

Ibudhou Marjing Sacred Grove at Indo-Burma Biodiversity Hotspot: Significance of Customary Belief in Effective Conservation of Woody Plant Species

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ABSTRACT

Sacred groves serve as critical biodiversity hotspots intertwined with cultural heritage, particularly in Northeast India, where anthropogenic pressures threaten their integrity. This study evaluates the woody plant species of the Ibudhou Marjing Sacred Grove and the adjoining Heingang Reserved Forest in the Imphal East district of Manipur, India, covering an area of 9.71 km². Regeneration study revealed greater seedling density in the Reserved Forest, whereas sapling density was greater in the sacred grove. The study found significantly greater species richness in the sacred grove forest (52 species) than in the adjoining Heingang Reserved Forest (29 species). The sacred grove harbours significantly higher tree diversity with 1096 individuals ha⁻¹ and a basal cover of 52.25 m² ha⁻¹, compared to that of the Heingang Reserved Forest, bearing 843 individuals ha⁻¹ and a basal cover of 22.36 m² ha⁻¹. A higher Shannon-Wiener diversity value was observed in the sacred grove (2.49) than in the Reserved Forest (2.14). These results highlight the grove's role in conservation through Meitei traditions, advocate for integrated management to conserve ecosystem services amid urbanisation, and suggest future studies to enhance resilience.

Key words: Phytosociology, Species Richness, Anthropogenic Pressure, Shannon-Wiener Index, Meitei Traditions

INTRODUCTION

Sacred groves are defined as forest patches rich in biodiversity and natural vegetation, often linked to indigenous religious beliefs, cultural myths, and taboos. They connect nature with human society, religious practices, ethnic traditions, and historical legacies (Sen and Bhakat 2021, Sharma and Kumar 2021, Upadhyay et al. 2019). For centuries, these small forest areas have provided safe havens for rare and endemic plants unique to particular regions. Protected by local communities, they shield threatened flora and fauna from extinction threats. In human history, religion has played a key role in society. Linking faith to important causes is an effective way to gain community support. Sacred groves offer the best example of this blend between belief and nature conservation (Kandari et al. 2014). These groves are set aside for spiritual reasons or tied to religious systems, marked as holy or revered places. They range in size from as little as 0.0001 ha to over 26,326 ha and occur across diverse global ecosystems, playing a key role in biodiversity protection and management. Recent research

shows that sacred groves, as part of community-led conservation efforts, face growing risks from soil erosion, land use and land cover changes, population growth, increased modernisation linked to cultural changes, and pressure on natural resources (Kumar et al. 2022, Warriar et al. 2023). In five Northeastern Indian states, sacred groves cover more than 40,000 ha. India, with its vast religious and ethnic diversity, is estimated to have 100,000 to 150,000 sacred groves (Rath and Ormsby 2020; Sharma and Kumar 2021). Though species diversity in the Western Ghats and Northeast India has been extensively studied, the sacred forests of Eastern India remain poorly documented (Rath and Ormsby 2020). Manipur state alone has 365 sacred groves (Singh and Devi 2009). Of the 166 sacred groves in four districts of Manipur, only 11% are well conserved. In contrast, 58% are at high risk and 31% at moderate risk due to human activities such as urbanisation, land encroachment, and development (Singh and Devi 2009). Growing evidence also suggests that biodiversity is linked to key ecosystem services, including food production, climate regulation, pest regulation, pollination, and other processes vital for

human well-being, rather than merely responding to environmental shifts (Mori et al. 2017). Woody plant species are essential in shaping forest communities, where forest ecosystems vary widely in composition due to factors like geography, habitat types, and disturbances (Devi Khumbongmayum et al. 2006). Species diversity is an essential component that affects how well an ecosystem functions (Kumar et al. 2010). Studying the structural composition of trees reveals energy flow, nutrient cycles, and signs of ecological disruption within the system (Bhuyan et al. 2003, Ulfa et al. 2024). Such information aids in assessing the regeneration capacity of current tree populations. Regeneration maintains the original species composition and is an important step towards the long-term survival of forests, with important implications for natural forest management (Malik and Bhatt 2016). With rising population pressures, urbanisation, and developmental activities such as highways, tourist sites, roads, and buildings, there are enhanced threats to sacred groves (Rath and Ormsby 2020, Upadhyay et al. 2019).

Considering the significant role of the sacred grove, the present study evaluates tree species diversity, community structure, and regeneration status based

on seedling, sapling, and adult populations in the Ibudhou Marjing Sacred Grove and the Heingang Reserved Forest in the Indo-Burma Biodiversity hotspot. All significant community parameters were calculated using standard procedures.

MATERIAL AND METHODS

Study area

The present study was conducted in the Ibudhou Marjing Sacred Grove and its adjoining Heingang Reserved Forest, located in the Imphal East district of Manipur (Fig. 1), during August 2023. Both sites cover an area of approximately 9.71 km². Geographically, both sites lie between approximately 24.845°N and 24.905°N latitude, and 93.935°E and 93.975°E longitude, at elevations of 780-920 m amsl. The terrain of both sites is moderately undulating, with slopes ranging from 17.6 to 36.4%, and the sites predominantly face southwest. The forest is primarily composed of semi-evergreen vegetation interspersed with the sacred grove, which is maintained through traditional ecological knowledge and religious practices. The area is culturally significant to the Meitei community, as it is home to the shrine of

