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Tree Diversity and Population Structure in Sacred and Non-sacred Forests on Karst Landscape in Meghalaya, Northeast, India

Bshar Samir Bdoor[1,2]
[1]Directorate of Environmental Affairs, Latakia, Syria
[2]School of Environmental Sciences, Jawaharlal Nehru University, New Delhi-110067, India
Email: bsharbdoor@yahoo.com

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Abstract

Forest sacredness as a concept and practice is embedded in the indigenous Khasi religion. Changes in the social values can have profound impacts on the environment. The present study assessed tree diversity and population structure in adjacent sacred and non-sacred community forests on karst landscape in East Khasi Hills, Meghalaya, India. Tree richness, density, and stand basal area were markedly lower in the non-sacred forest than in the sacred forest, indicating the impact of the past disturbance on ecological integrity of the karst landscape. With the gradual disappearance of forest sacredness and the accompanying excess resources exploitation, flora of the sacred forests of Meghalaya is under threat. Hence, local community-oriented initiatives for the conservation and management of sacred and non-sacred community forests are needed.

Introduction

Meghalaya, which is a part of *Indo-Myanmar* biogeographic *region* has a high concentration of India's plant species. It harbours 3331 plant species, among which 133 are restricted to sacred groves. Of these 133 species, 96 species are endemic to the state of Meghalaya (Khan *et al*., 1997). The state is a home to 79 sacred forests (Jeeva *et al*., 2006). In present time, these sacred groves could be described as islands of biodiversity in a degraded landscape (Ramakrishnan, 2000).

Myers *et al*. (2000) identified *Indo-Myanmar* region to be one of the world's 25 biodiversity hotspots that have exceptional concentration of endemic species and undergo exceptional loss of habitat. The quantitative characters such as density and diversity could act as indicators of disturbances threatening the forest ecosystem, and therefore such studies could help in forest conservation (Reddy and Ugle, 2008). Despite recent efforts to probe the phytoscociological characteristics of Meghalayan forests (e.g. Tripathi, 2003; Upadhaya *et al*., 2004; Mishra *et al*., 2005; Kumar *et al*., 2006; Laloo *et al*., 2006; Tripathi *et al*., 2010; Tynsong and Tiwari, 2010; Upadhaya, 2015), the phytoscociological characteristics of the sacred groves of East Khasi hills of Meghalaya and their relation to disturbances are not fully addressed. Tree diversity is an important expression of forest ecosystem diversity (Rennolls and Laumonier, 2000). The present study investigates the impact of disturbances on tree diversity and population structure in karst landscape taking adjacent sacred and non-sacred forests as representative sites.

Study site

The study was carried out in Mawsmai village, East Khasi Hills district, Meghalaya, India (Figure 1). The village is located between 25^{o}14'21.86" and 25^{o}15'08.61" North latitudes and 91^{o}43'05.45" and 91^{o}43'57.02" East longitudes. The altitude ranges between 1150 and 1240 m. Mawsmai village landscape is part of Cherrapunji (Sohra) Plateau.

The climate of the area is humid subtropical, divided into three seasons: rainy season during May to October, dry winter season during November to February and short spring season during March and April. For the ten years from 2004 to 2013, the annual rainfall at Cherrapunji ranged between 7560 to 14791 mm with an average of 10953 mm. The annual rainfall for the year 2013 was 7560 mm and the mean monthly temperature varied between a minimum of 11.9 ^{0}C in January and a maximum of 21.8 ^{0}C in June, while humidity levels ranged from 60% in February to 96% in July. Wind is northeasterly during winter season and southwesterly during monsoon season. The meteorological data were obtained from Indian Meteorological Department office at Lower Cherrapunji, about 3 km north of Mawsmai village.

The vegetation of Mawsmai is developed on limestone formations having distinct karst topography. There is an abrupt boundary between the forest land and the surrounding landscape, which is primarily grassland. Limestone formations underlie the fragile, highly leached soil of Mawsmai forest (Ramakrishnan, 1997).

Forest land of Mawsmai village was stratified based on its nominative and historical status into Mawlong Syiem sacred forest, Ramjadong forest and other forest land. Mawlong Syiem sacred forest, called also as Mawlong sacred forest, represents forest land of about 70 ha and have Mawsmai show cave. The forest is the historically sacred portion of about 120 ha forest land. The unsacred portion of the 120 ha forest land is the western portion adjacent to locally confirmed historical shifting cultivation plot. Ancient field marking stones demarcating the plot are still present. This non-sacred forest land has no distinct name and would be referred to in this study as “other forest land”. Ramjadong forest, represents non-sacred forest to the east of Mawlong forest with an area of about 5 ha. Mawlong and Ramjadong forests are about 200 m apart at their closest points, and both forests adjoin a major limestone quarry located next to their northern boundaries.

