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Vegetation dynamics of an old-growth lowland tropical rainforest in North-east India: Species composition and stand heterogeneity

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The North East India forms an important hotspot of biodiversity by virtue of its unique biogeographical situation and healthier growing conditions. The region has an area of 13302.80 km^2 under the protected area network (PAN), which is not yet systematically inventorised. In this paper, we investigated Namdapha National Park that comprises 14% of the total PAN of the region and forms the largest remnants of the tropical dipterocarp forest. We examined land use pattern of Namdapha National Park and studied the vegetation dynamics of lowland tropical rainforest communities in the buffer zone area. The study revealed a total of eight cover classes and four vegetation categories with three forest types, namely, Stand I: Altingia-mixed species, Stand II: Shorea-Dipterocarp (both are tropical wet evergreen forests), and Stand III: Albizia (riverine tropical semi-evergreen forest) types. These three stands were systematically studied for general physiognomy, vegetation stratification, species area curve, plant structure and stand heterogeneity (species richness, diversity and dominance), tree girth class structure, and dominance-diversity relationship. These three stands collectively comprised 198 species (including 135 tree species), thus exhibited 34% of total floral and 50% of total tree diversity of the Namdapha National park, which is significant. The tropical wet evergreen forests showed five distinct vegetation strata. The species area curve depicted 123 and 19 tree species ha^{-1} in tropical wet evergreen and riverine semi-evergreen forests, respectively. Higher frequencies of lauraceae, diperocarpaceae, Euphorbiaces, Fagaceae, Leguminosae, Meliaceae and Magnoliaceae species clearly show that the forest had all attributes of tropical rainforests. The Stands I, II and III showed densities of 418, 390, and 245 trees ha^{-1}, and total basal area of 45.47, 49.68 and 18.33 m^2 ha^{-1}, respectively, which is well comparable with other similar forests. Species dominance and rarity analysis revealed that 63, 35, and 45% of the species were rare at local level in Stands I, II and III respectively, however such species contributed highly to forest stand diversity. The species number and density declined with increasing tree-girth sizes that denotes an evolving population with old growth trees. Comparisons of the floristic data with other similar stands have been discussed.

Key words: Rainforest, tropical evergreen and semi-evergreen forest, protected area network, tree diversity, species area curve, dominance-diversity curve, forest management.

INTRODUCTION

Tropical forests occupy 7% of the earth's area, about half of the world's forest cover and 65% of global biodiversity (FRA, 2002). These forests, however, are extremely susceptible to biotic pressure (Zent and Zent, 2004). Therefore, nature reserves and protected areas have high implications for conservation of genetic resources of the world (McNeely and Nees, 1996). At present protected areas (PAs) form the only repositories of biological wealth and refugia for native plants, animals and microorganisms that act as an outdoor laboratory for harboring rich biodiversity of a given region (Myers et al.,

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2000). In Asia as well as in other tropical regions the primary forests have been the foremost victim of anthropogenic pressure to the extent that most areas are either replaced by secondary vegetation or denuded completely (Menon et al., 2001). Such loss is witnessed at a time when knowledge on their structure and dynamics still considered inadequate (Romero-Duque et al., 2007) and may alter the habitats, and spatial and temporal variation in species richness, composition and productivity (Zent and Zent, 2004).

In India the tropical forests occupy 84% of the total forest cover (637293 km^2), which is 19.39% of the total geographic area. The tropical wet evergreen forest extends up to 15010 km^2, thus covers 10% of the tropical forest cover of the country (IIRS, 2002). Such forests face serious threats because of widespread landuse changes, leading to hamper species survival (Menon et al., 2001). This emphasizes the need to conserve biodiversity rich sites by bringing more area under conservation network, at the same time update our knowledge on species distribution, floristic composition, ecosystem diversity and plant structure protected areas (Rodgers et al., 2000). To protect biodiversity rich areas of the country, a protected area network (PAN) programme initiated by bringing large number of habitats and ecosystems under PAN in the Himalaya as well as other parts of India (Kothari et al., 1989; Rodgers et al., 2000). Unfortunately, most of the protected areas are not well investigated with relation to species structure and stand heterogeneity, though such information forms the basis for conservation and management along with further scientific investigations on such stands.

The northeast India is a global hotspot of biodiversity because of its geographical position, climatic conditions and altitudinal variations (Myers et al., 2000). The region has 49 protected areas (11 national parks and 38 wildlife sanctuaries) covering a land area of 13936.80 km^2, which comprises 5.46% of the total area of the northeast (Rodgers et al., 2000). Namdapha National Park, Arunachal Pradesh comprised the largest area among all (14.24% of total PAN of the northeast) with extremely diverse vegetation and habitat types (Chauhan et al., 1996; Ghosh, 1987; Deb and Sundriyal 2008). Although there are a few studies on biodiversity characterization of selected vegetation types in the northeast India (Rao et al., 1997; Khan et al., 1986, 1987; Barik et al., 1996). However such information is highly limiting for protected areas, which otherwise has significant implications for forest management and biodiversity conservation of the region (Proctor et al., 1998; Nath et al., 2005). A thorough understanding of dynamics of the forest stand with relation to species composition is essential to maintain forest structure and productivity, and conserve plant diversity (Oliver and Larsons, 1990; Philips, 1994; Bhat et al., 2000). In this study, we sampled vegetation of Namdapha National Park and specifically addressed the following questions: Which are the major landuses/covers in the buffer zone area? Which are the tree and shrub species distribution pattern along with the floral diversity, tree structure, species diversity and dominance, and how the plant-family contributes to the stand diversity in different forests? Finally, we discussed the conservation implications of our findings to provide a strong basis to frame more targeted management strategy for the area.

Study area

Namdapha National Park (27°23'30''- 27°39'40'' N to 96°15'2'' - 96°58'33'' E longitude) located in the Changlang district of Arunachal Pradesh state, northeast India (Deb and Sundriyal, 2008). It comprised an area of 1985.25 km^2 with 177.43 km^2 in buffer zone and 1807.82 km^2 in the core zone (Figure 1). The park shares southern and eastern boundaries with Myanmar, and the northern boundary with the Kamlang wildlife sanctuary of Lohit district of the state. The park area falls under the Eastern Himalaya (2D) biogeographic province, which covers the Paleartic and the Indo-Malayan (Oriental) realms (Rodgers et al., 2000). It is wedged between the Dapha Bum range of Mishmee Hills, an outspur at the tail end of North Eastern Himalaya, and the Patkai range with an elevational variance of 200 to 4571 m above sea level. General topography of the park is rugged with steep hills and narrow valleys intersected by several streams. Geologically the park is of recent origin and owes its formation to the upheaval of the Himalaya in Pleiocene period of the tertiary age (Chauhan et al., 1996). The area exhibits tropical climate, it receives an annual rainfall of 2500 to 3000 mm, and the temperature and relative humidity remains high throughout the season (Deb and Sundriyal, 2008). The present study was confined to the buffer zone area, which mainly comprised the lowland tropical wet evergreen and semi-evergreen forest types (Kaul and Haridasan, 1987). The core zone of the park is mostly inaccessible except for the river banks and mainly visited during the biennial Tiger Census. The soil of the forests was sandy-loam and acidic in nature (Table 1). The nitrogen, phosphorus and carbon content of the soil recorded higher under lowland tropical evergreen forests sites than and semi-evergreen (riverine) forest (Table 1). The former site also maintained a good humus and litter depth though it was <2 cm in riverine forest (Deb, 2006).

METHODS

Land use-cover of buffer zone

The buffer zone area was delineated using the maps prepared by the office of the Field Director, Namdapha National Park, Department of Environment and Forests, Government of Arunachal Pradesh, which was traced on the Survey of India topo sheets. To assess landuse-cover of buffer zone area we used satellite images

