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Community characteristics of a climax subtropical humid forest of Meghalaya and population structure of ten important tree species

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Abstract: The present study was conducted in a subtropical humid forest (sacred grove) at Mawnai, West Khasi hills district of Meghalaya. A total of 133 woody species (92 genera and 48 families) were present. Tree (gbh >15 cm) density (1256±64 individuals ha^{-1}) and basal area (42.8±3.9 m^2 ha^{-1}) were markedly high. Species richness index and diversity index were also high, while dominance index was low. *Citrus medica* (Rutaceae), the dominant species, was the only species exhibiting random distribution. All other species showed contagious distribution. *Cryptocarya amygdalina*, family Lauraceae, was the co-dominant species. Lauraceae (17 species) was the species rich family in the grove and exhibited maximum tree density and basal area. However, generic composition was highest (9 genera) in the case of Euphorbiaceae, which is the co-dominant family in the grove. Majority of the families were represented by single genus and single species. Log-normal dominance-distribution curves at the levels of species and family, and wide girth structure signify the complexity and stability of the community. Density-distribution and population structure of ten important tree species indicated preponderance of young trees (gbh 15–50 cm) suggesting high regeneration potential of these tree species.

Resumen: El present estudio fue realizado en un bosque húmido subtropical (arboleda sagrada) en Mawnai, distrito de colinas de Khasi Occidental, Meghalaya. En total estuvieron presentes 133 especies leñosas (92 géneros y 48 familias). La densidad de árboles (perímetro a la altura del pecho, pap > 15 cm) (1256 ± 64 individuos ha^{-1}) y el área basal (42.8 ± 3.9 m^2 ha^{-1}) fueron notablemente altas. Tanto el índice de riqueza de especies como el de diversidad también fueron altos, mientras que el índice de dominancia fue bajo. *Citrus medica* (Rutaceae), la especie dominante, fue la única que tuvo una distribución aleatoria; todas las especies respetantes mostraron distribuciones contagiosas. *Cryptocarya amygdalina*, de la familia Lauraceae, fue la especie codominante. Lauraceae (17 especies) fue la familia más rica en especies en esta arboleda y exhibió los valores máximos de densidad arbórea y área basal. Sin embargo, la composición genérica fue más alta (9 géneros) en el caso de las Euphorbiaceae, la familia codominante en la arboleda. La mayoría de las familias estuvieron representadas por un solo género y una sola especie. Las curvas log-normales de dominancia-distribución en los niveles de especies y familia, y la estructura perimétrica ejemplifican la complejidad y la estabilidad de la comunidad. La distribución de la densidad y la estructura poblacional de diez especies arbóreas importantes mostraron la predominancia de árboles jóvenes (pap 15–50 cm), lo que sugiere que existe un potencial alto de regeneración de estas especies arbóreas.

Resumo: Este estudo foi efectuado numa floresta subtropical húmida (floresta sagrada) em Mawnai, nas colinas ocidentais de Khasi, distrito de Meghalaya. Um total de 133 espécies lenhosas (92 géneros e 48 famílias) encontrava-se presente. A densidade de árvores (PAP > 15 cm) (1256 ± 64 indivíduos ha^{-1}) e uma área basal (42,8 ± 3,9 m^2ha^{-1}) foi marcadamente alta. Os índices de riqueza específica e de diversidade foram igualmente altos, enquanto o índice de dominância era baixo. A *Citrus medica* (Rutaceaa), a espécie dominante, foi a única espécie que exibia uma distribuição casual. Todas as outras espécies mostraram uma distribuição do tipo contagioso. A *Crptocarya amygdalina*, da família das Lauracea, era a espécie co-dominante. A família das Lauracea (17 espécies), era a família mais rica em espécies na floresta e exibiu a densidade arbórea máxima e a maior área basal. Contudo, a composição genérica foi a mais elevada (9 géneros) para o caso das

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Euphorbiaceae que é a família co-dominante na floresta. A maioria das famílias estava representada por um único género e uma única espécie. A dominância de curvas do tipo log-normal para as distribuições ao nível das espécies e famílias, e uma larga estrutura para os perímetros significa a complexidade e estabilidade da comunidade. A distribuição de densidades e a estrutura da população de dez espécies arbóreas importantes indicam a preponderância de árvores jovens (PAP 15–50 cm) sugerindo o elevado potencial regenerativo destas espécies arbóreas.

Key words: Community characteristics, diversity, dominance-distribution, population structure, sacred grove, species richness, subtropical humid forest.

Introduction

The structure and function of forest ecosystem is determined by the plant component more than any other living component of the system (Richards 1996). The most important characteristics of the tropical and subtropical humid forests are their species richness, heterogeneity and complex community organization. These forests, found all over tropical and subtropical belt, harbour maximum diversity of plant species found on the earth (WCMC 1992). Population structure, in terms of relative proportion of seedlings, saplings and young trees, provides an adequate information of the regeneration status of the forest. Population behaviour of component species in a community can be evaluated by density-diameter. The ratio of various diameter groups in a population determines the reproductive status of the population, and it indicates the future course of stability of forest communities (Odum 1971).

Forests cover about 41.6% (9330 km^2) of the total geographical area (22429 km^2) of the state of Meghalaya (FSI 1997). It includes 11.9% subtropical evergreen forest, 21.4% subtropical semi-evergreen forest, 0.1% sal forest and 7.6% subtropical pine forest (Pandey *et al*. 2003). Being a tribal dominated state, about 90% of the forested areas are directly controlled by Autonomous District Council (Tripathi *et al*. 1996). The subtropical semi-evergreen forest, which is the climax vegetation above 1000 m asl, covers about 51.3% of total forest area of the state. Most of the forest area (about 90%) in Meghalaya is under the control of the tribal communities (Tripathi *et al*. 1996), and are managed by them through traditional approaches. Because of strong religious beliefs in the past, several forest patches were protected and preserved through ages by different tribal communities in the state. These are popularly known as sacred groves. Ecologically, these sacred groves are remnant of climax vegetation of the area whose community structure is almost intact even today. Estimates suggest nearly 1000 km^2 of community forest is in the form of sacred groves in the state (Anonymous 1978).

