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Original Article

Tree Diversity and Their Regeneration in the Sacred Groves of Virajpet, Central Western Ghats, India

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Abstract

Sacred groves are one of the finest examples of informal way of conserving the forest wealth. Baseline data collection of their diversity, distribution and regeneration capacity becomes necessary for the management and conservation of these undisturbed forest patches. In this context, the present investigation was carried out using random quadrat method in the sacred groves of Virajpet, Karnataka, India. A total of 132 tree species belonging to 113 genera and 45 families were identified within five sacred groves. Higher basal area (51.73-85.65 m^2/ha) and tree density (453.33-515.9 individuals/ha) were observed as compared to other forests of Western Ghats region. The present investigation has revealed a healthy regeneration of tree species. Seedling and sapling composition differed to some extent from the mature tree species composition which could be used in predicting the future possibilities. Protection and conservation of such sacred groves should be of interest, for better regeneration of the rich diversity they harbour.

Keywords: conservation, density, Kodagu, regenerates, tropical forests

Introduction

The diversity of tree species is a fundamental component of total biodiversity in many ecosystems as they are the ecosystem engineers that provide resources and habitats for almost all other forest organisms. In tropical forests, trees form the major structural and functional basis of forest ecosystems and can serve as robust indicators of changes and stressors of the landscape (Jayakumar and Nair, 2013). Understanding their diversity, distribution pattern and regeneration would help in evaluating the complexity and potential resources of the forest. Further, management of a forest requires baseline data on understanding its composition, the effects of past impacts on the present status and the relationship of the forest with surrounding land uses (Devi and Yadav, 2006).

Sacred groves, as an example of informal way of protecting and managing the forest ecosystems, have been proved to sustain rich biodiversity as well as greater ecological services (Raghavendra and Kushalappa, 2011). In fact, they represent patches of virgin forest left as it is, in the name of local deity and are protected by the local people due to their cultural and religious beliefs and taboos that the deities reside in them (Khan *et al*., 2008). As they are protected for centuries, sacred groves harbour climax vegetation and relic specimens of plant world. They are known to possess endemic as well as threatened species. Ecological significance of sacred groves can be explained by the biological diversity found within them. The conservation of biodiversity is of foremost importance. Also, conservational attitude towards natural resources passed on through cultural beliefs to the younger generations is of immense importance.

Sacred groves of Karnataka are mainly found on the Western Ghats region. Though studies on assessment of biodiversity and management system of these sacred groves are taken up, vegetation analysis and regeneration studies are limited. Therefore, the present investigation was undertaken to evaluate the diversity, distribution and regeneration status of arboreal species of five sacred groves of Virajpet, Central Western Ghats.

Materials and Methods

Study area

Kodagu is one of the highly wooded Western Ghats regions of Karnataka, India. The altitude of the district ranges between 850 and 1,745 m. The average temperature varies from 14.2 °C (winter) to 28.6 °C (summer). The average annual rainfall is 2,725.5 mm, received mainly from South-Western monsoon concentrated during the months of June to September. Soil type of the area varies greatly due to geological heterogeneities, although sandy loamy soil type was found in the study sites. It is majorly composed of semi-evergreen to evergreen forests (Keshavamurthy and Yoganarasimhan, 1990).

The study was undertaken in five sacred groves of Virajpet, Kodagu District (Fig. 1). Higher density of sacred groves is found in this district, making it a 'hotspot of sacred groves' in the world (Raghavendra and Kushalappa, 2011). The district has 1,214 sacred groves covering an area of 2,550 ha, of which 508 sacred groves covering an area of 872.13 ha are in Virajpet. Of the five sacred groves studied (Table 1), SG1 has concrete temple

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constructed, SG2 and SG3 have medium sized temples, whereas remaining groves still enjoy nature worship. The deities in the groves are worshipped once a year during March/April.

Data collection and analysis

Field exploration was undertaken to record the tree species composition of the sacred groves. Quadrats of 20 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 (Saldanha, 1984; Pascal and Ramesh, 1987; Keshavamurthy and Yoganarasimhan, 1990; Saldanha, 1996; Poornika *et al*., 2011) 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 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 Shankar (2001), with some modifications: good regeneration - if seedlings > saplings > adults; fair regeneration - if seedlings > or < saplings > or < adults; poor regeneration - if the species survive only at sapling stage or only as seedling stage (seedlings and saplings may be less or more or equal to adults); no regeneration - if a species was present only in adult form; reappearing/immigrating- if the species has no adults, but only seedlings or saplings.

Floristic diversity was measured by using Simpson Index of Diversity (1-D) (Simpson, 1949), Shannon and Wiener's Index of Diversity (H) (Shannon and Wiener, 1963) and Pielou's Evenness Index (J') (Pielou, 1966). Importance Value Index (IVI) of each tree species was determined (Curtis and McIntosh, 1950) calculating frequency, density and basal area. Similarity was determined by Sorenson's Similarity Index (Sorenson, 1948). 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 impact 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 was expressed in-terms of all fourteen parameters as percentage of Combined Disturbance Index (CDI) (Gunaga *et al*., 2013). CDI values were compared with basal area, number of species, tree density, seedling density and sapling density of each sacred grove for possible correlation.

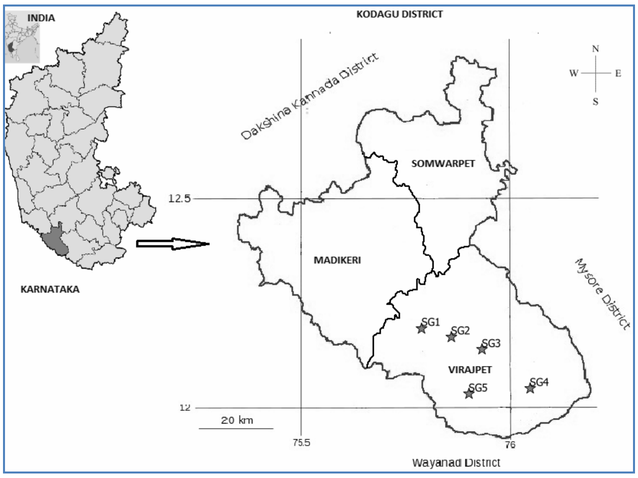

Fig. 1. Map of study area

Results

A total of 132 tree species belonging to 113 genera and 45 families were identified in the five sacred groves of Virajpet, Kodagu district, India. Of these, 105 species had mature individuals and 27 species were recorded only in regenerating stage (reappearing/immigrating status). Of the 45 families, Lauraceae was represented by the maximum of eleven species, followed by Euphorbiaceae, Fabaceae (ten species each) and Moraceae (nine species). Twenty one families were represented by single species (Table 2).