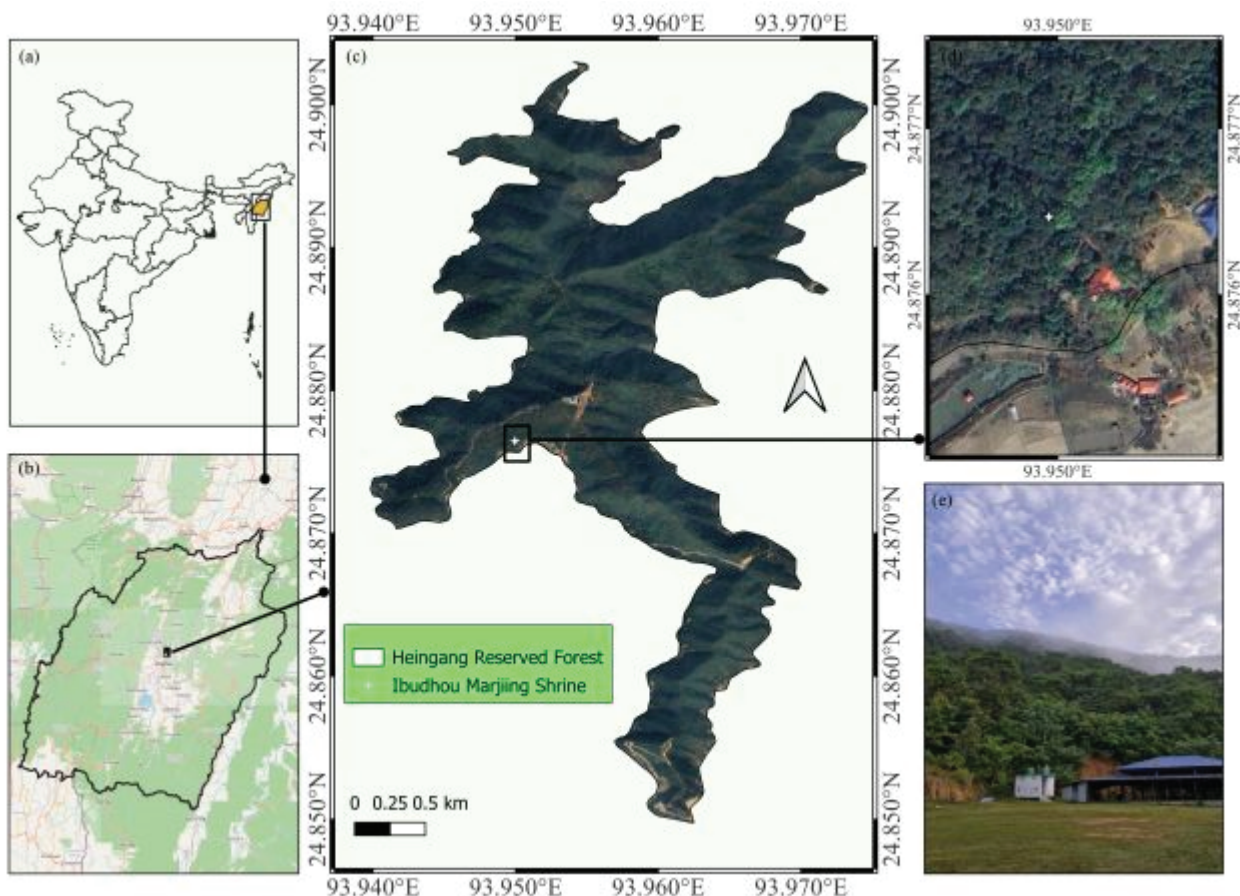


Figure 1. Study area map. The inset (c) is the map of Heingang Reserved Forest (HRF) with the location of Ibudhou Marjing Shrine clearly marked, along with its adjoining Sacred Grove area shown in the inset (d). The image shown in inset (e) is a field photograph of the Sacred Grove area. Inset (b) is the location of HRF within Manipur, and inset (a) the location of Manipur within India

Ibudhou Marjing, the guardian deity of the northeast and the mythological creator of Sagol Kangjei (polo). The shrine, located atop Heingang Hill, is believed to be the abode of Ibudhou Marjing and his sacred horse, Samadon Ayangba. The soil in the study area was sandy clay loam, typical of upland terrain with good drainage. Rich biodiversity, coupled with its spiritual significance, has led to its conservation as a sacred grove, supporting diverse flora and fauna.

Vegetation analysis

For phyto-sociological analysis, the belt transect method was used, in which 3 belts, each 50 m long were laid along the elevational gradient. Within the belt, 3 quadrats of 30×30 m for trees, 6 quadrats of 5×5 m for saplings, and 6 quadrats of 1×1 m for seedlings were randomly laid for both the sacred grove and the reserved forest. Trees ≥ 30 cm girth at breast height (GBH) were categorised as adults, where individuals with a collar circumference between 10 to 30 cm were considered as saplings and < 10 cm were considered as seedlings. For multistem trees, girth was measured for each stem. Species identification was done through consultation with local and regional flora and was also verified using the updated taxonomic details from Plants of the World Online (POWO).

Phytosociological parameters were determined following the methods as outlined by Misra (1968) and Ellenberg and Mueller-Dombois (1974). Following standard methodologies, species richness index (S) was determined using Margalef (1973), species diversity index (H') following Shannon and Wiener (1963), Simpson (1949) for Simpson's dominance index (D), Pielou (1966) for evenness (J), Whittaker (1960) for alpha diversity (α), Sorensen (1948) for similarity indices and species distribution pattern following Whitford (1949).

Regeneration status was determined using the methods as outlined by Shankar (2001), where conclusions are drawn as: (a) good regeneration, if seedlings $>$ saplings $>$ adults; (b) fair regeneration, if seedlings $>$ or $\leq$ saplings $\leq$ adults; (c) poor regeneration, if the species survives only in sapling stage, but no seedlings (saplings may be $<$, $>$ or $=$ adults); (d) no regeneration if a species is present only in adult form; (e) new regeneration if the species has no adults but only seedlings and saplings.

Statistical analysis

Statistical analysis was conducted using SPSS v. 21.0. One-way ANOVA was performed to assess significance.

RESULTS AND DISCUSSION

The phytosociological assessment of woody species in the Ibudhou Marjing Sacred Grove and its adjoining Heingang Reserved Forest in Imphal

East district, Manipur, revealed distinct patterns in floristic composition, community dynamics, and regenerative potential.

