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# Diversity and population characteristics of woody species in natural forests and arecanut agroforests of south Meghalaya, Northeast India

H. TYNSONG[1*] & B. K. TIWARI[2]

[1]*Regional Centre National Afforestation and Eco-Development Board, North Eastern Hill University, Shillong 793022, India*
[2]*Department of Environmental Studies, North-Eastern Hill University, Shillong 793022, India*

**Abstract:** In this study, we investigated the woody species diversity and community characteristics of natural forests and arecanut agroforests of south Meghalaya, Northeast India. A total of 117 tree species (≥ 5 cm dbh) belonging to 98 genera were identified in the natural forests and 83 tree species, belonging to 62 genera were identified in the arecanut agroforests. In natural forests, Lauraceae (18 species), Euphorbiaceae (16 species) and Fagaceae (11 species) were the dominant families. In the case of arecanut agroforests, Euphorbiaceae (16 species), Lauraceae (14 species) and Moraceae (11 species) were the dominant families. Arecaceae was the only monocot family represented by *Caryota* spp. in both natural forests and arecanut agroforests, and there was only one gymnospermic family (Pinaceae) recorded only in the natural forests. Arecanut agroforests are less diverse and less dense than the natural forests. In arecanut agroforests, the density of economically important species was significantly higher indicating deliberate promotion of such species.

**Resumen:** En este estudio se investigó la diversidad de especies leñosas y las características de la comunidad de bosques naturales y de agrobosques de nuez de areca en el sur de Megalaya, noreste de la India. En los bosques naturales se identificaron en total 117 especies arbóreas (DAP ≥ 5 cm) pertenecientes a 98 géneros, mientras que en los agrobosques de nuez de areca se registraron 83 especies arbóreas pertenecientes a 62 géneros. En los bosques naturales, Lauraceae (18 especies), Euphorbiaceae (16 especies) y Fagaceae (11 especies) fueron las familias dominantes. En los agrobosques dominaron Euphorbiaceae (16 especies), Lauraceae (14 especies) y Moraceae (11 especies). Arecaceae fue la única familia de monocotiledóneas, representada por *Caryota* spp., tanto en los bosques naturales como en los agrobosques de nuez de areca, y sólo hubo una familia de gimnosperma (Pinaceae), registrada sólo en los bosques naturales. Los agrobosques de nuez de areca son menos diversos y menos densos que los bosques naturales. En estos agrobosques la densidad de las especies económicamente importantes fue significativamente mayor, lo que indica una promoción deliberada de dichas especies.

**Resumo:** Neste estudo investigou-se a diversidade das espécies lenhosas e as características de comunidade das florestas naturais e agro-florestas de noz de areca no sul de Meghalaya, nordeste da Índia. Nas florestas naturais e num total de 117 espécies arbóreas (DAP ≥ 5 cm), identificaram-se 98 géneros e nas agro-florestas de noz de areca 83 espécies arbóreas, pertencentes a 62 géneros. Nas florestas naturais as famílias dominantes foram as Lauraceae (18 espécies), Euphorbiaceae (16 espécies) e as Fagaceae (11 espécies). No caso das agro-florestas as famílias dominantes foram as Euphorbiaceae (16 espécies), Lauraceae (14 espécies) e Moraceae (11espécies). A Arecaceae foi a única família monocotiledónea

* *Corresponding Author*; e-mail: herotynsong@yahoo.com

representada pela *Caryota* sp. tanto na floresta natural como na agro-floresta de noz de areca e só se registou uma família das gymnospérmicas (Pinacea) nas florestas naturais. A agro-floresta de noz de areca, a densidade das espécies economicamente importantes foi significativamente maior, indicando uma promoção deliberada das referidas espécies.

**Key words:** Species richness, basal area, population structure, ecological importance, sub-tropical evergreen forest.

## Introduction

Almost all types of world's natural forests have been commercially logged to cope with the demand of forest products and land for agriculture (Uma Shaankar *et al.* 1998). Millions of hectares of natural forests have been degraded by logging (Putz *et al.* 2000) and for agricultural uses (Lenne & Wood 1999). It is generally considered that human exploitation causes major changes in the biodiversity of these forests, eventhough research on this subject has been limited and results often controversial (Turner 1996). Some studies reveal conspicuous reduced species richness in secondary rain forests (Parthasarathy 1999), even in over 100 years old regrowth stands (Turner *et al.* 1997), while other studies have reported increase in species richness in secondary forests (Kappelle *et al.* 1995).