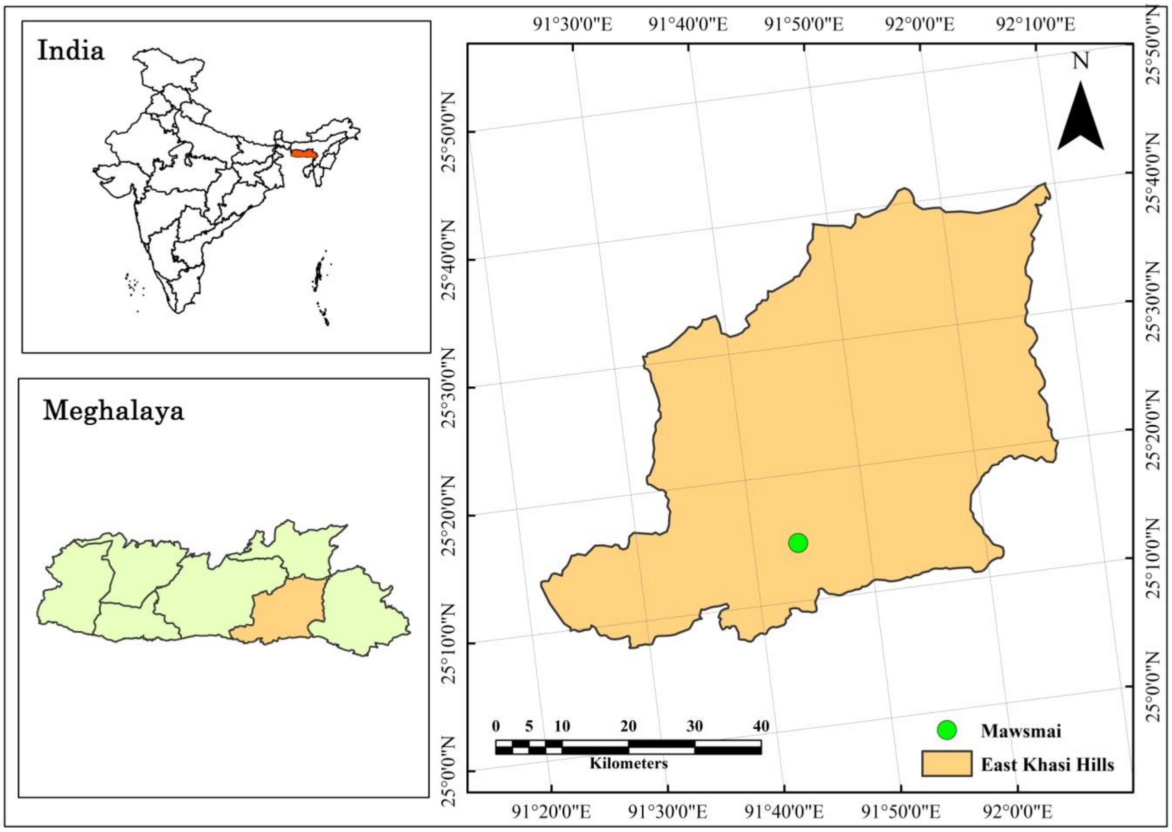

Figure 1. Location map of the study area

Materials and Methods

The study was carried out between August 2013 and May 2014. Six plots, each of 1000 m^2 area, were used for the identification of tree species ≥ 10 cm diameter at breast height (DBH). The sampling plots were distributed randomly in the sacred forest Mawlong and the non-sacred forest Ramjadong, three in each forest so direct comparison could be made. Sampling intensity [(sample *area*/*Total area*) x100] in the present study was 0.43 and 6 for Mawlong and Ramjadong forests respectively. Synnott (1979) considered sampling intensity of 0.25% to 0.4% for relatively uniform forests to be adequate. Each tree was labeled, measured for height and DBH. Local names of tree species were reported and a herbarium was made. The specimens were identified through consulting Botanical Survey of India, Shillong, regional flora and literature.

Disturbance magnitude for Mawlong and Ramjadong forests was calculated as a ratio of the basal area of cut trees to the total basal area of all trees (intact and felled) following Kanzaki and Yoda (1986) as cited in Rao *et al*. (1990). The disturbance was calculated for tree diameter class ≥ 10 cm. The forest communities where then classified as undisturbed forest (disturbance index 0%), mildly disturbed forest (disturbance index >

0% and ≤ 20%), moderately disturbed forest (disturbance index > 20% and ≤ 40%), or highly disturbed forest (disturbance index > 40%).

Species richness was determined as the number of species found in the sampled area. As presented in Magurran (2004), Margalef index of species richness, Shannon index of diversity, Simpson index of dominance, Pielou index of evenness and Sørensen's index of similarity were calculated for tree and palm species ≥ 10 cm DBH. The tree community structure was investigated with regard to tree density, basal area, and DBH class distributions. Density was measured as the total number of individuals of all species per hectare. Stand basal area (m^2 ha^{-1}) was calculated for live trees by multiplying average basal area of all tree species by tree density. DBH class distribution was constructed based on 10 cm interval as per Stas (2014). The tree and palm species were grouped into three broad height classes (small tree 5-8 m, medium tree 8-15 m, large tree ≥ 15 m) adapted from Upadhaya *et al*. (2004).

Results

The disturbance index was calculated to be 8.51% and 39.45% for Mawlong and Ramjadong forests respectively. Hence, Mawlong sacred forest can be described as mildly disturbed while Ramjadong forest as moderately to highly disturbed forest. Stand characteristics of Mawlong and Ramjadong forests are presented in table 1.

Tree diversity (tree and palm species ≥ 10 cm DBH)

A total of 254 individuals belonging to 41 different species (31 genera and 22 families) were encountered in the 3000 m^2 sampling area of Mawlong sacred. For same sampling size, the study recorded 120 individuals belonging to 24 species (22 genera and 18 families) in Ramjadong forest. *Margalef's* species *richness index* was calculated to be 7.22 and 4.80 for Mawlong and Ramjadong forests respectively.

Table 1. Stand characteristics (trees ≥ 10 cm DBH) of Mawlong and Ramjadong forests, Mawsmai village, Meghalaya, northeast India.

Variables	Forest	
	Mawlong sacred	Ramjadong non-sacred
Area sampled (m^2)	3000	3000
Disturbance index	8.51%	39.45%
Density (trees ha^{-1})	847	400
Basal area (m^2 ha^{-1})	32.31	15.25
Average tree height (cm)	1251	1194
Species richness (number of species)	41	24
Magralef species richnes index	7.22	4.80
Shannon diversity index	3.22	2.61
Pielou evenness index	0.87	0.82
Simpson dominance index	0.06	0.12

Table 2. Family-wise species richness (number of species in 3000 m^2), density (number of individuals ha^{-1}), and basal area (m^2 ha^{-1}) for trees and palms ≥ 10 cm DBH in Mawlong sacred forest and Ramjadong forest of Mawsmai village.