Higher species richness was observed in all the sacred groves. However, lowest and highest values were recorded in SG5 and SG2 respectively. Overall, Shannon's index value was 3.3228, Simpson's index value was 0.9424 and Pielou's index value was 0.8586. On average, basal area of 68.5721 m^2/ha and tree density of 477.48 individuals/ha was recorded (Table 2). All the five sacred groves showed a reverse-J shaped curve for different girth classes (Fig. 1). Overall, 61.84% of individuals found in the study sites were within 30-90 cm girth class. Only 5.14% of mature individuals were in the group with >270 cm girth class.

Reverse J-shaped curve was observed in SG1, SG3 and SG4 for four regeneration classes (Fig. 3). Percentage of class I was lesser than class II and class III in SG2 and SG4 respectively altering the reverse J-shaped curve. Regeneration status of each tree species was tabulated (Table 2). Overall, 42.07% of tree species showed regeneration (Fig. 4), of which 9.31% of species had good regeneration, 13.20% of species had fair regeneration and 19.55% of species had poor regeneration status, while 26.08% of tree species had no regeneration and 31.82% of species had no mature individuals. Seedling and sapling densities among the sacred groves varied greatly. Higher seedling and sapling densities (855.35 regenerates/100 m^2 and 641.96 regenerates/100 m^2 respectively) were recorded from SG5 and lowest from SG4.

Among the groves, Sorenson's similarity index value ranged from 57.55% (SG1 and SG4) to 69.86% (SG3 and SG4) (Table 4). It was observed that nine species namely *Antidesma montanum*, *Artocarpus heterophyllus*,

Table 1. Geographical details of the study area

Name of the studied sacred grove	Residing deity	Area (acres)	Location	Elevation
Betoli sacred grove (SG1)	Bhadrakali	23.83	N12° 11.339' E75° 47.291'	882 m
Kolthodu sacred grove (SG2)	Ayyappa	29.2	N12° 10.107' E75° 51.550'	842 m
Huduru sacred grove (SG3)	Ayyappa	16.54	N12° 08.288' E75° 55.965'	877 m
Thaila sacred grove (SG4)	Ayyappa	25.1	N12° 02.707' E76° 02.862'	877 m
Birunani sacred grove (SG5)	Ayyappa	15.62	N12° 01.908' E75° 54.069'	824 m

Artocarpus hirsutus, *Celtis tetrandra*, *Caryota urens*, *Cinnamomum malabatrum*, *Dimocarpus longan*, *Glochidion ellipticum* and *Mangifera indica* were common to all the sacred groves with good density of mature individuals. However, of these, *Dimocarpus longan* showed good regeneration with higher number of seedlings and saplings in all the sacred groves.

Betoli sacred grove (SG1)

A total of 67 tree species belonging to 56 genera and 33 families were recorded from SG1 sampling area, among which 16 species were represented by one individual (singleton species) and 17 species had no mature individuals. Tree density and basal area were recorded to be 515.9 individuals/ha and 64.14 m^2/ha respectively.

Table 2. Importance Value Index values and regeneration status of tree species among the five sacred groves in Virajpet, Kodagu district