Agroforestry is often viewed as an alternate landuse management system that offers solutions to land and forest degradation and loss of biodiversity in the tropics (Oke & Odebiyi 2007). The arecanut agroforests of south Meghalaya, northeast India, are good examples of multistrata agroforestry in which woody species provide important products for human use such as fuel-wood, food, medicine, spice, latex and timber (Tynsong & Tiwari 2010). Traditionally, arecanut farmers established their arecanut plantation by removing most of the woody species in the first year, creating gaps for planting of arecanut (*Areca catechu* L.), which is the principal cash crop. From the second year onwards people start enriching the gaps with economically important plant species and local fruit species to provide shade and soil protection (Tynsong 2009). These practices are reported to have great potential for conservation of biodiversity (Oke & Odebiyi 2007) because they create forest-like habitats, which harbour tropical biodiversity even in rapidly degrading landscapes. The retention of forest trees and the introduction of native and exotic plants determine the composition and structure of the arecanut agroforests. About 30,000 farmers are currently growing arecanut in south Meghalaya on an approximately 70,000 ha of land (Tynsong & Tiwari 2010). The objectives of this research were to determine the taxonomic composition and structural diversity of the woody species of the natural forests and arecanut agroforests in the area.

## Material and methods

### *Study area*

The survey was conducted in two natural forests, namely Raid Shabong Law Adong Py-nursla and Law Adong Siatbakon as well as two arecanut agroforests at Mawriang village and Sohlong village of south Meghalaya, an area very close to the international boundary of Bangladesh. The study area is located between 25° 6' 25"- 25° 18' 29" N and 91° 57' 38"-92° 1' 26" E. Cherrapunjee-Mawsynram Plateau, one of the wettest places in the world is located in this region. The altitude varies from 10 to 1,200 m. The mean annual maximum and minimum temperatures are around 23 and 13 °C respectively. The mean annual rainfall is about 11,560 mm (Fig. 1). The slope of the area is predominantly towards the south and the angle of the slope varies between 10 - 40°. The area has large numbers of rivers and rivulets, which drain into the plains of Bangladesh. Agriculture is limited to some small valleys where mainly tuber crops are grown. Arecanut, orange, betel leaf, jack fruit, bay leaf, honey and broom grass are the important produce of the region. People collect, process and market a large variety of non-timber forest products (NTFPs) and medicinal and aromatic plants (MAPs) such as *Cinnamomum tamala*, *Piper peepuloides*, *Phrynium capitatum*, bamboo, honey, mushrooms, nuts, tubers, edible

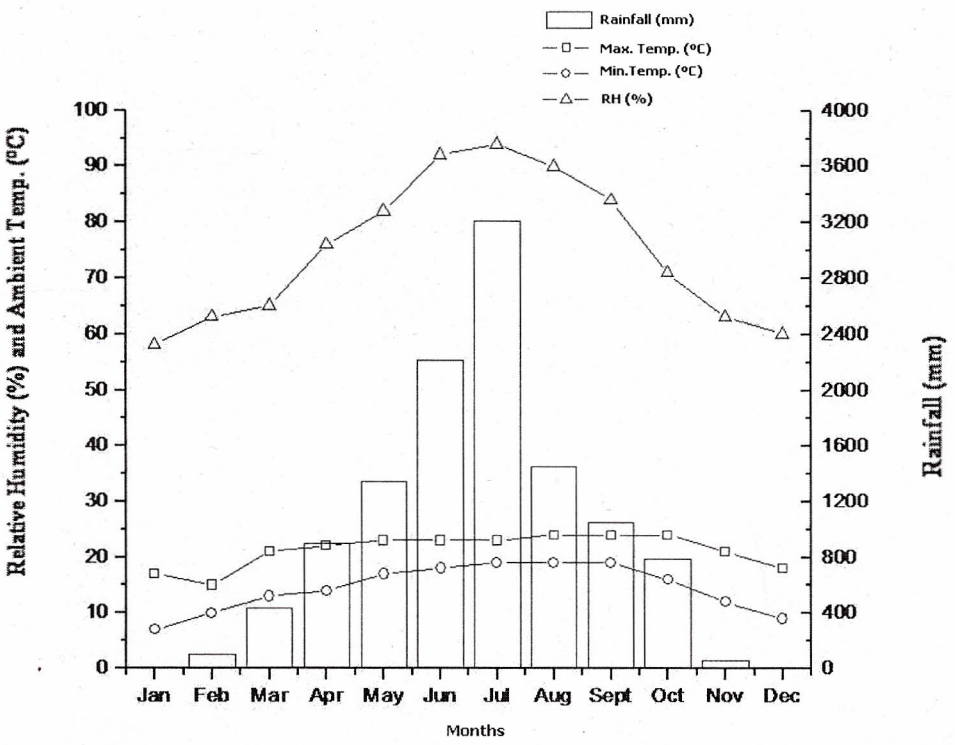


**Fig. 1.** Avarage monthly rainfall (mm), relative humidity (%) and ambient temperature (maximum and minimum °C) of the study area during 2004-2007.

worms, insects and leafy vegetables from the forests. Farmers of south Meghalaya have developed a system in which arecanut groves are deliberately and intimately grown while maintaining most biodiversity elements of the natural forests (Tiwari 2005).