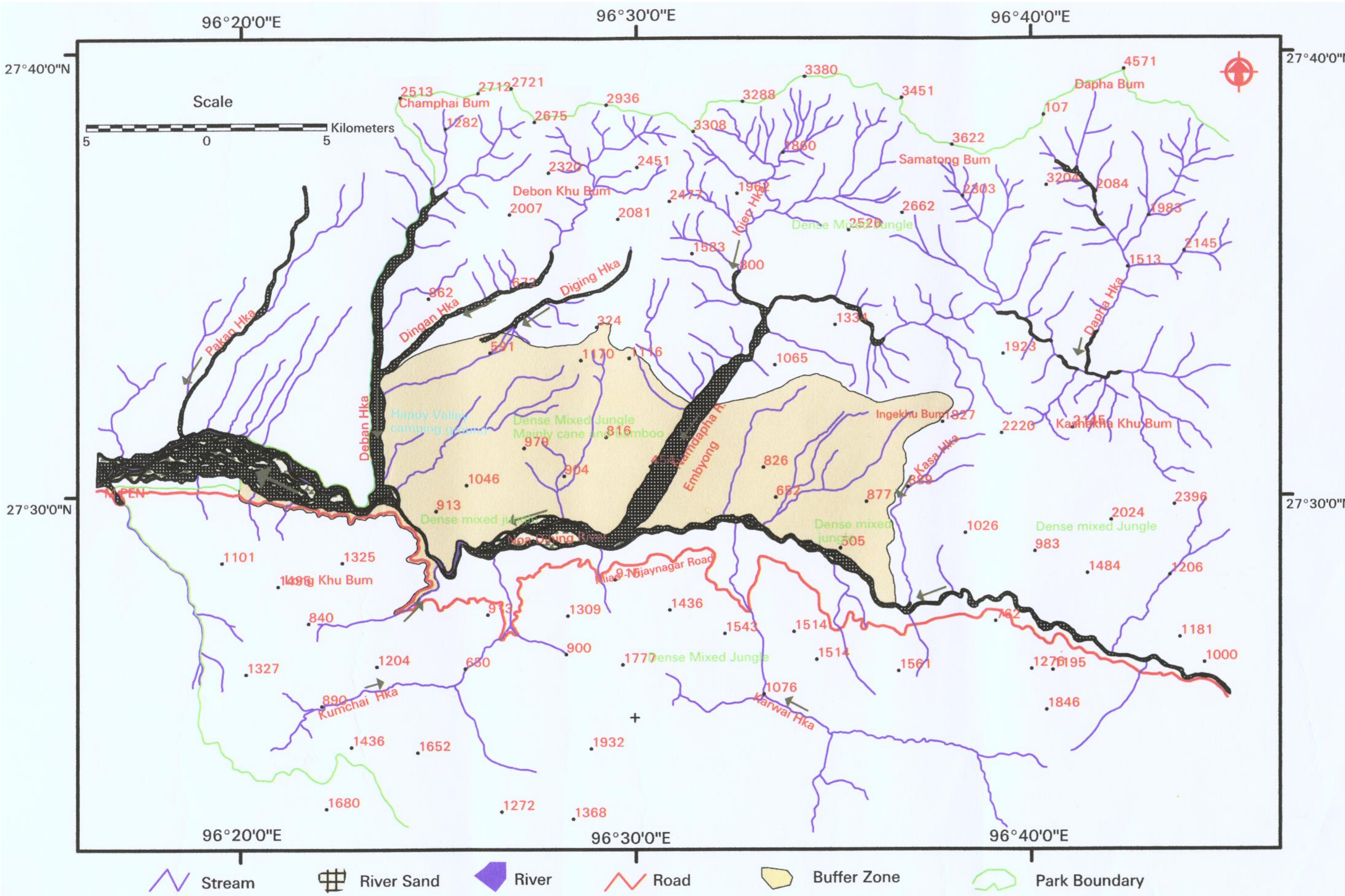


Figure 1. Digitized map of the buffer zone of Namdapha National Park in the northeast India.

Table 1. Soil characters of the study sites comprising *Altingia*-mixed species, *Shorea-Dipterocarp*, and *Albizia* stands in Namdapha National Park.

Parameters	***Altingia*- mixed species stand**	***Shorea-Dipterocarp* stand**	***Albizia* stand**
Soil type	**Sandy loam**	**Sandy loam**	**Loamy sand**
texture	Clay: 10.5 Silt: 21 Sand: 68.5	Clay: 9.5 Silt: 19 Sand: 71.5	Clay: 3 Silt: 26.5 Sand: 70.5
pH	5.35±0.23	4.5±0.45	6.29±0.46
Moisture (%)	23.22±2.56	22.49±1.87	30.39±13.57
N (%)	0.37±0.09	0.215±0.014	0.20±0.0034
P (%)	0.23±0.021	0.21±0.014	0.19±0.02
Organic carbon (%)	2.69±1	1.98±0.14	1.11±0.11
Na (ppm)	0.016±0.001	0.016±0.001	0.012±0.001
K (ppm)	0.07±0.003	0.065±0.002	0.072±0.0032

comprising path 115 and row 52 of IRS-1D, LISS III for February 2003 procured from the National Remote Sensing Agency (NRSA). The area was verified through Survey of India topo sheets (1:50,000 scale) No. 92 A/6, 7, 10 and 11. Using the software ERDAS Imagine (8.6 Version), the LISS-III data were geo-referenced for which feature controls obtained from the Survey of India topo sheets. The forest types categorized as per available classifications of Champion and Seth (1968), and Kaul and Haridasan (1987).

Vegetation stratification and structural analysis of the stands

For detailed structural analysis of the buffer zone, three major canopy compositions (namely, Altingia-mixed species (Stand I), Shorea-Dipterocarp (Stand II), and Albizia forest (Stand III) were considered. The Altingia-mixed species and Shorea-Dipterocarp stands fall under lowland tropical evergreen rainforest category while Albizia stands is composed of riverine semi-evergreen forest type. Five strata, that is, top canopy or emergent (A- stratum), mid canopy (B-stratum), lower canopy (C-stratum), shrub layer (D-stratum) and herb layer (E-stratum) were considered (Magurran, 2004). The structural analysis was done for three stands using the transect method that were placed randomly to cover stand diversity and maximum possible species (Muller-Dombois and Ellenberg, 1974). Transects (50×20 m size) were laid 50 m inside the forest trail to avoid any outside interference. A total of 12, 10 and 18 transects were identified for Stands I, II and III, respectively. Each transect was further sub-divided into 10×10 m quadrat size, and ten 100 m^2 quadrats were studied randomly from each transect. Care was taken to cover slopes, altitude, and most possible species in view of rapid changes in vegetation (Kent and Coker, 1994). Altogether 120, 100 and 180 quadrats were studied for the three stands, respectively. The total number of quadrats sampled was based on number of species and tree individuals repeated, (Sundriyal and Sharma, 1996; Magurran, 2004).

All tree individuals falling in each quadrat were marked with a permanent aluminum tag. Each individual tree was measured for its circumference at breast height (CBH), that is, at 1.3 m above ground level. Individuals with buttresses or other deformities at breast height were measured for its girth just above buttresses. Samples of all plant individuals were collected and later identified to family, genera and species, level using existing flora (Haridasan and Rao, 1985; Chauhan et al., 1996) and with the help of the experts of State Forest Research Institute (SFRI) and Botanical Survey of India (BSI), Itanagar, Arunachal Pradesh. The data gathered for each stand from all transect were subsequently pooled together for further analysis. All woody species ≥31.5 cm CBH (circumference at breast height) that is, ≥10 cm DBH (diameter at breast height) were considered as trees, and <31.5 cm CBH (<10 cm DBH) were considered as regenerating individuals (Sundriyal and Sharma, 1996; Uma, 2001). Regenerating individuals were further categorized into sapling (DBH <10 cm and height >20 cm) and seedling (individuals <20 cm in height). The vegetation data subsequently analyzed for each species for its frequency, density, and total basal area (Kent and Coker, 1994; Maguran, 2004). To provide comparative data among species, we analyzed the relative density, relative frequency and relative cover for each species in a stand (Philips, 1959). To assess dominance of species in stand Importance Value Index (IVI) was computed by summing up the relative density, relative frequency and relative dominance for each tree species for all individuals ≥31.5 cm CBH (Philips, 1959). Species represented with an IVI <1 were considered rare (Maguran, 2004).

All the identified species were grouped into genera and family for presenting floristic composition for each stand, thus plant families contributing maximum number of species were assessed for each stand (Deb, 2006).

Tree diameter class structure

The diameter class structure of a forest is considered an important criterion for assessing maturity of the stand. The DBH of all trees was measured for interpreting population structure (Sundriyal et al., 1994; Sundriyal and Sharma, 1996). Based on tree diameter at breast height, individual tree species were separated into 8 classes (10-20, 21-30, upto >150 cm). To reflect the status of individual species in different forest stands, the DBH classes were further pooled into small (DBH 10 to 30 cm), medium (DBH 31 to 60 cm), adult (DBH 61to 90 cm), and mature (DBH >91 cm) trees as such data would represent evolving state of a given stand.

Shrub and herbaceous flora

The density of shrub and herbs was estimated for Altingia-mixed

Table 2. Landuse/ cover statistics for buffer zone area of Namdapha National Park, Arunachal Pradesh.

Landuse categories	Area (km^2)	Percentage of total area
*!South Bank tropical wet evergreen (*Dipterocarpus*) Forests (dense)	141.642	79.832
*!South Bank tropical wet evergreen (*Dipterocarpus*) forests (open)	13.100	7.383
**Riverine semi-evergreen forests	0.640	0.360
Grasslands	13.110	7.389
Water body	1.400	0.789
Built-up land	0.013	0.007
Landslide area	0.490	0.276
River sand	7.030	3.962
Total land area	177.425	100

Forest classification (Champion and Seth 1968, Kaul and Haridasan 1987).

species and Albizia stands only. We used all 10×10 m size quadrat that were placed for tree structure analysis. Each 10×10 m^2 quadrate was sub-divided into four 5×5 m quadrats, of which one quadrat was randomly selected for assessing shrub and sapling species composition. A total of 120 and 180 quadrats were analyzed for two stands, respectively. The herbaceous flora was also assessed from same quadrate by placing at least two 2×2 m size quadrats. A total of 240 and 360 quadrats of 2×2 m^2 were analyzed for assessing density of herbaceous species in two stands, respectively. The herbarium of all shrub and herbaceous species were prepared for identification.