In spite of recent attempts to investigate diversity patterns in few sacred groves of the Jaintia hills of Meghalaya (Jamir 2000 ; Upadhaya *et al*. 2003), the structural patterns of sacred groves is largely under explored in the state. In particular, information on population structure of forest species is inadequate as a result prediction on stability of these forest patches are poorly discussed. In view of the above, the present study deals with community characteristics and population structure of ten important tree species in a sacred grove located in the West Khasi hills district of Meghalaya.

Material and methods

Study site

The study was conducted in the sacred grove at Mawnai village near Mairang in the West Khasi hills district (latitude 25^0 33$^{'}$ N; longitude 91^0 38$^{'}$ E; altitude 1748 m asl) of Meghalaya. The grove (approx. 80 ha) is situated about 52 km south west of Shillong. Collection of fuel-wood and small timber, and cattle grazing are allowed in the peripheral buffer zone and the central core zone is almost untouched.

Vegetation

The forest over-storey was composed of both evergreen (*Beilschmiedia brandisii*, *B. roxburghiana, Cleidion javanicum*, *Echinocarpus* spp., *Macropanax undulatus*, *Ostodes paniculata*., *Phoebe attenuata*, *Polyalthia longifolia*, *Quercus* spp., *Sapium baccatum*, and *Trevesia palmata*,) and deciduous (*Aesculus assamica*, *Aporusa roxburghii*, *Citrus medica*, *Cryptocarya* spp., *Dysoxylum binectariferum*, *Rhus acuminata*, and *Schima wallichii*) species. About 30% trees in the over-storey were deciduous suggesting that the

forest is of semi-evergreen type (FSI 1997; NRSA 1995).

The under-storey was composed of evergreen species like *Actinidia callosa*, *Alphonsea ventricosa*, *Coffea khasiana*, *Eurya acuminata*, *Glochidion assamicum*, *Schefflera* spp., *Pittosporum glabratum* and *Symplocos* spp. A few deciduous elements like *Citrus medica* and *Dysoxylum binectariferum* were also present. The climbers (*Piper* spp., *Raphidophora* spp. and *Smilax* spp.) and creepers were abundant in the forest. Tree seedlings were predominantly present on moist and shaded areas along the stream traversing the grove.

Climate and soil

The climate of the area was monsoonic with distinct warm-humid and cool-dry seasons. The mean annual values of the climatic variables such as rainfall (2200 mm), maximum temperature (24^{0}C), minimum temperature (6^{0}C), and relative humidity (60%) were recorded. The soil was lateritic, sandy loam in texture and acidic (pH 5.5). The organic carbon and total nitrogen content varied between 10.3 and 56.2 mg g^{-1}, and 1.3 and 6.2 mg g^{-1}, respectively.

Vegetation analysis

Vegetation sampling was done during March 2000 to February 2001 using belt transect method. Three belts of 10 m width were laid across the grove and they were divided into 10 m x 10 m size units. Fifty such units were studied. All trees (>15 cm gbh) were considered for measuring various phytosociological parameters following the methods outlined by Misra (1968), and Mueller-Dombois & Ellenberg (1974). Species were identified using regional floras (Haridasan & Rao 1985; Kanjilal *et al.* 1934–40) and were counter-checked with herbarium of Botanical Survey of India, Eastern Circle, Shillong for correct identification.

The frequency, density, abundance, basal area and IVI of woody species were determined. Their distribution pattern was studied using Whitford index (Whitford 1948). Family importance value (FIV) was calculated according to Keel *et al.* (1993). The dominance-distribution pattern of species and family were determined on the basis of IVI and FIV values, respectively. Species richness index (Margalef 1958), Shannon diversity index (Shannon & Weaver 1949) and Simpson dominance index (Simpson 1949) were also calculated.

Density-distribution was studied by determining the number of individuals in different girth classes viz., 15–50, 50–100, 100–150, 150–200, 200–250 and above 250 cm. Population structure of ten tree species with high tree density was determined. For this purpose, number of seedlings (gbh 5 cm), saplings (gbh 5–15 cm) and trees (above six girth classes) of such species were recorded.

Results

Species richness, dominance-distribution and diversity

A total of 133 tree species (92 genera and 48 families) of angiosperms were recorded from 0.5 ha area of the grove (Table 1). *Citrus medica* was the dominant (IVI 14.3) species and it showed maximum tree density (90 individuals ha^{-1}).

Cryptocarya amygdalina, the co-dominant species had very low IVI (8.7) and tree density (26 individuals ha^{-1}) as compared to *C. medica. Alangium chinense* was the least important (IVI 0.25, density 4 individuals ha^{-1}) species (Appendix 1). Dominance-distribution curves showed MacArthur log-normal distribution indicating low dominance and high equitability among the species (Fig.1). Margalef species richness index and Shannon diversity index were 18.5, and 4.54, respectively. The Simpson dominance index (0.014) was very low (Table 1).

Distribution pattern

Among 133 species analysed, *C. medica* was the only species which showed random (Whitford index between 0.025 and 0.05) distribution, while the rest 132 species showed contagious (Whitford index >0.05) distribution (Table 1).

Distribution and dominance of family

Out of 48 families, 22 (45.6%) were monospecific and 31 (33.7%) were monogeneric. Lauraceae was the dominant family (FIV 49.3) with 7 genera and 17 species followed by

Table 1. Woody species composition and their community characteristics in the sacred grove.

Parameters	Value
Number of family	48
Number of genera	92
Number of species	133
Tree density (individuals ha^{-1})	1256±64
Basal area (m^2 ha^{-1})	42.8±3.9
Margalef species richness index	18.5
Shannon diversity index	4.5
Simpson dominance index	0.014

Euphorbiaceae (FIV 32.8) with 9 genera and 11 species. Lauraceae also showed highest tree density (140 individuals ha^{-1}) and basal area (10.84 m^2 ha^{-1}). Other important families in the grove were Araliaceae, Elaeocarpaceae, Rutaceae, Theaceae, Annonaceae, Anacardiaceae, Rubiaceae, Fagaceae (Table 2). Family dominance-distribution curve showed log normal distribution (Fig. 2).

