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Tree Diversity and Population Structure of a Protected Lowland Tropical Forest in Barail Hill Range, Northeast India

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ABSTRACT

Tree species diversity and population structure of a lowland tropical forest in Barail Wildlife Sanctuary, Assam falling under the important Barail Hill Range of Northeast India was carried out during 2012-2015. 42 quadrat (20m x 25m) were laid in three forest stands selected on the basis of location and species dominance in the lowland forests of the sanctuary following random sampling method. The vegetation data collected were analyzed for density, frequency, basal area, and the Importance Value Index (IVI). Familial importance value was also worked out. Tree Species diversity was calculated following Shannon diversity index and Concentration of Dominance was calculated by Simpson's Index. Population structure was worked out based on the girth of individual trees belonging to different species. A total of 109 tree species (≥ 30 cm gbh), belonging to 45 families were rerecorded from the sanctuary. Tree species richness was recorded highest for stand I that comprised 88 tree species, followed by stand III (69 tree species) and stand II (48 tree species). Meliaceae, Sapindaceae and Sterculaiceae were the dominant families in different stands. Shannon diversity index was found highest in stand I (4.01) followed by stand III (3.87) and stand II (3.61). The dominant species in stand I were *Canarium strictum* (IVI 17.58) While in stand II, it was *Maniltoa polyandra* (IVI 22.31) and *Elaeocarpus macrocerus* (IVI 19.84) in stand III. The population structure of all the three stands showed a reverse J-shaped curve where as in case of the dominant tree species, individuals in different stands were unequally distributed. The lowland forests of Barail Wildlife Sanctuary are a repository of huge biodiversity in the very important Barail Hill Range landscape of Northeast India that falls under the Indo-Burma Hotspot of biodiversity. Being the only protected area in the entire South Assam region, it acts as an important refuge for the native plants and animals, including the rare, endangered and threatened species of the region. The study would contribute a great deal towards the understanding of tree species composition, diversity, species coexistence and population structure of this very important wildlife sanctuary which will pave the way for its better management and conservation.

Key Words: Species Diversity, Richness, Structure, Lowland Tropical Forest, Barail Wildlife Sanctuary

INTRODUCTION

Lowland tropical forests consist of one of the most species-diverse terrestrial ecosystem (Richards 1996, Hubbell 1979). Trees contribute to the major structural and functional basis of the tropical forest ecosystem and also as an indicator of the change in the landscape (Misra 1968). However, tropical forest in the developing counties are now degrading at an alarming rate due to illegal felling, over-exploitation of forest resources, encroachment and other human-induced affects to the natural forest ecosystem (Kumar et al. 2002). Human uses of tropical forest resources in developing countries are in direct conflict with the conservation of biodiversity and habitat destruction and degradation of tropical forest and can be hailed as the major factor contributing to the decline of global biodiversity (Mishra et al. 2003).

When the natural areas are being rapidly depleted, conservation of the world genetic resources increasingly depends on a small percentage of land area called protected areas in nature reserves (Macdonald et al. 1989). This Protected Areas viz. national parks, wildlife sanctuaries, and other nature reserves act as repositories of biodiversity in a biogeographic unit. In other words, they function as a refuge for native plants, animals and micro-organisms and act as an outdoor laboratory (Brandt and Rickard 1994).

Northeast India harbours rich biodiversity, both in species number as well as in diversity (Rao and Murti 1990). However, this highly diverse area is undergoing rapid degradation due to unplanned development, logging and other anthropogenic issues. Many important flora and fauna of the region have lost its habitat and have become extremely vulnerable and may even lead to extinction in the future if preventive measures are not initiated in time. Tree diversity and population structure of a particular forest provides the baseline information for the management and conservation of biodiversity. Low elevation forests are found to be having higher diversity of species as compared to the higher elevation forests (Lovett et al. 2001, Vázquez and Givnish 1998, Lieberman et al. 1996). Various works have been carried out on the lowland tropical forest of the region (Khan et al. 1986, Bhuyan et al. 2003, Upadhaya et al. 2003, Kumar et al. 2006, Deb and Sundriyal 2008, Deb et al. 2009).

The Barail Wildlife Sanctuary is situated on the northern part of Cachar District of Assam, India and is the only protected area (Wildlife Sanctuary) in the entire south Assam and lies along the foothills of the very important Barail Hill range in Northeast India. The area also falls under the unique Indo-Burma Biodiversity Hotspot which is one of the protected priority key biodiversity area (www.conservation.org/ How/Pages/ Hotspots.aspx, Accessed 29 June 2016). With the habitats ranging from Tropical Evergreen to Tropical Semi-Evergreen forests at lower elevations and up to Sub-Tropical Broadleaf hill forest at upper reaches, this highest hill range of Assam state still largely remained unexplored biologically (Das 2008). The sanctuary is a habitat to many important flora and fauna many of which are endangered and threatened so far their conservation status goes. No efforts have been done till date to understand the ecological characteristics of this very important protected forested area. The present study was undertaken to evaluate the tree species composition, diversity and structural attributes of the forests in Barail Wildlife Sanctuary, Assam, India. The investigation would contribute a great deal towards the management and conservation of forest biodiversity of this very important protected area.

MATERIALS AND METHODS

Study Area

The Barail Hill Range in Northeast India runs in a Southwest-Northeast direction from Jaintia hill of Meghalaya through Assam up to Southern Nagaland forming a dispersal route for fauna from the higher ranges of Manipur-Nagaland to east and northeast (Das 2008). The present study was carried out in the Barail Wildlife Sanctuary (24º 58´- 25° 50' N & 92° 46' - 92° 52' E) (BWLS) that falls in the Barail Hill Range (Figure 1). The range forms a watershed between two largest river systems of Northeast India, the Brahmaputra and Barak and forms the famous Jatinga valley of Assam (Das 2008). The Barail Wildlife Sanctuary covers a total area of 326 km^2 (Anonymous 2011). The vegetation of the study area varies from tropical evergreen to tropical semi-evergreen forests at lower elevations that corresponds to the Cachar Tropical Evergreen Forest 1B/C3 and Cachar Tropical Semi Evergreen Forest 2B/C2 (Champion and Seth 1968).

The sanctuary has a tropical humid climate with average annual rainfall of 3383.5 mm (Das 2008). Monsoon starts from late May and continues up to October. Moreover, there is a prolonged pre-monsoon with heavy showers during mid-March to April. Mean maximum and minimum temperatures are 35^{0}C and 5^{0}C respectively. Average humidity is 78%. The soil is sandy-loam and sandy-clay. The varied topography has profound influence on the climate of the sanctuary which varies with elevation and location (Das and Sharma 2013).

Data Collection

Secondary information on Barail Wildlife Sanctuary was gathered from various sources (Anonymous 2011).