Stand heterogeneity

The heterogeneity among different stands was assessed by estimating species richness, diversity, concentration of dominance, and evenness in each stand by calculating Menhinick index, Shannon-Weiner information index, Simpson's concentration index, and Pielou's measure of evenness, respectively (Maguran, 2004).
The index of species richness was calculated following Menhinick (1964) as:

$$D=S/\sqrt{n}$$

Where S is the number of species and n is the number of individuals.
The diversity index was calculated using the following formula (Shannon and Wiener 1963):

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

Where, pi is the proportion of the ith species and the number of individuals of all the species (ni/N), and ln is the log base$_n$
The concentration of dominance (CD) was measured using the following formula (Maguran 2004):

$$CD = \sum p_i^2$$

Where, pi is same as in Shannon-Weiner information function.

Dominance-diversity curve

The dominance-diversity curve was plotted to assess species niche separation and partitioning of community resources (Whittaker, 1975; Kent and Coker, 1994). The Dominance-diversity curves for each stand were prepared based on the IVI for trees and density for the saplings and seedlings. Since the shape and slope of dominance-diversity curve vary, it was interpreted with the help of at least four different distribution functions, that is, the geometric series and niche pre-emption hypothesis, the log series, the log normal distribution, and broken stick series (Kent and Coker, 1994).

Similarity indices

Similarity was measured amongst three stands to assess the degree to which the species composition (tree, shrubs and herbs) of different forests matches together. The similarity index was calculated by the formula given by Sorensen (1948):

$$=S_S = 2C/ 100(A+B)$$

Where C is the number of common species in two stands being compared; and A and B denote the total number of species at stand I and stand II, respectively. The coefficient is multiplied by 100 to give a percentage similarity value.

RESULTS

Landuse and covers of buffer zone

Analysis of remote sensing image data for buffer zone area of Namdapha National Park delineated eight cover classes of which four were vegetation types and remaining others non-vegetation categories (Table 2). Of the three major forest categories the tropical wet evergreen (*Dipterocarpus*) forest in dense (79.8%) and open (7.4%) categories covered the major part of the buffer zone area (Table 2). A small area of buffer zone (0.36%) was occupied by the riverine semi-evergreen forest type. The grasslands also comprised sufficient area (7.4%), while water body and sand and landslide area were other main landcover categories (Table 2). A small part was also categorized as built-up land that comprised houses and huts (temporary structures) created by the Forest Department inside the Park.

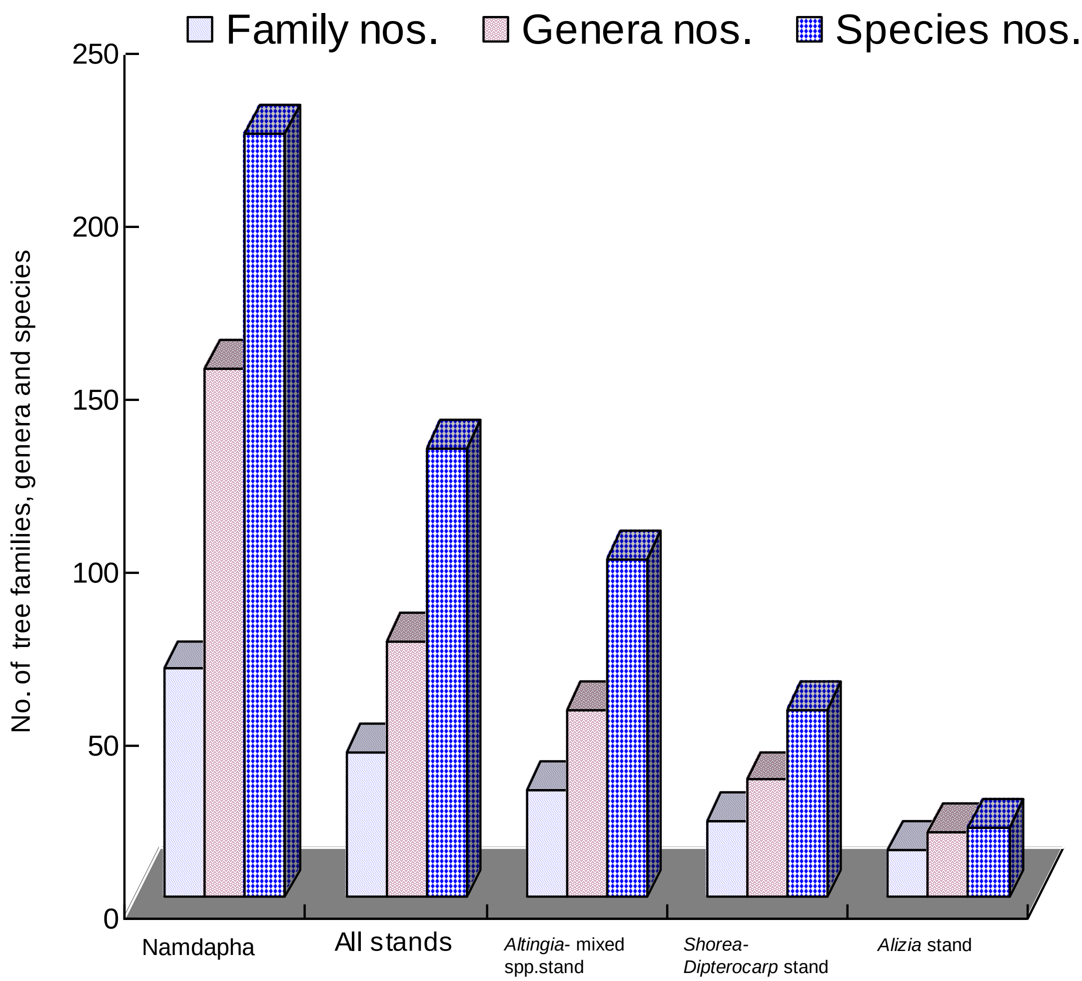


Figure 2. Status of tree species, genera and families at Namdapha National Park (all classes) and in three studied forest (for trees >31.4 cm CBH) stands in the buffer zone area.

Species number and vegetation stratification

A comparison of three different stands at Namdapha National Park in terms of plant family, genera and species is presented in Figure 2. The cumulative number of species, genera and families for three stand reached 130 species in 74 genera and 42 families (>10 cm DBH). The lowland tropical evergreen forest types exhibited five distinct strata. The A-stratum comprised emergent or top canopy species, mainly occupied by *Altingia excelsa*, *Dipterocarpus macrocarpus*, *Shorea assamica*, *Cinnamomum bejolghota*, *Ailanthes grandis*, *Michelia oblonga* and *Terminalia myriocarpa*, however they do not form a close canopy. Such trees had a straight bole reaching to 40 to 50 m height and a DBH of 60 to 120 cm. The B-stratum or mid-canopy comprised multitude of tree species, formed a close canopy, attained 20 to 30 m height, and mainly dominated with *Elaeocarpus aristatus*, *Ostodes paniculata*, *Mesua ferrea*, *Dysoxylum procerum*, *Talauma hodgsonii*, *Syzygium macrocarpum*, *Chisocheton paniculatus*, *Dysoxylum binecteriferum*, *Castanopsis indica*, *Castanopsis tribuloides* and *Beilschmiedia assamica*. The C-stratum or lower canopy had small trees with 10 to 15 m height, *Saprosma ternatum*, *Baccaurea ramiflora*, *Ardisia sp*., and Leea species being the major elements of this layer. The D-stratum composed of shrubs and lianas, while the E-stratum comprised herbs and newly germinated seedlings of tree species. The semi-evergreen forest (Albizia stand) that occurred along the river banks, riverine plains and swamps forming a narrow belt, showed emergent or top canopy (A-stratum) trees with a height of 25-40 m, comprising *Albizia procera*, *Bombax ceiba*, *A*. *grandis*, *Duabanga grandiflor*a and *T*. *myriocarpa*. Generally the stand was devoid of a clear second storey, though tree species, such as *Dalbergia pinnata*, *Dalbergia sericia*, *Melia dubia*, *Erythrina stricta*, *Ehretia acuminate* and *Cordia dichotoma* recorded up to a height of 10 to 20 m. Shrubs showed scattered distribution in this stand. This stand receives frequent

Table 3. Comparative account of tree species, density, total basal area and other parameters for three-studied forest stands in the buffer zone of Namdapha National Park, Arunachal Pradesh.

Parameter	Forest stands		
	***Altingia*-mixed species**	***Shorea-Dipterocarp***	***Albizia***
Total number of species			
Tree*	98	54	20
Sapling	72	36	20
Seedling	36	20	3
Herb	29	17	16
Density (individuals ha^{-1})			
Trees	418	390	245
Saplings	4464	3860	345
Seedlings	13184	12250	423
Herb	43281	17500	25461
Total tree basal area (m^2 ha^{-1})	45.47	49.68	18.29
Trees with maximum total basal area	*Altingia excelsa*	*Terminalia myriocarpa*	*Albizia procera*
Their contribution to total basal area (m^2 ha^{-1})	17.58	8.09	13.03
No. of trees with buttressed	69	40	2
No. of deciduous	26	20	196

*The number of unidentified tree species was 31, 16 and 3 at *Altingia*-mixed species, *Shorea-Dipterocarp*, and *Albizia* stands, respectively.

flood during rains that adversely affect the ground flora. Saccharum grass was major E-stratum that dominates in riparian alluvial patches, which was categorized as grassland area.

