regenerates /100m^2. Highest seedling and sapling density was recorded by *Dimocarpus longan* with a value of 447.91 seedlings/ 100m^2 and 265.62 saplings/ 100m^2. *Vernonia arborea* recorded the second highest seedling and sapling density with a value of 33.33 seedlings /100m^2 and 22.9 saplings /100m^2.

Dimocarpus longan, *Nothapegia racemosa*, *Litsea oleoides* and *Schleichera oleosa* showed good regeneration in SG5, followed by nine species showing fair regeneration. Eleven species showed poor regeneration. 33.33% of species were found without any regenerates and 18.52% of species found only in regenerating stage. Seedling and sapling density were recorded to be 504.16 regenerates/ 100m^2 and 380.55 regenerates/ 100m^2 respectively. Highest seedling and sapling density was shown by *Dimocarpus longan* with a value of 176.38 seedlings/ 100m^2 and 204.86 sapling/ 100m^2. *Nothopegia racemosa* showed the second highest density of seedlings (159.72 /100m^2) and saplings (12.5 /100m^2).

In SG6, *Canarium strictum*, *Elaeocarpus tuberculatus*, *Exocoecaria crenulata* and *Schleichera oleosa* showed good regeneration. Fair and poor regeneration was observed in 20.25% and 12.65 % of the total species respectively. 19% of species did not show any regeneration while, 43.04% of species had no matured individuals in the studied area. The seedling density was 235.79 regenerates /100m^2 and sapling density was 604.54/100m^2. The highest density was recorded by *Schleichera oleosa* with a value of 113.63 seedlings /100m^2 and 164.2 saplings /100m^2, followed by *Dimocarpus longan* with a value of 8.52 regenerates /100m^2 and 118.75 regenerates /100m^2 respectively.

Of the 87 species recorded in SG7, 23 species had no regeneration. However, *Dimocarpus longan*, *Nothapegia racemosa* and *Syzygium laetum* showed good regeneration followed by 13.79% of species showing fair regeneration and 27.58% of species with poor regeneration status. Of the total species, 28.73% were found to be reappearing in the sacred grove. The seedling and sapling density were found to be 137.02 regenerates /100m^2 and 385.12 regenerates /100m^2 respectively. *Dimocarpus longan* showed highest density with regard to seedlings (58.54/100m^2) and saplings (89.55/100m^2). Second highest density of seedlings (13.92/100m^2) and saplings (43.35 /100m^2) was shown by *Syzygium laetum*.

Among the eight sacred groves, SG8 showed highest percentage of no regeneration (42.71%). Only four species showed good regeneration. Poor regeneration was observed in 14.58% of species while 19.79% of species were found to be reappearing. Seedling density was 319.15 regenerates /100m^2 and sapling density was 353.24 regenerates /100m^2 in this sacred grove. Highest seedling and sapling density was shown by *Dimocarpus longan* with a value of 198.70 seedlings/ 100m^2 and 131.16 saplings/ 100m^2. *Nothopegia racemosa* showed second highest seedling (78.57 regenerates /100m^2) and sapling (21.75 regenerates /100m^2) density.

In a wider sense, the term regeneration applies to all life stages of the plant beginning with flowering and ending with formation of adult trees, passing through the stages of fruits, seeds, seedlings, saplings and poles [27]. Therefore, in a forest, the population structure at each life stages, viz., adult trees, flower, fruit, seed, seedling, sapling, and pole determine the structure of mature tree populations of the future. The forest communities depend on adequate regeneration of tree species to be healthy and sustainable. A population structure characterized by the presence of sufficient number of seedlings, saplings, and young trees implies satisfactory regeneration behavior, while inadequate number of seedlings and saplings of tree species in a forest indicates poor regeneration [28]. The regeneration behavior of different species is characterized by their population structure, which in turn depends upon the presence of adequate number of seedlings, saplings, and mature trees. The whole process is dependent on the internal community process and exogenic disturbances. Micro-environment and characteristics of local canopy are important for the germination and survival of seedlings and sprouts [29]. Environmental factors such as fire, light, grazing, canopy density, soil moisture, soil nutrients and anthropogenic activities also affect the process of regeneration [30].

Chauhan *et al.*, [31] opined that the species composition of forests depends on the regeneration of species composing the forest in space and time. As the degree of disturbance increase, the abundance and composition of regenerating species change. In the present study, overall regeneration was observed to be healthy in five sacred groves except SG3, SG6 and SG7. In these three sacred groves, number of class-I regenerates found to be lesser than other three classes. Grazing, logging, presence of mud roads and collection of firewood could be the reason for this. Chauhan *et al*. [32] opined that the regeneration of a species does not account for its adult density: meaning there is no linear relationship between seedling density and adult density of a species. Jones *et al.*, [33] opined that seedling layer in various forests differs in composition from their respective overstories. Similar results were observed for the present study areas where the similarity between the adult and regenerating tree species composition varied greatly among the sacred groves.

