PLANT DIVERSITY AND COMMUNITY ATTRIBUTES OF WOODY PLANTS IN TWO CLIMAX SUBTROPICAL HUMID FORESTS OF MEGHALAYA, NORTHEAST INDIA

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Abstract. The present study was conducted in two sacred forests, representing subtropical humid forest of the state of Meghalaya, India. Measurement of canopy cover, light interception and disturbance index revealed that these two sacred forests are comparable with respect to plant diversity and community attributes. The disturbance index was slightly higher in Mairang sacred forests, which had supported high species richness, better recruitment of seedlings leading to high regeneration potential. This was due to formation of gaps within forest. On other hand, gaps facilitated expansion of crown of trees, which inhibited growth and survival of saplings, the retarded growth of saplings had resulted in low conversion of saplings to trees. This condition could also be a reason for high basal area and low tree density in Mairang sacred forest. Endemic, rare and rare endemics were also reported from both the forests. Altitude had impacted composition, and dominance of species and families. Both the forests were highly dissimilar with respect to species composition. Contagious distribution was prevalent in both the forests, clumping is a characteristic feature of natural forest in tropical and subtropical region. Wide-girth structure and log-normal dominance-distribution curves justify complexity and stability of communities that lead to climax vegetation.
Keywords: *Population attributes, regeneration potential, sacred forest, subtropical humid forest, woody species diversity*

Introduction

Biodiversity refers to the quality, range or extent of variation between the biological entities in a given set. Plant community dynamics and vegetation management is intricately interrelated, and an understanding of the basic processes involved in vegetation change is essential for the sound manipulation of plant communities (Niering, 1987). Larger environmental variation within a small geographical area makes altitudinal gradients ideal also for several ecological and biogeographical hypotheses (Wilson *et al.,* 1990; Korner, 2000; Ohlemuller & Wilson, 2000), therefore, altitudinal gradient has become increasingly popular for investigating patterns in species richness (Rohde, 1992; Rahbek, 1995; Odland & Birks, 1999; Kessler, 2000; Srinivas & Parthasarathy, 2000; Grytnes, 2003).

In India, northeast region is an extension of eastern Himalaya. It has stable geological history, equable climate, heavy and uniform rainfall, which support a wide range of sub-tropical forest ecosystem (Champion & Seth, 1968) and considered as hot spot of plant diversity (Myers, 1988; Groombridge, 1992; Myers *et al.,* 2000; Behera *et al.,* 2002). Phytogeographically, forests of this region are species rich, and harbor a number of phylogenetically primitive plant species and regarded as a "treasure trove" of ancient and unique vegetation (Champion & Seth, 1968). Takhtajan (1969) has considered these forests as the cradle of flowering plants.

As per an estimate of Forest Survey of India (1997), the actual forest cover in Meghalaya is about 41.6 % (9330 km^2) of the total geographical area (22429 km^2) of the state. The subtropical semi-evergreen forests topped the list with coverage of 21.4 % land and is followed by subtropical semi-evergreen forest (11.9 %), subtropical pine forest (7.6 %) and sal forest 0.1 % (Mishra *et al.,* 2005a). That the subtropical humid forests are found in tropical and subtropical belts, and inhabit major population of plant species, act as reservoirs of biodiversity (Whitmore, 1984; Whitmore & Sidiyasa, 1986; WCMC, 1992; Richards, 1996; Whitmore, 1998; Fashing & Gathua, 2004; Fashing *et al.,* 2004).

The sacred forests of Meghalaya are the best example of subtropical humid forests. Indigenous people of Meghalaya protect some forest patches traditionally since time immemorial due to strong religious beliefs anointed with groves (sacred forests), such tracts of forests are species rich and regarded as virgin forests, and are popularly known as sacred forests or sacred groves (Gadgil & Vartak, 1975, 1976). The forefathers of indigenous people made a simple way for conservation of sacred forests by attaching various orthodox religious laws, myths and taboos attached with them. Over the years, these forests have become a part of the cultural life of the indigenous people of the Meghalaya. These forests often act as a gene bank, as they are rich in genetic resources (UNEP, 1995; Mc.Neely, 1996; Edwards & Cyrus, 1998). Moreover, these forests are considered as a repository of plant diversity and refugia for rarity and endemism (Jeeva & Anusuya, 2005; Jeeva *et al.,* 2005, 2006a; Mishra *et al.,* 2005b, 2005c). Previously, the sacred forests were found near each and every village. Ongoing struggle between a popular belief and need of people has resulted in extinction of several sacred forests, many are on verge of extinction, some are facing different degrees of disturbance and few forests are still protected and they harbor climax vegetation.

Change in landscape due to human interference has been identified as the major threat to biodiversity in terms of loss of species and change in community structure (Daniels *et al.,* 1991; Daniels *et al.,* 1995; Gadgil, 1996; Daniels, 1997; Menon & Bawa, 1997; Pramod *et al.,* 1997*;* Nagendra & Gadgil, 1998*;* Nagendra & Gadgil, 1999a*,* 1999b*;* Nagendra, 2001; Nagendra & Utkarsh, 2003). Oldfield and his coworkers (1998) have reported 10% of the world's tree species under threat. Anthropogenic disturbance causes maximum loss to trees layer than other plant groups such as shrubs, climbers and herbs. Thus, conservation of plant resources has become a global issue owing to habitat destruction, deforestation, climate change and environmental degradation (Phillips, 1997; Myking, 2002).

The conservation and forest management operation requires quantitative information of biodiversity inventories such as species diversity, population structure, and distribution pattern of species and other community attributes (Andel, 2001; Singh, 2002). Such biodiversity inventories are best integrated with the timber resources in order that forest

management operations can be planned (Rennolls & Laumonier, 2000). Being a dominant life form, trees are easy to locate precisely and to count (Condit *et al.*, 1996) and are also relatively better known, taxonomically (Gentry, 1992; Sagar *et al.,* 2003). Quantification of tree species diversity is an important aspect as it provides resources and habitat for many species (Cannon *et al.,* 1998).

