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Sacred grove as remnant forest: A vegetation analysis

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Abstract. *Manna S, Manna S, Ghora TK, Roy A. 2017. Sacred grove as remnant forest: A vegetation analysis. Biodiversitas 18: 899-908.* Sacred groves are the remnants of ancient virgin forest sustaining veritable gene pool that have been gained century-long protection through the inherent cultural and religious belief of the ethnic communities. These important local biodiversity hotspots, representing the climatic climax of regional plant communities, are gradually being under threat by natural disturbances or anthropopression. Thus vegetation analysis of sacred groves is very important to find out their lineage to nearby existing forest. To reach the goal, significant plant compositional similarity between the sacred groves with changing distance was measured by 2X2 contingency analysis from presence/absence data matrix of major tree species (MTS) and major climber and liana species (MCLS) of 13 sacred groves of a particular soil zone. The observation reveals a significant gradual decrease in chi-square value with the increasing distance between the groves. Jaccard and Sorensen Coefficients for community similarity also reflect an inverse relationship of any two groves with increasing distance. Agglomeration Hierarchical Clustering (AHC) depicts that all the 74 families are found to be clustered into three significant groups. In respect of Multiple Correspondence among sacred groves, symmetric and asymmetric plots indicate that there two distinct groups have theirs within similarities among families in the groves. The plexus diagram shows a confluence zone of all the 13 sacred groves which might be the maximum probable area of an ancient riverine wood forest. The study would be helpful in restoration of threatened/degraded sacred groves and also guide in the preparation of management plan for the conservation of these relic forest fragments.

Keywords: Ancient forest community similarity multiple correspondence sacred groves vegetation composition

Abbreviations: MTS = Major Tree Species, MCLS = Major Climber and Liana Species, AHC = Agglomerative Hierarchical Clustering, CSA = Community Similarity Analysis, CC*j* = Jaccard Coefficient for Community similarity, CC*s* = Sorensen Coefficient for Community similarity, OI = Ochiai Index, DI = Dice Index, MCA = Multiple Correspondence Analysis, SGs = Sacred Groves

INTRODUCTION

One of the most ancient traditions and wide spread phenomenon of old world cultures is the nature conservation in form of sacred groves - the community-based monuments of biological heritage. Every sacred grove own legends, lore, and myths as its intricate parts that link between the present and past society in terms of biodiversity, culture, religious and ethnic belief existing in the individual sacred grove (Khan et al. 2008).These sacred groves had been a feature of the mythological landscape and cultural practices in most of the countries of the globe predominantly in Asia, Africa, Australia and part of America (South America) (Agbogidi and Benson 2014). In various countries, the concept of sacred groves has its roots before the prehistoric period of the hunting-gathering phases of civilization and particularly in India it started long before the Vedic age (Kosambi 1962; Gadgil and Vartak 1976).

Sacred groves of India exist in various forms, including burial grounds (Mgumia and Oba 2003; Wadley and Colfer 2004) and sites of ancestral or deity worship with different forms of gesture (Ramakrishnan et al. 1998). The local communities established unique taboos which had been percolating to the generations since a long period in the form of their cultural belief and practice; these often prohibit felling of trees and poaching of wild animals, though in some cases do allow the collection of firewood, fodder, and medicinal plants by local people (Hughes and Chandran 1998).

With the increase in population and change in land and land use pattern, human beings have had their footprints on the forests, a very common global scenario (Roy and Roy 2010). The gradual encroachment from the fringes towards the forests in the form of agricultural expansion for more productivity to meet the increasing demand of human population and their settlement results in the fragmentation of forest with a patchy distribution. Thus these forest patches are the representative of the old forests that has been disappeared in the course of time (Yadav et al. 2010) and still, some are thriving as remnants (Dendy et al. 2015). During the last two centuries, extensive degradation of forested land produced a mosaic of semi-natural and managed ecosystems especially in the northeast central Indian landscape (Roy et al. 2013). As ecological patterns, function, and processes are associated with landscape shape, contiguity and distribution (Kupfer 2006), removal of forest cover has created isolated patches of forests, resulting in alteration of the composition, structure, extent and spatial patterns of forested land (Heilman 2002).

The remnant patches were socially protected by the ancient people through the tradition of nature worship with customary taboos and sanctions that have cultural and ecological implications (Anthwal et al. 2006; Drohan et al. 2012). The compositions of such groves depend on the vegetation history which may be multi-species, multi-tier primary forest or a cluster of trees (Gokhale et al. 2001). Thus, these fragmented landscapes containing diversified life forms and geographical features that are delimited and protected by traditional ethnic societies to keep these in a relatively undisturbed state. This creates a haven for variable gene-pools, besides nurturing a lot of threatened and endemic taxa representing the ancient way of *in-situ* conservation (Mgumia and Oba 2003). The groves are also a very potential source of the genetic resources of wild relatives, ancient populations which are significant in climate change adaptation and bio-prospecting (Oba 2003; Brown et al. 2006).

Considering the role in nature conservation through socio-cultural management practices, sacred groves are a center of attraction to many workers for studying plant diversity, phytosociology, architecture, ethnomedicine and conservation practices (Lebbie and Raymond 1995; Anbarashan et al. 2011; Manna et al. 2013; Jayapal et al. 2014). Thus, present study would focus the level of vegetation composition similarities in the different sacred groves at a specific terrain to understand the approximate size and nature of the ancient forest of which these selected sacred groves were in part and also to establish these groves as the remnants of ancient forest. Krystal et al. (2011) tested the hypothesis to explain the high diversity in forest patches due to the establishment of more species because of radiation within refugial habitat or retention of older paleoendemic species in the forest patches and finally supported the latter one in his study.The analysis in the present work may be helpful to understand the ancient vegetation history including the predominant flora, which would be very significant in environmental development through better management of the groves and afforestation of ancient plants and create conducive conditions for restoration and sustenance of wild biodiversity both in local demes and wider ranges.