The natural vegetation of south Meghalaya ranges from tropical evergreen to sub-tropical evergreen forests (Balakrishnan 1981-1983). The plant species in the forests are distributed in distinct vegetation layers. The important evergreen trees found in the south Meghalaya include: *Cinnamomum tamala, Daphniphyllum himalayanse, Myrica esculenta, Sarcosperma griffithii,* and *Syzygium tetragonum.* The deciduous elements include: *Betula alnoides, Cedrela toona, Engelhartia spicata* and *Ficus roxburghii.* The shrub layer is thick and is predominantly composed of *Ardisia griffithii, Boehmeria malabarica, Goniothalamus sesquipidalis, Mahonia pycnophylla* and *Wallichia densiflora.* The ground vegetation (herbs) is dominated by *Borreria pilosa, Commelina benghalensis, Impatiens* spp., *Ophiorrhiza hispida, Sonerila khasiana* and a large number of ferns. There are a good number of lianas and other climbers seen twining on the trees. The tree trunk and branches are covered with large number of mosses, epiphytic ferns and different varieties of orchids. The invasive weedy species like *Artemisia* spp., *Eupatorium* spp. and *Mikania micrantha* are also present in good number.

## *Methods*

For woody species diversity studies, extensive survey was carried out in the two natural forests and two arecanut agroforests of south Meghalaya during the months of January 2004 to October 2006. The woody vegetation was sampled by laying fifty quadrats of 100 $m^2$ size randomly in the two natural forests and two arecanut agroforests. Species diameter at breast height (dbh) $\geq$ 5 cm in both forest types were individually counted, measured and numbered and their densities per plot and frequencies were estimated. Plant specimens collected were identified with the help of the Flora of Jowai (Balakrishnan 1981-1983), Forest Flora of Meghalaya (Haridasan & Rao 1985-1987) and Flora of Assam (Kanjilal *et al.* 1934-1940). The Herbarium of Botanical Survey of India, Eastern Circle, was consulted for confirming the identification of plant specimens. The nomen-

**Table 1.** Distribution of woody species richness (number) in natural forest and arecanut agroforest of south Meghalaya.

| Growth form | Natural forest | | Agroforest | | Over all |
|---|---|---|---|---|---|
| | Pynursla | Siatbakon | Mawriang | Sohlong | |
| Canopy layer (15 - 30 m height) | 35 | 33 | 29 | 29 | 64 |
| Sub-canopy (8 - 15 m height) | 42 | 31 | 37 | 38 | 79 |
| Under-canopy (< 8 m height) | 14 | 12 | 12 | 12 | 35 |
| Total | 91 | 76 | 78 | 79 | 178 |

**Table 2.** Number of woody species and their density (individual/0.5ha) and basal area of thirty important families in natural forest and arecanut agroforest of south Meghalaya.