In the state of Meghalaya hilly terrain and undulating topography have resulted in marked variation in altitude, irrespective of distance. The similar kind of forests situated in nearby area having differed altitude, the species composition varied greatly. The ecologists have paid little attention on researches to gather information, that how altitudinal variation affects species composition, plant diversity, community attributes and population structure in similar kinds of forests. Pooling the data from such kind of studies could be an effective tool for development of appropriate measures for rehabilitation of degraded forests land using plant species regenerating efficiently in respective edapho-climatic conditions.

In view of the above, the present study was carried out to determine extent of change in species composition, plant diversity, community attributes and population structure in Mairang and Mawphlang sacred forests of Meghalaya, representing of subtropical humid forest.

Materials and methods

Study area

The present study was conducted in two sacred forests of Meghalaya namely, Mawphlang and Mairang sacred forests, representing subtropical humid forests. (*Fig.1*). The Mawphlang sacred forest ($25^0$34'N, $91^0$56E, altitude 1430m asl) is located about 28 km southwest of Shillong in the East Khasi Hills district of Meghalaya. It occupies an area of about 75 hectare and is surrounded by a landscape covering grassland vegetation. Another study site, the Mairang sacred forest (l$25^0$33'N, $91^0$38'E, 1748 m asl) is situated near Mawnai village at Mairang town in the West Khasi Hills district of Meghalaya and it has an area of about 80 ha. The distance between the two forests is about 30 km, but they are situated at an altitudinal variation of about 300 m asl.
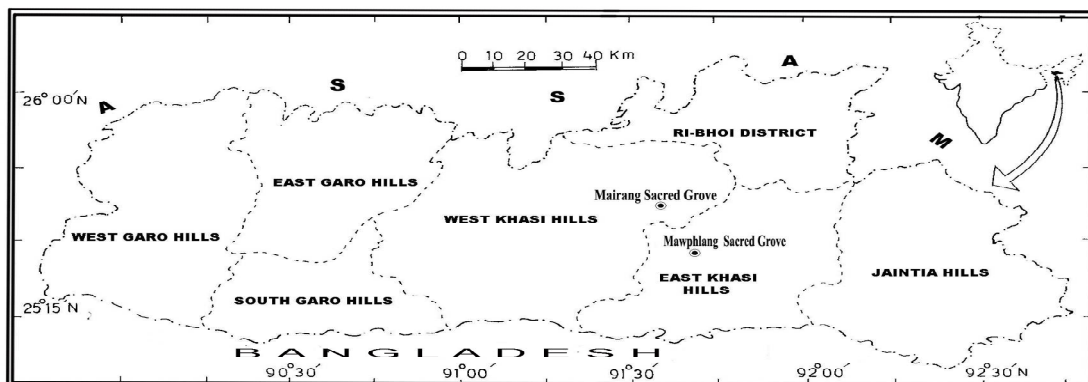

Figure 1. Geographical location of study area

Vegetation profile

The vegetation of both sacred forests falls under semi-evergreen subtropical broad-leaved wet-hill forests (Champion & Seth, 1968). The canopy tree species are *Aporusa dioica, Castanopsis kurzii, Camellia caduca, Corylopsis himalayana, Engelhardtia spicata, Exbucklandia populnea, Ficus nerifolia, Garcinia cowa, Ficus nerifolia, Myrica esculenta, Pyrus pashia, Quercus griffithi, Quercus dealbata, Quercus glauca, Rhododendron arboreum and Taxus baccata* in Mawphlang sacred forest. However, canopy layer of Mairang sacred forest is composed of *Aesculus assamica, Aporusa roxburghii, Beilschmiedia brandisii, Beilschmiedia roxburghiana, Citrus medica, Cleidion javanicum, Cryptocarya amygdalina, Cryptocarya andersonii, Dysoxylum binecteriferum, Echinocarpus assamicus, Echinocarpus dasycarpus, Echinocarpus murex, Fissistigma wallichii, Macropanax undulatus, Ostodes paniculata, Phoebe* sp., *Quercus griffithii, Quercus smiserrata, Rhus acuminata, Sapium baccatum Schima wallichii* and *Trevesia palmata*. The tree species composition suggests that these forests are semi-evergreen types (NRSA, 1995; FSI, 1997). The canopy cover, light interception, and disturbance index justify that there is no marked variation in status of two sacred forests, in terms of disturbance. The disturbance index was very low and it was slightly higher in the Mairang sacred forest than Mawphlang sacred forest. The value of disturbance index depicts that both the forests are undisturbed/mildly disturbed (*Table 1*).

Table 1. *Canopy cover, light interception and disturbance index in the two sacred forests of Meghalaya*

Parameters	Sacred forests	
	Mairang	**Mawphlang**
Canopy cover (%)	50 – 100	60 – 100
Light interception (%)	40 – 100	50 – 100
Disturbance index (%)	0 – 3	0 – 1

Climate and soil

The monsoon season is characteristics of the climate of Meghalaya. The state receives rainfall throughout the year and about 85% of the annual rainfall is received during the wet season (June to September). The mean annual rainfall is accounted as 2500mm (Jeeva et al., 2006b). The soil is mainly lateritic and derived from gneisses, schists and granites of Archean age (Gansser, 1964).

Methodology

The field study was conducted during 2000-2001 following the methods as outlined by Misra (1968), Kershaw (1973), Muller-Dombois and Ellenberg (1974). The vegetation analysis was done by quadrat method. In each forest, 50 quadrats were laid randomly for trees (gbh > 20cm) and shrubs (gbh 5cm to 20cm and/or individuals more than 1m height), using quadrats of size 10m × 10m and 5m × 5m, respectively. For seedlings (gbh < 5cm and/or individuals up to 1m height), 100 quadrats (1m × 1m size) were laid in each forest. The density, frequency, basal area and importance value index (IVI) were computed. The

distribution pattern of species was determined by computing Whitford index (Whitford, 1948). The dominance-distribution pattern was determined at both the species and family levels. The disturbance index was calculated by using the formula used by Mishra *et al.* (2003). The species richness index (Margalef, 1958), Shannon diversity index (Shannon and Weaver, 1949) and Simpson dominance index (Simpson, 1949) were determined.

Species richness index (Margalef, 1958) = S – 1/ ln N
where, S is the total number of species, N is total number of individuals and ln is log2.