	Family	Species richness	Density	Basal area
Mawlong sacred forest	Euphorbiaceae	4	73.3	2.43
	Fagaceae	4	73.3	2.41
	Rubiaceae	4	83.3	3.94
	Lauraceae	3	43.3	1.09
	Moraceae	3	53.3	2.30
	Oleaceae	3	213.3	9.35
	Theaceae	3	83.3	2.03
	Anacardiaceae	2	23.3	2.97
	Annonaceae	2	16.7	0.24
	Arecaceae	1	10.0	0.80
	Caprofoliaceae	1	20.0	0.40
	Clusiaceae	1	3.3	0.05
	Erythroxylaceae	1	3.3	0.05
	Hamamelidaceae	1	6.7	0.12
	Juglandaceae	1	13.3	0.18
	Myrtaceae	1	3.3	0.08
	Pandanaceae	1	50.0	0.87
	Proteaceae	1	43.3	2.08
	Symplocaceae	1	13.3	0.28
	Others	3	16.7	0.63
Ramjadong forest	Fagaceae	4	33.3	0.78
	Caprofoliaceae	2	33.3	0.36
	Lauraceae	2	53.3	3.59
	Rubiaceae	2	116.7	2.57
	Anacardiaceae	1	16.7	1.02
	Elaeocarpaceae	1	10.0	0.44
	Erythroxylaceae	1	3.3	0.11
	Euphorbiaceae	1	3.3	0.03
	Hamamelidaceae	1	16.7	0.54
	Moraceae	1	3.3	0.04
	Myrtaceae	1	10.0	0.20
	Oleaceae	1	10.0	0.32
	Pandanaceae	1	26.7	0.26
	Proteaceae	1	20.0	3.72
	Rosaceae	1	10.0	0.12
	Symplocaceae	1	3.3	0.03
	Theaceae	1	26.7	0.38
	Others	1	3.3	0.75

With 4 species, Euphorbiaceae, Fagaceae and Rubiaceae were the dominant families in Mawlong sacred forest with regard to species richness. The following are the other dominant families: Lauraceae, Moraceae, Oleaceae, and Theaceae, each having 3 species. Thirteen families were represented by one species. Fagaceae (4 species) was the most dominant family in Ramjadong forest with respect to species richness. Caprofoliaceae, Lauraceae, and Rubiaceae were represented by 2 species each. Oleaceae (213 individuals ha^{-1}), Rubiaceae (83 individuals ha^{-1}) and Theaceae (83 individuals ha^{-1}) were the dominant families based on density in Mawlong sacred forest; whereas Rubiaceae (117 individuals ha^{-1}) and Lauraceae (53 individuals ha^{-1}) were the dominant families in Ramjadong forest (Table 2).

The Shannon diversity index was computed to be 3.22 in Mawlong forest and 2.61 in Ramjadong forest. The Simpson index of dominance was calculated to be 0.06 in Mawlong forest and 0.12 in Ramjadong forest. Pielou's eveness index was calculated for Mawlong sacred forest and Ramjadong forest to be 0.87 and 0.82 respectively (Table 1).

A total of 19 tree species (41.3% of the species) were common to both forests. High floristic similarity was reported between the two forests (Cs: 0.58). The species-area curves for Mawlong and Ramjadong communities did not approach an asymptote suggesting the need of more sampling plots. However, the curves were different. Species-area curve for Mawlong sacred forest rises steadily, indicating that additional sampling plots would add several new species. On the other hand, the species curve for Ramjadong forest showed a horizontal asymptote after 2000 m^2 area (Figure 2).

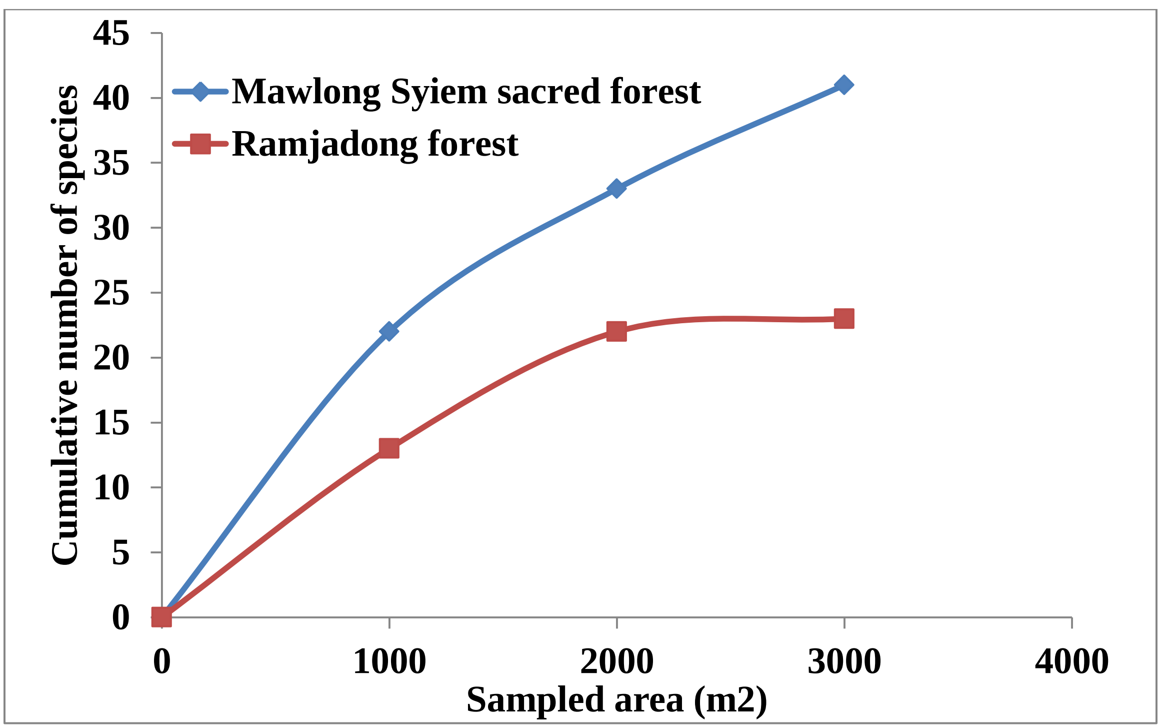

Figure 2. Species-area curve for Mawlong and Ramjadong forests of Mawsmai village