| Families | Natural forest | | | | | | Arecanut agroforest | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pynursla | | | Siatbakon | | | Mawriang | | | Sohlong | | |
| | Species | Density | Basal area ($m^2 ha^{-1}$) | Species | Density | Basal area ($m^2 ha^{-1}$) | Species | Density | Basal area ($m^2 ha^{-1}$) | Species | Density | Basal area ($m^2 ha^{-1}$) |
| Anacardiaceae | 2 | 6 | 1.76 | - | - | - | 2 | 24 | 0.65 | 1 | 10 | 0.90 |
| Apocynaceae | 1 | 2 | 1.64 | - | - | - | 2 | 15 | 0.15 | 2 | 84 | 0.55 |
| Araliaceae | 4 | 73 | 1.25 | 1 | 37 | 0.86 | 2 | 28 | 2.87 | 2 | 48 | 0.57 |
| Bignoniaceae | 2 | 40 | 5.55 | 2 | 29 | 1.79 | 1 | 48 | 0.11 | 2 | 46 | 0.48 |
| Boraginaceae | 1 | 26 | 0.54 | 1 | 10 | 0.88 | - | - | - | 1 | 8 | 0.77 |
| Clusiaceae | 3 | 108 | 0.62 | - | - | - | 3 | 21 | 9 | - | - | - |
| Elaeocarpaceae | 1 | 27 | 1.75 | 1 | 22 | 0.86 | - | - | - | 2 | 38 | 0.67 |
| Euphorbiaceae | 11 | 133 | 2.78 | 9 | 134 | 3.87 | 9 | 56 | 3.09 | 11 | 156 | 5.85 |
| Fagaceae | 7 | 330 | 2.73 | 8 | 594 | 2.78 | 2 | 13 | 1.02 | 4 | 34 | 0.81 |
| Jaglandaceae | 1 | 46 | 0.62 | 1 | 7 | 0.69 | 1 | 34 | 0.63 | 1 | 14 | 0.76 |
| Lauraceae | 16 | 252 | 5.77 | 12 | 258 | 3.53 | 7 | 215 | 3.64 | 13 | 242 | 4.40 |
| Magnoliaceae | 2 | 19 | 0.85 | 2 | 44 | 1.87 | 1 | 67 | 0.17 | 3 | 24 | 0.54 |
| Malpighiaceae | 1 | 134 | 0.63 | 2 | 25 | 1.57 | - | - | - | - | - | - |
| Meliaceae | 1 | 2 | 0.69 | - | - | - | 3 | 34 | 1.20 | 4 | 82 | 1.55 |
| Mimosaceae | 1 | 3 | 0.68 | - | - | - | 1 | 24 | 0.08 | 1 | 44 | 0.85 |
| Moraceae | 2 | 212 | 0.68 | 3 | 45 | 1.87 | 9 | 169 | 8.78 | 8 | 250 | 6.78 |
| Myristicaceae | 1 | 5 | 0.57 | 2 | 11 | 0.66 | 2 | 25 | 1.65 | 1 | 32 | 0.45 |
| Myrtaceae | 1 | 194 | 0.69 | 1 | 86 | 0.89 | 2 | 34 | 0.57 | 1 | 32 | 0.76 |
| Ochnaceae | - | - | - | 1 | 18 | 0.72 | 1 | 23 | 3.33 | 1 | 26 | 0.64 |
| Oleaceae | 1 | 7 | 0.59 | 1 | 8 | 1.66 | 1 | 24 | 0.05 | 1 | 26 | 0.36 |
| Proteaceae | 1 | 9 | 0.19 | 2 | 52 | 0.26 | - | - | - | 2 | 34 | 0.76 |
| Rubiaceae | 4 | 22 | 6.78 | 2 | 44 | 2.66 | - | - | - | 3 | 46 | 0.88 |
| Rutaceae | 1 | 22 | 0.90 | 1 | 6 | 1.71 | 3 | 17 | 0.93 | 2 | 22 | 0.85 |
| Sapotaceae | 1 | 81 | 0.19 | 4 | 122 | 1.67 | - | - | - | 2 | 148 | 0.66 |
| Sonneratiaceae | - | - | - | 2 | 15 | 1.26 | 1 | 62 | 0.61 | 1 | 58 | 2.34 |
| Sterculiaceae | 1 | 1 | 0.68 | 1 | 4 | 1.28 | 3 | 13 | 0.98 | 2 | 12 | 2.34 |
| Styraceae | 1 | 43 | 0.68 | 1 | 25 | 1.28 | - | - | - | 1 | 10 | 0.61 |
| Tetramelaceae | - | - | - | - | - | - | 1 | 41 | 8.30 | 1 | 22 | 3.48 |
| Theaceae | 4 | 114 | 0.88 | 3 | 76 | 0.56 | 1 | 8 | 0.77 | 2 | 34 | 0.44 |
| Unidentified | - | - | - | 4 | 54 | 0.91 | 3 | 31 | 0.61 | 1 | 16 | 0.59 |
| Others | 19 | 189 | 27.36 | 9 | 246 | 16.17 | 17 | 652 | 10.71 | 3 | 358 | 11.25 |
| Total | 91 | 2100 | 68.05 | 67 | 1972 | 52.26 | 61 | 1678 | 59.90 | 76 | 1956 | 51.89 |

- indicates absence.

**Table 3.** Consolidated summary of plant diversity and community characteristics of woody species (≥ 5 cm dbh) in natural forests and arecanut agroforests of south Meghalaya.

| Parameters | Natural forest | | Arecanut agroforest | | Mean | |
|---|---|---|---|---|---|---|
| | Pynursla | Siatbakon | Mawriang | Sohlong | Natural forest | Arecanut agroforest |
| Sampling size (ha) | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 (± 0) | 0.5 (± 0) |
| Number of families | 40 | 33 | 31 | 36 | 36.5 (± 3.5) | 33.5 (± 2.5) |
| Number of genera | 69 | 61 | 57 | 62 | 65 (± 4) | 59.5 (± 2.5) |
| Species richness | 90 | 75 | 76 | 79 | 82.5 (± 7.5) | 77.5 (± 1.5) |
| Density ($ha^{-1}$) | 2100 | 1972 | 1678 | 1956 | 2036 (± 64) | 1817 (± 139) |
| Basal area ($m^2 ha^{-1}$) | 68.05 | 52.26 | 59.90 | 51.89 | 60.15 (± 7.9) | 55.9 (± 4) |
| Diversity indices: | | | | | | |
| Pielou's eveness index | 0.78 | 0.83 | 0.53 | 0.77 | 0.81(± 0.02) | 0.65 (± 0.12) |
| Shannon diversity index | 3.74 | 3.87 | 3.11 | 3.37 | 3.81(± 0.06) | 3.24 (± 0.13) |
| Simpson dominance index | 0.04 | 0.02 | 0.12 | 0.09 | 0.03 (± .01) | 0.11 (± 0.01) |

clature of the species follows the regional flora (Balakrishnan 1981-1983, Haridasan & Rao 1985 - 1987 and Kanjilal *et al.* 1934-1940). The height of stems of each tree species were recoded by rough estimation in all plots and they were grouped into three height classes (large tree ≥ 15 m, medium tree 8 - 15 m, small tree < 8 m) and seven dbh classes (5 - 15, 15 - 25, 25 - 35, 35 - 45, 45 - 55, 55 - 65 and > 65 cm)