Diversity index (Shannon and Weaver, 1949)

$$H' = - \sum_{i=1}^{s} pi \ln pi$$

where, *H'* is the Shannon–Weiner diversity index, pi is the proportion of IVI of a species i.e. (*ni / N*).

Dominance index (Simpson, 1949)

$$Cd = \sum_{i=1}^{s} (pi)^2$$

$$\text{Disturbance index (\%)} = \frac{\text{Number of tree stumps}}{\text{Total number of trees including tree stumps} \times 100} \quad \text{(Eq.1)}$$

Plants species were identified using regional floras (Balakrishnan, 1981-83*,* Haridasan and Rao, 1985-87, Kanjilal *et al.,* 1934-40). Plant specimens were counter-checked with the reference material available at the Botanical Survey of India, Eastern Circle Shillong and herbarium of the Department of Botany, North-Eastern Hill University, Shillong. The Red Data Book (Nayar & Sastry, 1987, 1988, 1990) and Balakrishnan & Vasudeva (1983) were consulted to ascertain rarity and endemicity.

Results

Species composition, distribution pattern and similarity

Altogether, 186 woody species belonging to 124 genera and 59 families of angiosperms were recorded from one ha area of two forests (i.e., 0.5 ha area of each forest). Result showed that contagious distribution was predominant in both the forests. Of 133 species in Mairang sacred forest, 132 species showed contagious and one species namely *Citrus medica* was distributed randomly. On other hand, 62 species showed contagious, 9 species random and 10 species regular distribution in Mawphlang sacred forest. The Sϕrensen

index of similarity between two forests was calculated very low (27%), only 29 species were common in both the forests (*Appendix 1*).

Endemicity and rarity

From both the forests, 11 endemic, 7 rare and 5 rare as well as endemic species were recorded. The rare endemics were *Baliospermum micranthum, Cinnamomum pauciflorum, Ilex embelioides, Ilex khasiana* and *Lindera latifolia.* Among rare species, *Anomospermum excelsum, Antidesma roxburghii, Baliospermum micranthum, Beilshmiedia fagifolia, Cinnamomum pauciflorum, Cordia fragrantissima, Fagraea ceilanica, Helicia excelsa* and *Psychotria symplocifolia* and *Camellia caduca* were noticed. The endemic species were *Carpinus viminca, Daphniphyllum himalayense, Elaeocarpus acuminatus, Erythroxylum kunthianum, Michelia punduana, Neillia thyrsiflora, Persea kingii, Quercus glauca, Schima khasiana* and *Zanthoxylum khasianum* (*Appendix 1*).

Floristic richness, diversity and dominance

Woody species content was markedly high in Mairang sacred forest (133 species) than Mawphlang sacred forest (81 species). A similar trend of result was also obtained with respect to generic composition, a total of 92 genera in former and 65 genera in later case were recorded. Similarly, family richness was also higher in Mairang sacred forest (48 families) than Mawphlang (40 families) sacred forest. The number of species per 100 m^2 was reported very high in Mairang sacred forest (26) than Mawphlang sacred forest (12). Species richness index and Shannon diversity index were high in Mairang sacred forest. The Simpson dominance index was contrary to the diversity index. Both the forests had high diversity and low dominance indices (*Table 2*).

Table 2. Plant diversity and other community attributes in the two sacred forests of Meghalaya

Parameters	Sacred forests	
	Mairang sacred forest	Mawphlang sacred forest
Number of families	48	40
Number of genera	92	65
Number of species	133	81
Species richness (species per 100 m^2)	26 ± 1.5	12 ± 1.2
Tree density (individuals ha^{-1})	1256 ± 64	1490 ± 59
Sapling density (individuals ha^{-1})	5690 ± 114	4230 ± 80
Seedling density (individuals ha^{-1})	41700 ± 417	37900 ± 379
Tree basal area (m^2 ha^{-1})	42.8 ± 3.9	21.7 ± 2.3
Margalef species richness index	18.5	12. 4
Shannon diversity index	4.5	3.9
Simpson dominance index	0.014	0.01

In the Mairang sacred forest, *Citrus medica* was the dominant (IVI 14. 3) species, however, *Rhododendron arboreum* was the dominant (IVI 39. 65) species in Mawphlang sacred forest. *Alangium chinense* (IVI 0.25) and *Ardisia undulata* (IVI 0.24) were least dominant species in Mairang and Mawphlang sacred forests, respectively. The distribution of IVI among species was more uniform among the species in Mairang sacred forest (*Appendix 1*). The dominance-distribution curve followed a log-normal distribution pattern in both the forests, with short curve in Mawphlang sacred forest (*Fig. 2*).
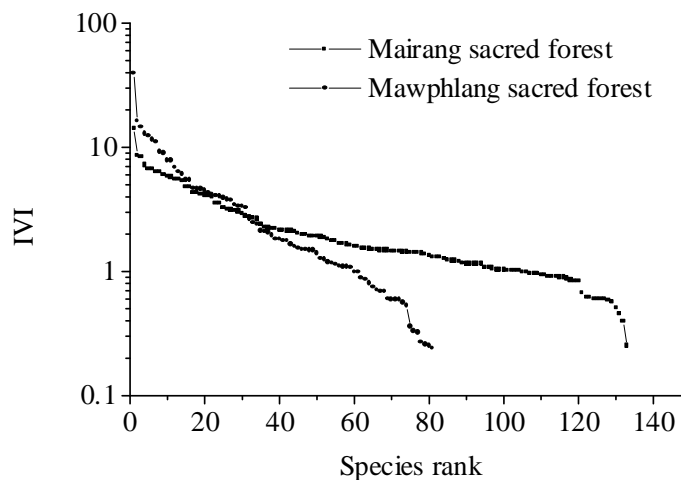

Figure 2. Dominance-distribution pattern of species in two sacred forests of Meghalaya

Density and tree basal area

Result showed that seedling recruitment was markedly high in both the forests, seedling density was high in Mairang sacred forest (41700 individuals ha^{-1}) than Mawphlang sacred forest (37900 individuals ha^{-1}). Sapling density also followed a similar trend. On the contrary, Mawphlang sacred forest had more tree density (1490 individuals ha^{-1}) than Mairang sacred forest (1256 individuals ha^{-1}). Irrespective of tree density, the basal area was about two folds higher in Mairang sacred forest (42.8 $\pm$ 3.9 m^2 ha^{-1}) than the Mawphlang sacred forest (21.7 $\pm$ 2.3 m^2 ha^{-1}) (*Table 2*).