Density-distribution

The total tree density was 1256±64 individuals ha^{-1} which had 42.8±3.9 m^2 ha^{-1} basal area (Table 1). Tree density declined sharply from lower to higher girth classes. Young trees (gbh 15–50 cm) were most abundant (784 individuals ha^{-1}) contributing about 62 % of total tree density. As such, the density–distribution of trees was pyramidal (Fig. 3).

Population structure

Population structure of ten important species showed log normal pattern (Fig. 4). Highest girth size was limited up to 51–100 cm for *C. medica*, *D. binectariferum* and *M. undulatus*. The girth size was up to 100–150 cm for *Q. semiserrata*, 150–200 cm for *A. assamica* and *E. dasycarpus* and 200–250 cm for *Q. griffithii* and *S. baccatum*. *C. amygdalina* (co-dominant species) and *S. wallichii* showed individuals above 250 cm girth. Seedlings, saplings and trees of all these species were present and *C. medica* contributed maximum density. The number of saplings of *C. amygdalina* was very low irrespective of high seedling density. Trees of *Q. griffithii* and *S. baccatum* were absent in some intermediate girth classes.

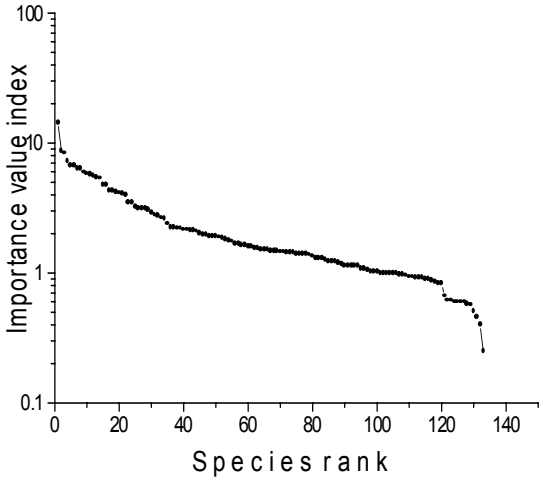

Fig. 1. Dominance-distribution of woody species in the sacred grove (species rank is given in Appendix 1).

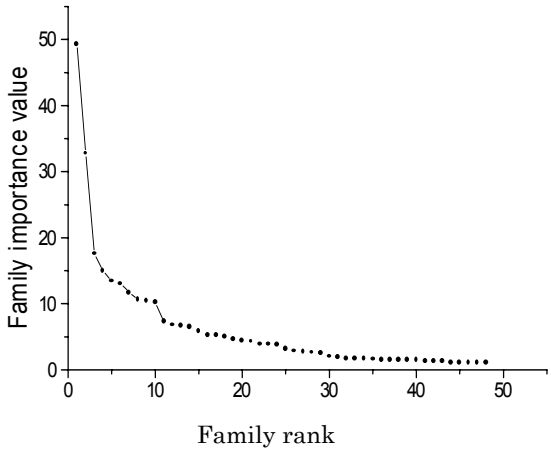

Fig. 2. Ranking of families based on their family importance values (FIV) in the sacred grove (family rank is given in Table 2).

Discussion

Species diversity is an important attribute of a natural community that influences functioning of an ecosystem (Hengeveld 1996). High species content per unit area is largely due to presence of synuisae in the forest (Richards 1996). Presence of 133 tree (gbh >15 cm) species in 0.5 ha area of the grove is comparable with the results obtained by Jamir (2000) from sacred forests of Jaintia hills in Meghalaya. He reported 135 woody species (gbh >15 cm) from 0.8 ha area. Greater diversity may lead to higher stability of the community (MacArthur 1955). Whittaker (1975) reported a similar result of high species diversity and low dominance in species rich communities. Washington (1984) has also reported high value of Shannon diversity index from the mid-montane region. Species diversity (4.54) obtained in the present study is similar to that of subtropical semi-evergreen forests (3.7–4.3) in Jaintia Hills district of Meghalaya, India (Jamir 2000).

Citrus medica (Rutaceae) and *Cryptocarya amygdalina* (Lauraceae) were dominant and co-dominant species, respectively. Lauraceae was the dominant family in the grove. This follows the results of Upadhaya *et al.* (2003) who recorded Lauraceae as the dominant family in Ialong and Raliang sacred groves of Jaintia hills in Meghalaya.

Except *C. medica*, contagious distribution was prevalent and this can be attributed to the interaction of many factors that are acting together on the population. As such, clumping indicates inefficient mode of seed dispersal (Richards 1996). While comparing dispersion pattern of trees in tropical to temperate climates of the world Armesto *et al.* (1986) concluded that

Table 2. Family-wise distribution of genera, species and their density and basal area in the sacred grove families are arranged in descending order of FIV).