Sl no	Botanical name	Family name	SG1		SG2		SG3		SG4		SG5	
			IVI	RS	IVI	RS	IVI	RS	IVI	RS	IVI	RS
1	*Holigarna arnottiana* Hook. f.	Anacardiaceae	1.2025	N	-	-	-	-	-	-	-	-
2	*Holigarna grahamii* (Wight) Kurz.	Anacardiaceae	2.4831	P	16.9601	P	-	R/I	13.8901	P	6.0373	P
3	*Holigarna nigra* Bourd.	Anacardiaceae	1.1589	N	2.2718	F	-	R/I	-	R/I	-	-
4	*Mangifera indica* L.	Anacardiaceae	2.7168	F	3.5552	G	7.029	F	1.1586	P	3.4546	F
5	*Nothopegia racemoosa* (Dalz.) Ramam.	Anacardiaceae	18.6243	G	6.9872	G	-	R/I	7.2105	G	22.1141	G
6	*Spondias pinnata* (L. f.) Kurz	Anacardiaceae	-	-	4.1579	N	3.4119	N	8.8182	P	1.9819	N
7	*Goniothalamus cardioupetalus* (Dalz.) Hook. f. & Thoms.	Annonaceae	-	-	-	R/I	-	R/I	-	R/I	-	R/I
8	*Alstonia scholaris* (L.)R. Br.	Apocynaceae	1.5129	N	2.4454	N	-	-	-	-	-	-
9	*Tabernaemontana heyneana* Wall.	Apocynaceae	1.4023	N	1.1855	N	-	R/I	1.9485	N	1.9422	P
10	*Caryota urens* L.	Arecaceae	19.2563	F	2.1588	P	18.4811	F	0.9946	P	21.7639	P
11	*Vernonia arborea* Ham.	Asteraceae	-	-	-	R/I	-	-	-	-	-	-
12	*Stereospermum colais* (Buch.-Ham. Ex Dillw.)	Bignoniaceae	-	-	-	-	21.9126	P	5.7744	N	9.8832	N
13	*Pajanelia longifolia* (Willd.) K. Schum.	Bignoniaceae	1.2585	N	-	-	-	-	-	-	-	-
14	*Canarium strictum* Roxb.	Burseraceae	29.0486	P	19.8749	P	-	R/I	5.358	P	2.6222	N
15	*Euonymus indicus* Heyne ex Wall.	Celastraceae	6.7661	F	1.109	F	-	R/I	-	R/I	-	R/I
16	*Euonymus* sps	Celastraceae	-	R/I	-	-	-	-	-	-	-	-
17	*Cassine glauca* (Rottb.) Kuntze	Celastraceae	-	-	-	R/I	-	-	-	R/I	-	R/I
18	*Calophyllum polyanthum* Wall. ex Choisy.	Clusiaceae	-	-	-	-	-	-	5.905	P	-	-
19	*Garcinia gummi-gutta* (L.) Robson.	Clusiaceae	-	R/I	-	R/I	-	R/I	-	-	-	R/I
20	*Mesua ferrea* L.	Clusiaceae	-	-	3.7262	N	-	-	-	-	-	-
21	*Garcinia indica* (Thouars) Choisy	Clusiaceae	-	-	0.9754	N	-	-	-	-	-	-
22	*Terminalia paniculata* Roth	Combretaceae	-	-	-	-	2.05	N	-	-	-	-
23	*Mastixia arborea* (Wight) Bedd.	Cornaceae	-	-	4.0671	F	-	-	3.8641	G	-	-
24	*Dichapetalum gelonioides* (Roxb.) Engl.	Dichapetalaceae	-	R/I	-	-	-	-	-	-	-	R/I
25	*Hopea ponga* (Dennst.) Mabberly	Dipterocarpaceae	-	-	-	-	1.4688	P	-	-	-	-
26	*Vateria indica* L.	Dipterocarpaceae	-	-	-	-	-	-	-	-	28.1918	G
27	*Diospyros montana* Roxb.	Ebenaceae	1.2748	N	-	-	-	-	-	R/I	-	-
28	*Diospyros candolleana* Wight	Ebenaceae	-	-	2.0929	N	-	-	1.2474	N	-	-
29	*Diospyros crumenata* Thw.	Ebenaceae	-	-	-	R/I	-	-	0.9491	N	-	-
30	*Elaeocarpus serratus* L.	Elaeocarpaceae	1.2705	N	1.2238	N	3.4668	N	-	-	-	-
31	*Elaeocarpus tuberculatus* Roxb.	Elaeocarpaceae	-	-	-	-	3.5183	N	-	-	3.5329	F
32	*Antidesma montanum* Blume.	Euphorbaceae	5.1093	N	6.6833	G	1.6138	P	4.9892	P	6.0639	P
33	*Bischofia javanica* Bl.	Euphorbaceae	-	-	-	-	-	R/I	1.3022	P	-	-
34	*Glochidion ellipticum* Wight.	Euphorbaceae	6.0024	P	5.5751	P	3.6079	N	5.1798	N	1.9925	N
35	*Mallotus philippensis* (Lam) Muell.-Arg.	Euphorbaceae	-	-	0.9582	P	1.4688	F	7.978	F	7.6063	P
36	*Mallotus tetracoccus* (Roxb.) Kurz.	Euphorbaceae	2.5175	N	6.2706	P	36.7543	N	5.4663	N	-	-
37	*Cleidion javanicum* Bl.	Euphorbaceae	-	R/I	-	R/I	-	-	20.614	G	-	-
38	*Macaranga peltata* (Roxb.) Mueller	Euphorbaceae	-	-	-	-	-	-	2.3768	N	8.9266	N
39	*Aporusa lindleyana* (Wt.) Bail.	Euphorbaceae	-	-	-	R/I	-	R/I	-	R/I	-	R/I
40	*Antidesma menasu* Miq. Ex Tul.	Euphorbaceae	-	-	7.7997	N	-	-	-	-	-	-
41	U1	Euphorbaceae	-	-	1.0902	N	-	-	-	-	-	-
42	*Acrocarpus fraxinifolius* Wight & Arn.	Fabaceae	-	R/I	-	R/I	-	-	-	-	-	R/I
43	*Archidendron monadelphum* (Roxb.) Nielson.	Fabaceae	-	-	-	-	-	-	-	-	9.1067	P