Tree structure

The tree density and basal cover was recorded highest for Altingia-mixed species (Stand I), followed by Shorea-Dipterocarp (Stand II), and minimum for Albizia (Stand III) forests. When all the life forms, namely, trees, sapling, seedling, lianas, shrubs and herbs considered together, 198 species varying from 151 genera and 74 families were recorded from three studied stands (Figure 2). A total of 31, 16 and 3 tree species at Altingia-mixed species, *Shorea-Dipterocarp*, and Albizia stands, respectively, could not identified though definitely were new genera. The highest number of tree, sapling, seedling and herb species were recorded for Stand I, followed by Stand II and Stand III (Table 3). Similar was the trend for stand tree, sapling and seedling density. The total tree basal cover was recorded highest at Stand II, followed by Stand I and minimum at Stand III.

At least 14 to 21% of tree stems were recorded having buttresses at the two stands of lowland tropical evergreen forest. *A*. *excelsa* contributed 55% of total buttressed stems at Altingia-mixed species stand. *S*. *assamica* (8%) and *D*. *macrocarpus* (5%) also had buttressed stems at *Shorea-Dipterocarp* stand. Only two individuals of *B*. *ceiba* were recorded having buttresses at Albizia stand (Table 3). The percentage of deciduous stems was estimated 6.27 and 5.13% in Altingia-mixed species and *Shorea-Dipterocarp* stands though it was as high as 80% in Albizia stand, and 5, 6, and 14 tree species showed deciduous habit in respective stands.

The data for tree structure with reference to relative density and relative basal cover for different stands are given in Table 4. Of the total 98 tree species at Altingia-mixed species stand maximum relative density was recorded for *O*. *paniculata*, followed by *A*. *excelsa*, *D*. *macrocarpus*, and *T*. *hodgsonii*. It was interesting to note that 82 tree species recorded <1% relative density though collectively they contributed 42.47% of total stand density (Table 4). The species contribution to total basal cover (that is relative cover) was estimated highest for *A*. *excelsa*, followed by *D*. *macrocarpus*, *Schima wallichii* and *O*. *paniculata*. 84 tree species recorded a relative cover of <1% each, however when pooled together they contributed 31.33% of total relative cover at same stand (Table 4). The data showed that rare species contribute significantly to the stand density and total basal cover.

At Shorea-Dipterocarp stand, of the total 54 tree species, the maximum relative density was recorded for *D*. *macrocarpus*, followed by *S*. *assamica*, *O*. *paniculata*, *B*. *ramiflora*, and *Leea indica*. Nearly 29 tree species recorded <1% relative density though their total contribution to the stand density was 23.75% (Table 4). A total of 16 tree species of this stand contributed nearly 82% of total basal cover, while remaining 38 species,

Table 4. Relative density (%) and relative basal cover (%) of important tree species at *Altingia*-mixed species, *Shorea-Dipterocarpus*, and *Albizia* stand in the buffer zone area of Namdapha National Park (only tree individuals with ≥31.5 cm CBH are considered; species with <1% contribution for relative density and cover are pooled together).

Species	*Altingia*-mixed species stand		*Shorea-Dipterocarpus* stand		*Albizia* stand	
	Relative density (%)	Relative cover (%)	Relative density (%)	Relative cover (%)	Relative density (%)	Relative cover (%)
Actinodaphne obovata			1.54	0.82		
Ailanthus grandis			0.51	1.36		
Albizia procera					51.429	71.086
Altingia excelsa	8.37	38.66	1.54	10.93		
Aporusa dioca	0.24	0.02	2.05	0.29		
Baccaurea ramiflora	1.44	0.31	6.67	0.91		
Beilschmiedia sp.	0.24	0.02				
Bischofia javanica			1.03	2.94		
Bombax ceiba					7.347	6.601
Calicarpa arborea					1.024	0.927
Canarium strictum	0.24	0.07	3.59	3.54		
Castanopsis indica	0.72	0.24	0.51	2.79		
Castanopsis sp. 3	0.48	0.57	1.03	3.68		
Cedrella toona	0.48	2.31				
Chisocheton paniculatus	2.87	1.63	0.51	0.13		
Cinnamomum bejolghota	1.20	1.58				
Cinnamomum glaucescens	0.60	1.14	1.54	7.19		
Cinnamomum sp.	0.24	0.13	1.03	0.41		
Croton roxburghii	0.24	0.02	2.56	2.40		
Dalbergia pinnata					12.653	3.655
Dalbergia sericia					9.796	3.219
Dipterocarpus macrocarpus	4.31	5.08	10.26	10.06		
Dysoxylum binecteriferum	2.39	1.17				
Dysoxylum procerum	3.83	1.14				
Elaeocarpus aristatus	0.60	0.31	3.08	1.17		
Eriobotrya bengalensis	1.03	0.31				
Glochidion lanceolarium					3.673	0.873
Gmelina arborea					7.347	2.073
Griffithianthus fuscus	0.60	0.15	2.56	0.58		
Helicia robusta			1.03	0.26		

Table 4. Contd.

Leea indica			4.62	0.48		
Leea indica	2.15	0.29				
Lindera sp.			2.05	0.37		
Magnolia griffithii	0.24	0.02	1.54	2.16		
Ostodes paniculata	15.07	3.58	7.69	1.41		
Quercus lamellosa	0.24	0.02	1.03	0.35		
Saprosma ternatum	2.39	0.20	3.08	0.27		
Schima wallichii	1.79	3.91	0.51	3.34		
Shorea assamica	0.48	0.53	8.21	11.51		
Syzygium cumini	1.67	2.11	1.03	0.71		
Syzygium macrocarpum	3.11	1.17	2.05	0.35		
Talauma hodgsonii	4.19	2.55	1.54	0.95		
Talauma hodgsonii					0.816	0.382
Terminalia chebula			0.51	1.62		
Terminalia myriocarpa	0.48	2.64	3.59	16.28	1.633	5.619
Other species*	37.83	28.12	21.20	10.74	4.29	5.56

*No. of other species comprised 68, 24, and 10 species in *Altingia*-mixed species, *Shorea-Dipterocarp*, and *Albizia* stands, respectively.

which are rare in distribution, comprised just 18% of total basal cover. *S. assamica, T. myriocarpa*, *D. macrocarpus, A. excelsa, Cinnamomum glaucescens, S. wallichii* contributed most to the total cover of the stand (Table 4).

In contrary to the tropical wet evergreen stands, a few species showed clear dominance at semi-evergreen stand, of which *A. procera* comprised more than half of the relative density and two-third of the relative basal cover (Table 4). Other species contribution was much lower, that is, *D. pinnata* (31 trees ha^{-1}), *D. sericia* (24 trees ha^{-1}), *G. arborea and B. ceiba* (each having 18 trees ha^{-1}). Besides *A. procera*, other major contributors to the total basal area were *B. ceiba, T. myriocarpa, D. pinnata, Dalbergia sericia* and *G. arborea* (Table 4). Ten other species individually contributed <1% to total stand density and basal cover.

Plant family-density ranking of stands

Taxonomically the number of plant families representing different tree species were more in Altingia-mixed species stand (32 families), followed by Shorea-Dipterocarp stand (23 families) and minimum in Albizia stand (16 families) (Table 5). For tree stratum six families, namely, Lauraceae, Euphorbiaceae, Meliaceae, Magnoliaceae, Combretaceae and Verbenaceae were common among the three stands. Nearly 17 families were common between Altingia-mixed species and *Shorea-Dipterocarp* stands, and 8 families each between Altingia-mixed species and Albizia stands, and *Shorea-Dipterocarp* and Albizia stands (Table 5).

The density ranking of plant families also varied within and amongst different stands (Table 5). In Altingia-mixed species stand, Euphorbiaceae comprised 20% of total stand density, while Meliaceae, Magnoliaceae, Dipterocarpaceae and Lauraceae ranked subsequently with 10, 5, 5, and 4% contribution at Altingia-mixed species stand (Table 5). In Shorea-Dipterocarp stand, Dipterocarpaceae and Euphorbiaceae contributed 18 and 17% of the total stand density, respectively, and Fagaceae, Leeaceae, Lauraceae and Magnoliaceae contributed 7, 5, 4 and 3.5% to total stand density (Table 5). In Albizia stand, Leguminosae contributed 75% to

Table 5. Important plant families and no. of tree species, density (ha^{-1}, CBH >31.5 cm) and total basal area (TBA, m^2 ha^{-1}) in different forest stands in the buffer zone area.