Family rank	Family	Genera	Species	Tree density (ha^{-1})	Basal area ($m^2\ ha^{-1}$)
1	Lauraceae	7	17	140	10.84
2	Euphorbiaceae	9	11	116	6.53
3	Araliaceae	6	8	104	1.42
4	Elaeocarpaceae	2	5	64	2.62
5	Rutaceae	3	3	104	1.25
6	Theaceae	3	5	56	2.05
7	Annonaceae	3	3	26	3.18
8	Anacardiaceae	2	4	44	1.76
9	Rubiaceae	7	7	54	0.37
10	Fagaceae	1	3	58	1.44
11	Verbenaceae	3	4	28	0.86
12	Symplocaceae	1	4	40	0.28
13	Magnoliaceae	1	4	24	0.79
14	Sapindaceae	2	2	38	0.83
15	Oleaceae	2	4	26	0.36
16	Juglandaceae	1	1	4	1.82
17	Rosaceae	4	4	20	0.3
18	Daphniphyllaceae	1	2	22	0.78
19	Buxaceae	1	3	18	0.39
20	Pittosporaceae	1	1	10	1.22
21	Ulmaceae	2	3	14	0.74
22	Myricaceae	1	1	10	0.22
23	Boraginaceae	1	2	14	0.53
24	Myrsinaceae	2	3	16	0.12
25	Meliaceae	1	1	24	0.2
26	Myrtaceae	2	2	14	0.11
27	Asteraceae	1	1	14	0.09
28	Aquifoliaceae	1	2	14	0.03
29	Fabaceae	2	2	10	0.13
30	Berberidaceae	1	1	14	0.08
31	Simaroubaceae	1	1	10	0.18
32	Sterculiaceae	1	3	12	0.15
33	Erythroxylaceae	1	1	8	0.14
34	Salicaceae	1	1	8	0.13
35	Cannaceae	1	1	6	0.17
36	Combretaceae	1	1	8	0.07
37	Betulaceae	1	1	8	0.07
38	Moraceae	1	1	6	0.12
39	Thymeliaceae	1	1	8	0.02
40	Tiliaceae	1	1	6	0.08
41	Caprifoliaceae	1	1	6	0.04
42	Loganiaceae	1	1	6	0.04
43	Cappaceae	1	1	6	0.02
44	Sabiaceae	1	1	2	0.1
45	Urticaceae	1	1	4	0.03
46	Clusiaceae	1	1	4	0.02
47	Cornaceae	1	1	4	0.02
48	Caesalpiniaceae	1	1	4	0.02

clumping is the characteristic of natural forests. In general, the findings of the present work are in conformity with the work of Jamir (2000).

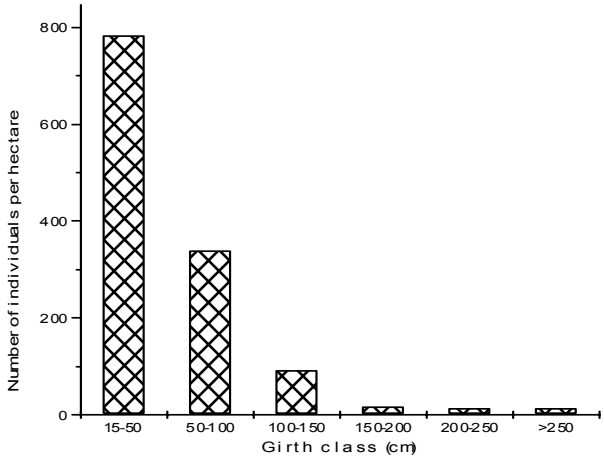

Fig. 3. Density-distribution of woody species in different girth classes in the sacred grove.

In respect of density-distribution of trees the present forest is similar to the tropical dry evergreen forests of southern India (Parthasarathy & Sethi 1997; Visalakshi 1995), and western ghats (Ayyappan & Parthasarathy 1999). The distribution of plants in different age groups (reverse J shaped curve) suggests that the sacred grove is climax or stable forest. High tree density in lower girth class could be attributed to rapid colonisation and turnover of gaps in the forest (Whitmore 1975). Similar results have been reported by Cao *et al.* (1996) for a rain forest in south west China, and Jamir (2000) in the sacred groves of Jaintia hills, Meghalaya, India. Also, suppressed growth of young plants due to dense overhead canopy as reported by Rao *et al.* (1997), may be one of the reasons for the presence of a large population of young plants. Similar age distribution pattern in tree populations has also observed by Johnston & Gillman (1995), and Kellman *et al*. (1998).

Number of individuals of ten important tree species contributed about one fourth of the total tree density and their population structure indicates sufficient recruitment of seedlings. A good number of seedlings attained sapling stage. Similarly, large number of saplings grew into adult (15–50 cm gbh) trees. This indicated high regeneration potential of these species. *C. amygdalina* showed reduced number of seedlings that grew into saplings as compared with other species. This may be due to arrest of growth of saplings under close canopy. Wide girth structure of tree populations indicates greater degree of stability and better regeneration potential of the community and this was supported by the findings of Jamir (2000). The population structure of trees reveals that the forest harbours a growing population, comparable to that of Costa Rica