Stand density, basal area and vertical structure

Density of trees (>10 cm DBH) in Mawlong sacred forest (847 ± 66 trees ha^{-1}) (mean ± standard error) is more than double than that in Ramjadong forest (400 ± 35 trees ha^{-1}). The densities were significantly different ($P < 0.05$). The stand basal area for trees ≥ 10 cm DBH in the sacred Mawlong forest (32.31 m^2 ha^{-1}) was markedly higher than in Ramjadong forest (15.25 m^2 ha^{-1}). Out of the 46 tree species (≥ 10 cm DBH) reported in the 6000 m^2 area of Mawsmai forest land, 11 species (24%) were large/canopy trees, 29 species (63%) were medium/subcanopy trees, and 6 species (13%) were small trees. Average height for tree species ≥10 cm DBH for Mawlong and Ramjadong forest was (1251 ± 33 cm) and (1194 ± 55 cm) respectively. The tree height of Mawlong and Ramjadong forests was not significantly different ($P > 0.05$).

Population structure

Tree DBH class (10-20) was the most abundant in both Mawlong sacred forest and Ramjadong forests (603 and 273 individual ha^{-1}) with a share of 71.3% and 68.3% of total tree density respectively. There was a sharp decline in tree density from lower to higher diameter classes. Density-diameter in both forests showed the reverse J-shaped distribution (Figure 3). Merely 1.2% and 1.7% of the individuals were in the mature >60 cm DBH class in Mawlong and Ramjadong forests respectively.

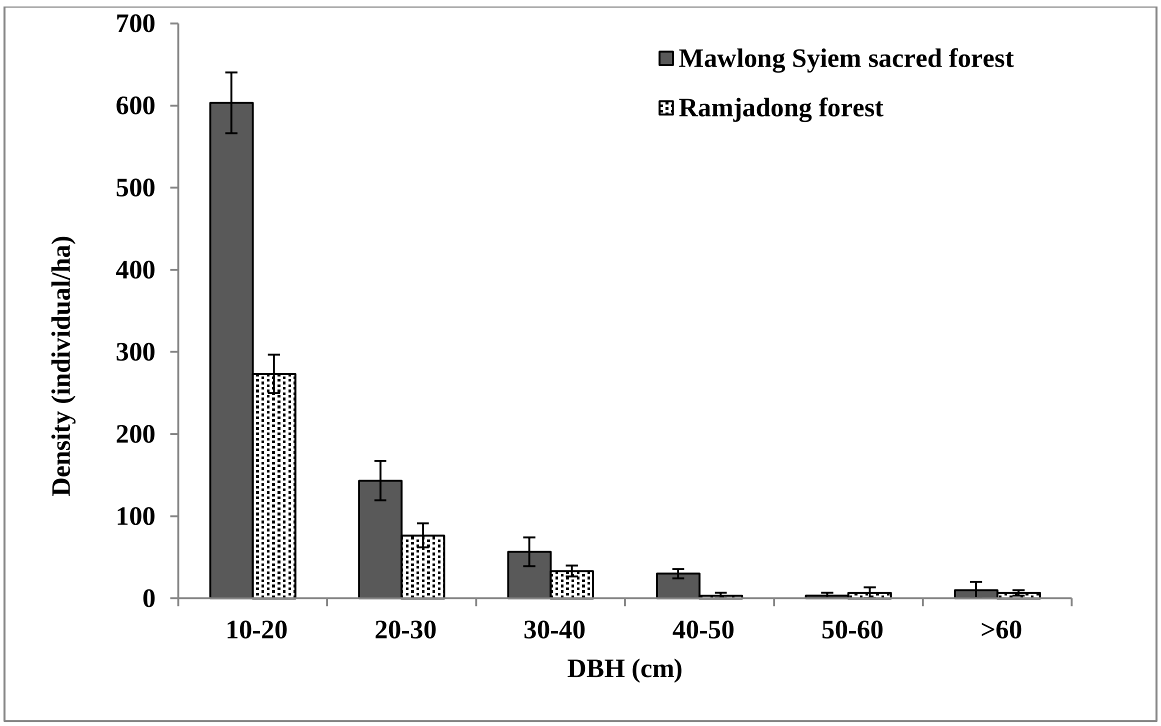

Figure 3. Tree density in different tree diameter classes in Mawlong Syiem sacred forest and Ramjadong forest of Mawsmai village, Meghalaya, northeast India.

With regard to the contribution of different tree diameter classes in basal area in Mawlong and Ramjadong forests, young trees class 10-20 cm DBH accounted for the largest share of basal area in both forests. Although both forests have few mature individuals >60 DBH, these individuals accounted for a relatively large share of the total basal area (Figure 4).

Distribution of species and family richness in different tree DBH classes in both forests reveals relatively high richness in 10-20 cm DBH class. A 0.1 ha plot averagely encompassed 20 and 12 species in 14 and 11 families in Mawlong and Ramjadong forests respectively in the tree DBH class 10-20 cm. The richness declined along higher DBH classes (Figure 5 and 6).