Girth class distribution of individuals declined sharply from lower to higher girth classes in both the forests and it showed a pyramidal structure. Both the forests had a wide-range girth structure. The Mawphlang sacred forest was represented by individuals up to girth class 250-300cm. However, Mairang sacred forest had a few individuals having girth more than 300cm. Adults (gbh 20-50cm) were predominantly present in both the forests, i.e., 62% and 80% in Mairang and Mawphlang sacred forests, respectively (*Fig. 3*).
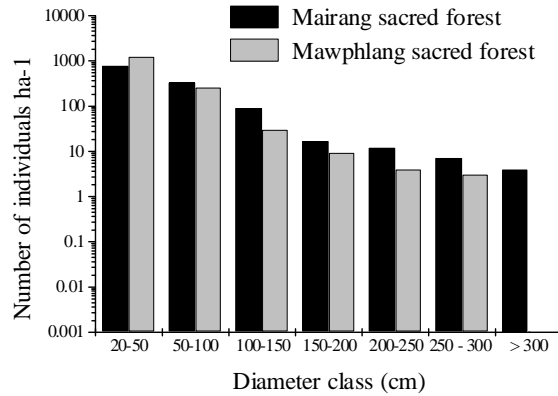
Figure 3. Girth-distribution of trees (gbh > 20 cm) in the Mairang and Mawphlang sacred forests Girth-distribution

Distribution and dominance of families of angiosperms

Altogether, 59 families of angiosperms were reported from both the forests. The Mairang sacred forest was represented by 48 families, however, 40 families were recorded from Mawphlang sacred forest. In Mairang sacred forests, Lauraceae (17 species) was the dominant family. Euphorbiaceae, the codominant family was represented by 11 species. Euphorbiaceae and Lauraceae with 12 and 10 species respectively, were dominant and co-dominant families in the Mawphlang sacred forest. The number of families represented by a single species was higher in Mawphlang sacred forest (26) than Mairang sacred forest (23). Generic composition had depicted that Euphorbiaceae dominating in both the forests as it had highest number of genera (*Table 3*). Dominance distribution of families has resulted in log-normal distribution of families in both the forests (*Fig. 4*).
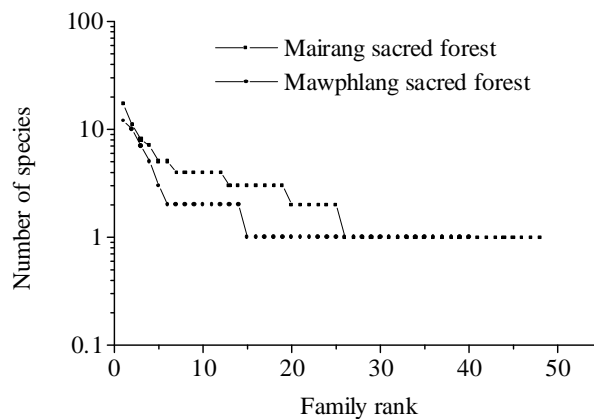

Figure 4. Dominance-distribution pattern of families in two sacred forests of Meghalaya

Table 3. *Genera and species composition of different families of angiosperms recorded from the two sacred forests of Meghalaya. The families are arranged with respect to family rank based on number of species in a particular family*

Family Rank	Family	Mairang sacred forest		Family	Mawphlang sacred forest	
		Genera	Species		Genera	Species
1	Lauraceae	7	17	Euphorbiaceae	10	12
2	Euphorbiaceae	9	11	Lauraceae	7	10
3	Araliaceae	6	8	Fagaceae	2	7
4	Rubiaceae	7	7	Theaceae	4	5
5	Elaeocarpaceae	2	5	Lamiaceae	3	3
6	Theaceae	3	5	Clusiaceae	1	2
7	Anacardiaceae	2	4	Elaeocarpaceae	2	2
8	Verbenaceae	3	4	Ericaceae	2	2
9	Symplocaceae	1	4	Hamamelidaceae	2	2
10	Magnoliaceae	1	4	Magnoliaceae	1	2
11	Oleaceae	2	4	Moraceae	1	2
12	Rosaceae	4	4	Myricaceae	1	2
13	Rutaceae	3	3	Proteaceae	1	2
14	Annonaceae	3	3	Rosaceae	2	2
15	Fagaceae	1	3	Actinidiaceae	1	1
16	Buxaceae	1	3	Apocynaceae	1	1
17	Ulmaceae	2	3	Aquifoliaceae	1	1
18	Myrsinaceae	2	3	Araliaceae	1	1
19	Sterculiaceae	1	3	Asteraceae	1	1
20	Sapindaceae	2	2	Berberidaceae	1	1
21	Daphniphyllaceae	1	2	Betulaceae	1	1
22	Boraginaceae	1	2	Caprifoliaceae	1	1
23	Myrtaceae	2	2	Corylaceae	1	1
24	Aquifoliaceae	1	2	Daphniphyllaceae	1	1
25	Fabaceae	2	2	Elaeagnaceae	1	1
26	Juglandaceae	1	1	Erythroxylaceae	1	1
27	Pittosporaceae	1	1	Juglandaceae	1	1
28	Myricaceae	1	1	Meliaceae	1	1
29	Meliaceae	1	1	Menispermaceae	1	1
30	Asteraceae	1	1	Myrsinaceae	1	1
31	Berberidaceae	1	1	Myrtaceae	1	1
32	Simaroubaceae	1	1	Olacaceae	1	1
33	Erythroxylaceae	1	1	Oleaceae	1	1
34	Salicaceae	1	1	Polygalaceae	1	1
35	Cannaceae	1	1	Rubiaceae	1	1
36	Combretaceae	1	1	Rutaceae	1	1
37	Betulaceae	1	1	Symplocaceae	1	1
38	Moraceae	1	1	Ulmaceae	1	1
39	Thymeliaceae	1	1	Urticaceae	1	1
40	Tiliaceae	1	1	Verbenaceae	1	1
41	Caprifoliaceae	1	1			
42	Loganiaceae	1	1			
43	Cappaceae	1	1			
44	Sabiaceae	1	1			
45	Urticaceae	1	1			
46	Clusiaceae	1	1			
47	Cornaceae	1	1			
48	Caesalpiniaceae	1	1			