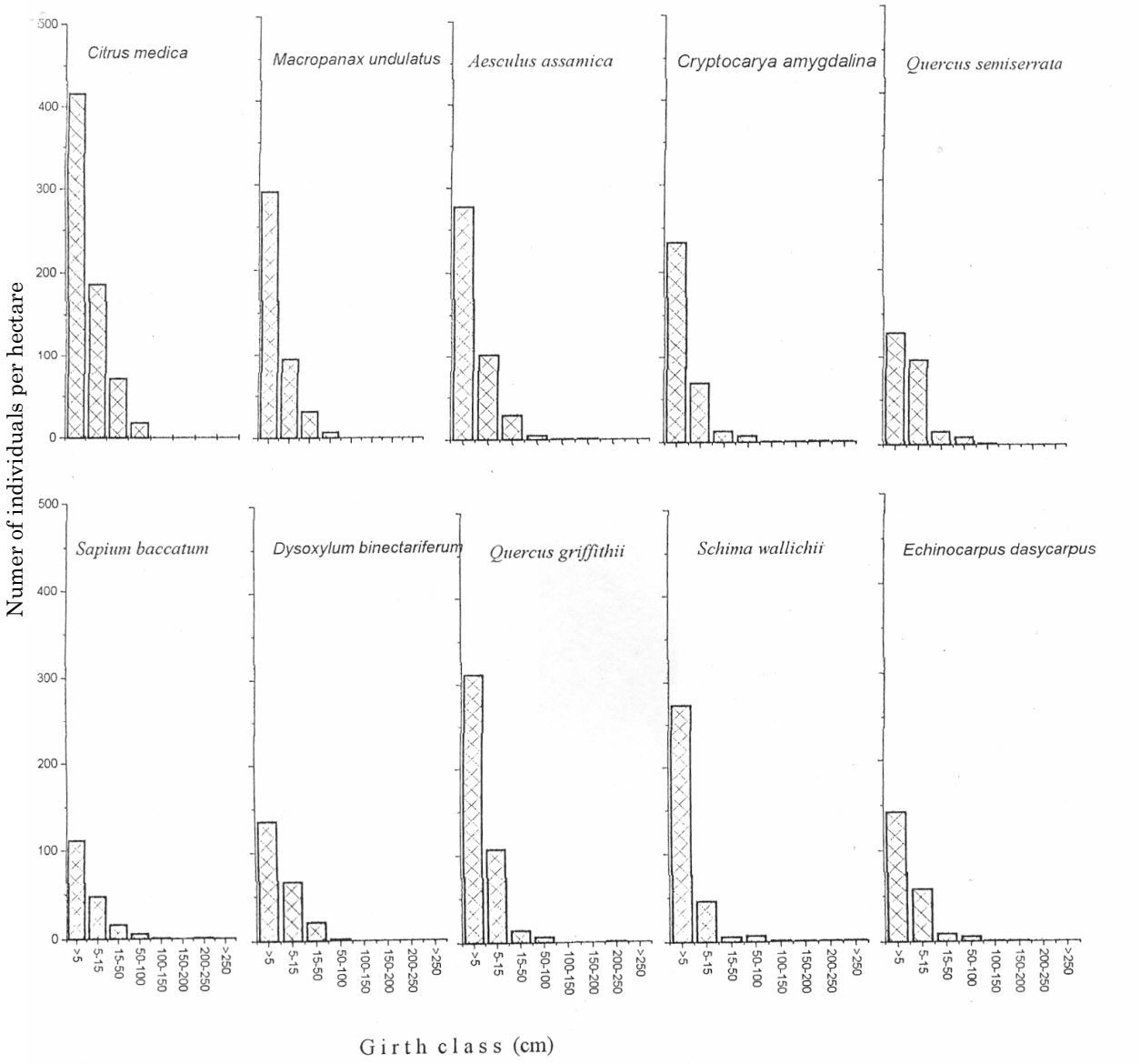

Fig. 4. Population structure of ten important tree species in different girth classes in the sacred grove.

(Lieberman *et al.* 1985), Brazilian amazon (Campbell *et al.* 1992) and Eastern Ghats, India (Kadavul & Parthasarathy 1999).

Ethnobotanical knowledge of old aged indigenous people of the area was recorded. Out of ten important tree species selected for population studies, four species are identified medicinally important. The whole plant of *Citrus medica* is medicinal, root and fruits are used in digestive disorder and dysentery. Leaf and bark of *Aesculus assamica* are used in fever and fish poisoning. The pounded stem and bark of *Schima wallichii* are used in fever, stomachache, bone fracture and sprain. Its leaf and bark paste is applied on cuts and wounds, and also to kill intestinal worms. Wood and seeds of *Dysoxylum binectariferum* are useful in leprosy and ulcer. Besides medicinal use, leaf of *Aesculus assamica* and *Quercus semiserrata* is used as cattle fodder, young leaves of *Schima wallichii* is used as vegetable and sapling of *Quercus griffithii* is used in christening ceremony of a child.

Population structure depicts that majority of important tree species showed high population of seedlings resulting in good regeneration. Low population of seedlings of *D. binectariferum* was mainly due to collections of seeds for medicinal use. However, presence of a large number of saplings and trees has resulted in good regeneration in *D. binectariferum*. Cattle grazing adversely affected seedling population of *Quercus semiserrata*, but regeneration potential of this species is maintained as saplings were in good number. Study suggests, the ethnobotanical

knowledge of indigenous people has helped in conservation and management of economically and medicinally important species of the sacred grove.

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References

Anonymous. 1978. *Tropical Forest Ecosystem: A State of Knowledge Report*. UNESCO/ UNEP/ FAO, Paris.

Armesto, J.J., J.D. Mitchell & C. Villagran. 1986. A comparison of spatial pattern of trees in some tropical and temperate forests. *Biotropica* **18:** 1–11.

Ayyappan, N. & N. Parthasarathy. 1999. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagaliar, Annamalais, western ghats, India. *Biodiversity and Conservation* **8:** 1533–1554.

Campbell, D.G., J.L. Stone & J.A. Rosas. 1992. A comparison of the phytosociology and dynamics of three floodplain verzea Forest of known ages, Rio Jurua, western Brazilian Amazon. *Botanical Journal of the Linnaean Society* **108:** 213–237.

Cao, M., J. Zhang, Z. Feng, J. Deng & X. Deng. 1996. Tree species composition of a seasonal rain forest in Xishuangbanna, south west China. *Tropical Ecology* **37:** 183–192.

FSI. 1997. *The State of Forest Report*. Forest Survey of India, Ministry of Environment & Forests, New Delhi, India.

Haridasan, K. & R.R. Rao. 1985. *Forest Flora of Meghalaya.* 2 Vols. Bishen Singh Mahendra Pal Singh, Dehra Dun.

Hengeveld, R. 1996. Measuring ecological biodiversity. *Biodiversity Letters* **3:** 58–65.

Jamir, S.A. 2000. *Studies on Plant Biodiversity, Community Structure and Population Behaviour of Dominant Tree Species of Some Sacred Groves of Jaintia Hills, Meghalaya*. Ph.D. Thesis. North-Eastern Hill University, Shillong, India.

Johnston, M. & M. Gillman. 1995. Tree population studies in low-diversity forests, Guyana.I. Floristic composition and stand structure. *Biodiversity and Conservation* **4:** 339–362.

Kadavul, K. & N. Parthasarathy. 1999. Structure and composition of woody species in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India. *Tropical Ecology* **40:** 247–260.

Kanjilal, U.N., P.C. Kanjilal, A. Das, R.N. De & N.L. Bor. 1934–40. *Flora of Assam*. 5 vols., Government Press, Shillong.

Keel, S., H.A. Genetry & L. Spinzi. 1993. Using vegetation analysis to facilitate the selection of conservation sites in eastern Paraguay. *Conservation Biology* **7***:* 66–75.

Kellman, M., R. Tackaberry & R. Lesley. 1998. Structure and function in two tropical gallery forest communities, implication for forest conservation in fragmented system. *Journal of Applied Ecology* **35:** 195–206.