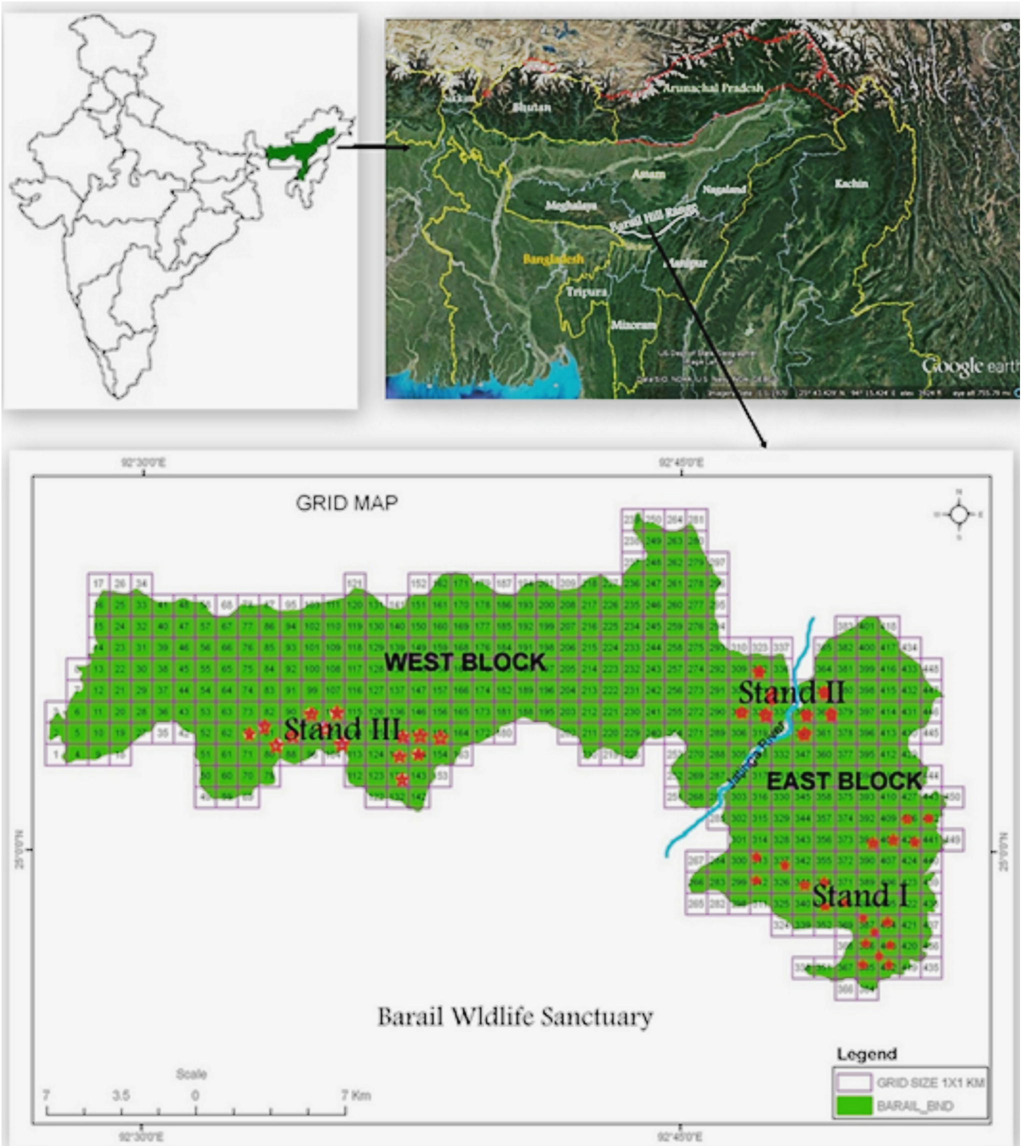

Figure 1. Map of the study area

Based on the location and the distance, the lower elevation forest of the sanctuary (below 500 m asl) was categorised into three forest stands (Figure 1). After doing a preliminary survey, a grid map (each grid measuring 1 sq. km) of the sanctuary was prepared with the help of remote sensing and GIS (Figure 1). Field exploration was done from 2012 through 2015. Tree diversity study was done using stratified random sampling technique (Singh et al. 2006).

A total of 42 quadrats were laid; the size of the each quadrat being 20 × 25 m based on species-area curve method (Misra 1968, Muller-Dombois and Ellenberg 1974). Individuals having ≥30 cm circumference at breast height (CBH i.e. 1.37 m above the ground) were `considered as trees, (Knight 1963, Sundriyal et al.1994, Deb and Sundriyal 2008, Deb et al. 2009). Tree species occurring in each of the quadrats were listed and their CBH measured (Knight 1963). The spatial location (latitude, longitude and altitudes) of each quadrat was recorded using a Global Positioning System (GPS).

Voucher samples for all the plant specimen were collected with photo record and identified by consulting the Herbaria of Botanical Survey of India, Shillong. Regional floras were also consulted for plant identification (Kanjilal et al. 1934-1940, Haridasan and Rao 1985, Deb 1983, Hooker 1872-1879).

Data Analyses

Phytosociological analysis of forest stands was done following (Curtis and McIntosh 1950, Phillips 1959, Curtis 1959, Saxena and Singh 1982, Sundriyal et al. 1994, Deb et al. 2009). The vegetation data collected were analyzed for density, frequency and dominance (Phillips 1959) and the sum of values for these parameters represented by their relative values were used to work out the Importance Value Index (IVI) for different tree species (Curtis 1959). Ten species with highest IVI values in each stand were worked out. Among them, the most dominating five tree species were selected for comparing number of individuals in different girth class in all the three stands (Deb and Sundriyal 2011). Tree Species diversity was calculated following Shannon diversity index (Shannon and Wiener 1963) and Concentration of Dominance was calculated by Simpson's Index (Simpson 1949). The Familial Importance Value was quantified following Mori et al. (1983).

Population structure was worked out on the basis of girth of individual trees of each species. The CBH of all trees was measured and classified into different classes (30-60 cm, 60-90 cm, 90-120 cm….>210 cm) (Sundriyal 1994, Kadavul and Parthasarathy 2000, Deb and Sundriyal 2008). Based on the dominant species, the three stands were distinguished as Stand I (*Canarium*-mixed species stand), stand II (*Maniltoa*-mixed species stand) and stand III (*Elaeocarpus*-mixed species stand). Chi-square test (Emden 2008) was done to see the difference in species richness of trees among three forest stands. Stand density and basal area among different stands were compared by one-way ANOVA. The relationship between girth class and tree density as well as the basal area was tested by Spearman rank correlation coefficient test. All the analyses were done by using the PAST (Hammer 2001) software.

RESULTS

Tree Species Richness, Diversity and Concentration of Dominance

A comparative account of the three forest stands in the lower elevation forests of Barail Wildlife Sanctuary is presented in Table 1 and Appendix 1. A total of 109 tree species belonging to 45 families were recorded from the three stands. Among the three stands, species richness was recorded significantly highest in Stand I (88 tree species belonging to 72 genera) followed by stand III (69 tree species belonging 55 genera) and stand II (48 tree species belonging to 46 genera) ($\chi^2 = 11.72$, $p < 0.01$, df = 2). Shannon and Wiener diversity index (H') was also recorded highest in the stand I (4.01), followed by stand III (3.87) and stand II (3.61). The Concentration of Dominance was highest for stand II (0.033) followed by stand III (0.028) and lowest for the stand I (0.025).

Stand Density, Basal Area, Population Structure and Importance Value Index

The highest stand density was observed in stand II (553 stem ha^{-1}) followed by stand I (538 stem ha^{-1}) and stand III, (499 stem ha^{-1}) (Table 1). However, there was no significant difference among them ($F_{2,39}$= 0.31, p = 0.71, NS). The stand basal area was recorded highest for stand II (44.38 m^2 ha^{-1}) followed by stand III (41.75 m^2 ha^{-1}) and stand I (36.02 m^2 ha^{-1}); however, there is no significant difference among them ($F_{2,39}$=0. 92, p = 0.41, NS). In stand I, *Dysoxylum binectariferum* of the family Meliaceae had the highest basal area (2.27 m^2 ha^{-1}). In stand II, *Maniltoa polyandra* belonging to Leguminosae family had the highest basal area of 4.49 m^2 ha^{-1} and in stand III *Elaeocarpus macrocerus* belonging to Calophyllaceae) had the highest basal area (3.35 m^2 ha^{-1}) (Table 1). Relationship of stand density and basal area along with population structure of three stands are shown in Figure 2. The density showed a decreasing trend with increase in stem girth classes in all the three stands. However, though the basal area increased till 90-120 cm girth class in all the three stands (Figure 2), it dropped in the girth class of 120-150 cm, but the basal area shot up again in the girth class of 150-180 cm in stands II and III. There is significant negative correlation between girth class of trees and tree density in Stand I (r_s = -1, n = 7, p < 0.01), Stand II (r_s = -0.99, n = 7, p < 0.01) and Stand III (r_s =- 0.96, n = 7, p < 0.01). However, there was no significant relationship between girth class and basal area of trees in all the stands (Spearman Rank Correlation Coefficient test).