Regeneration status of each tree species in the studied sacred groves showed an overview of possible tree species composition in the near future. Invariably, tree species with no regeneration status and reappearing status were higher than to regenerating status. Nazir *et al.*, [34] reported that overall maximum percentage of species showed no regeneration followed by fair, good and poor regeneration for sacred and protected landscapes of Garhwal Himalaya, India. In the sacred grove of Manipur, greater number of tree species had good and fair regeneration followed by reappearing species and a very few species showed no regeneration [35]. Gunaga *et al*., [17] reported better regeneration status in the kaan forests of Shimoga, Central Western Ghats. Present study results hence indicate the possible changes in the floristic composition of these sacred groves in the coming future.

Considerably high density was observed for seedlings (325.73/100 m^2) and saplings (518.02 /100m^2 in the study areas. Chauhan *et al*., [31] recorded 158.7 seedlings and 496.0 saplings per hectare respectively in Terai-Bhabhar of Sohagibarwa Wildlife Sanctuary, India. Pokhriyal *et al.*, [36] reported a seedling density of 3.70 to 7.01 /100m^2 and a sapling density of 23.29 to 34.96/100 m^2 in the watersheds of Garhwal Himalaya. Nazir *et al.*, [34] reported the seedling density ranged from 11.36 to 18.74 seedlings/100 m^2 and sapling density from 8.84 to 15.2 saplings/100 m^2 in the sacred groves of Garhwal Himalaya, suggesting that lesser canopy opening and minimum gap creation could have resulted in the reduced seedling and sapling density in the area. Nagamtsu *et al*., [37] opined that canopy openness influences the survival rate of seedlings. Boraiah *et al*., [38] reported that more medicinally important plant species were found regenerating among disturbed sacred groves than either in conserved sacred groves or in reserve forests. But, the greater regenerate density found in the present study could be owed to soil characteristics, higher rainfall, very less anthropogenic activities and protection from the local people, as there was no positive relation was observed between canopy openness and regenerate density.

In the present study, it was observed that, *Dimocarpus longan* had the highest number of regenerates in all the study sites. Although the adult individuals of this species were not observed in SG3, seedling and sapling density was highest in it.

Degree of disturbance

Of the eight sacred groves, encroachment and conversion into coffee plantation was observed in SG1, SG2, SG3 and SG6. Sanskritization i.e., construction of concrete temples replacing age-old nature worshipping was observed in SG5, SG7 and SG8. Grazing, presence of footpath and collection of firewood were common in almost all the sacred groves.

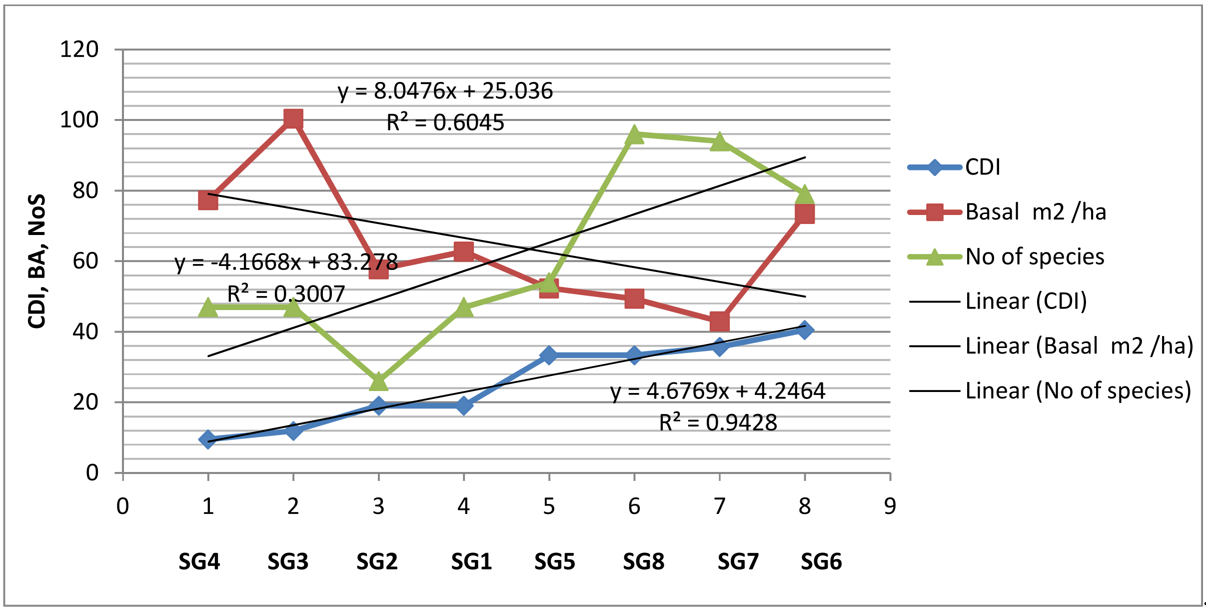

Figure 5: CDI in terms of Number of species and basal area among the eight sacred groves, Mercara, Central Western Ghats