45	*Pongamia pinnata* (L.) Pierre	Fabaceae	-	-	-	-	7.8627	P	-	-	-	-
46	*Albizia chinensis* (Osb.) Merr.	Fabaceae	-	-	-	-	5.3207	N	-	-	-	-
47	*Butea monosperma* (Lam.) Taub.	Fabaceae	-	-	-	-	1.5716	N	-	-	-	-
48	*Erythrina variegata* L.	Fabaceae	-	-	1.0939	N	-	-	-	-	-	-
49	*Humboldtia brunonis* Wall.	Fabaceae	-	R/I	-	-	-	-	-	-	-	-
50	*Saraca asoca* (Roxb.) de Wilde.	Fabaceae	-	-	-	-	-	-	5.2178	F	-	-
51	*Bauhinia purpurea* L.	Fabaceae	-	-	-	R/I	-	-	-	-	-	-
52	*Flacourtia Montana* Graham	Flacourtiaceae	-	-	-	-	-	R/I	1.9337	P	-	-
53	*Scolopia crenata* (Wight & Arn.) Clos	Flacourtiaceae	2.6953	P	4.3869	P	-	R/I	5.5362	P	1.935	N
54	*Hydnocarpus pentandra* (Buch.-Ham) Oken	Flacourtiaceae	4.1827	P	10.0081	P	23.1801	F	25.5181	F	-	R/I
55	*Apodytes dimidiata* E. Meyer ex Arn.	Icacinaceae	1.1752	N	0.9537	N	1.471	N	1.0524	N	-	-
56	*Nothapodytes nimmoniana* (Graham) Mabberley	Icacinaceae	-	-	-	R/I	-	R/I	-	R/I	1.9751	P
57	*Actinodaphne malabarica* Balak.	Lauraceae	-	-	3.1586	F	-	R/I	-	R/I	2.8365	F
58	*Cinnamomum malabatrum* (Burm. F.) Bl.	Lauraceae	22.2897	F	9.2068	F	3.9461	G	9.4092	G	9.5722	G
59	*Litsea floribunda* (Bl.) Gamble	Lauraceae	2.8485	F	1.9292	N	-	R/I	5.5774	P	6.0134	P
60	*Litsea oleoides* (Meissn.) Hook. f.	Lauraceae	-	R/I	5.7392	N	-	-	2.2189	N	2.2474	P
61	*Neolitsea zeylanica* (Nees) Merr., Philip.	Lauraceae	1.7071	N	-	-	-	-	2.3178	N	-	-
62	*Persea macrantha* (Nees) Kosterm.	Lauraceae	2.3222	N	-	-	1.9964	N	-	-	-	R/I
63	*Cryptocarya bourdillonii* Gamble.	Lauraceae	4.7525	G	-	-	-	-	-	-	-	R/I
64	*Cryptocarya* sps	Lauraceae	-	-	-	-	-	-	-	-	-	R/I
65	*Litsea laevigata* (Nees) Gamble	Lauraceae	-	R/I	-	-	-	-	-	-	-	-
66	*Litsea mysorensis* Gamble	Lauraceae	1.1458	P	0.9524	F	-	-	-	-	-	R/I
67	*Cinnamomum verum* J.S.Presl	Lauraceae	-	-	-	R/I	-	-	3.0842	N	-	-
68	*Leea indica* (Burm. F.) Merr.	Leeaceae	1.329	F	-	R/I	-	R/I	-	R/I	-	R/I
69	*Fagraea ceilanica* Thumb.	Loganiaceae	1.1656	P	-	-	-	-	-	-	-	-
70	*Lagerstroemia microcarpa* Wight	Lythraceae	-	-	-	-	4.0111	N	11.667	N	-	-
71	*Magnolia champaka* L.	Magnoliaceae	-	R/I	0.9511	N	6.8693	P	1.9448	N	-	-
72	*Memecylon malabaricum* (C.B. Clarke) Cogn.	Melastomataceae	3.5277	G	-	-	-	R/I	-	-	-	R/I
73	*Memecylon umbellatum* Burm.f.	Melastomataceae	-	-	-	R/I	-	-	-	-	-	-
74	*Memecylon edule* Roxb.	Melastomataceae	-	-	-	R/I	-	-	-	-	-	-
75	*Memecylon* sps	Melastomataceae	-	-	-	R/I	-	-	-	-	-	-
76	*Aphanamixis polystachya* (Wall.) Parker.	Meliaceae	-	-	-	R/I	1.4732	N	-	-	-	-
77	*Dysoxylum malabaricum* Bedd. ex Heirn	Meliaceae	25.4298	N	-	-	-	-	-	-	-	-
78	*Melia composita* Willd.	Meliaceae	-	-	-		1.4732	P	-	-	-	-
79	*Trichilia connaroides* (Wight & Arn.) Bentevelzen	Meliaceae	-	-	-	-	1.4829	G	0.9491	N	-	-
80	*Reinwardtiodendron anamalaiense* (Bedd.) Mabb.	Meliaceae	-	-	-	-	-	-	6.5966	G	-	-
81	*Aglaia barberi* Gamble	Meliaceae	-	-	3.1639	N	-	-	-	-	-	-
82	*Antiaris toxicaria* Lesch.	Moraceae	-	R/I	8.3969	N	-	-	-	-	-	-
83	*Artocarpus heterophyllus* Lam.	Moraceae	7.6116	F	11.3435	F	1.471	F	2.2046	P	20.9634	F
84	*Artocarpus hirsutus* Lam.	Moraceae	2.3632	F	9.2062	F	4.9829	G	12.0628	F	4.6637	F
85	*Ficus amplissima* Smith	Moraceae	-	-	1.214	N	1.6085	N	1.0109	N	2.571	N
86	*Ficus hispida* L. f.	Moraceae	1.2057	F	2.8287	P	4.4157	F	2.3187	F	-	-
87	*Artocarpus gomezianus* Wall. Ex Trec.	Moraceae	-	-	-	-	-	-	-	-	2.0254	P
88	*Ficus tsjahela* Rheede ex Burm. F.	Moraceae	-	-	8.3063	N	-	-	-	-	-	-
89	*Ficus exasperata* Vahl.	Moraceae	-	-		R/I	-	-	-	-	-	-
90	U1	Moraceae	-	-	0.9772	N	-	-	-	-	-	-
91	*Myristica dactaloides* Gaertn.	Myristicaceae	8.9227	P	6.1844	P	-	-	-	R/I	-	-
92	*Ardisia solonaceae* Roxb.	Myrsenaceae	-	-	-	-	-	R/I	-	R/I	-	-
93	*Syzygium sps*	Myrtaceae	4.014	P	-	R/I	1.4776	F	-	-	2.0124	N
94	*Syzygium hemisphericum* (Wight) Alston	Myrtaceae	-	R/I	-	-	-	-	-	-	-	-
95	*Syzygium zeylanicum* (L.) DC.	Myrtaceae	-	R/I	-	-	-	R/I	1.0606	F	-	-
96	*Syzygium cuminii* (L) Skeels	Myrtaceae	-		28.1666	F	14.7571	P	25.2512	N	4.344	N
97	*Chionanthus mala-elengi* (Dennst.) Green.	Oleaceae	-	-	3.7364	F	3.6984	F	1.0133	P	1.9785	P
98	*Olea dioica* Roxb.	Oleaceae	8.8503	P	0.9968	P	1.4688	P	-	R/I	7.6894	F