MATERIALS AND METHODS

Study area

Out of several states in the eastern lateritic parts of India (Chotanagpur plateau: Bihar, Jharkhand, Odisha, Chhattisgarh and West Bengal) the western part of West Bengal with its undulated topography is very significant for its forest coverage associated with tribal settlement, mainly the Santhals containing the largest tribal community having precious traditional knowledge as well as ritualistic belief. Several sacred groves with their climax community are dotted within these tribal settlements most of which are in the transition of village, agriculture and forest ecosystems. Deciduous trees like *Shorea robusta* Gaertn. (Vernacular name: Shal), *Buchanania lanzan* Spreng. (Vernacular name: Pial), *Modhuca latifolia* (Roxb.) Macb. (Vernacular name: Mohua) are the dominant trees of this dry deciduous forest of lateritic region. The tropical climatic condition with distinct seasonality [Pre-monsoon (March-May), Monsoon (June-August), Post-monsoon (September-November) and winter (December-February)] shows temperature range between 11-42^{o}C, with an annual rainfall of 1420 mm and relative humidity of 57.6%. Five distinct soil zones (Red Sandy Soil, Red Loamy Soil, Lateritic Soil, Older Alluvial Soil and Younger Alluvial Soil) are prevalent in that region from west to eastwards. Besides the dependence of composition, architecture, and physiognomy of the forest on several climatic and altitudinal factors, soil types also play a significant role in the structural and functional aspects of a particular forest.

So to know the nature of the ancient forest, 13 sacred groves viz. Mundomalini (21,500 sq.m.), Baba Dharmaraj (13680 sq.m.), Burobaba Than 1 (1743.2 sq.m.), Burobaba Than 2 (3366.66 sq.m.), ShemulBuro (5273.43 sq.m.), Nabadurga (1018.75 sq.m.), Jatadhari Baba (2544.44 sq.m.), Baba Diner Pir (8352 sq.m.), Jhakraburi (5655.55 sq.m.), KhetrafalTala (7900 sq.m.), Kali Than (788.88 sq.m.), Baro Thakur (1776 sq.m.) and RokaiBibir Than (15888 sq.m.) distributed within a specific soil zone (alluvial) were considered here in the present study (Figure 1). This alluvial zone was actually the basin of the River Mayurakshi and Ajay and extended from 23˚53'22.54"N to 23˚31'53.24"N and 87˚20'57.86"E to 87˚54'09.06"E covering an area of 2579.18 km^2.

Procedures

A total of 13 sacred groves were seasonally visited (especially during pre-monsoon, monsoon, post monsoon season) to encounter the plants at their phenological period in the study area. Plants were identified following standard literature (Hooker 1872-1897; Prain 1903) and matched with the material deposited at CAL. The information on historical background, rituals, cultures, taboos, possible threats were collected from ethnic communities through personal communication and community interaction through structured and semi-structured interviews. Area of each sacred grove was measured in the spot. The occurrence of species of different growth forms (herbs, shrubs, trees, lianas, and climbers) were noted to generate a presence-absence data matrix. It was hypothesized that if these 13 sacred groves are the representative of an entire old forest, there must be significant plant compositional similarities exist. So in accordance to the hypothesis, each of these 13 sacred groves are considered here as a sampling unit of that entire ancient forest.

Data analysis

To study if there is any significant plant compositional similarity between each and every sacred grove presence or not 2X2 contingency table was prepared from a present-absence data matrix of 13 sampling units, for pairwise comparison between them. A large number of sampling units were taken throughout the area to avoid biased chi-square value as much as possible. For further continuity