Family	*Altingia*-mixed species stand			*Shorea-Dipterocarp* stand			*Albizia* stand		
	Species	Density	TBA	Species	Density	TBA	Species	Density	TBA
Alangiaceae	-	-	-	-	-	-	1	1	0.01
Annonaceae	2	6	0.17	1	10	0.29	-	-	-
Araliaceae	1	2	0.11	-	-	-	-	-	-
Bignoniaceae	-	-	-	-	-	-	1	1	0.02
Bombaceae	-	-	-	-	-	-	1	18	1.21
Boraginaceae	-	-	-	-	-	-	1	0	0.01
Buseraceae	1	1	0.03	-	-	-	-	-	-
Capparadiaceae				2	2	0.28	-	-	-
Celestraceae	2	6	0.13	-	-	-	-	-	-
Clusiaceae	1	3	0.06	-	-	-	-	-	-
Combretaceae	1	2	1.2	1	16	8.89	1	4	1.03
Dilleniaceae	-	-	-	2	2	0.21	-	-	-
Dipterocarpaceae	2	20	2.55	1	72	10.71	-	-	-
Ebenaceae	1	2	0.05				-	-	-
Elaeocarpaceae	2	3.5	0.16	4	12	0.58	-	-	-
Euphorbiaceae	6	77.5	2.00	5	68	2.76	1	9	0.17
Fagaceae	5	9.5	0.48	1	26	5.17			
Hammemelidaceae	1	35	17.58	3	6	5.43			
Juglandaceae	-	-	-	-	-	-	1	1	0.06
Lauraceae	8	17	1.54	1	16	1.00	1	1	0.14
Leeaceae	1	9	0.13	3	18	0.24			
Leguminosae	1	2	0.09	-	-	-	4	183	14.45
Magnoliaceae	4	22	2.22	3	14	1.83	1	2	0.07
Meliaceae	5	41	2.86	2	16	1.46	1	1	0.12
Moraceae	3	4.5	1.00	-	-	-	-	-	-
Myrsinaceae	-	-	-	-	-	-	1	1	0.01
Myristicaceae	1	2	0.02	-	-	-	-	-	-
Myrtaceae	2	20	1.49	1	12	0.53	-	-	-
Oleaceae	2	2	0.06	-	-	-	-	-	-
Proteaceae	-	-	-	1	4	0.13	-	-	-
Rosaceae	-	-	-	1	4	0.15	-	-	-
Rubiaceae	2	12	0.11	1	12	0.13	-	-	-

Table 5. Contd.

Rutaceae	2	6	0.12	-	-	-	-	-	-
Sapindaceae	1	2.5	0.1	-	-	-	-	-	-
Saurauceae	1	1	0.01	-	-	-	-	-	-
Simorubiaceae	-	-	-	1	2	0.68	1	0	0.01
Sonneritiaceae	1	2	1.41	1	6	3.57	-	-	-
Sterculiaceae	2	2.5	0.04	1	2	0.02	-	-	-
Styraceae	2	3.5	0.13				-	-	-
Theaceae	1	7.5	1.78	1	2	1.66	-	-	-
Urticaceae	1	2.5	0.32	-	-	-	-	-	-
Verbenaceae	2	2	0.09	1	2	0.17	1	20.5	0.55
Unidentified	1	89	7.42	1	66	3.78	2	2	0.47
Total	70	417.5	45.46	39	390	49.67	1	244	18.33

total stand density while Verbenaceae and Bombaceae had much lower contribution (9 and 7%). With respect to contribution for total basal area, Hammemelidaceae, Dipterocarpaceae and Leguminoceae contributed maximum at three stands, respectively (Table 5).

Tree diameter class distribution

Distribution of tree species and their individuals in different DBH classes varied among stands (Figure 3, Table 6). The relationship between tree girth sizes and number of individuals varied among species in forest stands. Both, the number of tree individuals and number of species in different girth classes decreased with increase in girth sizes in all the studied stands. Of the total 418 tree individuals ha^{-1} in ≥10 cm DBH in Altingia-mixed species stand, 49% tree individuals were recorded in DBH class 10 to 20 cm, 23% in 21 to 30 cm, 18% in 31 to 60 cm, and 10% in DBH class >60 cm (Figure 3). The data revealed that individuals in middle to lower DBH classes showed an overall dominance and only *A. excelsa*, *D. macrocarpus* and few other species reached >60 cm DBH. *O. paniculata*, a middle canopy species of this stand, was mostly represented in the <30 cm DBH class (Figure 3A). Similarly in Shorea-Dipterocarp stand, of the total of 390 tree individual ha^{-1}, nearly 45, 21, 22 and 13% tree individual were recorded in DBH classes 10 to 20 cm, 21 to 30 cm, 31 to 60 cm, and >60 cm, respectively (Table 6). The stand showed that tree individuals of *S. assamica*, *D. macrocarpus* and *T. myriocarpa* could reach DBH class >60 cm (Figure 3B). *T. myriocarpa* was not represented in DBH <30 cm. With a total of 245 tree individuals ha^{-1} in Albizia stand, 46, 27, 25 and 2% individuals were recorded in DBH classes 10 to 30, 31 to 60 and >61 cm classes, respectively (Table 6). Tree individual distribution showed the dominance of individuals in DBH between 10 to 30 cm (Figure 3C). Only *A. procera*, *B. ceiba* and *T. myriocarpa* represented the DBH class >61 cm (Figure 3C). The representation of number of species in different DBH class structure showed an inverse relationship (Table 6). A total of 81, 60, 47, 37 and 18% species represented in DBH class <10, 11-20, 21-30, 31-60, and >61 cm in Altingia-mixed species stand, while 67, 52, 44, 41 and 26% species in *Shorea-Dipterocarp* stand, and 100, 80, 60, 40 and 20% species in Albizia stand represented similar girth class distribution (Figure 4). The individual: species ratio revealed higher values for lower girth sizes and it decreased as girth size increases (Table 6). The ratio showed a gradual lapse rate at Altingia-mixed species stand, and inconsistence trend in *Shorea-Dipterocarp* stand. For Albizia stand the ratio was higher than other stands showing lower number of species at this stand (Table 6). *A. excelsa* recorded a stem diameter up to 72 cm in Altingia-mixed species stand, and 457 cm in *Shorea-Dipterocarp* stand. Other large girth size species in tropical wet evergreen stands were

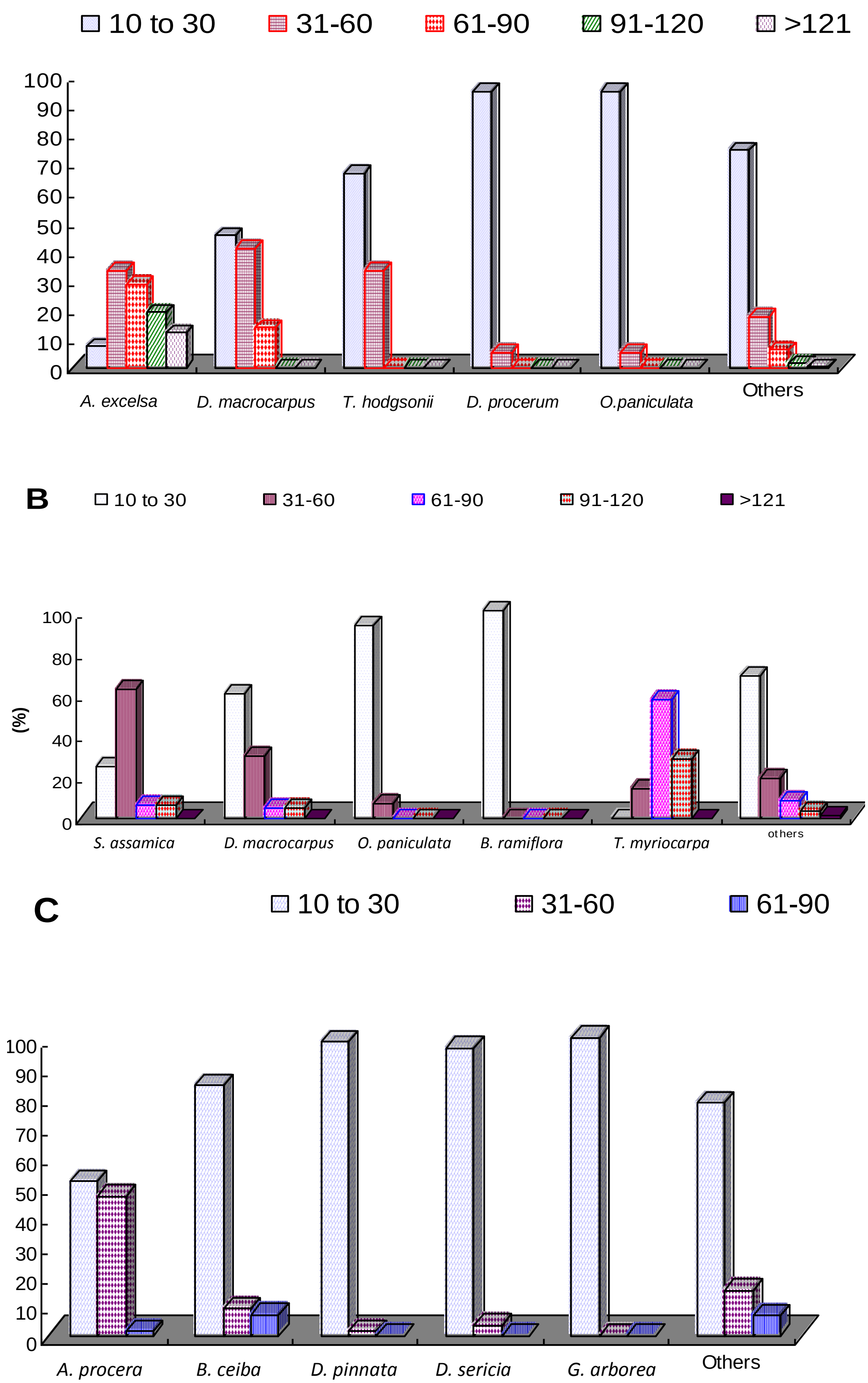


Figure 3. Diameter (DBH) classes of selected important trees species in different studied stands in the buffer zone of Namdapha National Park (A-*Altingia*-mixed spp., B-*Shorea-Dipterocarp*, and C- *Albizia* stands).