Tree species composition and diversity

The sacred grove recorded 46 genera distributed across 25 families (Table 1). Comparatively, the reserved forest supported 25 genera across 15 families. Overall, species richness (S) was significantly greater in the sacred grove (52 species) compared to the reserved forest (29 species) ($F = 5.786$, $P < 0.05$). Consistent with the findings of Bharathi and Devi Prasad (2017) and Mansingh et al. (2025), the majority of species recorded at both sites belonged to the family Fabaceae. A significantly higher number of tree species was recorded in the sacred grove than in the reserved forest (Fig. 2). The greater diversity observed in the sacred grove may also be linked to local people's commitment to conservation, as reported by Tynsong et al. (2022). The species diversity index (H') ranged from 2.49 (in the sacred grove) to 2.14 (in the reserved forest). Statistical analysis revealed no significant variation in H' between the two sites ($F = 4.398$, $p = 0.052$). Furthermore, the diversity index for Indian forests ranged between 0.83 and 4.10 (Dutta and Devi 2013). Except for the dominance index (D), all evaluated phytosociological indices were higher in the sacred grove than in the reserved forest. A lower D value showed that the stands are more active and stable (Odum 1971). While the Simpson diversity index (1-D) value in the present study falls within the range documented for Indian forests, it remains lower than those reported by Koushik Majumdar and Datta (2015) and Sarkar and Devi (2014). There was no significant variation ($p > 0.05$) in D and 1-D between the sacred grove and the reserved forest. Overall, an inverse relationship was observed between species diversity and the dominance index, with Simpson's index placing greater emphasis on the most abundant species in a sample and being less responsive to species with only a few individuals (Bharali et al. 2011, Malik and Bhatt 2015). Evenness (J) showed significant variation ($F = 2.623$, $p < 0.05$), although the values were notably lower than those documented by Sukumaran et al. (2018). Alpha diversity (α) differed significantly between the sites, with the sacred grove exhibiting greater floristic richness than the reserved forest ($F = 5.656$, $p < 0.05$). This difference was likely due to more favourable growth conditions. Furthermore, the richness recorded here was higher than that observed by Sukumaran et al. (2018) from the sacred grove of the tropical dry evergreen forest. Between the two study sites, the species similarity index revealed 31.3%. This low similarity index was likely attributable to variations in species composition and vegetation physiognomy, which may be driven by soil characteristics and other differing habitat

Table 1. Enumeration of family, genera, and species in the two study sites

Family	Sacred grove		Reserved forest	
	Genera	Species	Genera	Species
Anacardiaceae	3	3	3	3
Apocynaceae	1	1	0	0
Bignoniaceae	2	2	1	1
Boraginaceae	0	0	1	1
Cannabaceae	2	2	0	0
Combretaceae	1	1	0	0
Euphorbiaceae	1	1	0	0
Fabaceae	6	7	4	5
Fagaceae	2	3	2	2
Juglandaceae	1	1	0	0
Lamiaceae	2	2	1	1
Lauraceae	1	2	2	4
Loganiaceae	1	1	0	0
Lythraceae	1	1	0	0
Magnoliaceae	1	1	0	0
Malvaceae	2	2	1	1
Meliaceae	2	2	3	3
Moraceae	2	4	1	1
Myrtaceae	3	4	1	2
Phyllanthaceae	4	4	2	2
Oxalidaceae	1	1	0	0
Pentaphylaceae	1	1	0	0
Pinaceae	1	1	1	1
Rubiaceae	2	2	1	1
Salicaceae	2	2	0	0
Theaceae	1	1	1	1

conditions (Bharali et al. 2011).

Pinus kesiya retained the maximum dominance in both study sites. The dominance-diversity curve (Fig. 3) revealed a logarithmic decline in species rank-abundance. At the same time, the sacred grove showed a gentle slope. In contrast, the reserved forest displayed a steep, short profile, indicating that the latter was dominated by only a few species, such as *P. kesiya* and *L. polystachyus*. These curves also revealed that only a small number of species maintained high Important Value Index (IVI) values across both the study sites. The IVI of the dominant species in the sacred grove site was lower than the values documented by Devi Khumbongmayum et al. (2005). However, the high IVI and overall dominance of *P. kesiya*, alongside other co-dominant trees, indicated that these species possessed superior competitive abilities and the potential to survive and

outcompete other tree species in the community. Furthermore, the gentle slope of the dominance distribution curve for the sacred grove reflected greater community stability, while shorter, steeper curves in the reserved forest indicated increased species loss (Mishra et al. 2004, Bharali et al. 2011).

Tree density and basal area

The community structure differed notably between the two study areas: the sacred grove exhibited greater density, basal cover, and dominance hierarchies than the reserved forest (Table 2). Statistical analyses revealed significant differences in tree density among sites ($F = 5.786$, $P < 0.05$). Basal area varied significantly between the sites ($F = 7.242$, $p = 0.021$). Tree density was significantly higher at the sacred grove (1096 ± 158 individuals ha^{-1}) than that of the reserved forest (843 ± 66 individuals ha^{-1}). In the sacred grove, *F. auriculata* exhibited the highest frequency, followed by *P. kesiya*, *L. polystachyus*, and *Q. serrata*. *P. kesiya* accounted for the maximum basal cover at $42.04 \text{ m}^2 \text{ ha}^{-1}$. In contrast, the Heingang reserved forest displayed a different pattern, with *L. polystachyus* showing the highest frequency, followed by *L. tetranthera*, *S. colais*, and *W. glabrata*. Tree density was notably lower than in the sacred grove, recording 843 ± 66 individuals ha^{-1} . Among the species present, *L. polystachyus* exhibited the highest density, whereas *S. cumini* had the lowest. Basal cover stood at $22.36 \text{ m}^2 \text{ ha}^{-1}$. *P. kesiya* retained the maximum dominance in both study sites. The tree density observed in this study aligned with the findings reported by Sukumaran et al. (2018). Upadhaya et al. (2003) documented tree density ranging from 938 to 1476 individuals ha^{-1} in the sacred groves of the Jaintia hills of Meghalaya. Bharali et al. (2011) also recorded basal area values of 9.38 to $137.45 \text{ m}^2 \text{ ha}^{-1}$ in the Arunachal Himalaya. However, the basal cover recorded during the study is lower than in Kushalnagar, Karnataka, but comparable to that reported by Koushik Majumdar and Datta (2015) and Sarkar and Devi (2014).