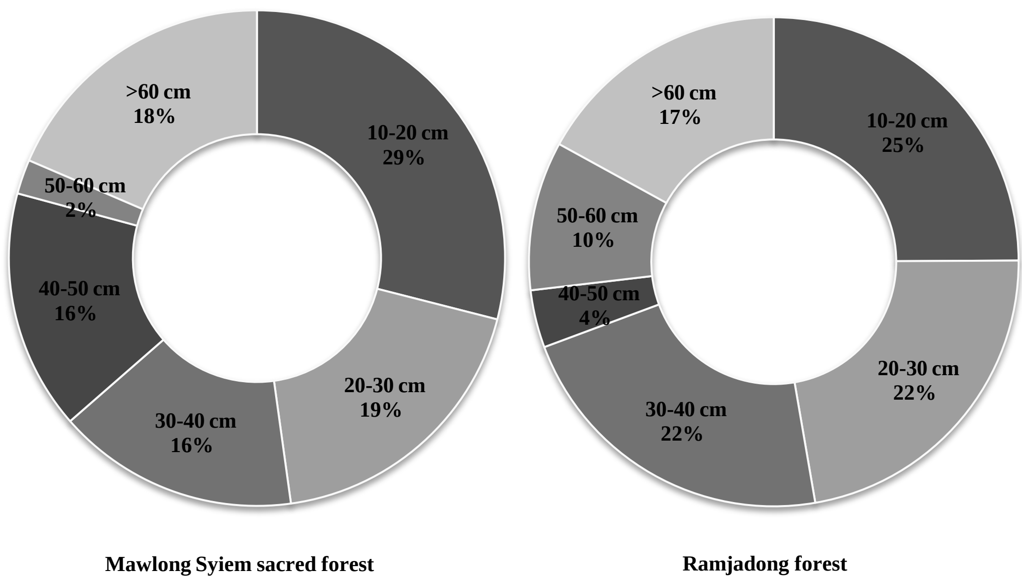

Figure 4. Tree diameter classes' contribution in basal area in Mawlong Syiem sacred forest and Ramjadong forest of Mawsmai village, Meghalaya, northeast India.

Discussion

The non-sacred Ramjadong forest was under disturbance (logging) of higher intensity (39.45%) than the sacred Mawlong forest (8.51%). The disturbance reported in Mawlong sacred forest reflects change in the social attitude toward the “sacredness” of the forest. The sacredness of Mawlong forest is derived from the indigenous Khasi religion that gradually vanished from Mawsmai village with the arrival of British missionaries in the mid of the nineteenth century (Anonymous Mawsmai village inhabitants, personal communication).

Tree diversity

Bearing in mind the differences in the DBH class and the sampling area, the species richness (number of tree species ≥ 10 cm DBH in the 3000 m^2 area) in Mawlong and Ramjadong forests was lower than that reported in Tynsong and Tiwari (2010), Upadhaya *et al*. (2003) and Mishra *et al*. (2005) for other Meghalayan forests. Shanmughavel *et al.* (2001) studied forest community structure and tree species diversity in a tropical rain forest in southwest China. Within the 1.04 ha sampling plot, their study identified 125 species > 5 cm DBH . In comparison with this value, even the maximum reported number of encountered species ≥ 10 cm DBH in a plot (1000 m^2) in Mawlong (24 species) and Ramjadong (18 species) could be considered as low. Species richness in Mawlong forest (41 species) is comparable to the richness of 55, 42, 38 and 38 tree species (>9.5 cm DBH) for four well preserved sacred groves in Manipur, Northeast India reported by Khumbongmayum *et al*. (2006) in sampling area of 4000 m^2 in each forest. The minimum number of species reported in an individual sampling plot of 1000 m^2 in Mawlong (22 species) and Ramjadong (13 species) was higher than the richness (6 tree species > 10 cm DBH in 2000 m^2) reported by Devi and Yadava (2006) for a tropical forest along the Indo-Myanmar Border, Manipur, India.