Table 6. Comparison of structural composition of three studied stands in the buffer zone area of Namdapha National Park, Arunachal Pradesh, India.

Parameter	Forest stand		
	***Altingia*-mixed species**	***Shorea-Dipterocarp* stand**	***Albizia* stand**
No. of tree individuals/ha (≥10 cm DBH)	418	390	245
dbh<10 cm	17791	16500	854
10-20 cm	202	176	114
21-30 cm	93	80	66
31-60 cm	74	84	61
>61 cm	43	50	6
No. of tree species	98	54	20
dbh <10 cm	79	36	20
10-20 cm	59	28	16
21-30 cm	43	24	12
31-60 cm	36	22	8
>61 cm	18	14	4
Ratio (individual : species*)			
dbh <10 cm			
10-20 cm	4.11	3.26	7.89
21-30 cm	2.60	2.86	9.9
31-60 cm	2.47	3.82	13.73
>61 cm	2.87	3.57	2.7
Percentage of most abundant species			
Species	*Altingia excelsa*	*D. macrocarpus*	*Albizia procera*
10-20 cm	0	30	13.73
21-30 cm	7.14	30	37.25
31-60 cm	33.33	30	47.06
>61 cm	59.52	10	1.96

*individuals ha^{-1} × total area sampled / No. of species.

Castanopsis sp. (DBH 50 cm), *D. macrocarpus* (DBH 55 cm), *D. grandiflora* (DBH 60 cm), Ficus sp. (DBH 55 cm), *S. wallichii* (DBH 55 cm), *S. assamica* (DBH 43 cm), *T. myriocarpa* (DBH 47 cm), and *T. myriocarpa* (DBH 57 cm). At Albizia stand, *T. myriocarpa* reached to a maximum diameter size (DBH 42 cm), while *C. dichotoma* (DBH 42 cm), *A. procera* (DBH 41 cm), and *B. ceiba* (DBH 38 cm) also attained higher diameter sizes. The percentage distribution of individuals from 10 to 20 cm to >61 cm DBH classes showed inverted pyramidical structure for A. excelsa in Stand I with increasing number of individuals from lower to higher girth classes (Figure 4). For *D. macrocarpus* in Stand II, it was fairly constant except for DBH >61 cm where it decreased. *A. procera* showed upright pyramidical structure (Figure 4).

The family wise distribution of tree individuals in different girth classes showed that Euphorbiaceae represented highest number of tree individuals (19.54%) in DBH >10 cm, followed by Meliaceae (9.72%) and Hamamelidaceae (8.50%) at Altingia-mixed species stand (Figure 5a). Dipterocarpaceae (18.46%), Euphorbiaceae (17.44%) and Fagaceae (6.67%) dominated the Shorea-Dipterocarp stand. Leguminosae was the dominant family at Albizia stand, followed by Verbenaceae (8.54%) and Bombacaceae (7.49%) (Figure 5b). By adding seedlings and saplings with mature tree individuals, Lauraceae and Euphorbiaceae showed dominance at Altingia-mixed stand, Dipterocarpaceae and Euphorbiaceae at Shorea-Dipterocarp stand, and Leguminosae at Albizia stand (Figure 5c).

Species dominance and rarity at stands

The dominance of each species in a stand was calculated by assessing their importance value index (IVI) (Appendix I). The IVI of different species varied greatly in

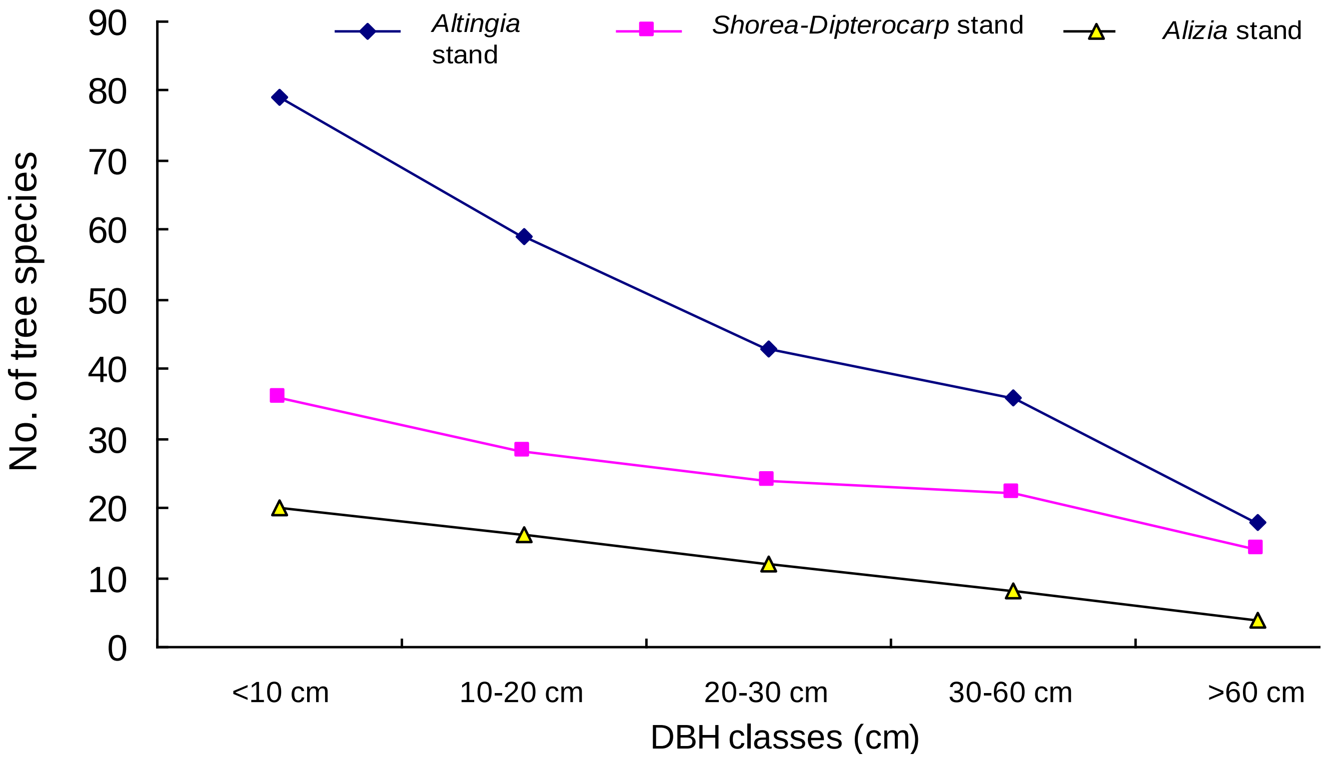


Figure 4. No. of species in different DBH classes in *Altingia*-mixed species stand, *Shorea-Dipterocarp* stand, and *Albizia* stand at the buffer zone area of Namdapha National Park, Arunachal Pradesh.

different stands. A. excelsa (IVI 51.72) was the most dominant species of the Altingia-mixed species stand. *O. paniculata, D. macrocarpus* and *T. hodgsonii* were the co-dominating species of the stand (Appendix I). Nearly 10 tree species had an IVI value between 5 to 8, while for another 20 species it varied between 2 to 5. The remaining 62 tree species recorded an IVI <2 which expressed their rarity in the stand (Appendix I).

In Shorea-Dipterocarp stand, the maximum IVI was recorded for *D. macrocarpus*, which was closely followed by *T. myriocarpa* and *S. assamica* (Appendix I). For *A. excelsa, C. indica, O. paniculata, B. ramiflora* and *D. grandiflora* the IVI value varied from 15 to 10. Other 46 tree species had an IVI value <10, which included 35 species with an IVI<5, and 19 species with an IVI value <2 (rare species) (Appendix I).