Lieberman, D., M. Lieberman, G. Hartshorn & R. Peralta. 1985. Growth rates and age size relationships of tropical wet forest trees in Costa Rica. *Journal of Tropical Ecology* **1:** 97–109.

MacArthur, R.H. 1955. Fluctuation of animal population and a measure of community stability. *Ecology* **36:** 533–536.

Margalef, R. 1958. Information theory in ecology. *General Systematics*. **3:** 36–71.

Misra, R. 1968. *Ecology Work Book*. Oxford Publishing Company, Calcutta.

Mueller-Dombois, D. & H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. John Wiley and Sons, USA.

NRSA. 1995. *Annual Report*. National Remote Sensing Agency, Hyderabad, India.

Odum, E.P. 1971. *Fundamentals of Ecology*. W.B. Saunders Co., Philadelphia.

Pandey, H.N., O.P. Tripathi & R.S. Tripathi. 2003. Ecological analysis of forest vegetation of Meghalaya. pp. 37–50 *In*: B.P. Bhatt, K.M. Bhuarbaruah, Y.P. Sharma & Patiram (eds.) *Approaches for Increasing Agricultural Productivity in Hill and Mountain Ecosystem*. ICAR Research Complex for NEH Region, Umiam, Meghalaya,

Parthasarathy, N. & P. Sethi. 1997. Tree and liana species diversity and population structure in a tropical dry evergreen forest in South India. *Tropical Ecology* **38:** 19–30.

Rao, P., S.K. Barik, H.N. Pandey & R.S. Tripathi. 1997. Tree seed germination and seedling establishment in treefall gaps and understorey in a subtropical forest of northeast India. *Australian Journal of Ecology* **22:** 136–145.

Richards, P.W. 1996. *The Tropical Rain Forest: An Ecological Study*. 2nd edn., Cambridge University Press, London.

Shannon, C.E. & W. Weaver. 1949. *The Mathematical Theory of Communication.* Urbana University, Illinois Press.

Simpson, E.H. 1949. Measurement of diversity. *Nature* **163:** 688.

Tripathi, R.S., H.N. Pandey & B.K. Tiwari. 1996. *State of Environment of Meghalaya.* North-Eastern Hill University, Shillong.

Upadhaya, K., H.N. Pandey, P.S. Law & R.S. Tripathi. 2003. Tree diversity in sacred groves of Jaintia Hills in Meghalaya, northeast India, *Biodiversity and Conservation* **12:** 583–597.

Visalakshi, N. 1995. Vegetation analysis of two tropical dry evergreen forests in Southern India. *Tropical Ecology* **36:** 117–127.

Washington, H.G. 1984. Diversity, biotic and similarity indices: A review with special relevance to aquatic ecosystems. *Water Research* **18:** 653–694.

WCMC. 1992. Global biodiversity strategy. *In*: B. Groombridge (ed.) *World Conservation and Monitoring Centre*. Chapman & Hall, London.

Whitford, P.B. 1948. Distribution of woodland plants in relation to succession and clonal growth. *Ecology* **30:** 199–208.

Whitmore, T.C. 1975. *Tropical Rain Forest of Far East*. Oxford University Press, Oxford.

Whittaker, R.H. 1975. *Communities and Ecosystems*. 2nd edn. MacMillan Publishing Co. Inc., New York.

Appendix 1. Phytosociological attributes of woody species in the sacred grove (species are arranged in descending order of IVI).

Species rank	Species name	Local name	Family	TD	WI
1	*Citrus medica* Linn.	Sohkwit	Rutaceae	90	0.04
2	*Cryptocarya amygdalina* Nees.	Dalgappa	Lauraceae	26	0.08
3	*Phoebe attenuata* (Nees) Nees.	Bonsum	Lauraceae	6	0.17
4	*Fissistigma* species	-	Annonaceae	10	0.16
5	*Aesculus assamica* Griff.	Dieng-sangkenrop	Sapindaceae	34	0.07
6	*Schima wallichii* (DC.) Korth.	Dieng-nganbuit)	Theaceae	18	0.09
7	*Echinocarpus murex* Benth.	-	Elaeocarpaceae	16	0.08
8	*Macropanax undulatus* (wall. ex G.Don) Seem.	Dieng-jarasi)	Araliaceae	38	0.08
9	*Sapium baccatum* Roxb.	Dieng-jalongeh	Euphorbiaceae	24	0.07
10	*Cleidion javanicum* Bl.	Theng-hogwai	Euphorbiaceae	18	0.13
11	*Aporusa roxburghii* Baill.	Chhamolja	Euphorbiaceae	14	0.14
12	*Beilshmiedia brandishii* Hk.f.	Dieng-soh-khyllam-bam-skei	Lauraceae	12	0.12
13	*Ostodes paniculata* Bl.	Dieng-jathung	Euphorbiaceae	10	0.16
14	*Quercus semiserrata* Roxb.	Dieng-triang	Fagaceae	26	0.08
15	*Engelhardtia spicata* Leschn ex Bl.	Dieng-lamba	Juglandaceae	4	1
16	*Quercus griffithii* Hk.f. & Th. ex DC. Prodr.	Dieng-wah	Fagaceae	22	0.15
17	*Rhus javanica* Linn.	Dieng-sohma	Anacardiaceae	14	0.14
18	*Pittosporum glabratum* Lindl.	Dieng-thyllong	Pittosporaceae	10	0.28
19	*Echinocarpus dasycarpus* Benth.	-	Elaeocarpaceae	18	0.13
20	*Cyclostemon assamicus* Hk.f.	Dieng-pankher	Euphorbiaceae	16	0.16
21	*Lindera pulcherrima* (Nees) Benth.	Dieng-jaburit	Lauraceae	10	0.28
22	*Cryptocarya andersonii* King ex Hk.f.	Bol-dujong	Lauraceae	8	0.13
23	*Daphniphyllum* species	-	Daphniphyllaceae	14	0.14
24	*Dysoxylum binectariferum* Hk.f. et Bedd.	Bol-narang	Meliaceae	24	0.24
25	*Celtis tetranda* Roxb.	Dieng-chini	Ulmaceae	10	0.16
26	*Tapiria hirsuta* Hk.f.	Du-chengbrup	Anacardiaceae	16	0.16
27	*Elaeocarpus acuminatus* Wall ex Mast.	-	Elaeocarpaceae	16	0.11
28	*Cinnamomum pauciflorum* Nees.	Dieng-lorthia	Lauraceae	8	0.22
29	*Eurya acuminata* DC.	Dieng-shit	Theaceae	18	0.18
30	*Alphonsea ventricosa* Hk.f. & Thunb.	Noga-kola	Annonaceae	10	0.16
31	*Michelia punduana* Hk.f.	Dieng-soh-niar	Magnoliaceae	10	0.16
32	*Schefflera wallichiana* (W & A) Harms.	Dieng-tampoh	Araliaceae	16	0.16
33	*Symplocos spicata* Roxb.	Dieng-japei	Symplocaceae	16	0.16
34	*Schefflera hypoleuca* (Kurz.) Harms.	Dieng-latymphu	Araliaceae	16	0.25
35	*Vitex vestita* Roxb.	-	Verbenaceae	8	0.22
36	*Elaeocarpus lancifolius* Roxb.	Dieng-sohkhyllam	Elaeocarpaceae	10	0.16
37	*Callicarpa arborea* Roxb.	Dieng-lakhiol	Verbenaceae	10	0.16
38	*Mahonia pycnophylla* (Fedde) Takeda	Diang-niangmat	Berberidaceae	14	0.28
39	*Olea dentata* Wall ex DC.	Dieng-sa-niriangblai	Oleaceae	10	0.16
40	*Cordia fragrantissima* Kurz.	Bahari	Boraginaceae	6	0.18
41	*Trevesia palmata* (Roxb.) Vis.	Dieng-lakor	Araliaceae	6	0.38
42	*Persea gamblei* (King ex Hk.f.) Kosterm.	Omgthat	Lauraceae	12	0.19
43	*Picrasma javanica* Bl.	Bor-jagreng	Simaroubaceae	10	0.16
44	*Persea duthiei* (King ex Hk.f.) Kosterm.	-	Lauraceae	10	0.16