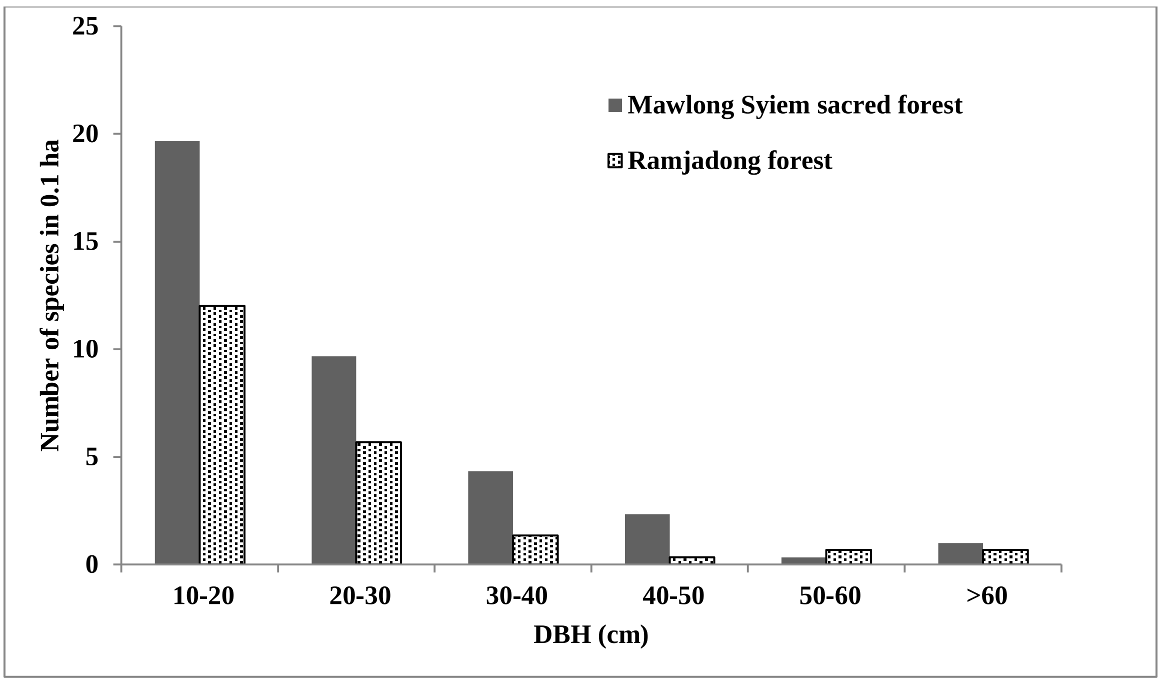

Figure 5. Tree species richness in different tree diameter classes in Mawlong Syiem sacred forest and Ramjadong forest of Mawsmai village, Meghalaya, northeast India.

Apart from comparing with other forests, when low diversity forest is characterized by having 50% to 100% of the canopy trees represented by one species (Connell and Lowman, 1989), Mawlong and Ramjadong forests can be considered as diverse forests. There are several factors that favour high species richness in Mawsmai forest land. Mawsmai forest is a relict rain forest ecosystem which contains climax vegetation found at higher elevations in Meghalaya (Ramakrishnan, 1997). Gentry (1988) noted that streams and tree falls contributed to microtopographic variations within each of his 1 ha sampling plot of highly diverse upper Amazonian forest. The phenomenon of live tree fall was reported during this study. The presence of streams and outcrops of different sizes is a common feature of Mawsmai village karst landscape. Therefore, it could be argued that habitat heterogeneity associated with karst topography may have contributed to tree diversity of Mawsmai forest land. Developing on karst landscape, the sacred forest of Cherrapunji is under stress caused by the leached nutritionally unbalanced substratum (Khiewtam and Ramakrishnan, 1993). However, heavy rainfall may increase soil nutrient heterogeneity and therefore contribute to species diversity (Wright *et al*., 1997).

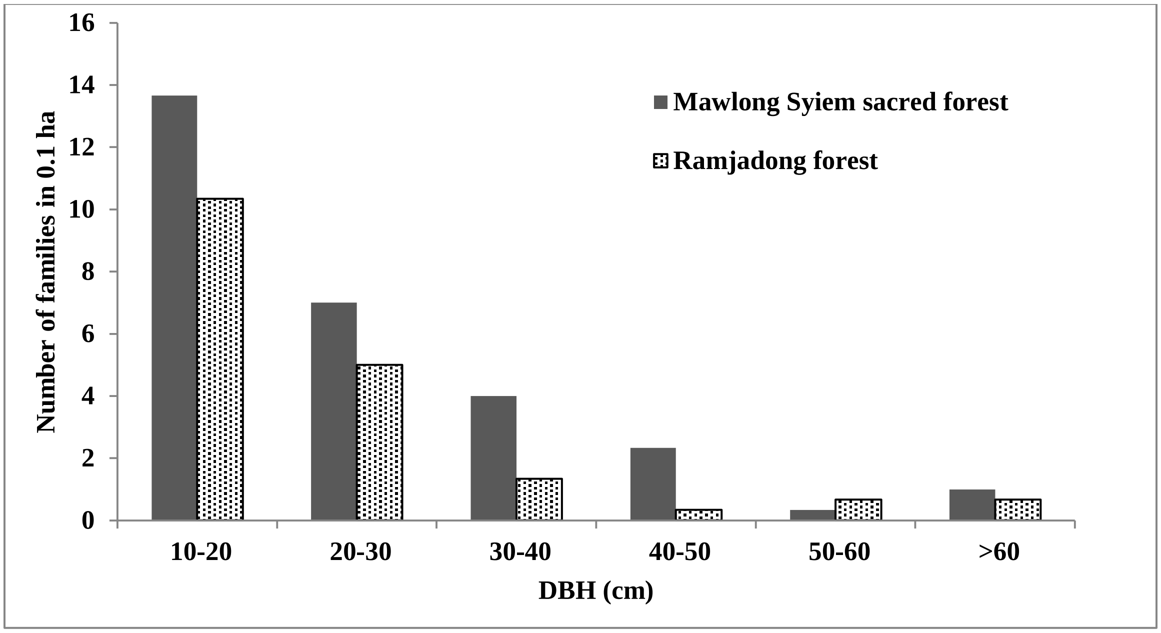

Figure 6. Tree family richness in different tree diameter classes in Mawlong Syiem sacred forest and Ramjadong forest of Mawsmai village , Meghalaya, northeast India.

For trees in rain forests, the non-equilibrium state brought by disturbances of intermediate intensity results in high diversity as a result of dynamical competition and adaptation processes (Connell, 1978). Bhuyan *et al*. (2003) studied tree diversity in four wet evergreen tropical forest stands of Arunachal Pradesh. For trees > 6.4 cm DBH in 0.9 ha sampling area, their study reported the highest richness (54 species) in the mildly disturbed stand, while the lowest species richness (16 species) in the highly disturbed stand. Similar impact of disturbance on species richness was reported in the present study. The mildly disturbed Mawlong sacred forest had higher species richness (41 tree species ≥ 10 cm DBH) in comparison with the species richness (24 tree species ≥ 10 cm DBH) of the moderately to highly disturbed Ramjadong forest. The difference in species richness can therefore be attributed mainly to the impact of past disturbance.