Discussion

The findings of present study revealed that both the forests inhabit climax vegetation and are best representative of subtropical humid forests of Meghalaya. During the investigation, 133 and 81 species were recorded from 0.5 ha area of Mairang and Mawphlang sacred forests, respectively. High species richness in former case may be due to formation of gaps due to felling of few mature trees, which had facilitated introduction of more species from neighboring forests. Mishra *et al.* (2003) have reported that mild disturbance supports species richness and have recorded high species richness in mildly/moderately disturbed stand of Swer sacred grove in Meghalaya. A similar result was also noticed by Upadhaya *et al.* (2003) and they have recorded 123 woody species from 1 ha area (0.5 ha each of Ialong and Raliang sacred groves in Jaintia hills of Meghalaya). High species richness in Mairang sacred forest showed that mild disturbance is linked with species turnover, colonization and high species richness (Whittaker, 1975; Connell, 1979). Mairang sacred forest had high species richness per unit area, which is due to presence of synuisae in the forest (Richards, 1996). Predominance of contagious distribution indicates interaction of abiotic and biotic factors acting together as population and it was more conspicuous in case of Mairang sacred forest. Insufficient mode of seed dispersal had resulted in clumping (Richards, 1996). Although clumping is the characteristic feature of natural forests (Armesto *et al.,* 1986). Jamir (2000) has also reported a similar result in sacred forests of Meghalaya.

Change in edapho-climatic conditions due to variation in the altitude has altered species composition in two similar kinds of forests. The result showed that change in species composition is highly linked with variation in altitude, as both the forests are highly dissimilar (dissimilarity index 73%) in terms of species composition. The present finding is in conformity with the work of Liberman *et al.* (1996) and Kadavul & Parthasarathy (1999). The change in the position of dominant and codominant species and families in these two forests is also associated with variation in altitude. Despite high family richness in Mairang sacred forest, the number of monospecific families were low. This could be attributed to elimination of some families, which are very sensitive to low level of disturbance. Moreover, there was chance of inclusion of more species in the families with increased dominance. These sacred forests had a number of endemic and rare plants. Haridasan & Rao (1985-87) have also pointed out that sacred forests of Meghalaya harbor a large number of such species, which are confined to sacred forests only.

Wide range girth-distribution in two forests indicates stability and complexity of community. Better recruitment of seedlings and predominance of individuals in lower girth classes (adults) showed high regeneration efficacy at forest stand level (Mishra *et al.,* 2003; Laloo *et al.,* 2006). Conversion of seedlings into saplings follows a similar pattern in two forests. Low conversion of saplings into trees in Mairang sacred forests could be due to presence of high canopy tree species. Gaps also facilitated expansion of crown of trees, and subsequently suppression of growth and survival of saplings growing beneath these trees (Mishra *et al.,* 2003). Population structure at forest stand level indicates that these forests harbor a growing population (Mishra, 2004). Girth-distribution follows reverse J shaped curve, which suggests that both the forests are climax and stable (Mishra *et al.,* 2005a).

The dominance-distribution pattern at the levels of species and family justifies mature, stable and complex nature of vegetation. High species content and more even distribution

of IVI among the species in Mairang sacred forest depict high degree of stability and complexity of community (Mishra *et al.,* 2004; Mishra et al, 2005a). It has been argued that the ecosystem with high species diversity is more stable and resilient to environmental disturbances than those having low species, diversity (Hurd *et al.*, 1971; McNaughton, 1977, 1985; Tilman, 1988; Frank & McNaughton, 1991; Tilman & Downing, 1994).

Conclusion

From the present study it can be concluded that altitudinal variation leads to change in species composition and taxonomic position even in similar kind of forest. This could be due to altered edapho-climatic conditions of the area. Low level of disturbance in terms of felling of few trees can favour natural regeneration of woody species, it involves increased percent conversion of seedlings to saplings, and saplings to trees. Form earlier studies it is evident that majority of sacred forests are facing different degrees of disturbance, few forests (*ca.* 10%) are still intact. In view of this, it is recommended that such kind of studies in addition to regeneration behaviour of dominant and important species need much attention of ecologists to find out appropriate strategy for *in situ* conservation of genetic resources on sustained basis. Strengthening researches and pooling data generated through extensive studies could be a tool for rehabilitation of degraded sacred forests, by planting suitable species.

Appendix 1. *Community attributes of woody plant species in the two sacred forests of Meghalaya.*
Species rank was determined o the basis of IVI of a species