A. procera showed a clear dominance at riverine stand (Appendix I). *D. pinnata, B. ceiba, D. sericia, G. arborea*, *Glochidion lanceolarium* and *T. myriocarpa* were the other co-dominant species at this stand. Remaining 11 tree species had an IVI value <3, which also include 9 species with an IVI value <2 (Appendix I).

Shrub and herbaceous layer

The density of shrub and liana was estimated for Altingia-mixed species and Albizia stands only and it was higher in the former stand than the latter stand (Table 7). The most common liana at Altingia-mixed species stand was *Byttnera aspera*, *Fissistigma bicolor*, and *Milletia sp*. Tree clasping climber *Pothos scandens* and *Roydsia suaveolens* were also recorded (Table 7). It was interesting to note that 8% of total trees sampled were having lianas. Strobilanthes and Boehmeria were the most common shrub species at this stand. Strobilanthes sp. particularly dominated under the canopy openings and forest fringes, attains a height of 4 m and is supported by stilt roots. The most common shrub in the Albizia stand was Elaeagnus, while *Citrus medica* was another sturdy shrub at this site. *Phrynium sp*., *Alpinia sp*. and *Phragmites karka* showed a gregarious presence at this site. An observation of the epiphytic loads on the trees showed that *Asplenium nidus*, *Ryncostylus retusus*, *Dendrobium sp*., and *Aerides odorata* grow profusely on trees. A terrestrial orchid namely, *Calanthe sp*. was also recorded from the Albizia stand.

The occurrence and floristic composition of ground herbs varied among the three studied stands (Table 8).

A total of 46 species varying from 38 genera and 22 families were recorded in all the three stands. Piperaceae with 5 species was the most diverse herbaceous family followed by Arecaceae and Asteraceae (4 species each) and Zingiberaceae (3 species). In terms of number of

Table 7. Climber and shrub species (density/ha) at selected forest stand in the buffer zone area of Namdapha National Park.

Species	*Altingia*-mixed species stand (density ha^{-1})	*Albizia* stand (density ha^{-1})
Shrubs		
Citrus medica	-	25
Cudrania cochinchinensis	-	1
Desmodium sp.	-	1
Elaeagnus sp.	-	10
Leea edgeworthii	-	1
Solanum torvum	-	31
Strobilanthus sp.	1752	0
Boehmeria sp.	40	12
Amblyanthus sp.	113	12
Climber		
Byttneria aspera	17	-
Combretum sp.	1	-
Fissistigma bicolor	1	-
Milletia sp.	6	-
Pothos scandens	2	-
Premna sp.	-	1
Roydsia suaveolens	1	-
Unidentified climbers	25	-

individuals per family, Commelinaceae followed by Bolibitidae and Chloranthaceae dominated the Altingia-mixed species stand (Table 8). In the Shorea-Dipterocarp stand, Musaceae and Chloranthaceae were dominating families. In the riverine Albizia stand Asteraceae dominated all other families in terms of number of individuals, followed by Thelypteridaceae and Athyriaceae. The species richness and density for herbs recorded maximum at Altingia-mixed species stand (29 species), followed by Shorea-Dipterocarp stand (17 species), and Albizia stand (16 species). The Albizia stand remained covered by *Mikenia mikrantha* during the monsoon months (July to September). The herbaceous species differed in their density at different stands (Table 8). Some epiphytes, terrestrial orchids (*Calanthe sp.*), and ferns (*Trigonospora cilliata*, *Athyrium asperum*, *Diplazium esculentum* etc) were also recorded at this stand. During rainy season the ground and major shrubs were covered by a thick blanket of a weed called *M. mikrantha*. The riverine Albizia stand despite being a open forest, was having low herbaceous population than other stands because the area was frequently under floods during monsoons that removed the ground flora.

Stand heterogeneity

The Menhinick's species richness index for trees, saplings, seedlings and herbaceous layers was estimated highest for Altingia-mixed species stand, followed by *Shorea-Dipterocarp* stand and minimum for Albizia stand (Table 9). The Shannon-Weiner diversity index (H) also recorded similar trend for different vegetation layers (Table 9). The concentration of dominance value was estimated low for Altingia-mixed species and *S. Dipterpcarp* stands than the Albizia stand, which showed that many species shared the dominance in former stands. In Albizia stand, however, only a few species showed their dominance.

Dominance-diversity curve

The dominance-diversity curves for the tree layer (on the basis of IVI) were drawn for all the three studied stands for eliciting the community organization in terms of resource share and niche space (Figure 6). The dominance-diversity curve for tree layer in Altingia-mixed species and the *Shorea-Dipterocarp* stands fits the log normal situation, whereas for Albizia stand it fits the geometric series. For the sapling layer as well the curves followed same patterns as for trees. However, the riverine Albizia forest stand showed a poor status of sapling and seedling (Figure 6).

Similarity Index

The similarity of trees, saplings and seedlings layers

Table 8. Herbaceous density (individuals/ha) of the three stands in the lowland tropical forests of Namdapha National Park.

Species	Family	*Altingia*-mixed species stand	*Shorea-Dipterocarp* stand	*Albizia* stand
Acanthus leucostachys Nees	Acanthaceae	260.42	0	0
Ageratum conyzoides L.	Asteraceae	0	0	1538.46
Alpinia sp.	-	0	0	576.92
Althia sp.	Malvceae	0	0	115.38
Amaranthus sp.	Amaranthaceae	0	0	38.46
Amphineuron immersum (Bl.) Holtt	Thelypteridaceae	0	0	2961.54
Athyrium asperum (Blume) Milde.	Athyriaceae	0	0	1115.38
Bidens pilosa	Asteraceae	0	0	115.38
Bolbitis heteroclite (Presl) Ching.	Bolibitidaceae	5000.00	1625.00	0
Calamus sp. (Hukabeth)	Arecaceae	104.17	125.00	0
Calamus sp. (Lejai beth)	Arecaceae	52.08	0	0
Calamus sp.(Beth)	Arecaceae	52.08	0	0
Chasalia sp.	-	156.25	0	0
Chloranthus elatior R.	Chloranthaceae	6458.33	1375.00	0
Cissus sp.	Vitaceae	2239.58	625.00	0
Collocasia sp.1	Araceae	52.08	0	0
Collocasia sp.2	Araceae	0	0	115.38
Crassocephalum crepidioides	Asteraceae	0	0	500.00
Diplazium esculentum (Retz.) Sw. Schrad	Athyriaceae	0	0	192.31
Elatastemma sessile Forst.	Urticaceae	52.08	375.00	0
Eugenofolia binectifida, Egenolfia bipinnatifida J. Sm.	Bolibitidaceae	1718.75	625.00	0
Forrestia sp.	Commelinaceae	16979.17	8125.00	0
Globba sp.	Zinziberaceae	312.50	0	0
Kharkaria loapani (local name)	-	677.08	0	0
Mikenia mikrantha	Asteraceae	0	0	14999.4
Musa sp.	Musaceae	156.25	1500.00	0
Peripinnate	-	520.83	125.00	0
Phrynium sp. (Koapat)	Marantaceae	104.17	0	0
Piper betleoides	Piperaceae	364.58	250.00	0
Piper rytidocarpum	Piperaceae	156.25	0	0
Piper sp.	Piperaceae	364.58	0	0
Piper sp.1	Piperaceae	0	0	576.92

Table 8. Contd.

Piper sylvaticum Roxb.	Piperaceae	1354.17	250.00	0
Ploygonum sp.	Polygonaceae	1562.50	125.00	0
Poaceae	Poaceae	0	0	269.23
Pteris biaurita L.	Pteridiaceae	364.58	250.00	0
Pteris semipinnata L.	Pteridiaceae	1718.75	0	0
Pteris sp.	Pteridiaceae	1822.92	500.00	0
Selaginella sp.	Selaginellaceae	364.58	1250.00	0
Trigonospora cilliata (Wall. ex Benth.)	Thelypteridaceae	0	0	2115.38
Urticia dioca	Urticaceae	0	0	192.31
Zalacca secunda	Araceae	0	250.00	0
Zinziberaceae	Zinziberaceae	104.17	0	0
Unidentified climber	-	156.25	125.00	0
Unidentified sp. 1	-	0	0	38.46
Unidentified Spiny sp	-	52.08	0	0
Total		43281.13	17500.00	10461.51

between Altingia-mixed species stand andShorea-Dipterocarp stand was estimated 28.19, 33.33 and 14%, respectively (Table 10). Between Altingia-mixed species and Albizia stands it was recorded 4.35, 4.17 and 0%, respectively, for trees, samplings and seedling layers; while between Shorea-Dipterocarp and Albizia stand, the same value was 11.94, 6.67 and 0% for respective layers (Table 10). The overall similarity showed that all the three stands were quite distinct, and it was more marked between tropical evergreen and semi-evergreen forests.