Forest stand structure and regeneration status

A marked difference was observed in the distribution pattern of tree density and basal area between the two study sites (Fig. 4). Within the sacred grove, individuals with 10-30 cm GBH contributed 48.89% of the total tree density, compared to a substantially higher 71.01% in the reserved forest. The deviation from the expected J-shaped curve in the sacred grove was likely attributable to reduced logging of mature trees. In contrast, the reverse J-shaped density distribution observed in the reserved forest was characteristic of forests affected by intense grazing or selective logging for firewood and household needs (Bharathi and Devi 2017). However, an increased number of individuals within the 90-120 cm and 120-150 cm girth classes contributed

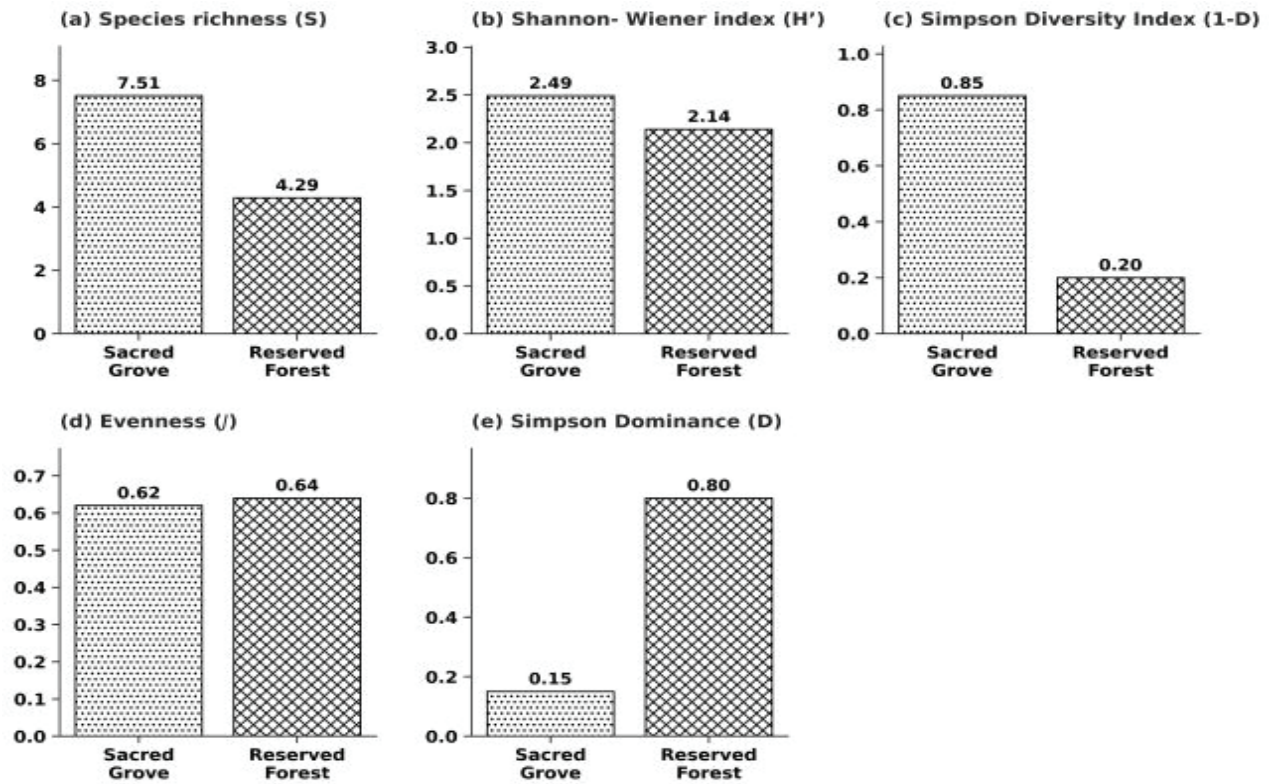


Figure 2. Comparison of Phytosociological Attributes of Tree Species between Ibudhou Marjing Sacred Grove (dotted bars) and its adjoining Heingang Reserved Forest (Crossed Bars). Subplots indicate distinct ecological metrics- (a) Species richness (S), (b) Shannon-Wiener Index (H'), (c) Simpson Diversity Index ($1-D$), (d) Evenness (J) and (e) Simpson Dominance (D)

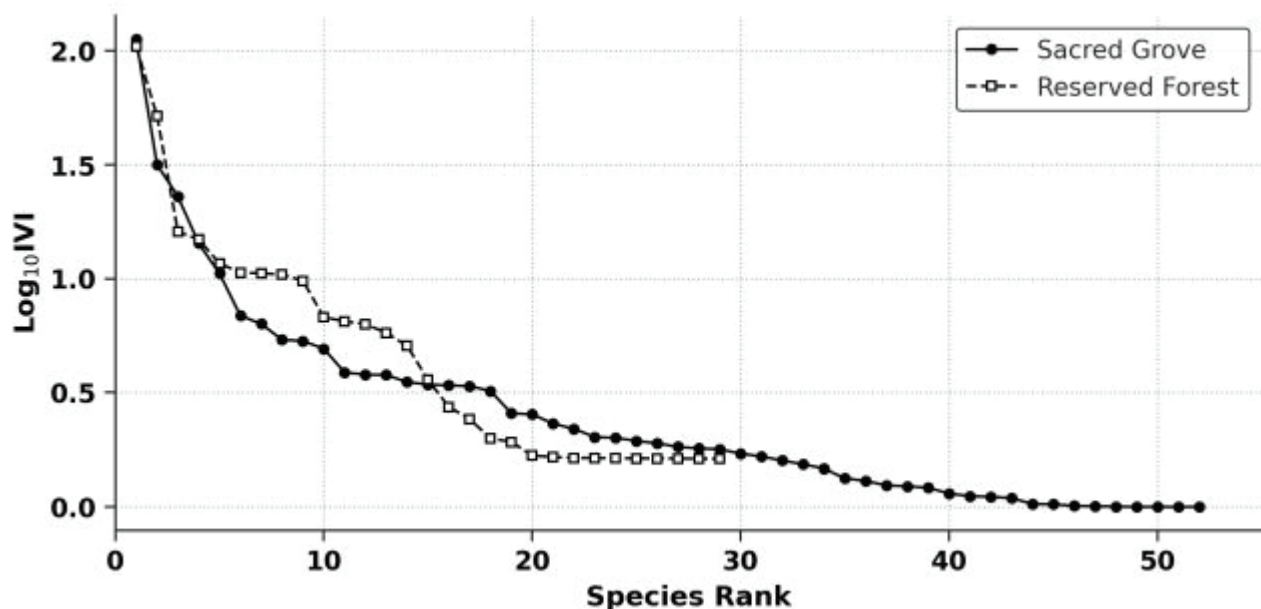


Figure 3. Dominance diversity (D-D) curves for trees in the Ibudhou Marjing Sacred Grove and its adjoining Heingang Reserved Forest