The IVI of top ten species in three stands are shown in Figure 3. The results show that in stand I, the highest IVI was represented by *Canarium strictum* (17.58) belonging to family Burseraceae followed by *Dysoxylum binectarifeum* (15.32) of family Meliaceae (Figure 3A), whereas in Stand II, *Maniltoa polyandra* (22.31) of family Leguminosae recorded the highest IVI followed by *Xerospermum glabratum* (21.10) belonging to family Sapindaceae (Figure 3B). In Stand III, *Elaeocarpus macrocerus* (19.84) belonging to family Elaeocarpaceae had the highest IVI followed by *Heritiera papilio* (17.54)

Table 1. Comparative account of tree species in three lowland forest stands in Barail Wildlife Sanctuary, Assam

PARAMETERS Name of the stand	Stand I *Canarium*-mixed species stand	Stand II *Maniltoa*-mixed species stand	Stand III *Elaeocarpus*-mixed species stand
Tree species richness	88	48	69
No. of genera	72	46	55
No. of families	44	36	36
Species diversity (H′)	4.01	3.61	3.87
Concentration of Dominance	0.025	0.033	0.028
Stand density (ha^{-1})	538	553	499
Stand basal area (m^2 ha^{-1})	36.02	44.38	41.75
Tree Species with highest IVI	*Canarium strictum* (17.58)	*Maniltoa polyandra* (22.31)	*Elaeocarpus macrocerus* (19.84)
Dominant family	Meliaceae	Sapindaceae	Elaeocarpaceae
Tree Species with highest basal area (m^2 ha^{-1})	*Dysoxylum binectariferum* (2.74)	*Maniltoa polyandra* (4.49)	*Elaeocarpus macrocerus* (3.35)

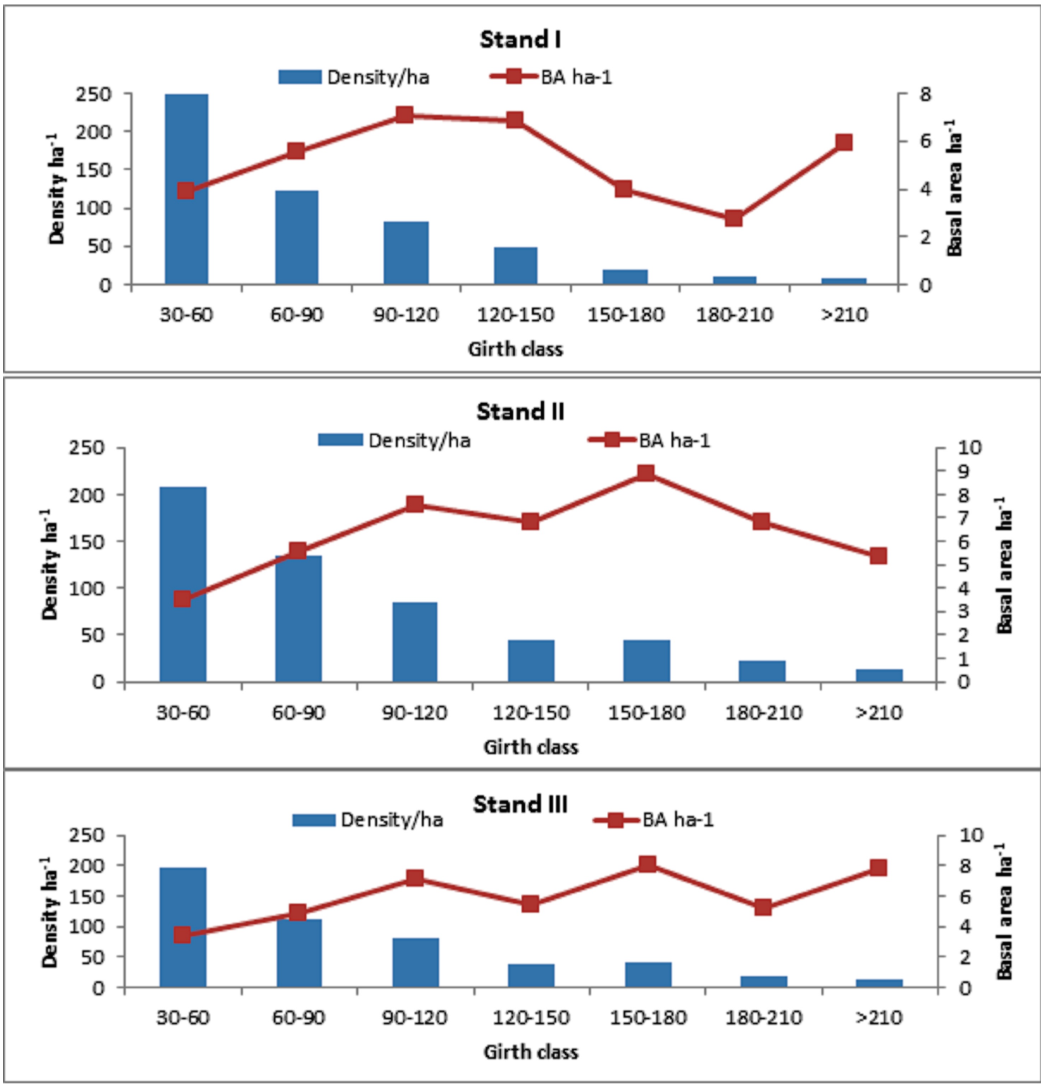

Figure 2. Stand structure based on tree density and basal area in three lowland forest stands of Barail Wildlife Sanctuary

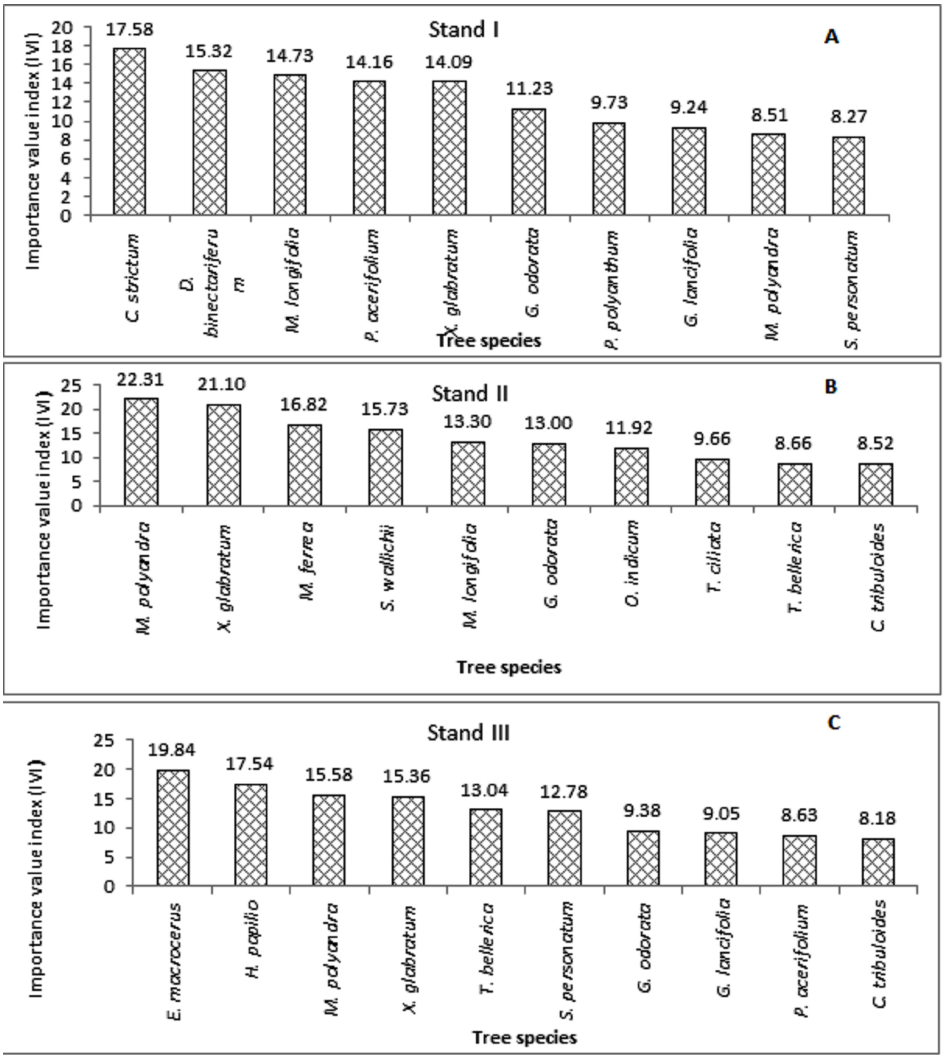

Figure 3. Ten dominant tree species recorded in three lowland forest stands of Barail Wildlife Sanctuary, Assam

belonging to family Sterculiaceae (Figure 3C). An interesting observation was that *Xerospermum glabratum, Maniltoa polyandra, Sterospermum personatum* were found to occupy the top ten IVI value positions in all the three stands.