### *Data analyses*

The density and basal area of each species were determined in different dbh classes according to Mueller-Dombois & Ellenberg (1974). Shannon-Wiener Index of Diversity (H') (Magurran 1988), Simpson Index of Dominance (D) (Simpson 1949) and Pielou's Evenness Index (E) (Pielou 1975) were calculated to analyze species diversity and dominance in the community. The importance value index was calculated by using the formula for tree: IVI = relative frequency + relative density + relative basal area (Misra 1968). Floristic similarity between the two forest types was compared by computing Sørensen's Index of Similarity (Sørensen 1948).

## Results

### *Species richness and distribution pattern*

A total of 117 (4 unidentified) woody species (≥ 5 cm dbh) were identified in one ha area of two natural forests and 83 tree species (3 unidentified) in two arecanut agroforests. Out of these, 64 species (40 %) were canopy trees (≥ 15 m height), 79 species (44 %) were sub canopy trees (8 - 15 m height) and the rest were under-canopy trees (Table 1). The natural forests at Pynursla and Siatbakon villages had 90 and 75 species, respectively, in 0.5 ha area belonging to 59 plant families. The arecanut agroforest at Mawriang and Sohlong had 76 and 79 species, respectively, belonging to 48 plant families. Lauraceae with 18 species was the dominant family followed by Euphorbiaceae (16 species) and Fagaceae (11 species). In the arecanut agroforests Euphorbiaceae was the dominant family with 16 species followed by Lauraceae (14 species) and Moraceae (11 species). Arecaceae was the only monocot family represented by *Caryota* spp. in both natural forests and agroforests (Table 2). The only gymnospermic family, namely Pinaceae represented by *Pinus kesiya*, was recorded only in the natural forests. Comparison between the two forest types showed variations in woody species composition with Sorensen's index of similarity being 43.34 %.

### *Species diversity and dominance*

Shannon-Wiener's Diversity Index varied from a minimum of 3.11 at Mawriang of arecanut agroforest to a maximum of 3.87 in Siatbakon of natural forests. Simpson's Index of Dominance varied from a minimum of 0.02 at Siatbakon to 0.12 at Mawriang Pielou's Eveness Index varied from 0.53 to 0.83 in the two forest types (Table 3).

**Table 4.** Density (individuals/0.5 ha) and importance value index (IVI) of dominant woody species (≥ 5 cm dbh) in natural forests and arecanut agroforest of south Meghalaya.