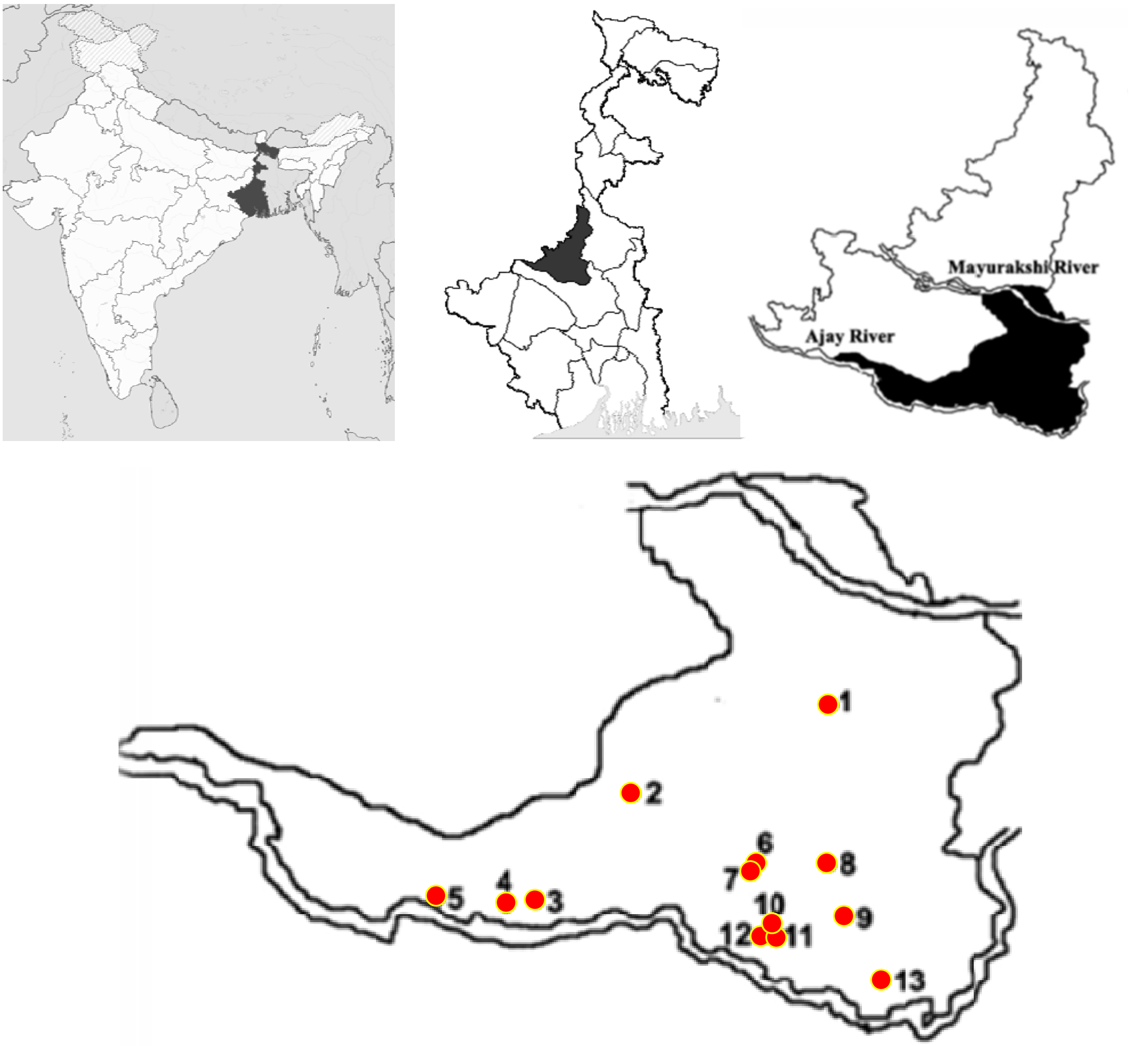

Figure 1. Location of the studied sacred groves in the alluvial soil zone of Birbhum district, West Bengal, India. Note: Coordinate sites number refer to Table 1.

Table 1. Sacred groves with their geographical position, area and vegetation composition in Birbhum district, West Bengal, India

SG Index No.	Name of scared grove	Coordinate	Area (sq. mt.)	No. of total sp.	No. of MTS	No. of MCLS
1	Mundomalini	23˚46’50.25” N, 87˚40’33.02” E	21500.00	69	35	6
2	Baba Dharmaraj	23˚42’02.19” N, 87˚40’37.48” E	13680.00	51	22	3
3	Burobaba than 1	23˚36’58.36” N, 87˚36’36.76” E	1743.20	45	17	6
4	Burobaba Than 2	23˚36’56.70” N, 87˚35’09.93” E	3366.66	86	24	18
5	ShemulBuro	23˚36’54.27” N, 87˚32’04.57” E	5273.43	18	9	0
6	Nabadurga (Bahiri)	23˚38’58.16” N, 87˚46’34.84” E	1018.75	20	11	1
7	Jatadhari Baba	23˚38’45.76” N, 87˚46’19.95” E	2544.44	51	14	4
8	Baba Diner Pir	23˚39’03.77” N, 87˚50’03.11” E	8352.00	52	17	6
9	Jhakraburi	23˚36’47.56” N, 87˚50’44.62” E	5655.55	16	7	2
10	KhetrafalTala	23˚36’18.99” N, 87˚47’13.20” E	7900.00	35	13	4
11	Kali Than	23˚36’04.23” N, 87˚47’18.60” E	788.88	26	6	4
12	Baro Thakur (Amdhara)	23˚35’59.83” N, 87˚47’08.68” E	1776.00	16	8	3
13	RokaiBibir Than	23˚34’12.19” N, 87˚52’08.72” E	15888.00	88	23	8

correction to ensure a closer approximation to the theoretical continuous chi-square distribution, Yate's correction formula was adopted. Community Similarity Analysis (CSA) was performed by computing Ochiai (OI), Dice (DI) index (Ludwig and Reynols 1988) along with Sorensen and Jaccard Coefficient (CC*s* and CC*j*) (Brower et al. 1998).The physical distance between different sacred groves was measured using GPS (Germin) and Google Earth. A pair of sacred groves with significant chi-square value and distance between them was used to see the relationship between plant compositional similarities with the distance. Change in chi-square value with the increasing of every 5 km interval of distance was studied to see the significant plant compositional change. Again XL STAT 6.01 was used for Multiple Correspondence Analysis (MCA) and Agglomerative Hierarchical Clustering (AHC) using 74 families containing 254 plant species spread within 13 sacred groves to see if there is any specific cluster of plant families dominated in these groves or not.

RESULTS AND DISCUSSION

Results

In the present soil zone out of 13 sacred groves, grove 1 (21500 sq. m.) is the largest comprising 35 major tree species (MTS) associated with 6 different species of major climber and lianas (MCLS). Grove 1 was followed by grove 13 (15888.00 sq. m.) harboring 23 MTS with a continuous top canopy contributed by 8 species of MCLS. Though grove 11 was the smallest sacred grove (788.88 sq. m.), it sustained 26 plant species out of which 6 were MTS and 4 were MCLS. In spite of large area, grove 12 and grove 9 harbored less number of plant species compared to grove 11, though the number of MTS was slightly higher in these two groves (Table 1).

A total of 254 plant species belonging to 201 genera under 74 families with different life forms (Trees, Shrubs, Herbs, Climber and Lianas) were found in those 13 sacred groves. Out of 254 plant species, 69 MTS supported a total of 29 MCLS. Among the 69 MTS, *Streblus asper* Lour. (Frequency 92.3%) was the most common tree species of the 13 sacred groves followed by *Azadirachta indica* A. Juss. (Frequency 76.92%). A total of 29 tree species were very less common in these sacred groves as each of the species was restricted to any of the grove (Frequency is only 7.69%). Out of all MTS, 65.51% was common to the flora of the local village ecosystem (though species like *Acacia auriculiformis* A. Cunn., *Ailanthus excelsa* Roxb., *Cocos nucifera* L., *Eucalyptus* sp. etc. were commonly planted) and 39.48% MTS were frequently observed in the nearby unclassed forests (Table 2).

Most of the MCLS were belonging to the family Dioscoreaceae (6 MCLS) followed by Fabaceae (3 MCLS). Lianas such as *Ventilago denticulata* Willd., *Derris scandens* (Roxb.) Benth., *Gymnema sylvestre* (Retz.) Schult. etc. were found mostly associated with the large MTS to occupy the top canopy whereas climbers were mostly abundant in the fringes of the groves, occupying the top of small trees and shrubs, creating dense bushes. Herbs and grasses mostly form the ground cover of the outer periphery of the groves or sometimes found to be occurred along with different alien invasive species like *Eupatorium odoratum* L., *Lantana camara* L., etc. in the groves where top canopy was damaged may be due to some pathogenic infection to the MTS. The clumpy occurrence of forbs/grasses in the grove floor was noted mainly the places where there was no existence of continuous canopy such as grove 5, grove 6 and grove 11 (Table 3).