Familial Importance Value and Girth Class Distribution

At the family level, the taxonomic composition of the habitat showed some variation across all the stands. A comparative account of 10 highest familial importance value (FIV) of the three forest stands are presented in Table 2. The highest number of families was found in Stand I (46 families) while 36 families were found in stand II and Stand III. However, Sapindaceae had the highest FIV (28.95) in Stand II, followed by Sterculiaceae family (FIV 27.25) in Stand III, and the lowest FIV (25.88) was recorded for Meliaceae family in Stand I. (Table 2).

Out of the 45 families found in the lower elevation forest of Barail Wildlife Sanctuary, Sterculiaceae showed the largest number of trees (83 numbers) representing all girth classes (Table 3). In addition to Sterculiaceae, six other families' viz. Meliaceae, Elaeocarpaceae, Bignoniaceae, Lauraceae and Malvaceae were also represented in all girth classes. Individuals of families Ebenaceae, Euphorbiaceae, Theaceae, Phyllanthaceae, Annonaceae and Actinidiaceae were not found beyond 150 cm CBH. The youngest trees were recorded for family Urticaceae where all individuals belonged to 30-60 cm CBH class.

Table 2. Comparative account of Familial Importance Value (FIV) in three lowland forest stands in Barail Wildlife Sanctuary, Assam

Canarium-mixed species stand I			*Maniltoa*-mixed species stand II			*Elaeocarpus*-mixed species stand III		
Family	No.of sp.	FIV	Family	No. of sp.	FIV	Family	No. of sp.	FIV
Meliaceae	5	25.88	Sapindaceae	2	28.95	Sterculiaceae	3	27.25
Sterculiaceae	3	23.62	Leguminosae	3	26.63	Sapindaceae	3	24.61
Burseraceae	3	21.98	Meliaceae	3	23.19	Elaeocarpaceae	2	22.08
Sapindaceae	2	16.41	Calophyllaceae	1	16.82	Combretaceae	3	19.28
Myristicaceae	1	14.73	Bignoniaceae	2	16.56	Meliaceae	6	18.59
Leguminosae	4	13.76	Theaceae	1	15.73	Leguminosae	1	15.58
Malvaceae	4	11.64	Sterculiaceae	3	15.43	Myrtaceae	4	12.82
Clusiaceae	3	11.50	Myristicaceae	1	13.30	Bignoniaceae	1	12.78
Achariaceae	1	11.23	Achariaceae	1	13.00	Clusiaceae	2	12.23
Moraceae	4	11.22	Euphorbiaceae	2	9.19	Malvaceae	3	9.97
Others (30 families)	58	138.02	Others (26 families)	29	121.19	Others (26 families)	41	124.79
Total	88	300		48	300		69	300

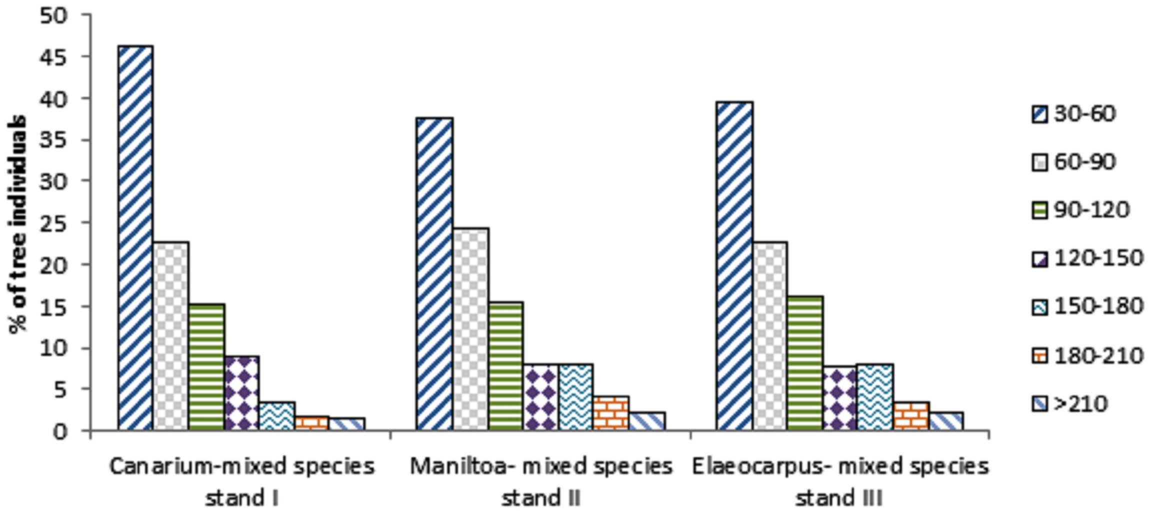

Figure 4. Girth class distribution of tree individuals in three stands of lowland forest in Barail Wildlife Sanctuary, Assam

Population Structure

Though the distribution of individuals in different CBH class varied among different stands, the trend of representing individuals remained similar (Figure 4). In all the stands, the highest number of young trees was found in the lower girth classes of 30-60 cm (46% in Stand I, 38 % in Stand II, and 40% in Stand III).

Tree size class distribution at the stand level followed a reverse J-pattern, whereas, in the case of five dominating tree species, the number of individuals in each stand had unequal distribution in different girth classes (Figure 5). In Stand I, the highest number of individuals was recorded in the lower most girth class (30-60 cm); *Myristica longifolia* contributed the highest (80%) followed by *Dysoxylum binectariferum* (52%), *Canarium strictum* (51%), *Xerospermum glabratum* (41%) and *Pterospermum acerifolium* (33%) (Figure 5 A). No tree belonging to *Myristica longifolia* were represented beyond 90-120 cm CBH. Only *Dysoxylum binectariferum* (4%) and *Pterospermum acerifolium* (5%) had representation in the girth class greater than 210 cm CBH (Figure 5 A).

Table 3. Girth class distribution of tree species of various families in the lowland forest stands of Barail Wildlife Sanctuary, Assam.

Family	Girth classes							
	30-60	60-90	90-120	120-150	150-180	180-220	>220	Total
Acanthaceae	1	0	0	0	0	0	0	1
Achariaceae	23	15	10	0	2	0	0	50
Actinidiaceae	10	2	2	0	0	0	0	14
Anacardiaceae	17	8	0	3	2	1	0	31
Annonaceae	6	5	4	2	0	0	0	17
Apocynaceae	2	0	2	0	0	0	0	4
Asparagaceae	1	0	0	0	0	0	0	1
Bignoniaceae	8	5	6	7	3	4	2	35
Burseraceae	33	22	8	4	2	0	0	69
Calophyllaceae	1	3	7	1	5	0	1	18
Cannabaceae	2	1	0	1	0	0	0	4
Clusiaceae	21	12	8	2	1	0	0	44
Combretaceae	9	4	6	6	10	0	0	35
Dilleniaceae	2	0	0	0	0	0	0	2
Ebenaceae	8	10	8	3	0	0	0	29
Elaeocarpaceae	12	11	7	5	2	2	2	41
Euphorbiaceae	17	7	4	1	0	0	0	29
Fabaceae	0	1	0	0	0	0	0	1
Fagaceae	11	4	5	2	2	0	1	25
Flacourtiaceae	2	2	4	0	0	1	0	9
Lauraceae	18	3	7	4	1	1	1	35
Leguminosae	22	12	17	7	3	3	0	64
Lythraceae	2	9	2	3	2	1	0	19
Magnoliaceae	5	1	0	3	0	1	1	11
Malvaceae	8	8	4	3	4	2	1	30
Meliaceae	32	15	11	7	3	4	3	75
Moraceae	14	5	3	0	1	1	2	26
Myristicaceae	39	13	2	0	3	0	0	57
Myrsinaceae	1	0	0	0	0	0	0	1
Myrtaceae	17	9	5	3	2	3	0	39
Phyllanthaceae	13	6	1	0	0	0	0	20
Rhizophoraceae	1	0	0	0	0	0	0	1
Rosaceae	0	2	0	0	0	0	0	2
Rubiaceae	4	4	1	3	2	3	1	18
Sapindaceae	27	9	16	10	11	3	0	76
Sapotaceae	9	12	3	4	0	0	1	29
Staphyleaceae	1	2	1	0	1	0	0	5
Sterculiaceae	35	22	14	4	2	3	3	83
Styraceae	2	0	0	0	0	0	0	2
Tetramelaceae	1	0	1	1	0	0	0	3
Theaceae	18	6	1	1	0	0	0	26
Urticaceae	13	0	0	0	0	0	0	13
Verbenaceae	2	2	2	3	1	0	0	10
Vitaceae	0	1	3	0	0	0	0	4