| Plant species | Family | Growth form | Natural forest | | | | Arecanut agroforest | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Pynursla | | Siatbakon | | Mawriang | | Sohlong | |
| | | | D | IVI | D | IVI | D | IVI | D | IVI |
| *Aglaia perviridis* Hiern. | Meliaceae | ST | 15 | 2.75 | 58 | 5.80 | 2 | 0.91 | 36 | 5.29 |
| *Antidesma diandrum* (Roxb.) Roth. | Euphorbiaceae | ST | 3 | 0.44 | - | - | 12 | 2.10 | - | - |
| *Aporosa dioica* (Roxb.) Muell. Arg. | Euphorbiaceae | ST | 6 | 0.91 | 12 | 2.98 | - | - | - | - |
| *Artocarpus heterophyllus* Ham. | Moraceae | LT | 10 | 1.80 | 18 | 1.82 | 111 | 25.13 | 132 | 2.45 |
| *Bauhinea semla* Wunderlin. | Caesalpiniaceae | ST | - | - | - | - | 9 | 2.16 | 18 | 3.34 |
| *Castanopsis hystrix* A.DC. | Fagaceae | MT | 136 | 20.40 | 56 | 10.48 | - | - | - | - |
| *Cinnamommum tamala* Fr. Nees. | Lauraceae | MT | 31 | 5.52 | 34 | 4.86 | 189 | 23.89 | 125 | 2.24 |
| *Cinnamomum bejolghota* Buch.-Ham. | Lauraceae | LT | 12 | 2.11 | - | - | 3 | 0.51 | 20 | 3.27 |
| *Duabanga grandiflora* (Roxb. Ex DC.) Walp. | Sonneratiaceae | LT | - | - | 12 | 2.07 | 2 | 1.61 | 58 | 32.78 |
| *Eleocarpus lancifolius* Roxb. | Elaeocarpaceae | LT | 27 | 3.70 | 22 | 2.58 | - | - | 6 | 1.13 |
| *Engelhardtia spicata* Blume. | Juglandaceae | LT | 46 | 7.82 | 7 | 0.94 | 3 | 1.83 | 14 | 1.80 |
| *Erythroxylum kunthianum* Wall. | Malpighiaceae | ST | 134 | 8.77 | 13 | 1.40 | - | - | - | - |
| *Ficus roxburghii* Wall. | Moraceae | MT | - | - | 13 | 1.81 | 8 | 3.07 | 46 | 5.72 |
| *Ficus* sp. | Moraceae | ST | 196 | 21.34 | - | - | 21 | 3.52 | - | - |
| *Glochidion khasicum* Hk.f. | Euphorbiaceae | ST | 44 | 5.81 | 13 | 1.40 | 2 | 1.41 | 10 | 1.66 |
| *Knema latifolia* (Roxb.) Warb. | Myristicaceae | MT | 5 | 0.85 | - | - | 2 | 1.41 | 32 | 4.79 |
| *Lithocarpus elegans* (Blume.) Soep. | Fagaceae | LT | 101 | 12.82 | 133 | 30.80 | 111 | 25.13 | 8 | 1.38 |
| *Macaranga peltata* (Roxb.)Muell.Arg. | Euphorbiaceae | MT | - | - | 13 | 1.74 | 11 | 4.90 | 20 | 2.07 |
| *Machilus bombycina* King. | Lauraceae | MT | 61 | 10.39 | 79 | 12.35 | 2 | 1.41 | 46 | 5.46 |
| *Macropanax undulatus* (Wall.ex D.Don) Seem. | Araliaceae | MT | 50 | 10.99 | - | - | - | - | 34 | 4.82 |
| *Magnolia* sp. | Magnoliaceae | LT | 14 | 2.68 | 41 | 4.51 | - | - | 4 | 0.83 |
| *Phoebe cooperiana* U.N.Kanjilal ex A.Das.Nov.sp. | Lauraceae | MT | - | - | 24 | 3.61 | 2 | 1.41 | 70 | 8.70 |
| *Quercus dealbata* Hk.f.&Th. | Fagaceae | LT | 25 | 3.94 | 24 | 3.86 | 5 | 1.92 | - | - |
| *Sapium baccatum* Roxb. | Euphorbiaceae | LT | 3 | 0.44 | 15 | 2.32 | 11 | 4.33 | 6 | 3.80 |
| *Sarcosperma griffithii* Benth. | Sapotaceae | MT | 81 | 9.88 | 104 | 16.18 | 20 | 8.74 | 132 | 16.36 |
| *Schima walichii* Choisy. | Theaceae | LT | 15 | 2.75 | 62 | 11.56 | 8 | 4.59 | 8 | 1.66 |
| *Styrax serrulatum* Roxb. | Styraceae | ST | 43 | 4.90 | - | - | - | - | 10 | 1.44 |
| *Syzygium tetragonum* (Wt.) Kurz. | Myrtaceae | MT | 194 | 23.63 | 86 | 12.50 | 5 | 0.41 | 2 | 0.36 |
| *Wenderhardia tinctoria* DC. | Rubiaceae | ST | 3 | 0.33 | - | - | - | - | 16 | 1.82 |
| *Wrightia tomentosa* Roem & Sch. | Apocynaceae | ST | 14 | 2.15 | - | - | 12 | 2.34 | 76 | 8.19 |
| Others | | | 831 | 132.88 | 1133 | 164.43 | 1127 | 177.27 | 1027 | 178.64 |
| Total | | | 2100 | 300 | 1972 | 300 | 1678 | 300 | 1956 | 300 |

-indicates absence, D-density, LT-large sized tree, MT-medium sized tree, ST-small sized tree.

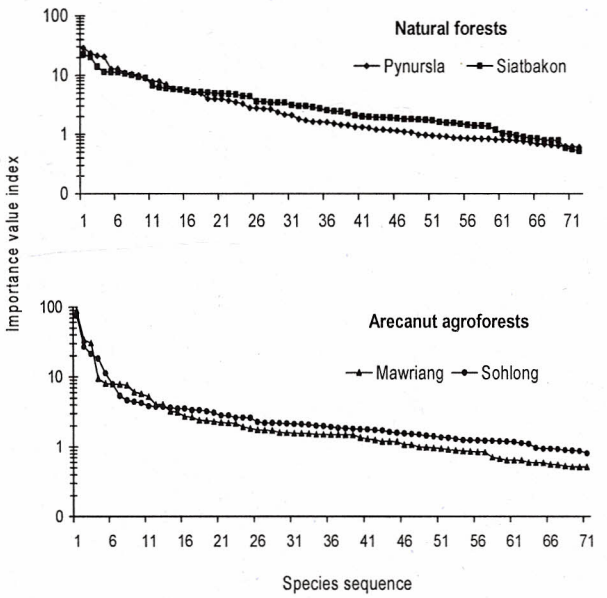


**Fig. 2.** Dominance-diversity curve of woody species in the two natural forests and arecanut agroforests of south Meghalaya.