With regards to family dominance, similarity was reported between the present study and the study of Tripathi (2003). In both studies, Euphorbiaceae, Rubiaceae, Lauraceae and Theaceae are among the most dominant families based on species richness. Euphorbiaceae and Lauraceae were reported in Mishra *et al*. (2005) to be the most species-rich families in a Meghalayan sacred grove at Mawnai village, West Khasi hills district. Similar dominance was reported in Laloo *et al*. (2006) for undisturbed sacred grove (Mairang) and disturbed sacred groves (Swer) of West Khasi hills, Meghalaya. Among the seven most dominant families based on species richness reported in the present study for Mawlong forest and in Upadhaya *et al*. (2004) for Ialong and Raliang sacred groves Jaintia hills, Meghalaya, five families where common to both forests. These are Euphorbiaceae, Fagaceae, Lauraceae, Moraceae, and Theaceae. Lauraceae and Fagaceae were reported in Tripathi *et al*. (2010) to be the most dominant families based on species richness in a Meghalayan sacred forest located near Laitryngew village in East khasi hills. Being the common denominator in all above studies, it is safe to say that with respect to species richness, Lauraceae has special status in Meghalayan forests.

Pitchairamu *et al*. (2008) investigated tree (≥10 cm DBH) diversity in undisturbed, moderately disturbed and disturbed 0.1 ha areas of the tropical forest of Piranmalai, Tamil Nadu. The study found that the Shannon index ranged between 1.33 and 2.184. The lowest tree diversity was reported in the disturbed stand while the highest in the undisturbed stand. Shannon diversity index value of the present study was also lower in the more disturbed forest Ramjadong forest (2.61) than the less disturbed Mawlong forest (3.22). Bearing in mind the differences in the DBH range, the value of Shannon diversity index reported in this study for Mawlong forest is within the range of Shannon index values 3.16 to 4.5 reported for other Meghalayan forests (Tripathi, 2003; Upadhaya *et al*., 2004; Mishra *et al*., 2005; Kumar *et al*., 2006; Tripathi *et al*., 2010; Tynsong and Tiwari, 2010).

As the value of Sørensen's index of similarity (Cs: 0.58) is higher than 0.25, then according to Ellenberg (1956), as cited in Faggi *et al*. (2006), the trees in both Mawlong and Ramjadong forests belong to same community. This comes in line with villagers' account that both forests were said to be part of a larger forest land that once expanded on the hills of Cherrapungi, particularly, before British colonial rule.

Stand density, basal area and vertical structure

Bearing in mind the differences in the included DBH range, several studies reported comparable tree density to the density 847 and 400 trees ha^{-1} of trees >10 cm DBH reported in the present study for Mawlong and Ramjadong forests respectively. For trees > 4.8 cm DBH in Mawlong forest, Tripathi (2003) reported a density of 1063 trees ha^{-1} which is comparable to the tree density of Mawlong forest in the present study. Another example is the study of Mishra *et al*. (2005) who studied community characteristics of trees (> 4.8 cm DBH) for subtropical humid forest (sacred grove) at Mawnai village, West Khasi hills district, Meghalaya. Their study reported tree density to be 1256 individuals ha^{-1} which is comparable to that of Mawlong sacred forest. Tree density of Mawlong forest was also comparable to the density of trees >5cm DBH (996 trees ha^{-1}) reported by Baishya *et al.* (2009) for a natural old growth Meghalayan humid tropical forest of past disturbance. Other comparable result was that of Devi and Yadava (2006) for a forest along the Indo-Myanmar Border, Manipur, India, which reported the stand density value to be (685-820 tree ha^{-1}). Tree density 642 ha^{-1} (trees >10 cm DBH) reported by Kho *et al.* (2013) for a Malaysian tropical forest of high annual rainfall was higher than tree density of Ramjadong forest but lower than that of Mawlong forest. Bhuyan *et al*. (2003) studied tree diversity (trees > 6.4 cm DBH) in four wet evergreen tropical forest stands of Arunachal Pradesh. Their study reported decreasing tree density along the elevating disturbance intensity. The nearly two-fold higher density of tree species in Mawlong sacred forest than in Ramjadong forest is attributed mainly to the more intense disturbance endured by the non-sacred Ramjadong forest.

For trees > 4.8 cm DBH in Mawlong forest, Tripathi (2003) reported the total basal cover to be 25.1 m^2 ha^{-1} which is lower than the present reported basal area (32.31 m^2 ha^{-1}). Both results were lower than that (73.41 m^2 ha^{-1} tree species >5cm DBH) estimated by Baishya *et al.* (2009) for a Meghalayan natural old growth humid tropical forest of past disturbance. In comparison with other studies, basal area of Mawlong forest was comparable to the 42.8 m^2 ha^{-1} basal area (trees > 4.8 cm DBH) for subtropical humid forest (sacred grove) at West Khasi hills district, Meghalaya reported by Mishra *et al*. (2005). The basal area value in the Mawlong sacred forest reported in this present study was markedly higher than that of Ramjadong forest 15.25 m^2 ha^{-1}. The lower basal cover of Ramjadong forest in comparison with Mawlong forest is due to more intense past disturbance in Ramjadong forest than in the sacred Mawlong forest represented by the removal of large trees. The number of large stumps (>40 cm DBH) in Ramjadong forest (26.7 stump ha^{-1}) was 4 times higher than that reported in Mawlong forest (6.7 stump ha^{-1}).

For a Malaysian old tropical forest of high annual rainfall, Kho *et al.* (2013) reported average height of trees ≥10 cm DBH to be 19.5 m. In this context, the average tree species height ≥10 cm DBH for Mawlong (12.5 m) and Ramjadong (11.9 m) forests can be considered as relatively low. Khiewtam and Ramakrishnan (1993) noted that the extensive fine root mat system present in Mawsmai forest land is determinant to its survival as it recycles litter nutrients before they get lost through infiltration and run off. The fine root mat system in the shallow soil developed over the karst may have affected the height of some tree species. The study reported the fall of large live tree >15 m height after a windy day. The root system of the tree (mainly root mat) clearly could not support the tree against the wind. However, it should be noted that several tree species in the forest have deep roots. The roots were visible through rock fissures as they penetrate cliffs of more than 10 m height. Another point noticed in this karst landscape regarding canopy, possibly applicable to other karst landscapes too, is that merely reporting tree height of a species may not surely decide whether it is a canopy species or not. The presence of trees on scattered rocks add to their height relative to the surrounding ground level and therefore determines their position in the actual vertical structure of the forest.