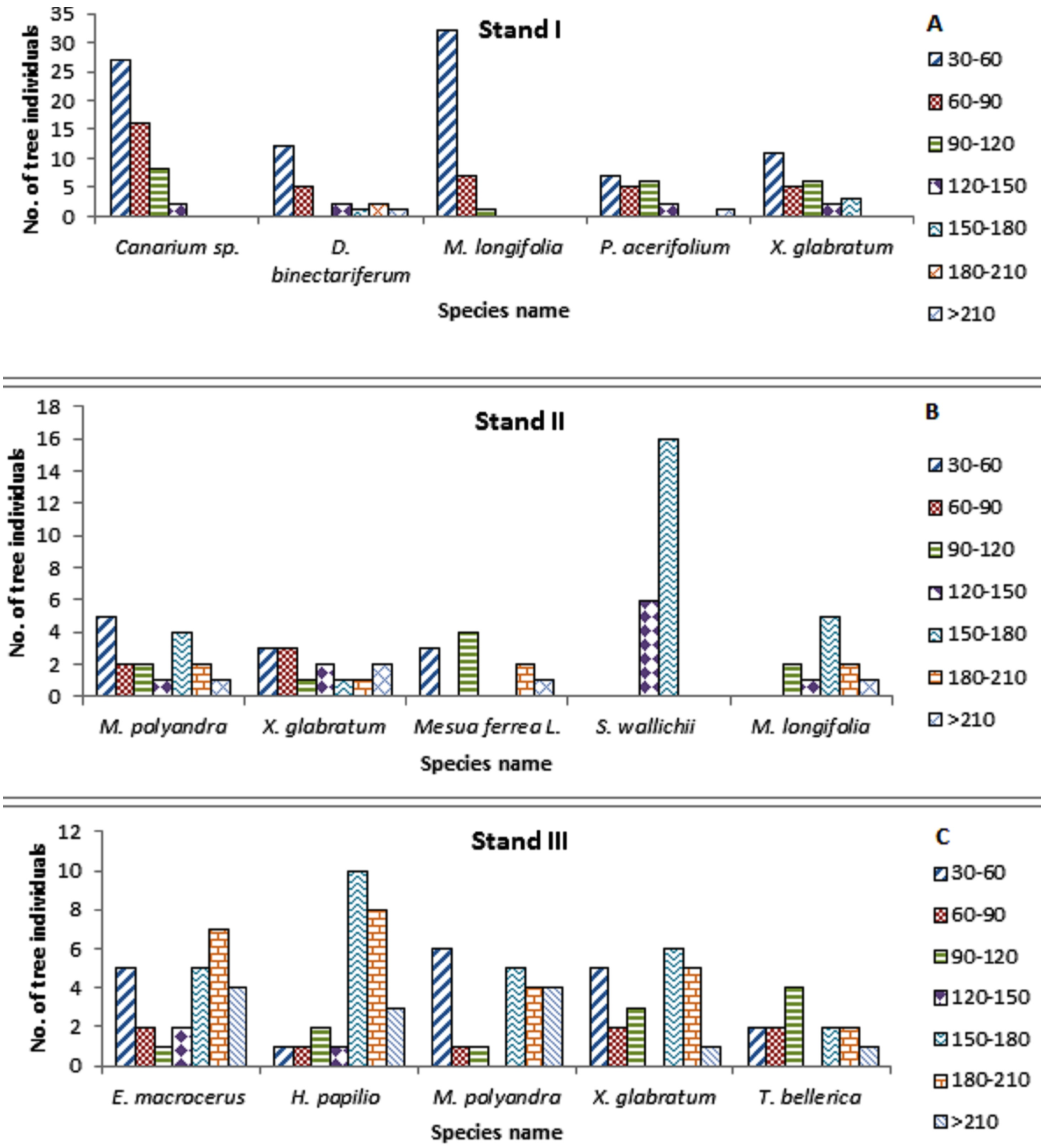

Figure 5. Variation in number of individuals of five dominant tree species in different girth classes in three lowland forest stands in Barail Wildlife Sanctuary, Assam

In stand II, among the five dominant tree species, distribution of trees was not continuous in all girth classes (Figure 5 B). Unlike in Stand II, where *Myristica longifolia* was restricted only to 120 cm CBH, in Stand II, here individuals were recorded beyond 120 cm girth classes. The individuals belonging to *Maniltoa polyandra* and *Xerospermum glabratum* were represented in all girth classes in Stand II. On the other hand, *Mesua ferrea* contributed 45% in 90-120 cm girth class, while *Schima wallichii* contributed 73% in 150-180 cm girth class having discontinuous distribution in different girth classes.

Similarly in Stand III distribution of individuals belonging to different species did not follow reverse J-shaped pattern with increasing girth classes (Figure 5 C). Individuals belonging to *Elaeocarpus macrocerus* and *Heritiera papilio* were found in all girth classes; however with no uniform trend in distribution. The biggest trees of *Elaeocarpus macrocerus* were recorded in 180-210 cm girth class (27%) while that of *Heritiera papilio* (38%) was recorded in 150-180 cm girth class. Individuals belonging to *Maniltoa polyandra*, *Xerospermum glabratum* and *Terminalia bellerica* were found in all girth classes except for 120-150 cm CBH.

DISCUSSION

Tree diversity of a tropical forest is fundamental to biodiversity because trees provide resources and habitat structure to almost all other forest species (Cannon et al. 1998). A total of 109 species were recorded from the lowland forests of Barail Wildlife Sanctuary, Northeast India. The number of tree species in the three stands ranged from 48-88 and that ranged in genera from 46-72, in 36-44 families, respectively. The number of species, genera and families were found to be higher in the stand I as compared to stand II and stand III. The structural pattern of the different stands showed heterogeneity in the distribution of tree species and can be considered as one of the highly diverse forests in the Eastern Himalaya (Bhuyan et al. 2003). The findings of the present study resembles to the one of Deb et al. (2009) who found 20-98 tree species in the lowland tropical rainforest in Arunachal Pradesh, Northeast India. However, Kumar et al. (2006) recorded more tree species richness that ranged from 87-162 in different types of forest in Garo Hills, Meghalaya. Khumbongmayum et al. (2006) recorded 96 woody species in the subtropical sacred groves in Manipur. Upadhaya et al. (2003) also recorded a total of 80-82 species from the two scared groves of the Jaintia hills in Meghalaya, Northeast India. The species richness of the present study area also corresponds to that in Western Ghats where they found 92 species in Kadamakal Reserve (Elourd et al. 1997) and 66-118 species in Veerapuli and Kalamalai forest reserve (Swamy et al. 2000). However, the species richness of the present study sites fall far below when we compare it with the Amazonian forest (> 275 ha^{-1}) and neotropical forests (133-187 ha^{-1}) (De Oliveira and Mori 1999). Thus, it can be seen from the above findings that the lowland tropical forests of Barail Wildlife Sanctuary is a rich repository of tree diversity in Northeast India.

The tree species diversity index in the present study ranged from (H′=3.61 to 4.01) which falls within the Shannon-Weiner diversity for the tropical forests that ranged from 0.8-4.1 for the Indian subcontinent (Singh et al. 1981, Parthasarathy 2001, Deb et al. 2009, Swamy et al. 2000, Bhuyan et al.2003). Our findings were also similar to the findings of (Rabha and Das 2014) that ranged from 3.66-3.99 from Karimganj district in Assam but higher as compared to findings of (Nandy and Das 2012) who recorded a species diversity of 3.30-3.36 in a traditional agroforestry system of Barak valley. The Shannon diversity recorded in the three stands also corresponds to the studies done in the subtropical broad-leaved forest of Meghalaya (Upadhaya et al. 2003, Jamir 2000, Kumar et al. 2006). However, the values are much lower when compared with the findings of those reported by young (H' = 5.06) and old (H′=5.4) tropical forest stands of Barro Colorado Island, Panama (Knight 1975). Tree species diversity, composition and function are the important attributes of forest ecosystems. These attributes change in respect to climate, topography, soil and disturbances (Timilina et al. 2007).