Grove 1 and grove 5 were the most distantly situated sacred groves in the same soil zone followed by grove 5 and grove 13 and grove 5 and grove 9. Only in these groves, 6, 1 and 2 MTS were common between them respectively. It was also interesting to note that out of 29 species of MCLS, though 16 species were supported by these groves, there was not a single common MCLS present between them. On the other hand, grove 11 and grove 12 were the closest of these 13 groves in term of physical distance followed by grove 11 and grove 10. Out of 27 MTS and 11 MCLS present in these groves, 4 and 5 MTS and 1 and 2 MCLS were common (Figure 2).

To know, whether these sacred groves are the remnants of the ancient vegetation of this specific soil zone or not, 2X2 association analysis (Table 4) was performed and noted that out of 78 possible pairing, there are 32 pairing which has significant similarities in their vegetation composition (at 5% probability level). Out of 13 sacred groves of this region, 12 groves took active part in these 32 possible significant vegetation similarity pairing. There seem to be some strong possibilities of maximum true similarities between grove 10 and grove 11 (at 1% probability level) followed by 8 and 11 (at 1% probability level). Community Similarity analysis such as Ochiai and Dice index (Table 4) and Jaccard and Sorensen Co-efficient (Table 5 and Figure 3) was also highest in the case of grove 10 and grove 11 (Ochiai 0.46, Dice 0.46 and Jaccard 0.3). Agglomeration Hierarchical Clustering depicts that all the 74 families of 254 species spread over 13 sacred groves are found to be clustered into three significant groups as C_1, C_2, and C_3 (Table 6) based on present/absent of the plant families in the studied sacred groves. The dendrogram (Figure 4) shows distinct similarity among families within groups. In respect of Multiple Correspondence among sacred groves, symmetric and asymmetric plots (Figure 5) indicate that there two distinct groups have their within similarities among families in the groves. In these plots, similar types of family clusters were noted in most of the sacred groves (10) except Rokaibibi, Baro Thakur (Amdhara) and Mundamalini.

To know the outer periphery and the area of the ancient forest of which these 13 sacred groves are the remnants, clusters were made by comprising the sacred groves in every next 5 km distance. A total of 6 clusters of the pairs of sacred groves with significant chi-square value were formed of which lowest level of significant similarity (at 5% probability level) was observed up to 30 km distance between two sacred groves (Table 4). A logarithmic pattern

Table 2. Major Tree Species (MTS) with frequency percentage (F%) in the sacred groves of Birbhum district, West Bengal, India

MTS	Family	Frequency percentage (F%)
Acacia arabica (Lam.) Muhl. ex Willd.	Fabaceae	46.15
Acacia catechu (L.f.) Willd.	Fabaceae	7.69
Acacia auriculiformis A. Cunn.	Fabaceae	15.38
Adenanthera pavonina L.	Fabaceae	7.69
Adina cordifolia (Roxb.) Hook. f.	Rubiaceae	7.69
Aegle marmelos (L.) Corr.	Rutaceae	30.76
Ailanthus excelsa Roxb.	Simaroubaceae	15.38
Alangium salviifolium (L.f.) Wang.	Alangiaceae	46.15
Albizia lebbeck (L.) Willd.	Fabaceae	53.84
Anthocephalus cadamba (Roxb.) Mig.	Rubiaceae	15.38
Artocarpus heterophyllus Lam.	Moraceae	23.07
Artocarpus lacucha Buch.-Ham.	Moraceae	23.07
Azadirachta indica A. Juss.	Meliaceae	76.92
Borassus flabellifer L.	Arecaceae	53.84
Breynia vitis-idaea (Burm.f.) Fischer	Euphorbiaceae	15.38
Bridelia retusa Spreng.	Euphorbiaceae	23.07
Buchanania lanzen Spreng.	Anacardiaceae	7.69
Butea monosperma (Lam.) Taub.	Fabaceae	15.38
Caesalpinia major (Medik.) Dandy & Exell	Fabaceae	15.38
Cassia fistula L.	Fabaceae	7.69
Ceiba pentandra (L.) Gaertn.	Bombaceae	23.07
Crateva adansonii DC.	Capparaceae	7.69
Dalbergia sissoo Roxb.	Fabaceae	23.07
Diospyros montana Roxb.	Ebenaceae	15.38
Eucalyptus sp.	Myrtaceae	23.07
Ficus bengalensis L.	Moraceae	53.84
Ficus carica L.	Moraceae	7.69
Ficus hispida L.f.	Moraceae	23.07
Ficus religiosa L.	Moraceae	30.76
Ficus reticulata Thunb.	Moraceae	7.69
Ficus rumphii Bl.	Moraceae	30.76
Flacoursia indica (Burm.f.) Merr.	Flacourtiaceae	23.07
Gardenia latifolia Ait.	Rubiaceae	7.69
Glycosmis pentaphylla (Retz.) DC.	Rutaceae	15.38
Holarrhena antidysenterica (Heyne ex Roth) A. DC.	Apocynaceae	7.69
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	30.76
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	53.84
Limonia acidissima L.	Rutaceae	38.46
Leucaena leucocephala (Lam.) de Wit.	Fabaceae	15.38
Madhuka latifolia (Roxb.) Macb.	Sapindaceae	7.69
Mangifera indica L.	Anacardiaceae	15.38
Mimosa rubicaulis Lamk.	Fabaceae	15.38
Mimusops elengi L.	Sapotaceae	7.69
Mitragyna parvifolia (Roxb.) Korth.	Rubiaceae	7.69
Morinda citrifolia L.	Rubiaceae	38.46
Morinda tomentosa Hayne ex Roth.	Rubiaceae	7.69
Murraya exotica L.	Rutaceae	15.38
Murraya koenigii (L.) Spreng.	Rutaceae	7.69
Pavetta indica L.	Rubiaceae	30.76
Phoenix sylvestris (L.) Roxb.	Arecaceae	76.92
Phyllanthus emblica L.	Euphorbiaceae	7.69
Polyalthia longofolia (Sonn.) Thw.	Annonaceae	7.69
Polyalthia suberosa (Roxb.) Hook.f. & Thomson	Annonaceae	7.69
Pongamia pinnata (L.) Pierre	Fabaceae	7.69
Putranjiva roxburghii Wall.	Euphorbiaceae	23.07
Saraca asoka (Roxb.) Wild.	Fabaceae	7.69
Shorea robusta Gaertn.	Dipterocarpaceae	7.69
Streblus asper Lour.	Moraceae	92.30
Suregada multiflora Baill.	Euphorbiaceae	15.38
Syzygium cumini (L.) Skeels.	Myrtaceae	30.76
Syzygium jambos L.	Myrtaceae	7.69
Tamarindus indica L.	Fabaceae	53.84
Tectona grandis L.f.	Verbenaceae	7.69
Terminalia arjuna (Roxb.) Wight & Arn.	Combretaceae	46.15
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	7.69
Thevetia peruviana (Pers.) K. Schum.	Apocynaceae	7.69
Thuja occidentalis L.	Cupressaceae	7.69
Trewia nudiflora Wight	Euphorbiaceae	7.69
Ziziphus mauritiana Lam.	Rhamnaceae	23.07