Plant species	Family	Mairang sacred forest			Mawphlang sacred forest		
		IVI	Species rank	Whitford index	IVI	Species rank	Whitford index
Acanthopanax aculeatum Seem.	Araliaceae	1.3	81	0.17	-	-	-
Actinidia callosa Lindl.	Actinidiaceae	-	-	-	0.26	23	0.15
Aesculus assamica Griff.	Sapindaceae	6.73	5	0.07	-	-	-
Alangium chinense (Lour.) Harms.	Cornaceae	0.25	133	0.83	-	-	-
Alnus nepalensis D. Don.	Betulaceae	-	-	-	4.07	10	0.21
Alphonsea ventricosa Hk.f. & Thunb.	Annonaceae	2.89	30	0.16	-	-	-
Anomospermum excelsum Dalz.	Euphorbiaceae	-	-	-	0.8	45	0.09
Antidesma khasianum Hk. f.	Euphorbiaceae	-	-	-	3.47	62	0.05
Antidesma diandrum (Roxb.) Roth.	Euphorbiaceae	1.63	59	0.17	-	-	-
Antidesma roxburghii Wall.	Euphorbiaceae	-	-	-	0.32	43	0.1
Aporusa dioica (Roxb.) Muell.-Arg.	Euphorbiaceae	-	-	-	4.17	9	0.22
Aporusa roxburghii Baill.	Euphorbiaceae	5.75	11	0.14	-	-	-
Aralia armata (G.Don) Seem.	Araliaceae	1.23	85	0.17	-	-	-
Ardisia nerifolia DC.	Myrsinaceae	1.01	103	0.38	-	-	-
Ardisia undulata Cl.	Myrsinaceae	0.6	124	1	0.24	51	0.08
Baliospermum micranthum Muell.-Arg.	Euphorbiaceae	-	-	-	0.25	44	0.1
Bauhinia variegata Linn.	Caesalpiniaceae	0.6	125	1	-	-	-
Beilshmiedia brandishii Hk.f.	Lauraceae	5.56	12	0.12	1.95	56	0.06
Beilshmiedia fagifolia Nees.	Lauraceae	1.51	66	0.22	-	-	-
Beilshmiedia roxburghiana Nees.	Lauraceae	1.96	47	0.17	-	-	-
Berberis wallichiana DC.	Berberidaceae	-	-	-	6.3	57	0.06
Betula alnoides Buch.-Ham. ex D.Don	Betulaceae	1.26	84	0.5	-	-	-
Bidens spinosa Linn	Asteraceae	-	-	-	0.27	58	0.06
Boehmeria platyphylla D.Don.	Urticaceae	0.62	123	1	-	-	-
Boehmeria sidaefolia Wedd.	Urticaceae	-	-	-	1.17	39	0.11
Brassiopsis aculeata Seem	Araliaceae	1.39	79	0.22	0	0	0
Breynia retusa (Dennst.) Alst.	Euphorbiaceae	-	-	-	0.59	46	0.09
Callicarpa arborea Roxb.	Verbenaceae	2.24	37	0.16	-	-	-
Callistemon citrinus (Curt) Skeels	Myrtaceae	1.44	74	0.22	-	-	-
Caloxylon leucocarpum Kurz.	Euphorbiaceae	-	-	-	1.82	52	0.07
Camellia caduca Cl. ex Brandis.	Theaceae	0.83	119	0.25	4.49	53	0.07
Camphora glandulifera Nees.	Lauraceae	-	-	-	1.77	36	0.12
Capparis assamica Hk.f. & Th.	Cappaceae	0.99	106	0.38	-	-	-
Carallia brachiata (Lour.) Merr.	Cannaceae	1.56	62	0.17	-	-	-
Carpinus viminca Wall. ex Lindl.	Corylaceae	-	-	-	1.19	32	0.13
Castanopsis armata Spach.	Fagaceae	-	-	-	1.77	47	0.09
Castanopsis kurzii (Hance).	Fagaceae	-	-	-	4.67	37	0.12
Castanopsis sp.	Fagaceae	-	-	-	3.77	40	0.11
Celtis cinnamomea Lindl. ex Planch.	Ulmaceae	0.99	105	0.25	-	-	-

Plant species	Family	Mairang sacred forest			Mawphlang sacred forest		
		IVI	Species rank	Whitford index	IVI	Species rank	Whitford index
Celtis tetranda Roxb.	Ulmaceae	3.22	25	0.16	0.69	12	0.19
Cinnamomum glanduliferum (Wall.) Meissn.	Lauraceae	0.58	128	0.5	11.03	16	0.17
Cinnamomum pauciflorum Nees	Lauraceae	3.12	28	0.22	3.99	48	0.09
Cinnamomum sp.	Lauraceae	-	-	-	1.58	54	0.07
Cissampelos pareira Linn.	Menispermaceae	-	-	-	1.47	41	0.11
Citrus medica Linn.	Rutaceae	14.34	1	0.04	-	-	-
Cleidion javanicum Bl.	Euphorbiaceae	5.82	10	0.13	2.67	33	0.13
Clerodendrum infortunatum auct. non Linn.	Verbenaceae	0.6	126	1	-	-	-
Cleyera grandiflora Hk.f. & Th. ex Dyer	Theaceae	-	-	-	1.64	59	0.06
Coffea khasiana Hk.f.	Rubiaceae	1.93	48	0.39	-	-	-
Combretum acuminatum Roxb.	Combretaceae	1.48	67	0.22	-	-	-
Cordia fragrantissima Kurz.	Boraginaceae	2.17	40	0.18	-	-	-
Cordia grandis Roxb.	Boraginaceae	1.55	63	0.22	-	-	-
Corylopsis himalayans Griff.	Hamamelidaceae	-	-	-	0.33	20	0.16
Croton caudatus Geisel.	Euphorbiaceae	0.85	118	0.25	-	-	-
Cryptocarya amygdalina Nees.	Lauraceae	8.68	2	0.08	-	-	-
Cryptocarya andersonii King ex Hk. f.	Lauraceae	3.96	22	0.13	5.45	71	0.03
Cryptocarya sp.	Lauraceae	-	-	-	3.78	67	0.04
Cyclostemon assamicus Hk.f.	Euphorbiaceae	4.13	20	0.16	-	-	-
Daphne cannabina Wall.	Thymeliaceae	1.15	93	0.5	-	-	-
Daphniphyllum himalayense (Benth.) Muell.-Arg.	Daphniphyllaceae	1.86	52	0.22	0.59	76	0.01
Daphniphyllum sp.	Daphniphyllaceae	3.53	23	0.14	-	-	-
Dysoxylum binectariferum Hk.f. & Bedd.	Meliaceae	3.51	24	0.24	1.1	63	0.05
Echinocarpus dasycarpus Benth.	Elaeocarpaceae	4.18	19	0.13	0.59	60	0.06
Echinocarpus murex Benth.	Elaeocarpaceae	6.39	7	0.08	-	-	-
Elaeagnus latifolia Linn.	Elaeagnaceae	-	-	-	1.07	34	0.13
Elaeocarpus acuminatus Wall ex Mast.	Elaeocarpaceae	3.13	27	0.11	-	-	-
Elaeocarpus floribundus Bl.	Elaeocarpaceae	0.94	110	0.25	-	-	-
Elaeocarpus lancifolius Roxb.	Elaeocarpaceae	2.26	36	0.16	-	-	-
Elaeocarpus sikkimensis Mast.	Elaeocarpaceae	-	-	-	9.21	29	0.14
Elsholtzia blanda Benth.	Lamiaceae	-	-	-	2.08	24	0.15
Embelia ribes Burm. f.	Myrsinaceae	0.87	117	1.5	-	-	-
Engelhardtia spicata Leschn ex Bl.	Juglandaceae	4.81	15	1	6.06	17	0.17
Eriobotrya dubia Decne.	Rosaceae	1.45	72	0.38	1.14	30	0.14
Erythrina stricta Roxb.	Fabaceae	1.01	104	0.38	-	-	-
Erythroxylum kunthianum Wall. ex. Kurz.	Erythroxylaceae	1.65	58	0.22	12.27	6	0.23
Eugenia lanceolaria Roxb.	Myrtaceae	-	-	-	0.99	18	0.17
Eupatorium odoratum Linn.	Asteraceae	1.3	83	0.63	-	-	-
Eurya acuminata DC.	Theaceae	3.05	29	0.18	16.3	74	0.02
Eurya japonica Thunb.	Theaceae	1.82	53	0.16	12.85	77	0.01
Exbucklandia populnea (R. Br. ex Griff) R. W. Br.	Hamamelidaceae	-	-	-	1.27	64	0.05
Fagraea ceilanica Thunb.	Loganiaceae	1.03	98	0.38	-	-	-
Ficus hispida Linn. f.	Moraceae	1.44	73	0.17	-	-	-
Ficus silhetensis Miq.	Moraceae	-	-	-	0.56	19	0.17
Ficus sp.	Moraceae	-	-	-	8.91	11	0.2