The stand densities in the present study ranged from 499 to 553 trees ha^{-1} in the three stands studied. The findings are well within the range of 300-700 tree ha^{-1} of tropical rainforest (Richards 1996). Nath et al. (2005) recorded the tree density in differently disturbed stand in a tropical wet evergreen forest in Arunachal Pradesh that ranged from (34-610 trees ha^{-1}). Upadhaya et al. (2003) recorded the stem density of two sacred groves of Meghalaya in the range of 938-1476 stem ha^{-1}. Borah and Garkoti (2011) also reported a tree density that ranged from (846 and 1110 trees ha^{-1}) in undisturbed forest which was higher when compared to the disturbed forest (572 and 396 trees ha^{-1}) on Barak valley and can be compared with the present study. However, here individuals ≥10 cm CBH were regarded as trees as contrary to our study where we took individuals ≥30 cm CBH as trees. The basal area ranged from 36.02 to 44.38 m^2 ha^{-1} in the three stands studied which is also within the range recorded for tropical forests of South East Asia (25.2-67.4 m^2 ha^{-1}) (Swamy et al. 2000). Our findings are similar to that of Borah and Garkoti (2011) in the undisturbed forest (36.88 m^2 ha^{-1} and 42.12 m^2 ha^{-1}) and but more when compared to their findings in the disturbed forest (9.47 m^2 ha^{-1} and 16.96 m^2 ha^{-1}) of Barak Valley, Assam. In Garo Hills, Meghalaya (Kumar et al. 2006) observed the tree basal area in native primary tropical forest to range from 50 to118 m^2 ha^{-1} while for secondary forest it was 16-93 m^2 ha^{-1} and 54 m^2 ha^{-1} in a Sal plantation. The present finding can also be compared with the basal area (m^2 ha^{-1}) of undisturbed, moderately disturbed and highly disturbed forests where it ranged from 7.81, 21.38 and 98.58 m^2 ha^{-1}, of the tropical wet evergreen forest in Arunachal Pradesh (Nath et al. 2005). This is a strong indicative that disturbance has a great role to play in the plant cover of an area. Tropical forests are rich in species density (Paijmans 1970) and many factors affect their diversity (Janzen 1970, Connell 1971, Hubbell 1979, Parthasarathy 1999). According to Whitmore (1984), in tropical rain forests the tree species number per hectare ranges from 20 to a maximum of 223. Species diversity is often correlated with rainfall, nutrient status (Hartshorn 1980) and disturbance level (Rao et al. 1990). Human-induced disturbance (such as mining, timber extraction, etc.) and livestock grazing also cause changes in species number, tree density and basal area (Rao et al. 1990).

The pattern of association of dominant species in a community can be obtained by the analysis of IVI of a species (Parthsarathy 2001). A comparative study of IVI in the three stand showed that the highest IVI was recorded for *Maniltoa polyandra* (22.31) in stand II, followed by *Elaeocarpus macrocerus* (19.84) in stand III, and *Canarium strictum* in stand I, (17.58). All these elements are reported as dominating canopy elements for the lowland forests of North eastern region (Kaul and Haridasan 1987, Proctor et al. 1998). However, in any given stand the dominance of any tree species is a function of tree species (Keel and Prance, 1979) and past damage (Jacobs 1987, Swamy et al. 2000) accumulation of varied environmental conditions result in accumulation of diverse species in forest stand (Richards 1996).

In the present study, tree density was decreasing with increasing CBH classes, which is a typical characteristic of tropical forest and similar trend has been reported from Malaysia (Poore 1968, Ho et al. 1987), Costa Rica (Lieberman et al. 1985, Nadkarni et al. 1995), Brazilian Amazon (Swaine et al. 1987, Campbell et al. 1992), Sungei Menyala in Malaysia (Manokaran and Kochummen 1987) and Mudumalai in India (Sukumar et al. 1992). Evidence of logging was witnessed inside the sanctuary. Decrease of girth class in the range 150-210 cm and density ha^{-1} in stand I is suggestive of historic logging in stand I as compared to the Stand II and stand III. Hence, very low abundance of mature voluminous tree and enough forest canopy gaps were observed in stand I.

Discontinuous population structure of tree species has been reported in various tropical forests (Whitmore 1984, Brokaw1987, Itow and Mueller-Dombois 1988). Parthasarathy (2001) also reported the dominance of middle to lower diameter classes depicting a reverse J-shaped structure, which denotes an evolving or expanding population in tropical evergreen forest in, Western Ghats, India. Similar, growing population structure of tree has also been observed by (Johnston and Gillman1995) and (Kellman et al.1998) and can be comparable to that of Costa Rica (Lieberman et al. 1985), Brazilian Amazon (Campbell et al. 1992) and Eastern Ghats, India (Kadavul and Parthasarathy1999). The reasons for the presence of large population of smaller girth individuals may be due to dense overhead canopy (Rao et al.1997). Tree population structure of wide girth structure indicates greater degree of stability and better regeneration potential of the community (Jamir 2000). However, so for the dominant tree species in each stand are concerned, the girth class was unequally distributed, when compared with the girth classes of all the families, a reserve J-shaped structure in all the families were seen expect for Sapindaceae and Combretaceae.

Studies in the tropics reveal that tree in the tropical forest condition are either aggregated or randomly dispersed than being uniformly dispersed (Hubbell 1979, Thorington et al. 1982). The dominant tree species in all the three stands studied also did not showed any uniform distribution in their population structure. The enumerated tree species in the present study belonged to the range of 36-44 families and falls within the range of 16-58 families found in the tropical forests (Swamy et al. 2000, Parthasarathy and Karthikeyan 1997). The family taxonomic status showed the dominance of Meliaceace, Sapindaceae and Sterculaceae in the different stands studied. Kessler et al. (2005) worked on different land use system in Central Sulawesi, Indonesia and found that primary forests are dominated by Meliaceae, whereas secondary forest were dominated by Lauraceae and Euphorbiaceae family. There is also a strong similarity with families and genera and also a number of species with forests in South-East Asia. The families Lauraceae, Meliaceae, Myrtaceae, and Sapindaceae are well represented in some South-East Asian forests (Sist and Saridan 1999).

CONCLUSION

Barail Wildlife Sanctuary is a repository of rich biodiversity and is an important part of the famous Barail Hill Range landscape in the Indo-Burma Hotspot of Biodiversity. The area has not recieved its due importance and no study have been attempted to understand its ecology so far. Quantitative ecological analysis of tree species diversity of Barail Wildlife Sanctuary will be useful for forest management and conservation as it acts as an important refuge for the native plants and animals, including the rare, endangered and threatened species of the region. The presence of many important tree species that includes many high quality timber species indicates that the sanctuary can act as an important germplasm bank for the entire region.

The forest still provided pristine vegetation and provides habitat to many important faunal and floral elements that needs to be preserved. The protection of such a diverse area has implications, not only for the state but for the entire region.

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Appendix 1. Quantitative parameters in the three lowland forest stands in Barail Wildlife Sanctuary, Assam
BA = Basal Area ($m^2\ ha^{-1}$); D = Density (number ha^{-1}); F = Frequency (%); IVI = Importance Value Index