Table 2. Population characteristics of trees of the Sacred Grove and the Reserved Forest

Species name	Sacred grove				Reserved forest			
	F (%)	D (ind/ha)	BC (m ² /ha)	IVI	F (%)	D (ind/ha)	BC (m ² /ha)	IVI
<i>Acacia auriculiformis</i> A. Cunn. Ex Benth.	11.1	2.5	0.034	1.117	-	-	-	-
<i>Albizia chinensis</i> (Osbeck) Merr.	44.4	12.3	0.198	4.811	55.6	17.3	0.263	10.170
<i>Albizia procera</i> (Roxb.) Benth.	11.1	1.2	0.015	0.968	55.6	9.9	0.284	9.387
<i>Artocarpus heterophyllus</i> Lam.	11.1	1.2	0.361	1.630	-	-	-	-
<i>Averrhoa carambola</i> L.	11.1	2.5	0.018	1.087	-	-	-	-
<i>Azadirachta indica</i> A.Juss.	-	-	-	-	11.1	1.2	0.003	1.550
<i>Bischofia javanica</i> Blume	33.3	6.2	0.020	3.081	-	-	-	-
<i>Bombax ceiba</i> L.	11.1	1.2	0.023	0.983	-	-	-	-
<i>Bridelia retusa</i> (L.) A.Juss.	33.3	6.2	0.045	3.129	33.3	17.3	0.070	6.529
<i>Camphora officinarum</i> Boerh. ex Fabr.	-	-	-	-	11.1	1.2	0.007	1.567
<i>Cassia fistula</i> L.	33.3	8.6	0.275	3.794	-	-	-	-
<i>Celtis australis</i> L.	22.2	8.6	0.034	2.506	-	-	-	-
<i>Chukrasia tabularis</i> A.Juss.	11.1	2.5	0.422	1.859	11.1	3.7	0.018	1.909
<i>Cordia fragrantissima</i> Kurz	-	-	-	-	11.1	1.2	0.003	1.548
<i>Delonix regia</i> (Bojer ex Hook.) Raf.	22.2	1.2	0.003	1.771	-	-	-	-
<i>Engelhardia spicata</i> var. <i>spicata</i>	11.1	1.2	0.031	0.998	-	-	-	-
<i>Entada phaseoloides</i> (L.) Merr.	-	-	-	-	11.1	1.2	0.001	1.538
<i>Enterolobium cyclocarpum</i> (Jacq.) Griseb.	11.1	1.2	0.326	1.562	-	-	-	-
<i>Eurya acuminata</i> DC.	33.3	8.6	0.025	3.316	-	-	-	-
<i>Ficus auriculata</i> Lour.	88.9	35.8	0.229	10.316	-	-	-	-
<i>Ficus hispida</i> L.f.	55.6	21.0	0.071	6.183	11.1	1.2	0.002	1.543
<i>Ficus religiosa</i> L.	11.1	2.5	0.424	1.863	-	-	-	-
<i>Flacourtia jangomas</i> (Lour.) Raeusch.	11.1	1.2	0.019	0.975	-	-	-	-
<i>Glochidion zeylanicum</i> var. <i>arborescens</i> (Blume) Chakrab. & M.Gangop.	22.2	2.5	0.003	1.885	-	-	-	-
<i>Gmelina arborea</i> Roxb. ex Sm.	11.1	2.5	0.236	1.503	11.1	6.2	0.119	2.655
<i>Holigarna longifolia</i> Buch.-Ham. ex Roxb.	-	-	-	-	11.1	3.7	0.113	2.335
<i>Kydia calycina</i> Roxb.	11.1	3.7	0.026	1.214	11.1	1.2	0.013	1.592
<i>Lithocarpus polystachyus</i> (Wall. ex A.DC.) Rehder	77.8	271.6	0.932	32.346	77.8	332.1	0.825	52.798
<i>Litsea monopetala</i> (Roxb.) Pers.	44.4	34.6	0.159	6.764	33.3	13.6	0.065	6.067
<i>Litsea tetranthera</i> Mirb.	33.3	12.3	0.045	3.692	55.6	44.4	0.118	12.742
<i>Magnolia champaca</i> (L.) Baill. ex Pierre	22.2	8.6	0.021	2.481	-	-	-	-
<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	11.1	1.2	0.011	0.960	-	-	-	-
<i>Mangifera indica</i> L.	22.2	12.3	0.310	3.372	-	-	-	-
<i>Melaleuca citrina</i> (Curtis) Dum.Cours.	11.1	2.5	0.133	1.306	-	-	-	-
<i>Neolamarckia cadamba</i> (Roxb.) Bosser	11.1	1.2	0.385	1.677	-	-	-	-
<i>Oroxylum indicum</i> (L.) Kurz	11.1	1.2	0.017	0.971	-	-	-	-
<i>Parkia speciosa</i> Hassk.	-	-	-	-	11.1	1.2	0.004	1.553
<i>Phoebe bootanica</i> (Meisn.) M.Gangop.	-	-	-	-	11.1	3.7	0.002	1.838
<i>Phyllanthus emblica</i> L.	33.3	8.6	0.012	3.291	11.1	1.2	0.001	1.540
<i>Pinus kesiya</i> Royle ex Gordon	77.8	286.4	42.048	112.387	33.3	148.1	18.481	104.390
<i>Plumeria alba</i> L.	11.1	3.7	0.021	1.204	-	-	-	-
<i>Psidium guajava</i> L.	11.1	2.5	0.007	1.065	-	-	-	-
<i>Punica granatum</i> L.	11.1	1.2	0.008	0.955	-	-	-	-
<i>Quercus acutissima</i> Carruth.	11.1	2.5	0.368	1.755	-	-	-	-