99	*Olea paniculata* R. Br.	Oleaceae	-	-	-	-	-	-	1.0047	N	-	-
100	*Ziziphus xylopyrus* (Retz.) Willd	Rhamnaceae	-	-	-	-	-	-	-	R/I	-	-
101	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	-	-	-	-	-	-	-	-	-	R/I
102	*Canthium dicoccum* (Gaertn.) Teijsm. & Binn.	Rubiaceae	1.1458	P	-	-	-	-	-	-	-	-
103	*Ixora brachiata* Roxb.	Rubiaceae	-	R/I	-	R/I	-	R/I	-	R/I	-	R/I
104	*Pavetta indica* L.	Rubiaceae	-	-	-	-	-	R/I	-	-	-	R/I
105	*Psychotria nigra* (Gaert.) Alston	Rubiaceae	-	R/I	-	R/I	-	R/I	-	R/I	-	-
106	*Wendlandia thyrsoidea* (Roth.) Steud	Rubiaceae	-	-	-	-	-	-	1.1732	N	-	-
107	*Ixora nigricans* R. Br. Ex Wight & Arn.	Rubiaceae	-	R/I	-	R/I	-	R/I	-	R/I	-	R/I
108	*Meyna laxiflora* Robyns	Rubiaceae	-	-	1.9935	N	-	R/I	4.0909	P	2.3828	P
109	*Psychotria truncata* Wall.	Rubiaceae	-	R/I	-	-	-	R/I	-	-	-	-
110	*Atalantia* sps	Rutaceae	-	-	-	-	-	-	-	R/I	-	-
111	*Euodia lunu-ankenda* Merr.	Rutaceae	4.5147	P	5.9624	N	1.551	N	0.9985	N	3.0441	N
112	*Atalantia monophylla* (L.) DC.	Rutaceae	-	R/I	-	R/I	-	R/I	-	-	-	R/I
113	*Vepris bilocularis* (Wight & Arn.) Engl.	Rutaceae	-	-	1.7146	N	-	-	2.3204	N	-	-
114	*Acronychia pedunculata* (L.) Miq.	Rutaceae	5.6573	P	-	R/I	-	R/I	5.9701	N	12.4148	N
115	*Scleropyrum pentandrum* (Dennst.) Mabb	Santalaceae	1.5129	N	-	-	-	R/I	-	-	-	-
116	*Dimocarpus longan* Lour.	Sapindaceae	28.2142	G	13.095	G	16.5608	G	5.6827	G	51.1393	G
117	*Herpullia arborea* (Blanco) Radlk.	Sapindaceae	1.2153	N	-	-	-	-	5.3519	F	-	-
118	*Sapindus trifoliatus* auct. Non. L	Sapindaceae	-	-	-	-	-	R/I	4.3247	F	-	-
119	*Chrysophyllum roxburghii* G. Don.	Sapotaceae	1.1571	F	12.1321	P	4.805	P	2.2491	F	-	R/I
120	*Mimusups elengi* L.	Sapotaceae	2.7441	N	1.8239	N	-	-	-	-	-	-
121	*Sterculia guttata* Roxb.	Sterculiaceae	-	-	2.3051	F	-	-	7.288	F	-	R/I
122	*Symplocos macrophylla* Wall. ex A. DC	Symplocaceae	2.4101	F	1.986	P	-	-	-	-	4.7937	G
123	*Eurya nitida* Korth.	Theaceae	-	-	-	-	-	-	-	-	6.3382	N
124	*Grewia tiliifolia* Vahl.	Tiliaceae	-	-	-	-	18.1611	P	-	-	-	-
125	*Aphananthe cuspidate* (Bl.) Planch.	Ulmaceae	7.325	N	1.6127	N	16.5963	N	6.886	F	-	-
126	*Celtis tetrandra* Roxb.	Ulmaceae	6.2938	P	1.9183	F	2.9563	P	18.7388	F	3.1142	P
127	*Trema orientalis* (L.) Bl.	Ulmaceae	2.695	N	1.5389	N	10.0086	P	-	-	-	-
128	*Callicarpa tomentosa* (L.) Murr.	Verbenaceae	5.5043	F	3.9582	P	1.808	G	-	R/I	-	R/I
129	*Vitex altissima* L.f.	Verbenaceae	-	-	-	-	1.4754	F	-	-	-	-
130	*Clerodendrum infortunatum* L.	Verbenaceae	4.866	P	-	R/I	-	R/I	0.9491	G	1.935	F
131	*Tectona grandis* L.	Verbenaceae	-	-	-	-	25.2553	P	-	-	-	-
132	*Xanthophyllum arnottianum* Wt.	Xanthophyllaceae	15.5942	F	25.8827	F	-	R/I	-	-	8.784	F

RS=Regeneration status; G=Good, F=Fair, P=Poor, N=None, R/I=Reappearing/Immigrating

Among the species, *Cinnamomum malabatrum* recorded the highest density with 63.63 individuals/ha, followed by *Dimocarpus longan* (52.27 individuals/ha) and *Nathopegia racemosa* (50 individuals/ha). The highest basal area was shown by *Canarium strictum* (13.75 m^2/ha) followed by *Dysoxylon malabaricum* (5.47 m^2/ha) and *Dimocarpus longan* (3.37 m^2/ha). However, *Canarium strictum* scored the highest IVI value of 29.04, followed by *Dimocarpus longan* (28.21) and *Dysoxylon malabaricum* (25.42).

In the study area, 47.75% of species showed regeneration, 26.86% of tree species had no regenerates and 25.37% of species were recorded only in regenerating stage. *Dimocarpus longan* showed good regeneration (with 296.02 seedlings/100 m^2 and 104.54 saplings/100 m^2), whereas *Dysoxylum malaabricum* showed no regeneration and *Canarium strictum* showed poor regeneration (with 3.4 saplings/100 m^2).

Kolthodu sacred grove (SG2)

In SG2, 81 tree species belonging to 65 genera and 33 families were recorded, among which 20 (35.71%) were singleton species and 25 were found only in regenerating stage. A density of 457.14 individuals/ha and a basal area of 67.49 m^2/ha were observed in the study area. *Xanthophyllum arnottianum* showed the highest density (50 individuals/ha), followed by *Holigarna grahamii* (28.57 individuals/ha) and *Dimocarpus longan* (25 individuals/ha). *Syzygium cumini* showed the highest basal area of 15.91 m^2/ha with 12.5 individuals/ha, followed by *Canarium strictum* (7.33 m^2/ha with 21.42 individuals/ha) and *Xanthophyllum arnottianum* (5.70 m^2/ha). Highest IVI values were scored by *Syzygium cumini* (28.16) followed by *Xanthophyllum arnottianum* (25.88) and *Canarium strictum* (19.87).

Only four species (4.93%) showed good regeneration in this grove, whereas 14 species showed poor regeneration. However, 25 tree species each (30.8%) showed no regeneration as well as reappearing / immigrating status. *Syzygium cumini* (0.44 seedlings/100 m^2 and 0.44 saplings / 100 m^2) and *Xanthophyllum arnottianum* (3.125 seedlings/100 m^2 and 9.82 saplings/100 m^2) showed fair regeneration, where as *Canarium strictum* showed poor regeneration with only 0.44 seedlings/100 m^2. However, *Dimocarpus longan* recorded highest seedling (86.60 /100 m^2) and sapling (120.53/100 m^2) density, followed by *Nathopegia racemosa* (0.89 seedlings and 15.17 saplings per 100 m^2) and *Mastixia arborea* (1.78 seedlings/100 m^2 and 31.63 saplings/100 m^2).