Table 3. Major Climber and Liana Species (MCLS) with frequency percentage (F%) in the sacred groves of Birbhum district, West Bengal, India

MCLS	Family	Freq. percent (F%)
Ampelocissus sp	Vitaceae	7.14
Cocculus hirsutus (L.) Diels	Menispermaceae	50
Ventilago denticulata Willd.	Rhamnaceae	21.42
Asparagus racemosus Willd.	Asparagaceae	7.14
Capparis zeylanica L.	Capparidaceae	42.85
Cardiospermum helicacabum L.	Sapindaceae	7.14
Cayratia pedata (Lam.) Gagnep.	Vitaceae	7.14
Cuscuta reflexa Roxb.	Cuscutaceae	7.14
Cassytha filiformis L.	Lauraceae	7.14
Cissampelos pareira L.	Menispermaceae	14.28
Cissus quadrangularis L.	Vitaceae	7.14
Coccinia grandis (L.) Voigt	Cucurbitaceae	42.85
Clitoria ternatea L.	Fabaceae	7.14
Cryptolepis elegans Wall. & G.Don	Asclepiadaceae	7.14
Derris scandens (Roxb.) Benth.	Fabaceae	21.42
Derris uliginosa (DC.) Benth.	Fabaceae	7.14
Dioscorea belophylla Voigt	Dioscoreaceae	7.14
Dioscorea bulbifera L.	Dioscoreaceae	35.71
Dioscorea sp.	Dioscoreaceae	7.14
Dioscorea alata L.	Dioscoreaceae	7.14
Dioscorea daemona Roxb.	Dioscoreaceae	7.14
Dioscorea pentaphylla L.	Dioscoreaceae	7.14
Gloriosa superba L.	Liliaceae	14.28
Gymnema sylvestre (Retz.) Schult.	Asclepiadaceae	14.28
Ichnocarpus frutescens (L.) R.Br.	Apocynaceae	64.28
Mikania scandens (L.) Willd.	Asteraceae	21.42
Passiflora foetida L.	Passifloraceae	14.28
Trichosanthes cucumerina L.	Cucurbitaceae	7.14

Table 4. Chi-square similarity index with changing distance between the sacred grove pairs of Birbhum district, West Bengal, India

Grove pair	Distance (km)	Chi sq.	Yet's Chi sq	Association Index	
				Ochiai	Dice
11-12	0.31	20.87	17.16	0.34	0.33
10-11	0.49	39.14	35.47	0.46	0.46
6-7	0.58	12.11	10.17	0.31	0.28
10-12	0.62	12.91	10.36	0.3	0.27
7-10	4.77	10.04	8.65	0.33	0.33
6-10	5.03	8.23	6.4	0.26	0.25
7-11	5.23	12.27	10.53	0.33	0.31
7-12	5.29	9.53	7.64	0.28	0.24
8-9	5.31	5.68	4.26	0.24	0.21
6-11	5.53	5.15	3.55	0.22	0.22
6-12	5.6	12.86	9.65	0.28	0.28
6-9	5.9	5.08	3.87	0.25	0.22
9-11	6	20.87	17.16	0.34	0.33
9-10	6.16	18.86	15.74	0.34	0.31
7-8	6.33	13.77	12.37	0.39	0.39
9-12	6.33	4.48	2.52	0.19	0.19
8-10	7.02	23.89	21.74	0.42	0.41
8-11	7.21	24.65	22.16	0.41	0.38
8-12	7.51	5.68	4.26	0.24	0.21
7-9	8.93	5.69	4.49	0.25	0.21
11-13	9.14	6.79	5.71	0.31	0.26
2-6	11.53	8.4	6.8	0.28	0.25
1-8	14.35	5.77	4.97	0.35	0.35
2-10	15	10.04	8.65	0.33	0.33
3-6	17.34	7.39	5.83	0.27	0.25
2-5	17.39	10.81	8.89	0.3	0.26
3-10	18.06	13.83	12.11	0.35	0.35
1-9	19.3	10.78	8.95	0.3	0.24
1-10	20.08	3.95	3.22	0.3	0.29
2-9	20.34	9.53	7.64	0.38	0.24
1-11	20.58	7.63	6.4	0.31	0.27
5-10	25.73	6.23	4.59	0.24	0.23
4-9	26.7	6.26	4.69	0.27	0.2
1-3	29.85	8.25	7.23	0.36	0.35