Species name	Sacred grove				Reserved forest			
	F (%)	D (ind/ha)	BC (m ² /ha)	IVI	F (%)	D (ind/ha)	BC (m ² /ha)	IVI
<i>Quercus serrata</i> Murray	77.8	108.6	3.696	22.769	44.4	43.2	0.242	11.760
<i>Rhus chinensis</i> var. <i>chinensis</i>	66.7	103.7	0.287	14.968	33.3	21.0	0.078	7.003
<i>Schima wallichii</i> (DC.) Korth.	22.2	16.0	0.322	3.733	44.4	28.4	1.253	14.525
<i>Senegalia pennata</i> (L.) Maslin	-	-	-	-	11.1	1.2	0.002	1.544
<i>Spondias pinnata</i> (L.f.) Kurz	11.1	2.5	0.115	1.272	22.2	4.9	0.015	3.432
<i>Stereospermum colais</i> (Buch.-Ham. ex Dillwyn) Mabb.	44.4	19.8	0.053	5.209	44.4	33.3	0.130	10.090
<i>Strychnos nux-blanda</i> A.W.Hill	22.2	2.5	0.043	1.961	-	-	-	-
<i>Syzygium cumini</i> (L.) Skeels	11.1	2.5	0.015	1.080	11.1	1.2	0.001	1.542
<i>Syzygium praecox</i> (Roxb.) Rathakr. & N.C.Nair	22.2	4.9	0.017	2.136	33.3	4.9	0.016	4.824
<i>Tamarindus indica</i> L.	11.1	1.2	0.033	1.002	-	-	-	-
<i>Tectona grandis</i> L.f.	11.1	3.7	0.011	1.185	-	-	-	-
<i>Terminalia arjuna</i> (Roxb. ex DC.) Wight & Arn.	11.1	6.2	0.027	1.442	-	-	-	-
<i>Toona ciliata</i> M.Roem.	44.4	6.2	0.202	4.255	33.3	14.8	0.072	6.248
<i>Trema orientale</i> (L.) Blume	22.2	2.5	0.034	1.944	-	-	-	-
<i>Wendlandia glabrata</i> DC.	33.3	29.6	0.064	5.304	44.4	80.2	0.161	15.793
<i>Xylosma longifolia</i> Clos	11.1	1.2	0.020	0.978	-	-	-	-

F= Frequency, D= Density, BC= Basal cover, IVI= Important value index

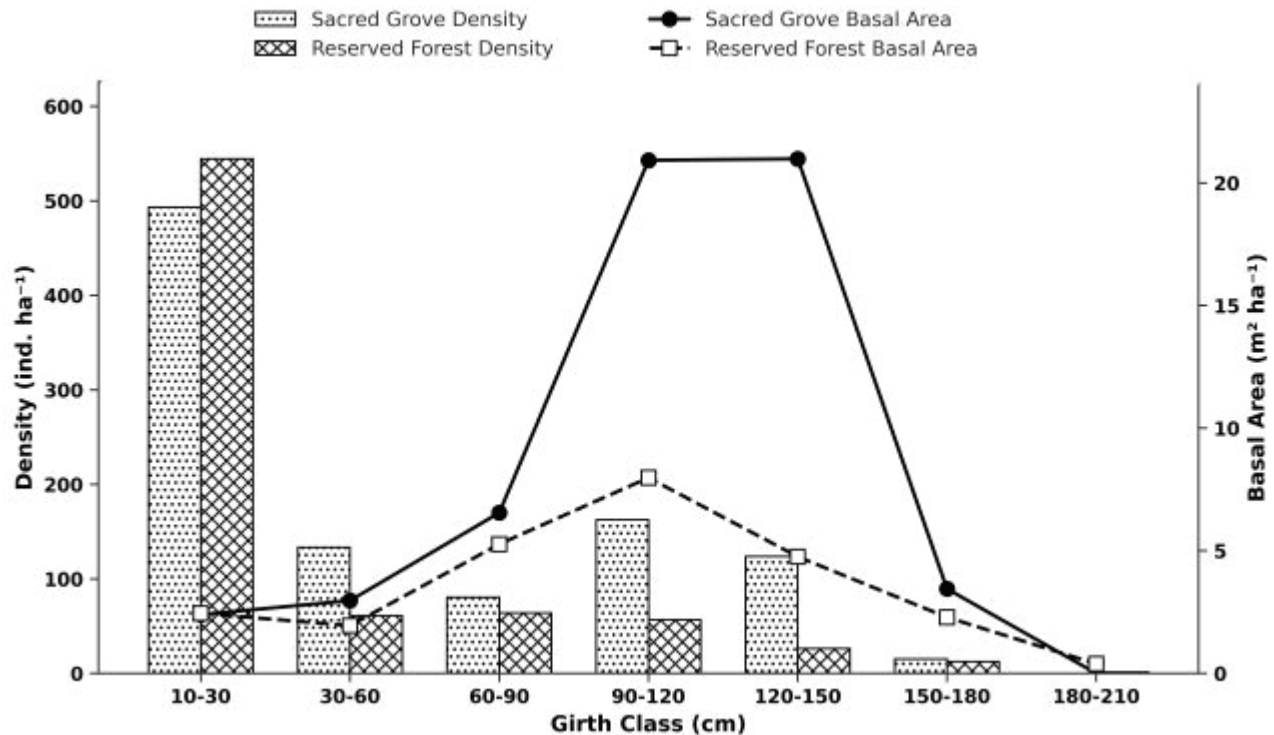


Figure 4. Distribution of tree density and basal area across girth classes in Ibudhou Marjing Sacred Grove and its adjoining Reserved Forest. Tree density is represented by grouped bars, while basal area is represented by superimposed line

significantly to greater basal cover observed in the sacred grove. These results contrasted with those of Devi Khumbongmayum et al. (2006), who reported the highest stand density in the 60-90 cm GBH class. Furthermore, the distribution of basal area across girth classes exhibited an asymmetrical pattern; individuals in the 120-150 cm class accounted for the maximum basal area (36.63%) in the sacred grove, while trees in the 90-120 cm class contributed the most (31.80%) in the reserved forest. The reserved forest, characterised by the lowest basal area and the highest density of younger trees (10-30 cm), was likely more disturbed than the sacred grove, which exhibited a lower density of younger

individuals. This observation aligned with findings from other regions, indicating that forests dominated by younger trees generally exhibited higher stem density but lower basal area, likely due to selective logging or natural disturbance (Mansingh et al. 2025). Davidar et al. (2007) reported that larger GBH trees contributed significantly to total basal area, whereas smaller GBH trees enhanced overall species diversity in the region.