Plant species	Family	Mairang sacred forest			Mawphlang sacred forest		
		IVI	Species rank	Whitford index	IVI	Species rank	Whitford index
Fissistigma wallichii (Hk.f. & Th.) Merr.	Annonaceae	7.19	4	0.16	-	-	-
Garcinia cowa Roxb. ex DC.	Clusiaceae	0.83	120	0.25	0.99	13	0.19
Garcinia lancifolia (G. Don) Roxb.	Clusiaceae	-	-	-	1.25	25	0.15
Gaultheria ovalifolia Wall.	Ericaceae	-	-	-	0.53	21	0.16
Glochidion assamicum Hk.f.	Euphorbiaceae	1.41	75	0.13	4.61	7	0.23
Glochidion khasicum Hk.f.	Euphorbiaceae	0.9	115	0.25	0.71	68	0.04
Grewia multiflora Juss.	Tiliaceae	1.35	80	0.17	-	-	-
Helicia excelsa Bl.	Proteaceae	-	-	-	2.06	49	0.09
Helicia nilagirica Bedd.	Proteaceae	-	-	-	4.28	26	0.15
Ilex embelioides Hk.f.	Aquifoliaceae	1.15	94	0.5	-	-	-
Ilex khasiana Purk.	Aquifoliaceae	0.96	109	0.38	3.34	2	0.29
Ixora acuminata Roxb.	Rubiaceae	0.6	127	1	-	-	-
Leptodermis griffithii Hk.f.	Rubiaceae	1.03	99	0.38	-	-	-
Ligustrum indicum (Lour) Merr.	Oleaceae	1.48	68	0.22	-	-	-
Ligustrum robustum (Roxb.) Bl.	Oleaceae	0.57	129	1	-	-	-
Lindera caudata (Nees) Hook. f.	Lauraceae	-	-	-	1.4	42	0.11
Lindera latifolia Hk.f.	Lauraceae	0.97	107	0.25	-	-	-
Lindera pulcherrima (Nees) Benth.	Lauraceae	4.11	21	0.28	-	-	-
Litsea citrata Bl.	Lauraceae	1.78	54	0.13	-	-	-
Litsea salicifolia (Roxb. ex Nees.) Hk.f.	Lauraceae	1.08	95	0.38	-	-	-
Machilus bombycina King ex Hk. f.	Lauraceae	-	-	-	0.6	72	0.03
Macropanax undulatus (wall. ex G.Don) Seem.	Araliaceae	6.37	8	0.08	-	-	-
Magnolia excelsa Wall.	Magnoliaceae	-	-	-	0.86	50	0.09
Magnolia insignis (Wall.) Bl.	Magnoliaceae	-	-	-	1.83	55	0.07
Mahonia pycnophylla (Fedde) Takeda	Berberidaceae	2.21	39	0.28	-	-	-
Meliosma wallichii Planch. ex Hk.f.	Sabiaceae	0.62	122	0.5	-	-	-
Melodinus khasianus Hook. f.	Apocynaceae	-	-	-	3.24	31	0.14
Michelia champaca Linn.	Magnoliaceae	1.52	64	0.17	-	-	-
Michelia lanuginosa Wall	Magnoliaceae	0.92	112	0.25	-	-	-
Michelia oblonga Wall. ex Hk.f.	Magnoliaceae	1.01	101	0.25	-	-	-
Michelia punduana Hk.f.	Magnoliaceae	2.8	31	0.16	-	-	-
Micromelum pubescens (non Bl.)	Rutaceae	1.76	55	0.22	-	-	-
Millettia pulchra (Benth.) Kurz.	Fabaceae	1.01	102	0.25	-	-	-
Mussaenda roxburghii Hk.f.	Rubiaceae	1.22	87	0.5	-	-	-
Myrica esculenta Buch-Ham. ex D.Don.	Myricaceae	-	-	-	2.12	65	0.05
Myrica nagi Hk.f	Myricaceae	1.6	61	0.22	1.11	69	0.04
Nauclea griffithii Hav.	Rubiaceae	1.22	86	0.38	-	-	-
Neillia thyrsiflora D.Don.	Rosaceae	0.4	132	0.5	-	-	-
Neolitsea cassia (Linn.) Kosterm.	Lauraceae	-	-	-	11.6	35	0.13
Olax acuminata Benth.	Olacaceae	-	-	-	0.75	3	0.28
Olea dentata Wall ex DC.	Oleaceae	2.21	38	0.16	-	-	-
Olea dioica Roxb.	Oleaceae	0.92	113	0.25	-	-	-
Olea salicifolia Wall. ex. Cl.	Oleaceae	-	-	-	3.92	5	0.25