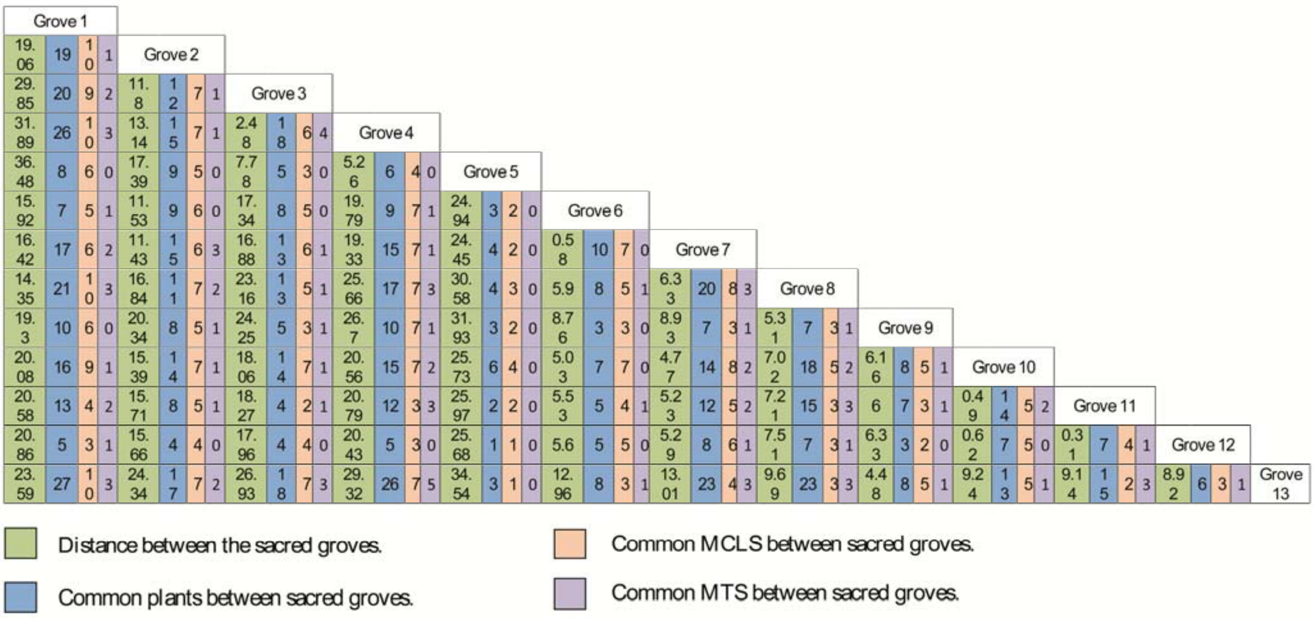

Figure 2. Comparison between sacred groves in terms of distance (km), common plant species, common MTS and common MCLS in the sacred groves of Birbhum district, West Bengal, India

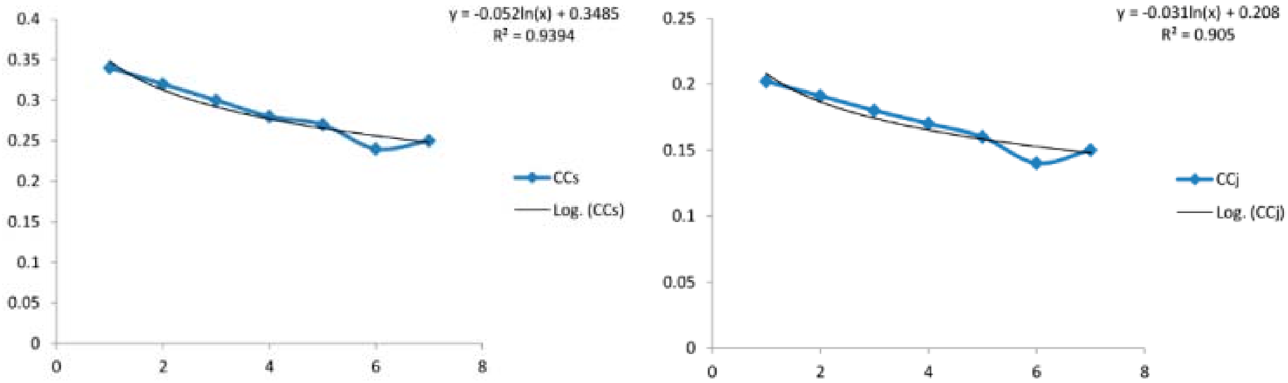

Figure 3. Relationship of CC*s* and CC*j* value with changing distance

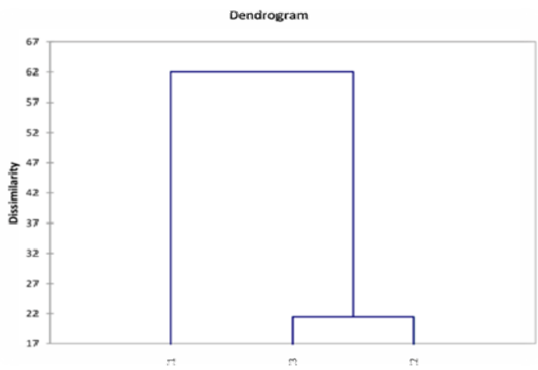

Figure 4. Dendrogram of plant family clusters in the sacred groves of Birbhum district, West Bengal, India

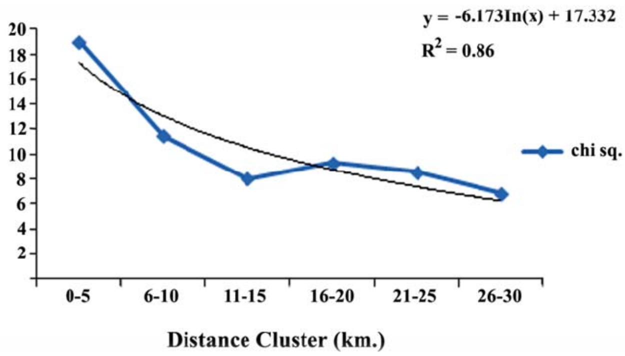

Figure 6. Relationship between compositional similarities of sacred groves in Birbhum district, West Bengal, India with changing distance