Assessments of seedlings and saplings population, alongside adult tree density, indicated a greater sapling density in the sacred grove (7475 individuals ha^{-1}) compared to the reserved forest (7400 individuals ha^{-1}) (Fig. 5). Conversely, seedling density was

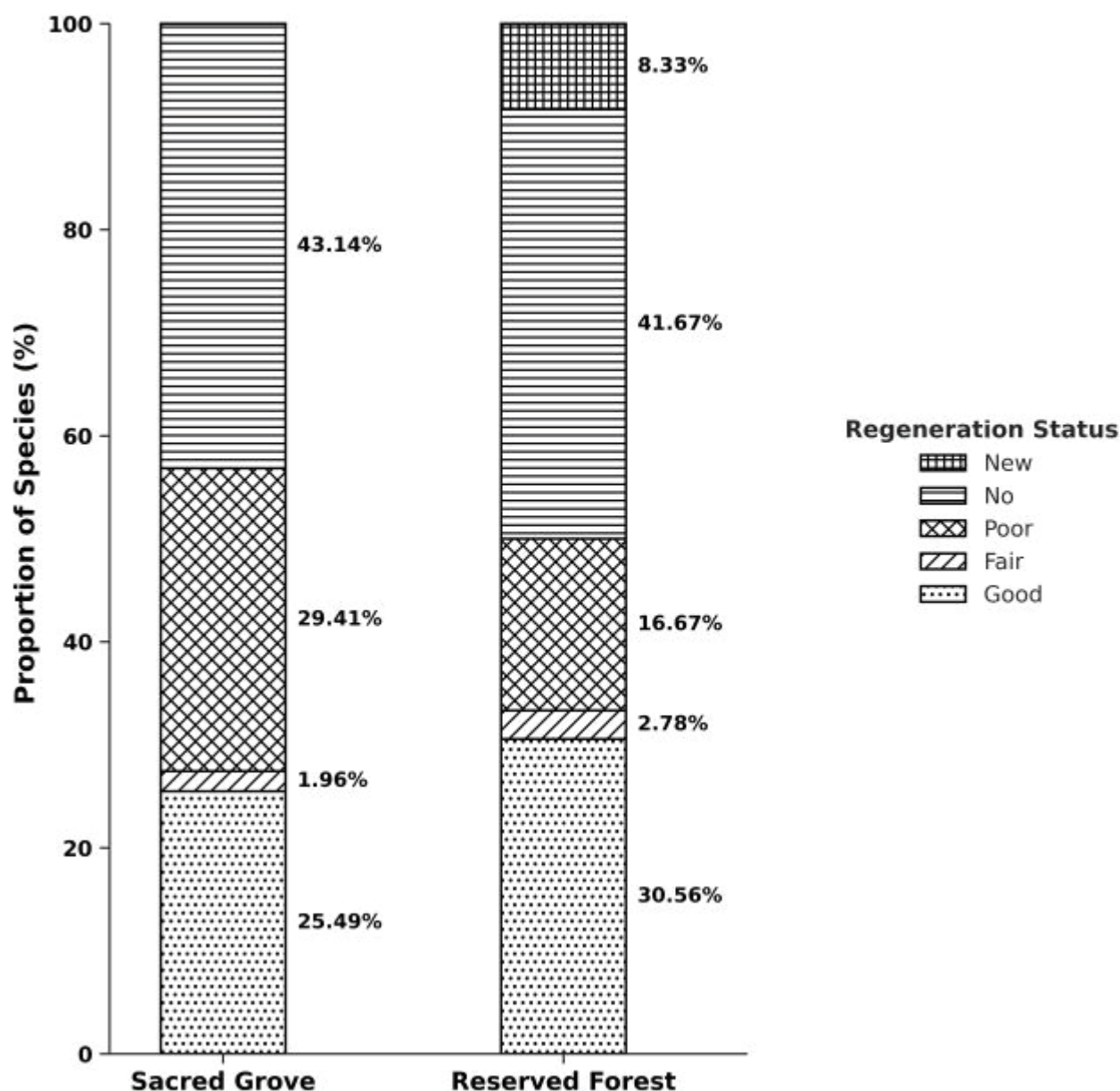


Figure 5. Comparative regeneration status of woody species in the Sacred grove and its adjoining Heingang Reserved Forest. Stacked bars represent the relative proportion (%) of species falling into five distinct regeneration categories (Good, Fair, Poor, No, and New)

substantially greater in the reserved forest (74375 individuals ha^{-1}) than in the sacred grove (50000 individuals ha^{-1}). Seedling density was significantly higher than both sapling and adult tree densities, which indicated an overall "Good" regeneration status. Consequently, 25.49% of the tree species in the sacred grove and 30.56% in the reserved forest were classified under the "Good Regeneration" category. Meanwhile, a similar proportion of tree species fell under the "Poor Regeneration" category across both sites. However, 43.14% of species in the sacred grove and 41.67% in the reserved forest are recorded as having "No Regeneration". This lack of regeneration indicated a high sensitivity to ongoing disturbances and that these species were at risk of local extinction in the future (Buragohain et al. 2023). *Rhus chinensis* showed the highest regeneration potential across both study sites. In the sacred grove, the species recorded a seedling density of 11,875 individuals ha^{-1} , alongside 2,050 saplings and 117 adult trees ha^{-1} . Conversely, in the reserved forest, seedling density was 23,750 individuals ha^{-1} , with 375 saplings and 24 adult trees ha^{-1} . The robust regeneration capacity of *R. chinensis* in the sacred grove was likely favoured by the limited regeneration potential of

competing species. In contrast, its dominance in the reserved forest was likely driven by disturbance and its opportunistic traits (Buragohain et al. 2023). Furthermore, the presence of new individuals in the reserved forest may result from plant enrichment. This observation was comparable to the findings of Bhuyan et al. (2003), regarding species enrichment in highly disturbed stands using a taungya system (personal observation).