### *Density*

The stand density in the natural forests ranged from 1,972 to 2,100 individuals $ha^{-1}$ with a mean value of 2036 (± 64) stems $ha^{-1}$. The stand density in arecanut agroforests ranged from 1,678 to 1,956 individuals $ha^{-1}$ with a mean value of 1,817 (± 139) stems $ha^{-1}$ (Table 3). At Pynursla, *Ficus* sp., (196 stem $ha^{-1}$), *Syzygium tetragonum* (194 stem $ha^{-1}$) and *Castanopsis hystrix* (136 stem $ha^{-1}$) had the highest density and together accounted for 25 % of the stand density. At Siatbakon, *Lithocarpus elegans* (133 stem $ha^{-1}$), *Sarcosperma griffithii* (104 stem $ha^{-1}$) and *Syzygium tetragonum* (86 stem $ha^{-1}$) accounted 16 % of the stand density. At Mawriang, *Cinnamomum tamala* (189 stem $ha^{-1}$), *Artocarpus heterophyllus* (111 stem $ha^{-1}$) and *Lithocarpus elegans* (111 stem $ha^{-1}$) accounted 24 % of the stand density. At Sohlong, *Artocarpus heterophyllus* (132 stem $ha^{-1}$), *Sarcosperma griffithii* (132 stem $ha^{-1}$) and *Cinnamomum tamala* (125 stem $ha^{-1}$) constituted 20 % of the stand density (Table 4).

### *Ecological importance of the species*

The dominance distribution curve showed high equitability and low dominance in both the natural forests and arecanut agroforests. At Pynursla, *Syzygium tetragonum* (IVI = 23.63) and *Ficus* sp. (IVI = 21); at Siatbakon, *Lithocarpus elegans* (IVI = 30.8) and *Sarcosperma griffithii* (IVI = 16.18) were dominant and co-dominant species respectively in the natural forests. Among arecanut agroforests, at Mawriang, *Artocarpus heterophyllus* (IVI = 23.89) and *Cinnamomum tamala* (23.89); at Sohlong, *Duabanga grandiflora* (IVI = 32.78) and *Phoebe cooperiana* (IVI = 8.7) were the dominant and co-dominant species respectively (Fig. 2).

### *Population structure*

Distribution of species richness in different classes showed high richness in 5 - 15 and 16 - 25 cm dbh classes. The density in different dbh classes showed that 50 and 44 % of the total stem at Pynursla, and 53 and 41 % at Siatbakon were in the 5 - 15 and 16 - 25 cm dbh classes at the two natural forests, respectively. Only 0.06 % of trees had > 66 cm dbh. The density in different dbh classes showed that 95 and 4 % of the total stems at Mawriang, 58 and 34 % at Sohlong were in the 5 - 15 and 16 - 25 cm dbh classes at the two arecanut agroforests, respectively (Fig. 3). The density-diameter distribution yielded reverse J-shaped curves in both forest types. However, in the two stands of arecanut agroforests, stem density in 5 - 15 cm dbh class was markedly higher than in natural forests. Despite the fact that density of young trees (5 - 15 cm dbh) was very high, their total basal area was much less than the basal area of matured trees, thereby, resulting in J-shaped distribution of basal area.

## Discussion

The natural forests and arecanut agroforest of south Meghalaya are multilayered sub-tropical evergreen forest communities composed of large, medium and small trees distributed in three distinct strata. The canopy, sub-canopy and under-canopy layers were composed of large (15 - 30 m height), middle-sized (8 - 15 m height) and small (< 8 m height) trees, respectively. High species richness of the sub-and under-canopy layers is attributed to the presence of individuals of canopy species, which are either young or whose growth was arrested due to heavy shade by the overhead canopy (Jamir *et al.* 2006). Similar observation has been reported by Upadhaya *et al.* (2003) from two sub-tropical humid forests of Jaintia Hills district of Meghalaya and Quigley & Platt (2003) from nine seasonally deciduous forests in the Americas.