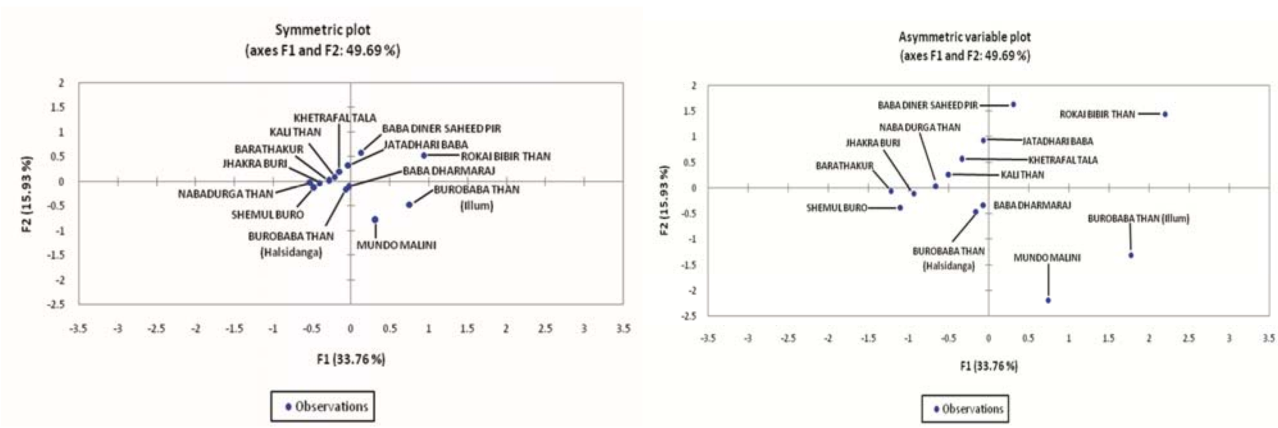

Figure 5. Symmetric and asymmetric plots of sacred groves in Birbhum district, West Bengal, India

of decreasing of chi-square value with the increasing distance between the sacred groves was observed in the present study (Figure 6). Plexus diagram based on chi-square value between the pairs of significantly similar sacred groves, was made. Each ellipse in that diagram represents the area of similar ancient vegetation with significant probability. A 40 km^2 area of common intersecting ellipses represents the confluence zone of all the 13 sacred groves (Figure 7).

Discussion

Unlike the sacred groves of different bio-geographic zones of India, groves of plateau region, as in the present study, have a dual origin. One can easily visualize a unique landscape of ridges and furrows having creeks fed by rainwater. Ridges are mostly dominated by agriculture and human settlement whereas the furrows are the haven for local vegetation along the side of creeks due to the availability of water throughout the year. Groves like grove 1, grove 4, grove 7 and grove 8 are such examples where the local vegetation along the side of creeks, are traditionally conserved based on ethnic culture, belief, and taboos. Rest of the groves located in the ridges, are also the conglomeration of the local vegetation developed through gradual shrinking due to the expansion of agricultural land. It was observed that 51% plant species including 78% of MTS and 66.66% of MCLS were found to be common with the floristic diversity of a nearby natural forest (Garh Jungle, 23°36'22.53" N to 23°35'40.83" N latitude and 87°27'00.32" E to 87°24'51.51" E longitude, at the southern side of the river Ajay) in the same soil zone (Bhattacharya and Mukherjee, 2006) unlike the planted forest such as Choupahari forest (dominated by *Shorea robusta* Gaertn., *Madhuka latifolia* (Roxb.) Macb., *Buchanania lanzen* Spreng., *Semecarpus anacardium* L.f. etc.) situated at the western side of the study area. This result clearly supports that these sacred groves are the remnants of common ancient local vegetation.

Association of most of the liana species to the large MTS may be due to the reliable support of their heavy branches. Secondary wood formation also helped them to achieve the top canopy of large MTS and rendered them fittest in the highly competitive climax community. On the other hand, climbers reduce their niche width through selecting shrubs and short height trees in the periphery to spread their branches to the top canopy creating a bushy structure (Manna et al. 2010).

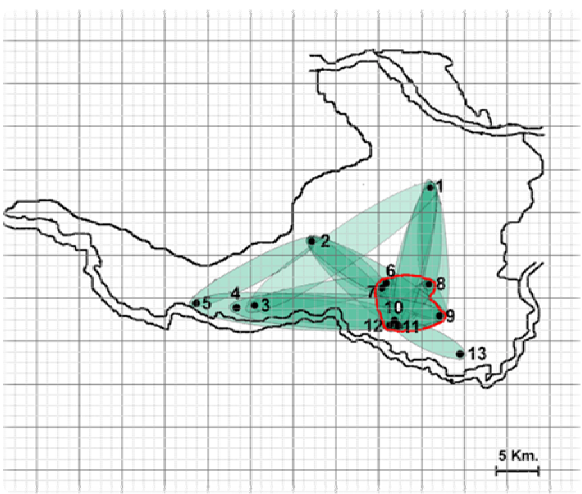

Figure 7. Plexus diagram of probable area of ancient forest cover in the sacred groves of Birbhum district, West Bengal, India

Table 5. Jaccard and Sorensen Coefficient of Community Similarity (CC*j* and CC*s*)

Distance cluster (km)	**CC*j***	**CC*s***
1—5	0.202	0.34
5—10	0.191	0.32
10—15	0.18	0.3
15—20	0.17	0.28
20—25	0.16	0.27
25—30	0.14	0.24
30—35	0.15	0.25

Table 6. Agglomerative hierarchical clustering (AHC) of plant families in the sacred groves of Birbhum district, West Bengal, India