Distribution pattern

The majority of species at both sites exhibited a contiguous (clumped) distribution pattern, accounting for 92% of the total species in the sacred grove and 93% in the reserved forest (Fig. 6). A smaller proportion of species showed a random distribution, comprising 15% in the sacred grove and 7% in the reserved forest. Meanwhile, only a negligible percentage of species showed a regular distribution across both sites: 2% in the sacred grove and 4% in the reserved forest. These findings closely aligned with a similar distribution pattern previously documented in other forest vegetation studies (Malik and Bhatt 2015, Sukumaran et al. 2018, Tynsong et al. 2022).

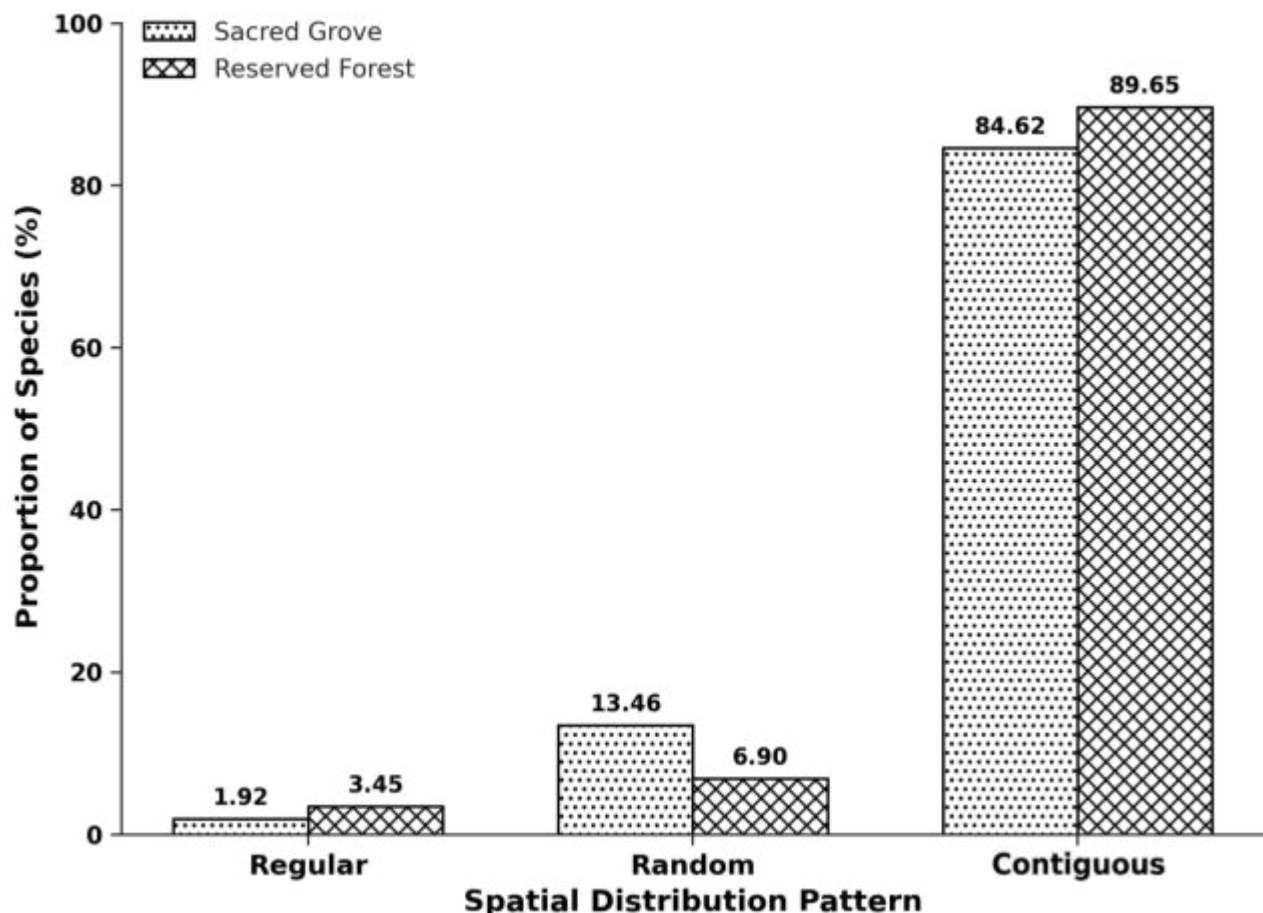


Figure 6. Species distribution pattern in Sacred Grove and its adjoining Heingang Reserved Forest. Grouped bars illustrate the relative proportion (%) of species exhibiting regular, random and contiguous dispersion

CONCLUSIONS

In conclusion, this study illuminates the vital ecological and cultural value of the Ibudhou Marjing Sacred Grove as a biodiversity stronghold in Manipur, outperforming its adjoining Heingang Reserved Forest in terms of species richness, structural complexity, and regeneration vigour. The higher diversity indices, mature tree cohorts, and robust seedling recruitment of groves underscore how indigenous Meitei traditions foster resilient forest communities amid regional threats such as urbanisation and habitat fragmentation. By safeguarding 52 woody species and promoting equitable resource distribution, sacred groves exemplify community-driven conservation models that enhance ecosystem services, from carbon storage to cultural heritage preservation.

These findings advocate for policy innovations, such as integrating sacred sites into national biodiversity frameworks with incentives for local guardianship, potentially through digital mapping tools for real-time monitoring. Future research could explore climate-resilient traits in dominant species such as *Pinus kesiya* via genomic analyses, assess faunal dependencies on grove flora, or evaluate the socio-economic impacts of eco-tourism on regeneration dynamics. Longitudinal studies incorporating remote sensing and participatory citizen science would further unravel disturbance thresholds, paving the way for adaptive management strategies that harmonise tradition with modern sustainability goals.

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