Huduru sacred grove (SG3)

Along with 17 singleton species and 31 species with no mature individuals, SG3 recorded a total of 74 tree species belonging to 65 genera and 34 families. Tree density and basal area of the grove were 468.18 individuals/ha and 51.73 m^2/ha respectively. Highest basal area was showed by *Stereospermum colais* (6.85 m^2/ha with 22.72 individuals), followed by *Syzygium cumini* (6.14 m^2/ha with 4.54 individuals/ha) and *Hydnocarpus pentandra* (5.27 m^2/ha with 29.54 individuals/ha). However, higher tree density was observed by an entirely different set of species: highest value was observed in *Mallotus tetracoccus* (86.36 individuals/ha), followed by *Tectona grandis* (72.72 individuals/ha) and *Grewia tiliifolia* (38.63 individuals/ha). Higher IVI values were scored by *Mallotus tetracoccus* (36.75) followed by *Tectona grandis* (25.25) and *Hydnocarpus pentandra* (23.18).

Only 36.47% of the total species recorded in SG3 showed regeneration, of which 6.75% of species had good regeneration, 12.16% had fair regeneration and 17.56% of species had poor regeneration. A highest of 41.89% of tree species were recorded only at regenerating stage and 21.62% of species had no regenerates at all. Regeneration density was dominated by *Dimocarpus longan* in this grove, with a value of 346.02 seedlings and 157.35 saplings per 100 m^2 area. *Mallotus tetracoccus* showed no regeneration even though it had the highest tree density in the study area; *Tectona grandis* showed poor regeneration and *Hydnocarpus pentandra* showed fair regeneration.

Thaila sacred grove (SG4)

A total of 72 tree species belonging to 61 genera and 32 families were recorded at SG4, among which 17 were singleton species and 18 were only in reappearing / immigrating stage. Basal area and tree density of the study site recorded to be 85.65 m^2/ha and 453.33 individuals/ha respectively. Highest IVI values were scored by *Hydnocarpus pentandra* (25.51) followed by *Syzygium cumini* (25.25) and *Cleidion javanicum* (20.61). However, the highest density was showed by *Cleidion javanicum* (48.33 individuals/ha) and highest basal area was recorded by *Syzygium cumini* (16.18 m^2/ha).

No regeneration was observed in 31.08% of total species in this site, while 24.32% of species were reappearing/immigrating in the area. A total of 44.57% of species showed regeneration, of which 18.91% had poor regeneration. *Hydnocarpus pentandra* showed fair regeneration, *Syzygium cumini* showed no regeneration and *Cleidion javanicum* showed good regeneration in the study area. Overall, the lowest seedling and sapling density was observed in this sacred grove compared to other study areas. Highest seedling and sapling density was recorded by *Reinwardtiodendron anamalainse* (30.41 seedlings/100 m^2 and 39.16 saplings/100 m^2).

Birunani sacred grove (SG5)

The lowest species richness was observed in SG5 with 60 tree species belonging to 54 genera and 32 families, of which 47% (18 species) were singleton species and 22 species had no mature individuals. Values for basal area and tree density per ha were 73.84 m^2/ha and 492.85 individuals/ha respectively. *Dimocarpus longan* showed the highest IVI value (51.13), basal area (17.76 m^2/ha) and density (92.85 individuals/ha). *Vateria indica* showed the second highest basal area (10.58 m^2/ha with 39.28 individuals /ha) and *Caryota urens* showed second highest density (57.14 individuals/ha with a basal area of 2.29 m^2/ha).

In SG5, 43.32% of species showed regeneration, of which 21.66% had poor regeneration. However, 20% of recorded species had no regenerates and 36.66% of species were found only in regenerating stage. Tree species with high IVI values also showed good regeneration. Among the five sacred groves, SG5 recorded higher regeneration density, with a value of 855.35 seedlings/100 m^2 and 641.96 saplings/100 m^2. *Vateria indica* showed a good regeneration with 466.07 seedlings/100 m^2 and 217.85 saplings/100 m^2.

Among the five study sites, higher CDI value was recorded for SG1 (42.85%). Temple construction and the effect of pilgrims were observed in SG1. Grazing, presence of weeds and footpath were common in all the sacred groves. Basal area showed inversely proportional relationship with CDI values of the studied groves. However, species richness and densities (seedling, sapling and tree density) did not show a clear relation with CDI values *per se* (Fig. 5a and 5b).

Discussion

Depending on climatic, edaphic and biotic factors (Ayyappan and Parthasarathy, 1999), species richness