Population structure

Both Mawlong and Ramjadong forests are multilayered forests. However, diameter class 10-20 cm DBH (young trees) encompassed the majority of tree individuals in Mawlong forest (71.3% with 603 individuals ha^{-1}) and Ramjadong forest (68.3% with 273 individuals ha^{-1}). The reverse J shaped distribution of the Mawsmai forests which reflects the high tree density in lower diameter classes could be a result of rapid turnover of the forest gaps (Whitmore and Burnham, 1975). The reported cut trees in all the plots make it reasonable to conclude that tree logging is a main reason of gap formation. Tree fall could also be a reason of gap formation in this karstic landscape. Similar J shaped distribution was reported in Mishra *et al.* (2005) for subtropical humid forest (sacred grove) at Mawnai village, West Khasi hills district, Meghalaya. Upadhaya *et al*. (2004) also noted the same pattern of distribution in two subtropical forests (Ialong and Raliang groves) in the neighbouring district of Jaintia hills. With trees > 66 cm DBH as an exception, Upadhaya *et al*. (2003) reported that for two Meghalayan forests (Ialong and Raliang sacred groves) the number of species decreased along higher DBH class. Upadhaya *et al*. (2003) reasoned this pattern of species richness distribution by the combined effect of gap-phase dynamics and non-extreme stable environmental conditions within the forests. Similar pattern of species richness distribution was reported in the present study for Mawlong and Ramjadong forests.

Observations and suggestions for future studies

It was observed that depending totally on translating local names obtained from the field to corresponding botanical names from literature may yield inaccurate results. It was noticed that some local names have more than one corresponding species and even genera. That might be reasoned by presence of local variations in plant names in Khasi region. The presence of this variation also depends on the level of plant knowledge of the local identifier in the field. On the other hand, it should be noted that some of the local people developed high knowledge of the local plants. For example, by peeling off a little bark using local felling knife, the name of a tree could be determined through the colour and hardness of the tree stem interior without even looking at the foliage. It was noticed that local trees names are usually uttered proceeded with the Khasi word "dieng" meaning tree. The Khasi names of the plants themselves are composed of main part and affixes (e.g. soh, tiew, and lang). The affixes are not exclusive, they are present in the names of many plant species. An investigation into the matter may reveal an old botanical classification system.

The following is a note about the palm tree *Pandanus odorifer* (Forssk.) Kuntze. Upadhaya (2015) described the structure and composition of woody species (≥5 cm DBH) in 1 ha belt transect (20 m x 500m) in three primary forests of Cherrapunji hills, one of which is the forest land of Mawsmai village. Upadhaya (2015) reported *Pandanus odorifer* to be the most dominant species in Mawsmai forest land based on density with 315 individuals ha^{-1}. Tripathi (2003) reported tree density of *Pandanus odorifer* > 4.8 cm DBH in the same forest land, particularly in Mawlong forest, to be 18 individuals ha^{-1}. In the present study, the density of *Pandanus odorifer* ≥10 cm DBH was reported to be 50 tree ha^{-1} and 27 tree ha^{-1} for Mawlong and Ramjadong forests respectively. However, *Pandanus odorifer* was noticed to be abundant in the "other forest land" of Mawsmai village. Based on three random plots of 300 m^2 area in the other forest land, the density of *Pandanus odorifer* was reported to be 267 tree ha^{-1} which is markedly high. Therefore, the difference in *Pandanus odorifer* density in the three studies (i.e. Tripathi, 2003; Upadhaya, 2015; and the present study) could be attributed to different location of the sampling plots/transect. The differences in forest composition noticed among the three studies reflect the patchy nature of Mawsmai forest land that might be related to spatial heterogeneity of the karst landscape. It also indicates high tree diversity of Mawsmai forest land.

It was noted that *Pandanus odorifer* is not preferred as fuelwood by the villagers due to its heavy smoke. Selective logging in the western part of Mawsmai village "other forest land" may have favoured the survival and abundance of these palm trees. In addition, whether the large and thick *Pandanus odorifer* leaf litter is impacting the regeneration of other species is worth investigating. In Mawlong and Ramjadong forests respectively, 78% and 50% of Pandanus odorifer trees were on rocks of > 0.5 m height, while the remaining Pandanus odorifer trees were directly on forest floor. However, in the "other forest land" all *Pandanus odorifer* trees were on forest floor. The role of substrate of the rock-rich unevenly disturbed karst landscape in determining species composition is also worth investigating. Based on the above observations, the present study advocates extensive studies on *Pandanus odorifer*.

Within the Indian subcontinent, the Meghalaya Plateau is the richest location of karst features (Prokop, 2014). Upadhaya (2015) pointed out similarity on family level between Cherrapunji forests and southern China subtropical and evergreen broad leaved forests. Since Southern china has widespread karst topography (Gao et al., 2001), it is worthwhile to investigate whether the possibly common feature of having karst topography had facilitated this similarity.

Conclusion

Mawlong and Ramjadong forests were part of a larger forest land that stretched on the hills of Cherrapunji before British colonial rule. Tree richness, tree density, and stand basal area were markedly lower in the non-sacred forest Ramjadong than in the sacred forest Mawlong, indicating the impact of the past disturbance on ecological integrity of Mawsmai village karst landscape. With the gradual disappearance of the sacredness and the accompanying excess resources exploitation, flora of the sacred forests of Meghalaya is under threat. Hence, local community-oriented initiatives for forest conservation are needed.

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