Species	Family	Stand I				Stand II				Stand III			
		BA	D	F	IVI	BA	D	F	IVI	BA	D	F	IVI
Actinodaphne obovata (Nees) Blume	Lauraceae	0.01	1.00	5.00	0.56	-	-	-	_	0.13	1.43	7.14	1.14
Aglaia perviridis Hiern	Meliaceae	0.08	3.00	5.00	1.13	-	-	-	-	-	-	-	-
*Albizia lebbeck (*L.) Benth.	Fabaceae	-	-	-	-	-	-	-	-	0.07	1.43	7.14	0.99
Alstonia scholaris (L.) R. Br	Apocynaceae	0.02	1.00	5.00	0.58	0.25	5.00	25.00	3.72	0.15	1.43	7.14	1.18
Anthocephalus cadamba (Roxb.) Miq	Rubiaceae	-	-	-	-	0.80	2.50	12.50	3.37	-	-	-	-
Aporosa octandra (Buch. -Ham. ex D.Don) Vickery	Euphorbiaceae	0.07	2.00	10.00	1.25	0.54	22.50	25.00	7.53	-	-	-	-
Ardisia paniculata Roxb.	Myrsinaceae	0.01	1.00	5.00	0.55	- -	-	-	-	-	-	-	0.00
Artabotrys crassifolius Hook.f. & Thomson	Annonaceae	0.09	4.00	20.00	2.36	-	-	-	-	0.18	4.29	14.29	2.38
Artocarpus chaplasha Roxb	Moraceae	1.19	8.00	30.00	6.85	0.23	2.50	12.50	2.10	1.25	8.57	28.57	6.90
Baccaurea ramiflora Lour.	Phyllanthaceae	0.16	6.00	30.00	3.64	0.16	7.50	25.00	3.97	0.23	11.43	35.71	5.58
Bauhinia variegata L.	Leguminosae	0.16	4.00	15.00	2.23	0.12	2.50	12.50	1.84	-	-	-	-
Beilschmiedia roxburghiana Nees	Lauraceae	0.19	3.00	15.00	2.11	2.10	10.00	12.50	7.66	-	-	-	-
Beilschmiedia kunstleri Gamble	Lauraceae	0.09	1.00	5.00	0.79	-	-	-	-	-	-	-	-
Bombax ceiba L.	Malvaceae	0.65	4.00	20.00	3.93	0.51	2.50	12.50	2.73	0.95	8.57	28.57	6.19
Bridelia retusa (L.) A. Juss.	Phyllanthaceae	-	-	-	-	-	-	-	-	0.07	2.86	7.14	1.28
Bursera simaruba (L.) Sarg.	Burseraceae	0.53	7.00	15.00	3.82	-	-	-	-	-	-	-	-
Camellia kissii Wall.	Theaceae	0.04	1.00	5.00	0.63	-	-	-	-	-	-	-	-
Canarium sp.	Burseraceae	-	-	-	-	-	-	-	-	0.50	8.57	21.43	4.56
Canarium strictum Roxb.	Burseraceae	2.18	54.00	30.00	18.16	0.11	2.50	12.50	1.83	0.11	2.50	12.50	1.83
Carallia brachiata (Lour.) Merr. -	Rhizophoraceae		0.02	1.00	5.00	0.58	-	-	-	-	-	-	- -
Castanopsis tribuloides (Sm.) A.DC.	Fagaceae	0.77	8.00	40.00	6.38	0.68	20.00	37.50	8.52	1.20	12.86	35.71	8.18
Celtis tetrandra Roxb.	Cannabaceae	-	-	-	-	0.13	5.00	25.00	3.45	0.25	2.86	14.29	2.27
Chisocheton cumingianus subsp. *balansae*(C.DC.) Mabb.	Meliaceae	-	-	-	-	-	-	-	-	0.55	7.14	28.57	4.93
Choerospondias axillaris (Roxb.) B.L.Burtt&A.W.Hill	Anacardiaceae	0.06	4.00	5.00	1.24	0.15	5.00	12.50	2.36	0.06	1.43	7.14	0.98
Chrysophyllum roxburghii G.Don	Rubiaceae	0.71	5.00	20.00	4.29	0.13	2.50	12.50	1.87	0.06	2.86	14.29	1.82
Claoxylon longipetiolatum Kurz	Euphorbiaceae	-	-	-	-	-	-	-	-	0.11	4.29	14.29	2.22
Croton joufra Roxb.	Euphorbiaceae	0.08	1.00	5.00	0.76	-	-	-	-	0.04	1.43	7.14	0.92
Cryptocarya acuminate Merr.	Lauraceae	0.20	3.00	15.00	2.15	-	-	-	-	-	-	-	-
Cryptocarya amygdalina Nees	Lauraceae	-	-	-	-	-	-	-	-	0.47	4.29	7.14	2.54
Dillenia indica L.	Dilleniaceae	-	-	-	-	-	-	-	-	0.04	2.86	7.14	1.22
Diospyros cacharensis (Das & P.C.Kanjilal) H.B.Naithani	Ebenaceae	0.04	2.00	5.00	0.84	-	-	-	-	-	-	-	-
Diospyros kirkii Hiern	Ebenaceae	0.07	3.00	5.00	1.11	-	-	-	-	-	-	-	-
Diospyros lanceifolia Roxb.	Ebenaceae	0.14	1.00	5.00	0.91	1.26	17.50	12.50	7.14	-	-	-	-
Diospyros racemosa Roxb	Ebenaceae	0.76	13.00	30.00	6.59	0.47	7.50	25.00	4.65	-	-	-	-
Dracaena spicata Roxb.	Asparagaceae	0.01	1.00	5.00	0.55	-	-	-	-	-	-	-	-
Duabanga grandiflora (DC.) Walp.	Lythraceae	-	-	-	-	1.59	12.50	12.50	6.96	-	-	-	-
Dysoxylum binectariferum (Roxb.) Hook.f. ex Bedd.	Meliaceae	2.74	23.00	50.00	15.32	0.59	15.00	25.00	6.29	1.28	7.14	14.29	5.58
Dysoxylum sp.1	Meliaceae	0.08	3.00	15.00	1.80	-	-	-	-	0.03	1.43	7.14	0.90
Dysoxylum sp.2	Meliaceae	0.39	7.00	15.00	3.41	1.41	10.00	25.00	7.24	0.09	4.29	14.29	2.18
Dysoxylum sp.3	Meliaceae	-	-	-	-	-	-	-	-	0.18	4.29	7.14	1.83
Elaeocarpus floribundus Blume	Elaeocarpaceae	1.16	5.00	10.00	4.83	-	-	-	-	0.35	4.29	7.14	2.24