continued…

45	*Rhus acuminata* DC.	Dieng-khlaw	Anacardiaceae	6	0.17
46	*Quercus glauca* Thunb.	Dieng-rih	Fagaceae	10	0.28
47	*Beilshmiedia roxburghiana* Nees.	Dieng-sohlongar-khlaw	Lauraceae	6	0.17
48	*Coffea khasiana* Hk.f.	Dieng-supohniuroi	Rubiaceae	14	0.39
49	*Symplocos crataegoides* D.Don.	Dieng-iang	Symplocaceae	14	0.39
50	*Polyalthia jenkinsii* Benth. & Hk.f.	Diengther	Annonaceae	6	0.17
51	*Persea bombycina* (King ex Hk.f.) Kosterm.	Som	Lauraceae	8	0.13
52	*Daphniphyllum himalayense* (Benth.) Muell.-Arg.	Dieng-synrang-thuli	Daphniphyllaceae	8	0.22
53	*Eurya japonica* Thunb.	Dieng-pyrshit	Theaceae	10	0.16
54	*Litsea citrata* Bl.	Dieng-sying	Lauraceae	8	0.13
55	*Micromelum pubescens* (non Bl.)	Dieng-sohsat	Rutaceae	8	0.22
56	*Rhus insignis* Hk.f.	Brah	Anacardiaceae	8	0.22
57	*Sterculia hamiltonii* (O. Ktze.) Adelb.	Nak-chepeta	Sterculiaceae	8	0.22
58	*Erythroxylum kunthianum* Wall. ex Kurz.	Dieng-painkhar	Erythroxylaceae	8	0.22
59	*Antidesma diandrum* (Roxb.) Roth.	Dieng-japew	Euphorbiaceae	6	0.17
60	*Myrica esculenta* Buch-Ham. ex D.Don.	Sohphie	Myricaceae	10	0.22
61	*Schima khasiana* Dyer.	Dieng-ngan	Theaceae	6	0.17
62	*Carallia brachiata* (Lour.) Merr.	Dieng-sohsyllin	Cannaceae	6	0.17
63	*Cordia grandis* Roxb.	Dieng-jaing-nep	Boraginaceae	8	0.22
64	*Michelia champaca* Linn.	Shap	Magnoliaceae	6	0.17
65	*Beilshmiedia fagifolia* Nees.	Dieng-soh-long-ar-khlaw	Lauraceae	8	0.22
66	*Vitex negundo* Linn.	Pasutia	Verbenaceae	6	0.17
67	*Combretum acuminatum* Roxb.	Nagarlata	Combretaceae	8	0.22
68	*Ligustrum indicum* (Lour) Merr.	-	Oleaceae	8	0.22
69	*Skimmia laureola* (DC.) Sieb. & Zucc.	-	Rutaceae	6	0.38
70	*Schefflera venulosa* (W&A) Harms.	Dieng-masinghat	Araliaceae	8	0.22
71	*Sarcococca saligna* (D.Don) Muell-Arg.	Tiew-dieng	Buxaceae	4	0.25
72	*Eriobotrya dubia* Decne.	-	Rosaceae	8	0.38
73	*Callistemon citrinus* (Curt) Skeels	Bottle brush	Myrtaceae	8	0.22
74	*Ficus hispida* Linn. f.	Dieng-lapong	Moraceae	6	0.17
75	*Glochidion assamicum* Hk.f.	Dieng-soh-kassi	Euphorbiaceae	8	0.13
76	*Randia longiflora* Lamk.	Jyrmishiah-tiewkrot	Rubiaceae	8	0.22
77	*Sarcococca* species	-	Buxaceae	8	0.22
78	*Salix psilostigma* Anders.	Dieng-jiamon-roi	Salicaceae	8	0.5
79	*Brassiopsis glomerulata* (Bl.) Regel.	Dieng-lakor	Araliaceae	8	0.22
80	*Grewia multiflora* Juss.	Dieng-tyrbhong	Tiliaceae	6	0.17
81	*Acanthopanax aculeatum* Seem.	Shiah-ryngkhwai	Araliaceae	6	0.17
82	*Ulmus lanceifolia* Roxb.	Dieng-tyrsan	Ulmaceae	10	0.63
83	*Syzygium balsameum* (Wt.) Wall ex AM. & SM. Cowan.	Dieng-sohune	Myrtaceae	6	0.17
84	*Betula alnoides* Buch.-Ham. ex D.Don	Dieng-ling	Betulaceae	8	0.5
85	*Aralia armata* (G.Don) Seem.	Dieng-ta-tymphu	Araliaceae	6	0.17
86	*Mussaenda roxburghii* Hk.f.	Dieng-jalai	Rubiaceae	8	0.5
87	*Nauclea griffithii* Hav.	Dieng-soh	Rubiaceae	6	0.38
88	*Psychotria symplocifolia* Kurz	-	Rubiaceae	8	0.5
89	*Breynia retusa* (Dennst.) Alst.	Soh-matiar-Syurang	Euphorbiaceae	8	0.5
90	*Daphne cannabina* Wall.	Ka-dieng-baiong	Thymeliaceae	8	0.5
91	*Persea kingii* (Hk.f.) Kosterm.	-	Lauraceae	4	0.25
92	*Ilex embelioides* Hk.f.	-	Aquifoliaceae	8	0.5
93	*Prunus nepaulensis* (Ser.) Steud.	Soh-iong	Rosaceae	6	0.38