C1	**C2**	**C3**
Agavaceae	Alangiaceae	Anacardiaceae
Amaryllidaceae	Amaranthaceae	Apocynaceae
Annonaceae	Arecaceae	Arecaceae
Apiaceae	Asclepiadaceae	Capparidaceae
Aristolochiaceae	Asparagaceae	Euphorbiaceae
Bambusaceae	Asteraceae	Fabaceae
Bignoniaceae	Combretaceae	Malvaceae
Bombacaceae	Convolvulaceae	Meliaceae
Boraginaceae	Costaceae	Moraceae
Cactaceae	Cucurbitaceae	Poaceae
Commelinaceae	Dioscoreaceae	Rhamnaceae
Crassulaceae	Lamiaceae	Rutaceae
Cupressaceae	Menispermaceae	
Cuscutaceae	Myrtaceae	
Cyperaceae	Onagraceae	
Dipterocarpaceae	Rubiaceae	
Dryopteridaceae	Sapindaceae	
Ebenaceae	Scrophulariaceae	
Flacourtiaceae	Tiliaceae	
Haloragaceae	Ulmaceae	
Lauraceae	Verbenaceae	
Liliaceae	Vitaceae	
Linaceae		
Marsileaceae		
Molluginaceae		
Musaceae		
Nyctaginaceae		
Nymphaeaceae		
Ochnaceae		
Oleaceae		
Orchidaceae		
Pandanaceae		
Passifloraceae		
Sapotaceae		
Schizaeaceae		
Simaroubaceae		
Smilacaceae		
Solanaceae		
Sterculiaceae		
Urticaceae		

As community dynamics not only depend on the abiotic factors but also on the influence of neighboured or associated species which have the efficiency in modifying the community structure (Turkington et al. 1985 and Lobo et al. 2003) and as such we can predict the range of extension of a previously prevailed forest area only through the study of species compositional similarities between existing forest patches on the scale of their physical distance. This prediction likely to be much efficient if similar edaphic conditions were considered and thus the selection of a single soil zone (Alluvial) of a specific geographical region, as in the present study, was justified for prediction of the ancient nature of the vegetation. The comparative riverine vegetation analysis between the forest patches along the gradient of a stream in North France (Calcada et al. 2013) reveals that longitudinal integrity of streams likely increases connectivity within and between meta-communities which assist spreading of limited dispersal species. But if the intermediate connecting zones between the meta-communities along a specific edaphic gradient are lost, the range of vegetation influencing zone of a particular forest type can be predicted through studying similarity and dissimilarity indices of the remnant forest patches (plant communities). Jaccard and Sorensen Coefficients for community similarity (CC_J & CC_S) of the present 13 sacred groves distributed in a single soil zone (Alluvial) reflects an inverse relationship of any two groves with increasing distance (In every 5 km distance cluster). Devar (2008) also pointed out that the groves situated in distantly related geographical terrain and geological conditions show extreme dissimilarity and the reverse is also said to be true. In the present study, the 2X2 community analysis for vegetation similarity pattern also depicts that the maximum probability of true significant similarity took place between the groves that are closer in proximity (0-5 km distance cluster) and interestingly the probability of vegetation similarity decreases with the increasing distance cluster. Gradual decrease of similarities of the MTS and MCLS with increasing distance between sacred groves was also noted in this study. From the AHC, C_1 cluster comprising maximum families (40) was found to be dominant in most of the sacred groves and this indicates the vegetation similarity of the groves supporting the sacred groves of that region are the relic patches of a continuous forest. These findings do reveal that a previous contiguous vegetation existed that had been fragmented and reduced through expansion of agricultural land mostly during the settlement of agro-based civilization after hunting-gathering nomadic human life. As most of the groves are encircled by the agricultural land, that hinders germination of propagules, unlike in the fringes of nearby sacred groves, having strong inter and intra-specific competition, as evidenced in the islands (Page et al. 2010) These sacred groves act as meta-community consisting of several ancient plant populations with genetic interconnection through pollination and dissemination of propagules to other similar sets to maintain the gene flow.

All these 13 sacred groves were found to be distributed in a 250 km^2 area, represented in the plexus diagram (Fig 7). Intersecting space of the ellipses in the diagram represents a 40 km^2 area depicting the maximum probable area of an ancient forest sharing a common type of vegetation. Trees like *Streblus asper* Lour., *Azadirachta indica.* A. Juss., *Phoenix sylvestris* (L.) Roxb., *Borassus flabelifer* L., *Albizia lebbeck* (L.) Willd., *Ficus bengalensis* L., *Alangium salviifolium* (L.f.) Wang., *Laanea cormondalica* (Houtt.) Merr., *Pongamia pinnata* (L.) Pierre is the most common and predominant floral components of these historically fragmented relic forests similar to the lowland riverine wood forest rather the common composition of the tropical dry deciduous forests of the Chotanagpur plateau. It happens as this region is the basin of Mayurakshi (north) and Ajay River (south) which was under inundation in the intermittent flood. Deposition of silt admixed with older and younger alluvial soil created a fabulous environment for growth and development of this riverine wood forest that prevailed in the past.

The concept reflected in the present study is not only restricted to a particular landscape but also has the scope of application in predicting the previously existed forest area along with a clear reflection of the vegetation composition and predominant flora of any geographical region of the globe.

Indian landmass has around 20% under forest cover of its total geographic area and merely half of this landscape still have low fragmentation (Roy et al. 2013), probably owing to parliamentary/ institutional, and/or social protection (Anthwal et al. 2006). The fragmentation is associated with the socio-economic and cultural practices and to a large extent to the infrastructural development along with agricultural expansion in the region (Drohan et al. 2012). Thus development appears to act in a conflict with intact nature and its conservation. The continuous demand for resources to uplift the socio-economic status of the local inhabitants and constructing roads for better communication invariably lead to forest fragmentation (Forman and Sperling 2003). The areas that are losing the natural envelop due to anthropogenic pressure are actually losing the priceless gene pool of numerous medicinal and commercially important plants including the endemic species. The conservation practice of ancient forest patches in the form of sacred groves based on traditional socio-cultural belief is not confined only to the Indian subcontinent, rather having a wider spectrum in the world *e.g.* Estonia, Ghana, Malaysia, Nepal, Nigeria, Thailand, USA etc. Thus the sacred groves may be of immense importance to unravel the ancient vegetation history, through our present study, towards environmental development through ecological restoration in urban, semi-urban and village ecosystems. Such analyses may also be applicable to the sacred groves of densely populated urban/metropolitan areas to know the vegetation *vis-a-vis* ecological history, as other such disjunct patches are seldom to exist.

The present study may also get importance in the preparation of management action plan for conservation and revival of the areas under confluence zone of several sacred groves with the relic species both in local, regional and global level.

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