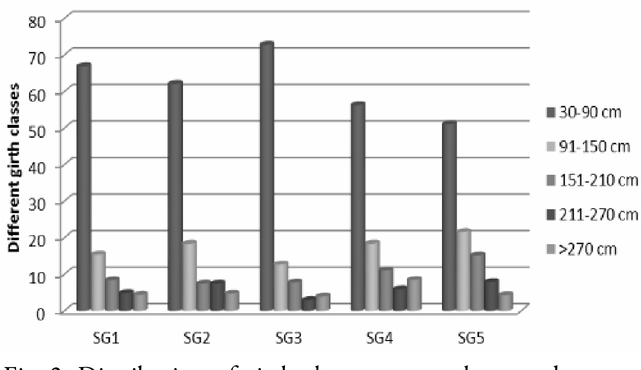

Fig. 2. Distribution of girth classes among the sacred groves, Virajpet

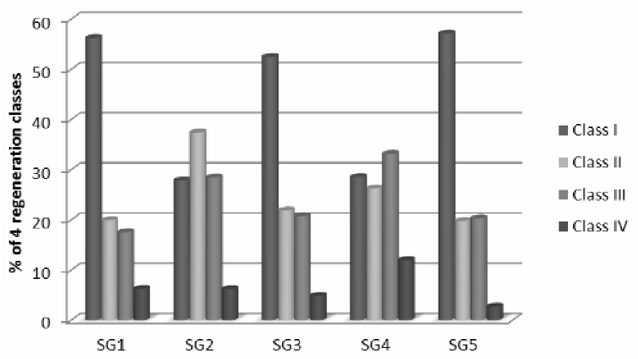

Fig. 3. Distribution of regeneration classes among the sacred groves, Virajpet

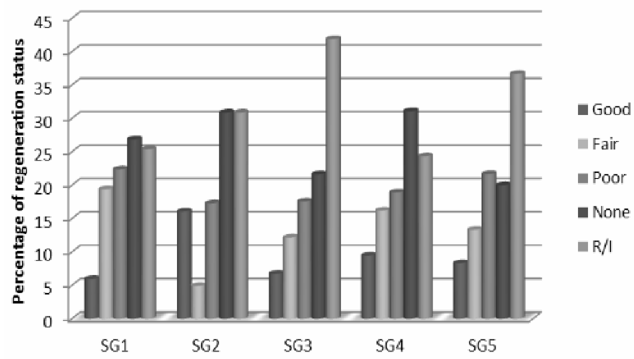

Fig. 4. Distribution of percentage of regeneration status of tree species in the five sacred groves, Virajpet

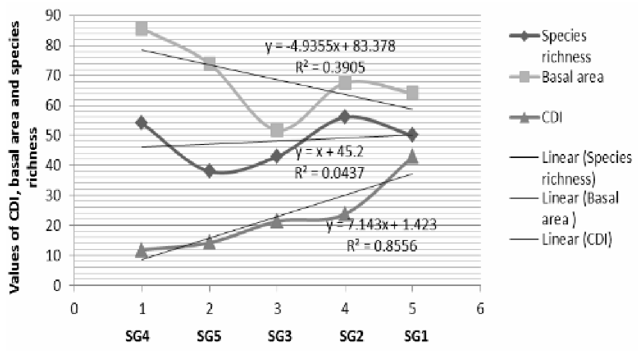

Fig. 5a. CDI values in terms of species richness and basal area in the sacred groves of Virajpet

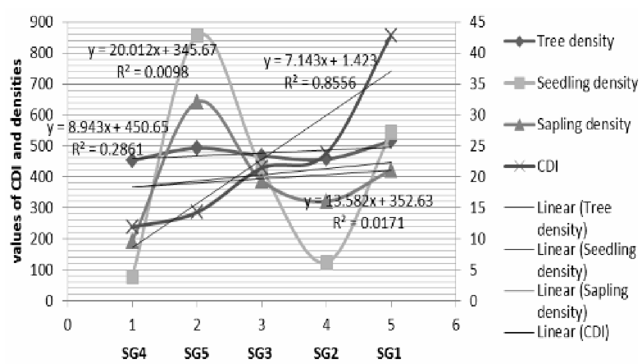

Fig. 5b. CDI values in terms of densities in the sacred groves of Virajpet

Table 3. Species richness, indices and density values of the five sacred groves

No	Parameters	SG1	SG2	SG3	SG4	SG5
1	No. of species	67 (50^a+17^b)	81 (56^a+25^b)	74 (43^a+31^b)	72 (54^a+18^b)	60 (38^a+22^b)
2	No. of genera	56	65	65	61	54
3	No. of families	33	33	34	32	32
4	Shannon's index	3.341	3.577	3.025	3.633	3.038
5	Simpson's index	0.9456	0.9613	0.9177	0.9653	0.9223
6	Pielou's index	0.8542	0.8887	0.8043	0.9107	0.8353
7	Basal area m^2/ha	64.145	67.4955	51.73	85.65	73.84
8	Tree density/ha	515.9	457.14	468.18	453.33	492.85
9	Seedling density/100 m^2	543.18	124.107	428.4	77.5	855.35
10	Sapling density/100 m^2	422.15	320.98	388.06	193.75	641.96

a: the number of tree species with mature individuals in the sacred grove; b = the number of tree species without mature individuals in the sacred grove.

Table 4. Sorenson's similarity index values (%) for the five sacred

	SG1	SG2	SG3	SG4	SG5
SG1	*				
SG2	64.86	*			
SG3	62.41	65.8	*		
SG4	57.55	69.28	69.86	*	
SG5	59.84	65.24	67.16	62.12	*

develops in an ecosystem. It is advocated that species richness of an ecosystem results from its complexity, variability and productivity. Therefore, diversity tends to increase as the environment becomes more favourable and more predictable (Putman, 1994). From the present investigation it was evident that, apart from the geological and climatic conditions, protection over a long period of time provided by local communities on the basis of socio-cultural belief system has an instrumental role in tree species richness, their distribution and regeneration in the studied sacred groves. Similar results, with high species richness within sacred groves has been reported from various researchers across the country (Ramakrishna *et al.*, 1998; Malhotra *et al.*, 2001; Ramanujam and Cyril, 2003; Khan *et al.*, 2008), upholding the significance of the role of these areas in conservation of biodiversity.

Higher similarity (64.41%) between the sacred groves as indicated by the Sorenson's similarity index could be attributed to the similar geographical and climatic conditions. Shannon's diversity index values (3.02-3.63) for the five sacred groves were within the range reported by various workers for the Western Ghats region: Jayakumar and Nair (2013) reported a range of 2.79 to 3.67 for New Amarambal reserve forest of Nilgiri Biosphere Reserve, Kerala; Vasanthraj and Chandrashekar (2006) reported a value of 4.9 for Charmadi reserve forest, Karnataka; Kanade *et al.* (2008) recorded 2.58 for Chandoli National Park, North Western Ghats, Maharastra; Gunaga *et al.* (2013) recorded a range of 2.55 to 3.48 in the Kaans of Uttara Kannada district, Karnataka. Simpson's index value of 0.9424 for the present study was found to be well in agreement with a few studies existing, as reported for Western Ghats where it ranged from 0.93 to 0.73 (Bhat and Kaveriappa, 2009), while for sacred groves of Meghalaya ranged from 0.95 to 0.93 (Upadhyaya *et al*., 2003) and in the forests of Little Andaman Simpson's index ranged from 0.97 to 0.56 (Rasingam and Parthasarathy, 2009).