Appendix 1. Continued

Species	Family	Stand I BA	D	F	IVI	Stand II BA	D	F	IVI	Stand III BA	D	F	IVI
Elaeocarpus macrocerus (Turcz.) Merr.	Elaeocarpaceae	0.36	6.00	25.00	3.84	-	-	-	-	3.35	37.14	57.14	19.84
Elaeocarpus sphaericus (Gaertn.) K.Schum	Elaeocarpaceae	-	-	-	-	0.45	2.50	12.50	2.59	-	-	-	-
Erythrina indica Lam.	Leguminosae	0.21	4.00	15.00	2.36	0.40	2.50	12.50	2.48	-	-	-	-
Eugenia sp.	Myrtaceae	0.03	1.00	5.00	0.62	-	-	-	-	0.94	7.14	28.57	5.87
Fabaceae sp.	Leguminosae	0.05	1.00	5.00	0.66	-	-	-	-	-	-	-	-
Ficus auriculata Lour.	Moraceae	0.01	1.00	5.00	0.56	-	-	-	-	-	-	-	-
Ficus hispida L.f.	Moraceae	0.03	2.00	5.00	0.80	0.03	2.50	12.50	1.64	0.09	2.86	7.14	1.34
Ficus racemosa L.	Moraceae	0.25	5.00	20.00	3.01	-	-	-	-	-	-	-	-
Friesodielsia sp.	Annonaceae	0.58	7.00	30.00	4.98	0.27	5.00	12.50	2.65	-	-	-	-
Garcinia lancifolia (G. Don) Roxb.	Clusiaceae	0.69	19.00	55.00	9.24	0.76	10.00	37.50	6.89	0.73	20.00	42.86	9.05
Garcinia Morella (Gaertn.) Desr.	Clusiaceae	0.22	2.00	10.00	1.69	-	-	-	-	0.39	5.71	14.29	3.18
Garcinia sp.	Clusiaceae	0.02	1.00	5.00	0.58	-	-	-	-	-	-	-	-
Glochidion lanceolarium (Roxb.)Voigt	Phyllanthaceae	0.05	1.00	5.00	0.66	-	-	-	-	-	-	-	-
Gmelina arborea Roxb.	Verbenaceae	0.11	3.00	10.00	1.56	0.88	10.00	25.00	6.03	0.60	4.29	7.14	2.85
Grewia laevigata Vahl	Malvaceae	0.74	3.00	10.00	3.29	-	-	-	-	0.06	2.86	7.14	1.27
Gynocardia odorata R.Br.	Achariaceae	1.06	26.00	50.00	11.23	1.86	30.00	37.50	13.00	0.88	17.14	50.00	9.38
Heritiera papilio Bedd.	Sterculiaceae	0.76	11.00	35.00	6.56	1.45	15.00	25.00	8.22	2.16	37.14	64.29	17.54
Hydnocarpus kurzii (King) Warb.	Flacourtiaceae	0.39	7.00	30.00	4.45	0.91	2.50	12.50	3.63	0.10	1.43	7.14	1.07
Ixora malabarica (Dennst.) Mabb.	Rubiaceae	0.41	4.00	5.00	2.22	-	-	-	-	-	-	-	-
Lagerstroemia speciosa (L.) Pers.	Lythraceae	0.43	6.00	5.00	2.64	-	-	-	-	1.05	11.43	7.14	5.34
Litsea cubeba (Lour.) Pers.	Lauraceae	0.00	0.00	0.00	0.00	0.05	2.50	12.50	1.68	-	-	-	-
Litsea laeta (Wall. ex Nees) Hook.f.	Lauraceae	0.09	4.00	10.00	1.68	-	-	-	-	0.04	2.86	7.14	1.21
Litsea oblonga Hook.f.	Lauraceae	-	-	-	-	-	-	-	-	0.04	2.86	7.14	1.23
Macaranga peltata (Roxb.) Müll.Arg.	Euphorbiaceae	0.04	3.00	15.00	1.71	-	-	-	-	0.27	2.86	14.29	2.31
Magnolia champaca (L.) Baill.ex Pierre	Magnoliaceae	-	-	-	-	-	-	-	0.00	2.23	2.86	7.14	6.47
Magnolia doltsopa (Buch. -Ham. ex DC.) Figlar	Magnoliaceae	0.03	2.00	5.00	0.81	-	-	-	-	-	-	-	-
Magnolia hodgsonii(Hook.f. & Thomson) H.Keng	Magnoliaceae	0.17	3.00	10.00	1.72	-	-	-	-	-	-	-	-
Mallotus paniculatus (Lam.)Müll.Arg.	Euphorbiaceae	0.12	2.00	10.00	1.39	0.04	2.50	12.50	1.66	0.28	7.14	14.29	3.20
Mangifera sylvatica L.	Anacardiaceae	0.71	14.00	40.00	7.34	0.56	5.00	12.50	3.30	0.15	5.71	21.43	3.14
Maniltoapolyandra (Roxb.) Harms	Leguminosae	1.19	15.00	35.00	8.51	4.49	42.50	50.00	22.31	1.94	30.00	64.29	15.58
Mesua ferrea L.	Calophyllaceae		0.49	3.00	15.00	2.96	3.96	25.00	37.50	16.82	0.40	7.14	28.57
4.59													
Michelia montana Blume	Magnoliaceae	0.17	1.00	5.00	1.00	-	-	-	-	0.27	4.29	14.29	2.60
Microcos paniculata L.	Malvaceae	0.41	3.00	5.00	2.04	-	-	-	-	-	-	-	-
Miliusa roxburghiana Hook.f. & Thomson	Annonaceae	-	-	-	-	-	-	-	-	0.01	1.43	7.14	0.86
Myristica longifolia Wall. ex Blume	Myristicaceae	0.89	40.00	70.00	14.73	1.70	27.50	50.00	13.30	0.52	8.57	28.57	5.14
Neolamarckia sp.	Rubiaceae	-	-	-	-	-	-	-	-	1.03	1.43	7.14	3.30
Neolitsea umbrosa (Nees) Gamble	Lauraceae	0.21	4.00	10.00	2.03	-	-	-	-	-	-	-	-
Nephelium longana Cambess.	Sapindaceae	0.20	4.00	15.00	2.32	1.68	10.00	25.00	7.85	1.29	8.57	28.57	6.99
Oreocnide integrifolia (Gaudich) Miq.	Urticaceae	0.04	3.00	15.00	1.71	-	-	-	-	0.15	14.29	14.29	4.32
Oroxylum indicum (L.) Kurz	Bignoniaceae	0.22	2.00	10.00	1.68	1.78	25.00	37.50	11.92	-	-	-	-
Pajanelia longifolia (Willd.)K.Schum.	Bignoniaceae	0.12	1.00	5.00	0.87	-	-	-	-	-	-	-	-
Palaquium polyanthum (Wall. ex G.Don) Baill.	Sapotaceae	1.51	15.00	40.00	9.73	-	-	-	-	0.73	18.57	28.57	7.67
Phlogacanthus sp.	Acanthaceae	-	-	-	-	-	-	-	-	0.03	1.43	7.14	0.91

Appendix 1. Continued

Species	Family	Stand I BA	D	F	IVI	Stand II BA	D	F	IVI	Stand III BA	D	F	IVI
Pterospermum acerifolium (L.) Willd.	Sterculiaceae	2.21	21.00	60.00	14.16	0.27	12.50	25.00	5.12	1.74	11.43	28.57	8.63
Pygeum sp.	Rosaceae	0.08	2.00	5.00	0.95	-	-	-	-	-	-	-	-
Randia wallichii Hook.f.	Rubiaceae	0.07	2.00	10.00	1.25	-	-	-	-	0.69	2.86	7.14	2.77
Sarcosperma griffithii Hook.f. ex C.B.Clarke	Sapotaceae	-	-	-	-	-	-	-	-	0.15	1.43	7.14	1.20
Saurauia roxburghii Wall.	Actinidiaceae	0.22	8.00	25.00	3.82	0.06	2.50	12.50	1.70	0.24	7.14	21.43	3.65
Schima wallichii Choisy	Theaceae	0.08	1.00	5.00	0.77	1.07	55.00	37.50	15.73	0.25	2.86	14.29	2.26
Spondias pinnata (L. f.) Kurz	Anacardiaceae	0.02	1.00	5.00	0.58	-	-	-	-	0.65	4.29	7.14	2.95
Sterculia villosa Roxb.	Sterculiaceae	0.21	5.00	20.00	2.90	0.23	2.50	12.50	2.08	0.10	1.43	7.14	1.07
Stereospermum personatum (Hassk.) Chatterjee	Bignoniaceae	1.76	9.00	25.00	8.27	0.46	7.50	25.00	4.65	2.54	14.29	50.00	12.78
Styrax serrulata F.B. Forbes & Hemsl.	Styraceae	0.02	2.00	5.00	0.78	-	-	-	-	-	-	-	-
Syzygium fruticosum DC.	Myrtaceae	1.07	18.00	25.00	8.04	0.42	10.00	25.00	5.01	0.49	2.86	14.29	2.85
Syzygium kurzii (Duthie) N.P. Balakr.	Myrtaceae	0.17	1.00	5.00	0.99	-	-	-	-	-	-	-	-
Syzygium aromaticum (L.) Merr. & L.M. Perry	Myrtaceae	-	-	-	-	-	-	-	-	0.40	5.71	14.29	3.20
Syzygium sp.1	Myrtaceae	0.11	3.00	5.00	1.21	-	-	-	-	-	-	-	-
Syzygium sp.2	Myrtaceae	-	-	-	-	-	-	-	-	0.03	1.43	7.14	0.90
Terminalia bellerica Roxb	Combretaceae	0.66	10.00	35.00	6.10	1.14	15.00	37.50	8.66	2.06	18.57	57.14	13.04
Terminalia chebula Retz.	Combretaceae	0.12	1.00	5.00	0.88	-	-	-	-	0.27	1.43	7.14	1.47
Terminalia myriocarpa Van Heurck & Müll Arg.	Combretaceae	0.17	1.00	5.00	1.02	-	-	-	-	0.95	4.29	21.43	4.77
Tetrameles nudiflora R. Br	Tetramelaceae	0.01	1.00	5.00	0.56	0.62	5.00	25.00	4.55	-	-	-	-
Tetranthera monopetala Roxb.	Lauraceae	-	-	-	-	0.97	12.50	25.00	6.69	-	-	-	-
Thespesia populnea (L.) Sol.ex Corrêa	Malvaceae	0.22	4.00	15.00	2.38	0.22	7.50	12.50	2.97	0.11	5.71	14.29	2.51
Toona ciliata M.Roem.	Meliaceae	0.81	5.00	15.00	4.22	1.79	12.50	37.50	9.66	0.63	2.86	14.29	3.17
Turpinia pomifera (Roxb.) DC.	Staphyleaceae	0.28	3.00	10.00	2.03	0.38	5.00	12.50	2.88	-	-	-	-
Vitex sp.	Vitaceae	0.24	4.00	15.00	2.45	-	-	-	-	-	-	-	-
Xerospermum glabratum Pierre	Sapindaceae	1.78	27.00	60.00	14.09	4.26	32.50	62.50	21.10	2.44	31.43	71.43	17.62