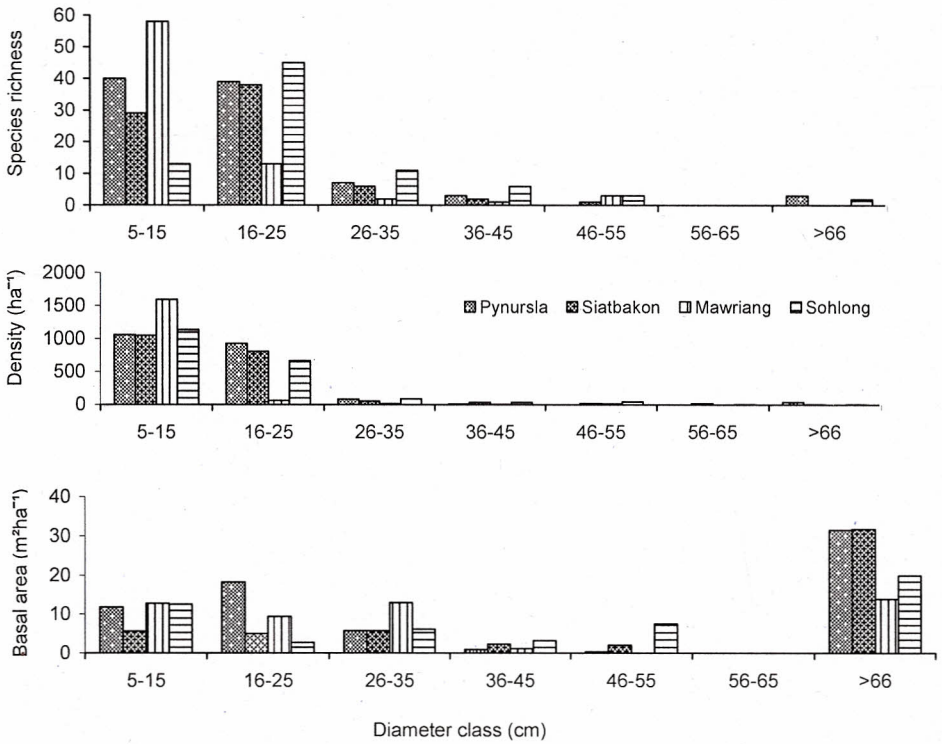


**Fig. 3.** Distribution of species richness, density and basal cover area in different diameter classes in natural forests (at Pynursla and Siatbakon) and arecanut agroforests (at Mawriang and Sohlong) of south Meghalaya.

High species richness in the natural forest is also due to geographical locations of north-eastern region at the influence of Indo-Malayan and Indo-Chinese biogeographical region and protection by the people over a long period of time. Species richness in the natural forests is comparable to tropical semi-evergreen forest of Western Ghats, India, with 107 tree species (Kanade *et al.* 2008) and other sub-tropical humid forests of Meghalaya ranging from 133 (Mishra *et al.* 2005) to 159 (Upadhaya *et al.* 2003). Species diversity recorded in the present study is similar to that of sub-tropical semi-evergreen forests (3.7 - 4.3) in Jaintia Hills district of Meghalaya (Jamir 2000).

Lauraceae and Euphorbiaceae in the natural forests and Euphorbiaceae, Lauraceae in the case of arecanut agroforests were the dominant and co-dominant woody species families, respectively. This corroborates the results of Upadhaya *et al.* (2003) and Mishra *et al.* (2005) who also recorded Lauraceae and Euphorbiaceae as dominant and co-dominant families in the sub-tropical humid forests of Meghalaya.

The tree basal cover of natural forests (60.15 ± 7.9) was higher than those of Jaintia Hills, Meghalaya, reported by Upadhaya (2002). It has been found that density of woody species (1817 ± 139 stem $ha^{-1}$) in arecanut agroforests was significantly lower than the density of natural forests (2036 ± 64 stem $ha^{-1}$). The lower basal area and density in the arecanut agroforests may be due to the fact that a number of woody species were felled during the conversion of natural forests to arecanut agroforests.

With respect to density distribution of woody species, the natural forests are similar to evergreen forests of southern India (Parthasarathy & Sethi 1997) and Western Ghats (Ayyappan & Parthasarathy 1999). The distribution of woody species in different age groups (reverse J-shaped curve) suggests that the natural forests in south Meghalaya are more stable compared to arecanut agroforests.

Comparison of woody species richness between the two forest types shows that over all natural forests are richer than arecanut agroforests. This pattern is consistent with the results of other studies in South Asia (Parthasarathy 1999; Turner *et al.* 1997). A comparison between the species richness of arecanut agroforest of South Meghalaya with that of cocoa agroforest in southern Cameroon reflects that the species richness of

woody species of arecanut agroforest of South Meghalaya was significantly higher (83 woody species) than species richness of woody species of cocoa agroforest (21 woody species) (Sonwa *et al.* 2007). The arecanut agroforests mimic, to some extent, the natural forests in structure and function (Tynsong & Tiwari 2010). Growing arecanut along with diversified native plant species contributes to biodiversity conservation within agricultural landscapes, complementing conservation in protected areas (Schroth *et al.* 2004). Arecanut agroforests can play a role in conservation strategies in fragmented landscapes of this area by providing habitat and resources for plant and animal species and by maintaining connectivity between forest areas. Although not always recognized by agronomists, native and exotic species promoted and maintained in arecanut agroforests have many more uses for local farmers than just providing a suitable microclimate for arecanut trees.

## Conclusions

This study revealed that the conversion of natural forests to arecanut agroforests have impacted the density and basal area of woody species. The woody basal area and density was significantly higher in the natural forests compared to arecanut agroforests while there is a minimal impact on the number of families, genera, evenness, diversity, dominance and species richness. Arecanut agroforests are less diverse and dense than the natural forests but are enriched by the farmers with economically important tree species that meet the needs of the local people.

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