Basal area of tree species is an important indicator of tree stocking which reflects biomass and carbon stock capacity of them. Significantly higher values recorded for the present study areas indicate their importance. Gunaga *et al*. (2013) reported a value of 22.60-48.80 m^2/ha basal area for the Kaans of Uttara Kannada district, Karnataka; Parthasarathy (2001) reported a value of 55.34-78.32 m^2/ha for Kalakad–Mundanthurai Tiger Reserve forest, Western Ghats; Jayakumar and Nair (2013) recorded a value of 48.00 m^2/ha for Evergreen forests of New Amarambalam Reserve Forests, Western Ghats; Muthuramkumar *et al.* (2006) recorded 46.3-99.67 m^2/ha of basal area for Anamalai hills forest, Western Ghats and Tripathi *et al.* (2010) reported a value of 35.12 m^2/ha for forests of East Khasi Hills.

Density of tree species and girth class distribution among the studied groves was found to be appreciably good. In comparison with other study reports such as a density of 999 stems/ha for sacred forests of Chittoor, Andhra Pradesh (Rao *et al*., 2011), 387 stems/ha in the Kaan forests of Shimoga (Gunaga *et al*., 2013), a range of 384-566 stems/ha of area for Valparai, Annamalai hills, Tamil Nadu (Muthukumar *et al*., 2006), the present investigation recorded notably higher values. A higher percentage of individuals in the lower girth in the present study sites indicate a lower disturbance, such as extraction of younger individuals for poles and firewood purpose. Social system of beliefs and taboos pertaining to these sacred groves have protected them from such anthropogenic activities.

The future tree species composition could be predicted from the relative number of present tree species seedlings and saplings. Overall, a good number of regeneration was recorded from these forest patches. A reverse J-shaped curve for different regeneration classes observed in the current studied groves means that the maximum number of regenerates counted for class I and the minimum number of regenerates for class IV. This reverse J-shaped curve is an indication of sustainable regeneration in the forest ecosystem. Prasad and Nageeb (2012) reported reverse J-shaped curves for regeneration in the eight Dipterocarp forests of Western Ghats, Karnataka. Boraiah *et al.* (2003) reported a similar curve for reserve forest, conserved and disturbed sacred groves of Kodagu. A population structure characterized by the presence of a sufficient number of seedlings, saplings and young trees implies satisfactory regeneration behaviour, while an inadequate number of seedlings and saplings of tree species in a forest indicates poor regeneration (Nazir *et al*., 2013).

In the present study highest percentage of species showed regeneration (42.07%) followed by reappearing/immigrating (31.82%) status. On the other hand, the number of tree species (26.08%) with no regeneration was recorded to be high. This could be due to a more or less consistent dominance of *Dimocarpus longan* in tree density, seedling density and sapling density values observed within all five sacred groves, which might be a cause of concern. Higher percentage of species found within the groves as reappearing or immigrating from other areas could be correlated to the fact that all the five study areas are surrounded by coffee plantations and agricultural fields. Hence, they serve as roosting/resting habitats for birds and animals, which cause the dispersal of seeds from other areas. In the sacred grove of Manipur (Khumbongmayum *et al*., 2006) a greater number of tree species had good and fair regeneration, followed by reappearing species and a very few species showed no regeneration. The authors opined that the presence of species that are represented only by adults in these sacred groves of Manipur could be due to their poor seed set, germination and establishment of seedlings in the forest. Nazir *et al.* (2013) 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, and opined that this could be a cause of concern in the future.

Evaluation of regeneration status of each species in all the sacred groves revealed that the density of mature individuals and regenerates were not proportionate. Chauhan *et al.* (2008) 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.* (1994) 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 density of mature individuals did not have proportional effect on density of regenerates. For example, in the case of SG3 - *Mallotus tetracoccus*, with the highest density, showed no regeneration and *Tectona grandis* with the second highest tree density showed poor regeneration, while *Dimocarpus longan* with just 13.63 individuals/ha had 346.02 seedlings and 157.95 saplings/100 m^2. In SG5, *Caryota urens* had the second highest density, but its regeneration status was found to be poor, without any seedlings. Khumbongmayum *et al.* (2006) opined that species diversity and population structure will be stable or reduced and regeneration potential will be negligible if the number of species represented only by adults becomes higher in any forest.

Survival rates of seedlings and saplings depend upon canopy openness (Nagamatsu *et al*., 2002), micro-environmental conditions, natural light gaps (Welden *et al*., 1991), soil, temperature and topography. In the present study, lower seedlings and sapling density observed in SG4 as compared with other groves could be attributed to lower light penetration as a result of closed canopy in the study area. Seedling and sapling density of tree species in the studied groves ranged from 77.5-855.85 seedlings/100 m^2 and 193.75-641.96 saplings/100 m^2. Relatively, these values are higher than other study results such as: Pokhriyal *et al.* (2010) reported a seedling density of 3.70 to 7.01/100 m^2 and a sapling density of 23.29 to 34.96/100 m^2 in the watersheds of Garhwal Himalaya. Khumbongmayum *et al*. (2006) reported a range of 3415-8803 seedlings/ha and 1943-4540 saplings/ha in the sacred groves of Manipur. Chauhan *et al.* (2010) recorded 158.7 seedlings and 496.0 saplings per hectare respectively in Terai-Bhabhar of Sohagibarwa Wildlife Sanctuary, India. Nazir *et al.* (2013) reported a seedling density ranging 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 Himalayas.

Conclusions

Even though sacred groves are protected on the basis of local beliefs and taboos, they are not immune from human activities. For example, sanskritization or replacement of nature worship system into idol worship, construction of concrete temples and celebration of festivals is becoming a common trend in many of the sacred groves, attracting large number of pilgrims. This is leading to unsustainable development, involving clearance of forests for road construction and indiscriminate dumping of wastes in natural groves. During the current investigation, it was observed that sanskritization, mud roads, footpath and grazing were found to be common disturbing factors in these sacred groves. The mild disturbance has favoured the overall species richness. A good regeneration of tree species among these sacred groves was witnessed with a significant difference in regenerating and mature tree species composition. As these sacred groves abode a rich diversity of arboreal species with good regeneration potential, prime importance should be given for their conservation.

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