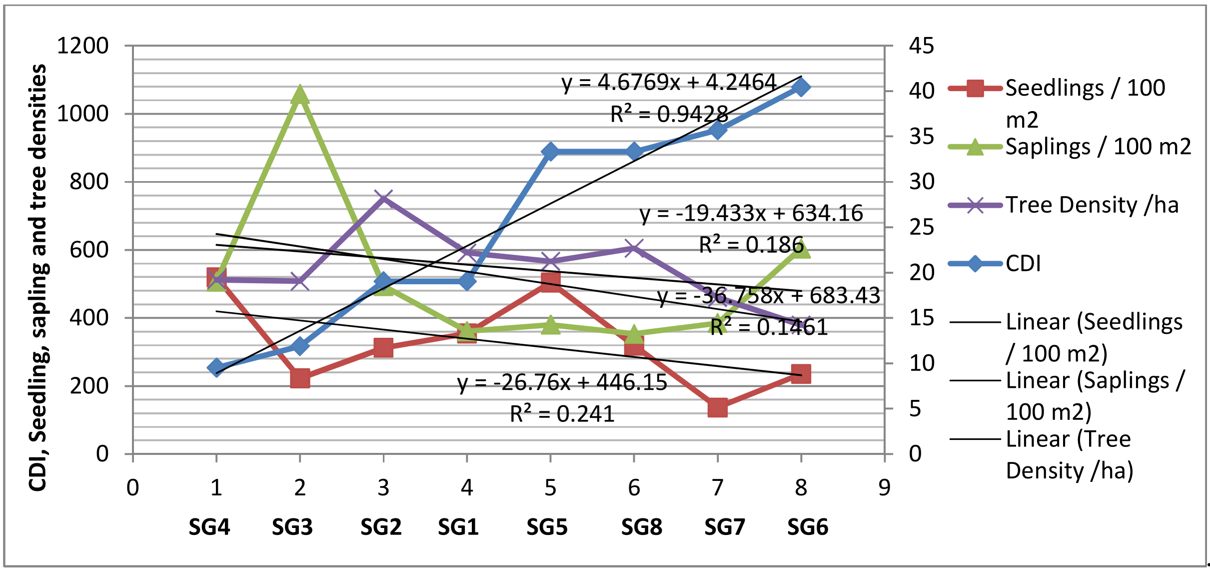

Figure 6: CDI in terms of Tree density, seedling density and sapling density among the eight sacred groves, Mercara, Central Western Ghats

Combined disturbance index values among the study sites varied greatly. The lowest value of 9.52% at SG4 and highest value 0f 40.47% at SG6 were recorded. An inversely proportional relationship was observed between CDI values and values of basal area, tree density, seedling density and sapling density while, number of species increased as the degree of disturbance increased (Figures 5 and 6).

During the study, it was observed that in many of the sacred groves, anthropogenic activities such as firewood collection, grazing and soil removal are prohibited and considered as a taboo till today. With the passing time and younger generation, these beliefs are wearing off. As a result, these untouched forest fragments are shrinking and the sanctity is becoming diluted. It was observed that as the area of sacred groves increased, human activities were also increased. However, as the degree of disturbance increased, species richness was also found to be increased. It has been argued that species richness and diversity decrease from undisturbed study area to disturbed area [4, 25, 39, 40]. Mishra *et al.*, [26] have emphasized that the activities of humans often do more to accelerate species loss than the operations of internal biological processes. However, an improved diversity at a moderate disturbance has also been reported. For example, forest grazing promoted regeneration of tree seedlings in conifer forests when grazing intensity was not too high [41]. Apart from species richness, all the parameters such as basal area, tree density, seedling density and sapling density were found to be decreasing as the disturbance level increased.

CONCLUSION

During the study, considerably, a high species richness, density and basal area were recorded in these sacred groves. A greater seedling and sapling densities were observed in all the study areas. Distribution of regeneration classes indicated a healthy and sustainable regeneration. However, evaluation of regeneration status of each tree species revealed that only 37.93% of tree species were regenerating and 30.6% of species were without any seedlings and saplings. An average of 31.45% of species was reappearing to these groves. As the degree of disturbance increased, basal area, tree density, seedling and sapling densities were found to be decreased and species richness was found to be increasing. Similarity between the adult and regenerating tree species ranged between 35% to 65% indicating a sure change in the tree species composition of these sacred groves in the coming years. All these results point towards the loss of originality of these pristine forest patches. Hence it becomes necessary to create awareness and support the local beliefs so that the joint management of these groves addresses the conservation efforts efficiently.

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