continued…

94	*Sapium eugeniaefolium* Ham. ex. Hk.f.	Dieng-sohmrit	Euphorbiaceae	4	0.25
95	*Litsea salicifolia* (Roxb. ex Nees.) Hk.f.	Dieng-lali	Lauraceae	6	0.38
96	*Sarcococca pruniformis* Lindl.	-	Buxaceae	6	0.38
97	*Symplocos racemosa* Roxb.	Bolimitap	Symplocaceae	6	0.38
98	*Fagraea ceilanica* Thunb.	Dieng-thiang	Loganiaceae	6	0.38
99	*Leptodermis griffithii* Hk.f.	-	Rubiaceae	6	0.38
100	*Viburnum foetidum* Wall.	Dieng-sohlang	Caprifoliaceae	6	0.38
101	*Ardisia nerifolia* DC.	Bhaujawa	Myrsinaceae	6	0.38
102	*Erythrina stricta* Roxb.	Dieng-songdkhar	Fabaceae	6	0.38
103	*Michelia oblonga* Wall. ex Hk.f.	Dieng-taroi	Magnoliaceae	4	0.25
104	*Millettia pulchra* (Benth.) Kurz.	Salang-tew	Fabaceae	4	0.25
105	*Capparis assamica* Hk.f. & Th.	-	Cappaceae	6	0.38
106	*Celtis cinnamomea* Lindl. ex Planch.	-	Ulmaceae	4	0.25
107	*Lindera latifolia* Hk.f.	Dieng-jalang	Lauraceae	4	0.25
108	*Sapindus rarak* DC. Prodr.	-	Sapindaceae	4	1
109	*Ilex khasiana* Purk.	-	Aquifoliaceae	6	0.38
110	*Elaeocarpus floribundus* Bl.	Jalpai	Elaeocarpaceae	4	0.25
111	*Vernonia vulkamerifolia* DC.	Dieng-duma	Asteraceae	4	0.25
112	*Michelia doltsopa* DC.	Dieng-rai	Magnoliaceae	4	0.25
113	*Olea dioica* Roxb.	Poreng	Oleaceae	4	0.25
114	*Symplocos theaefolia* D.Don.	Dieng-pei	Symplocaceae	4	0.25
115	*Glochidion khasicum* Hk.f.	Dieng-jirti	Euphorbiaceae	4	0.25
116	*Sterculia roxburghii* Wall.	Mimong-chitudari	Sterculiaceae	2	0.25
117	*Embelia ribes* Burm. f.	Bakul lata	Myrsinaceae	6	1.5
118	*Croton caudatus* Geisel.	Soh-lambrang	Euphorbiaceae	4	0.25
119	*Camellia caduca* Cl. ex Brandis.	Dieng-tyrnem	Theaceae	4	0.25
120	*Garcinia cowa* Roxb. ex DC.	Rengran	Clusiaceae	4	0.25
121	*Pyrus pashia* D.Don.	Soh-shur	Rosaceae	4	1
122	*Boehmeria platyphylla* D.Don.	Labit-iong	Urticaceae	4	1
123	*Meliosma wallichii* Planch. ex Hk.f.	Dieng-sngit	Sabiaceae	2	0.5
124	*Ardisia undulata* Cl.		Myrsinaceae	4	1
125	*Clerodendrum bracteatum* Wall. ex Walp.	Dieng-kylasla	Verbenaceae	4	1
126	*Ixora acuminata* Roxb.	-	Rubiaceae	4	1
127	*Bauhinia variegata* Linn.	Dieng-long	Caesalpiniaceae	4	1
128	*Cinnamomum granduliferum* (Wall.) Meissn.	Dieng-pingwail	Lauraceae	2	0.5
129	*Ligustrum robustum* (Roxb.) Bl.	Dieng-sohsiang	Oleaceae	4	1
130	*Sterculia villosa* Roxb.	Dieng-star	Sterculiaceae	2	0.5
131	*Persea Khasyana* Missn.	-	Lauraceae	2	0.5
132	*Neillia thyrsiflora* D.Don.	Dieng-sohsteit	Rosaceae	2	0.5
133	*Alangium chinense* (Lour.) Harms.	Diengsohkympel	Cornaceae	4	0.83

TD = Tree density, WI = Whitford index, and - = not known.
(Source: Local names of species - Haridasan & Rao (1985), and Kanjilal *et al.* (1934-40).