Plant species	Family	Mairang sacred forest			Mawphlang sacred forest		
		IVI	Species rank	Whitford index	IVI	Species rank	Whitford index
Ostodes paniculata Bl.	Euphorbiaceae	5.51	13	0.16	-	-	-
Panax armatus G. Don	Araliaceae	-	-	-	1.1	14	0.19
Persea bombycina (King ex Hk.f.) Kosterm.	Lauraceae	1.9	51	0.13	-	-	-
Persea duthiei (King ex Hk.f.) Kosterm.	Lauraceae	2.1	44	0.16	-	-	-
Persea gamblei (King ex Hk.f.) Kosterm.	Lauraceae	2.12	43	0.19	-	-	-
Persea Khasyana Missn.	Lauraceae	0.46	131	0.5	-	-	-
Persea kingii (Hk.f.) Kosterm.	Lauraceae	1.15	90	0.25	-	-	-
Phoebe attenuata (Nees) Nees.	Lauraceae	8.43	3	0.17	-	-	-
Phyllanthus retusus Dennst.	Euphorbiaceae	1.17	89	0.5	1.47	27	0.15
Picrasma javanica Bl.	Simaroubaceae	2.12	42	0.16	-	-	-
Pittosporum glabratum Lindl.	Pittosporaceae	4.32	18	0.28	-	-	-
Plectranthus striatus Benth. in Wall.	Lamiaceae	-	-	-	1.5	1	0.31
Pogostemon strigosus Benth.	Lamiaceae	-	-	-	1.55	4	0.27
Polyalthia jenkinsii Benth. & Hk.f.	Annonaceae	1.91	50	0.17	-	-	-
Polygala arillata Buch.-Ham in D. Don	Polygalaceae	-	-	-	2.4	22	0.16
Premna racemosa Schauer in DC.	Verbenaceae	-	-	-	0.89	8	0.23
Prunus cerasoides D. Don. Prodr.	Rosaceae	-	-	-	1.49	38	0.12
Prunus nepaulensis (Ser.) Steud.	Rosaceae	1.15	92	0.38	-	-	-
Psychotria symplocifolia Kurz.	Rubiaceae	1.19	88	0.5	5.42	78	0.01
Pyrus pashia D.Don.	Rosaceae	0.67	121	1	-	-	-
Quercus dealbata Hk. f. & Th. ex Miq	Fagaceae	-	-	-	4.61	73	0.03
Quercus glauca Thunb.	Fagaceae	1.98	46	0.28	7.75	79	0.01
Quercus griffithii Hk.f. & Th. ex DC. Prodr.	Fagaceae	4.76	16	0.15	14.55	70	0.04
Quercus kamroopii D. Don.	Fagaceae	-	-	-	6.89	66	0.05
Quercus semiserrata Roxb.	Fagaceae	5.39	14	0.08	-	-	-
Randia longiflora Lamk.	Rubiaceae	1.41	76	0.22	-	-	-
Rhododendron arboreum Sm.	Ericaceae	-	-	-	39.65	80	0.01
Rhus acuminata DC.	Anacardiaceae	2.03	45	0.17	-	-	-
Rhus insignis Hk.f.	Anacardiaceae	1.69	56	0.22	-	-	-
Rhus javanica Linn.	Anacardiaceae	4.34	17	0.14	-	-	-
Salix psilostigma Anders.	Salicaceae	1.4	78	0.5	-	-	-
Sapindus attenuatus Wall. Ex Hiern.Rark DC.	Sapindaceae	0.97	108	1	-	-	-
Sapium baccatum Roxb.	Euphorbiaceae	5.97	9	0.07	0.69	15	0.18
Sapium eugeniaefolium Ham. ex. Hk.f.	Euphorbiaceae	1.15	91	0.25	-	-	-
Sarcococca pruniformis Lindl.	Buxaceae	1.08	96	0.38	-	-	-
Sarcococca saligna (D.Don) Muell-Arg.	Buxaceae	1.46	71	0.25	-	-	-
Sarcococca sp.	Buxaceae	1.41	77	0.22	-	-	-
Schefflera hypoleuca (Kurz.) Harms.	Araliaceae	2.65	34	0.25	-	-	-
Schefflera venulosa (W&A) Harms.	Araliaceae	1.46	70	0.22	-	-	-
Schefflera wallichiana (W & A) Harms.	Araliaceae	2.75	32	0.16	-	-	-
Schima khasiana Dyer.	Theaceae	1.6	60	0.17	-	-	-

Plant species	Family	Mairang sacred forest			Mawphlang sacred forest		
		IVI	Species rank	Whitford index	IVI	Species rank	Whitford index
Schima wallichii (DC.) Korth.	Theaceae	6.72	6	0.09	3.36	81	0.01
Skimmia laureola (DC.) Sieb. & Zucc.	Rutaceae	1.48	69	0.38	-	-	-
Sterculia hamiltonii (O. Ktze.) Adelb.	Sterculiaceae	1.67	57	0.22	-	-	-
Sterculia roxburghii Wall.	Sterculiaceae	0.9	116	0.25	-	-	-
Sterculia villosa Roxb.	Sterculiaceae	0.51	130	0.5	-	-	-
Symplocos racemosa Roxb.	Symplocaceae	1.06	97	0.38	-	-	-
Symplocos crataegoides D.Don.	Symplocaceae	1.93	49	0.39	-	-	-
Symplocos spicata Roxb.	Symplocaceae	2.66	33	0.16	7.8	75	0.02
Symplocos theaefolia D.Don.	Symplocaceae	0.92	114	0.25	-	-	-
Syzygium balsameum (Wt.) Wall ex AM. & SM. Cowan.	Myrtaceae	1.3	82	0.17	-	-	-
Tapiria hirsuta Hk.f.	Anacardiaceae	3.17	26	0.16	-	-	-
Trevesia palmata (Roxb.) Vis.	Araliaceae	2.16	41	0.38	-	-	-
Vernonia vulkamerifolia DC.	Asteraceae	0.94	111	0.25	-	-	-
Viburnum foetidum Wall.	Caprifoliaceae	1.03	100	0.38	2.48	61	0.06
Vitex negundo Linn.	Verbenaceae	1.51	65	0.17	-	-	-
Vitex vestita Roxb.	Verbenaceae	2.4	35	0.22	-	-	-
Zanthoxylum khasianum Hk. f.	Rutaceae	-	-	-	0.36	28	0.15

Abbreviation: -, absent.

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