DISCUSSION

Baseline information on forest inventories, resource assessment and status are prerequisites for long-term planning and strategy development for management of any forest stand (Magurran, 2004). Arunachal Pradesh has nearly 11.44% of its total area under protected area network (Ringu, 2002). The state also has other legal forest categories, such as Reserve Forests with nearly 11.61% area and Unclassed State Forests (USF) with 36.91% area. Namdapha National Park with an area of 1985 km^2 forms 20.71% of the total protected area of the state. It comprised 1119 species of plants of which 674 were angiosperms with 60 to 70% of the state's total floral wealth (Chauhan et al., 1996). The park has all major forest types of the region and also had floral and faunal affinities with other northeastern states, Indo-Malayan, Indo-Chinese and oriental regions (Chauhan et al., 1996; Deb and Sundriyal, 2005). Therefore, the park deserves significant conservation measures, which is often jeopardized due to lack of information on floristic composition, species structure, and dominance-diversity relationship. The RS/GIS study was used for the first time to map buffer zone of the park. The RS/GIS reconnaissance of the buffer zone area (177.425 km^2) of Namdapha National Park revealed species rich and diverse tropical wet evergreen forests extended over 80% land area while open forest on 7% area. It also has a small area (<1%) under semi-evergreen riverine forest. Besides, considerable area also falls under grasslands (7%) and river sand (4%). Of three studied stands in this investigation, two comprised tropical wet evergreen forests, which are reported of restricted distribution in revised classification (Kaul and Haridasan, 1987). The landuse map of the buffer zone could also be used for future monitoring of the area, thus may play a leading role for management and conservation of this highly diverse park. The Tropical wet evergreen forest

Table 9. Stand heterogeneity (species richness, species diversity and concentration of dominance) of three studied forest stands in the buffer zone of Namdapha National Park, Arunachal Pradesh.

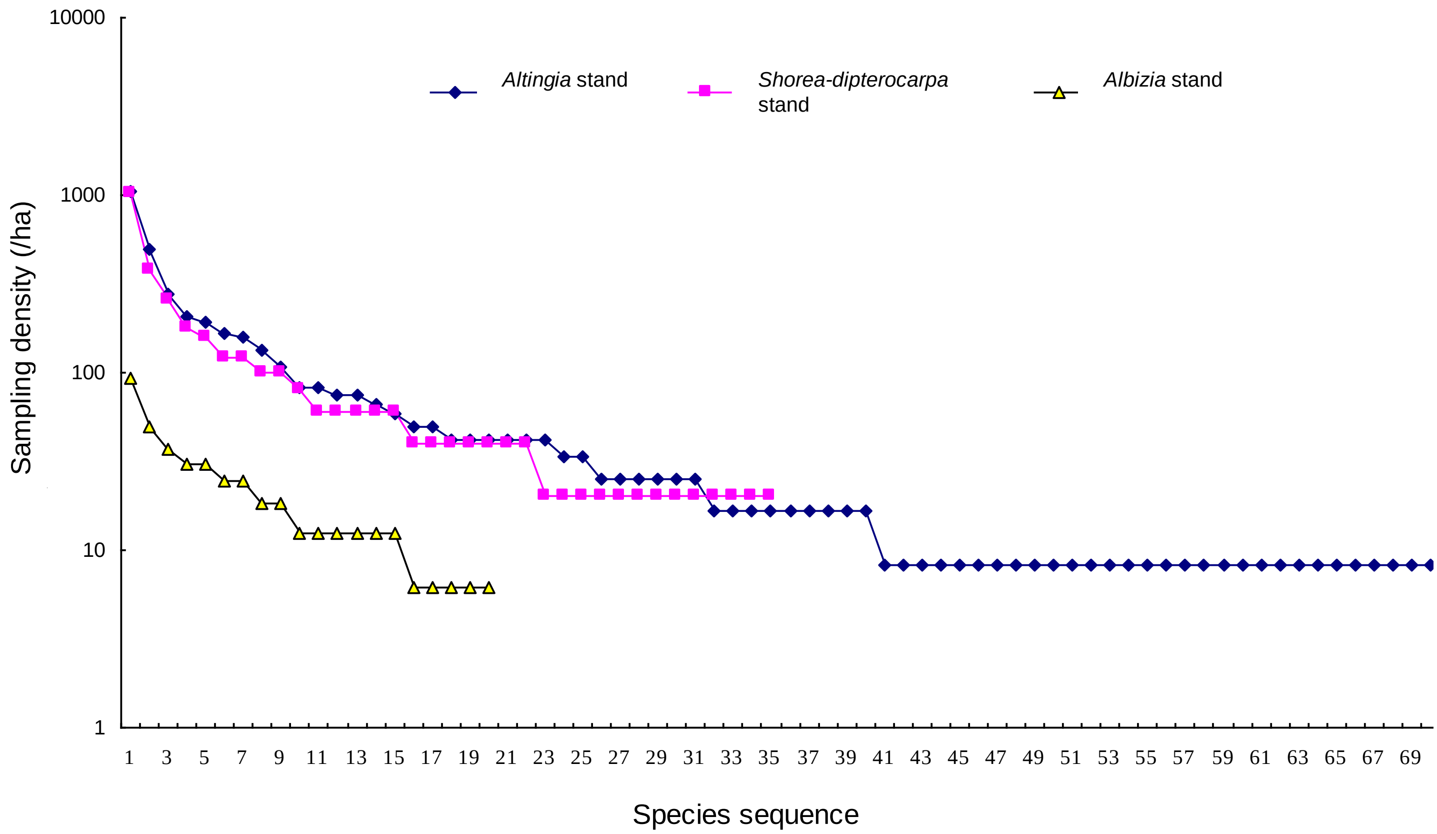
Parameter	Forest stands		
	Altingia-mixed species	*Shorea-Dipterocarp*	*Albizia*
Species richness (Menhinnick index)			
Tree	4.79	2.73	1.27
Sapling	1.17	0.55	0.81
Seedling	0.36	0.17	0.15
Herb	0.14	0.13	0.10
Species diversity (Shannon-Weiner index)			
Tree	3.85	3.55	1.71
Sapling	3.29	2.69	2.35
Seedling	2.54	2.36	1.04
Herb	2.18	1.98	1.54
Concentration of dominance (Simpson index)			
Tree	0.044	0.042	0.31
Sapling	0.08	0.11	0.09
Seedling	0.17	0.13	0.37
Herb	0.20	0.25	0.37

showed high species richness and also a tiered forest structure. The emergent top canopy (A stratum) included *D. macrocarpus*, *S. assamica*, *A. excelsa*, *A. grandis* and *T. myriocarpa*. The Riverine semi-evergreen forests occur along river banks, riverine plains and swamps forming a narrow belt, the trees were mostly deciduous, lack a dense canopy, and categorized as 3C/C3b East Himalayan moist deciduous forests and 3/1S2 Eastern Hollock forests (Champion and Seth, 1968).

The tropical evergreen forests under this investigation exhibited similar feature as those of 'Lowland evergreen tropical rainforest formation' sensu Whitmore (1998) and Proctor et al. (1998). The top canopy species were 25 to 40 m high consisting *B. ceiba*, *A. procera*, *A. grandis*, and *T. myriocarpa*. There were distinct middle and lower canopy species. Besides, the woody climbers were abundant and trees comprise considerable epiphytic loads. Such distinct stratification of the vegetation is well reported for other tropical evergreen rainforests as well (Whitmore, 1998; Richards, 1996; Sist and Saridan, 1988; Swamy et al., 2000; Wilkie et al., 2004). Buttresses are common features in Dipterocarp rainforests. In this study A. excelsa contributed 55% of total buttressed stems, which was similar to other Dipterocarp lowland evergreen rainforests (Whitmore, 1998).

For the three sampled plots altogether 198 species (trees, shrubs and herbs) in 151 genera and 74 families were recorded. Such high diversity of tree and other species within the sampled area represent about 34% of total floral species and 50% of total tree species of Namdapha National Park, which is significant. The tree species richness of 98, 54 and 20 species in the three studied stands was close to the richness recorded in various parts of western Ghats (Ganesh et al., 1996; Elouard et al., 1997; Swamy et al., 2000), Amazonian forest (De Oliveira and Mori, 1999), neotropical forests (Zent and Zent, 2004), and Peninsular (Kochummen et al., 1990). 31 species were not identified to genera or species levels though they were clearly different specimens, such species categorized as morphospecies (Proctor et al., 1983; Wilkie et al., 2004). There is inherent problem of identification of the tropical trees because of sporadic flowering and fruiting, which take several years for many species as well as difficulty of collecting material from some tall trees (Whitmore, 1998; Wilkie et al., 2004). Altogether, the floristic richness of Namdapha National Park reveals 674 species of flowering plants of which 266 were reported as tree species (Chauhan et al., 1996).

All enumerated tree species in the present study belonged to 44 families (range 16 to 32), which falls well within the range of 16 to 58 families found in other tropical forests (Campbell et al., 1992; Pascal and Pelissier, 1996; Parthasarathy and Karthikeyan, 1997; Swamy et al., 2000). Our values are higher than 36 families recorded for Haldibari area (Proctor et al., 1998) and for core and other neighboring areas (27 families) of Namdapha National Park (Nath et al., 2005). The difference in family wise distribution may be attributed to heterogeneity in the habitats of the park. When all individuals (seedling, sapling and adult trees) of tree species of the families Lauraceae, Dipterocarpaceae,



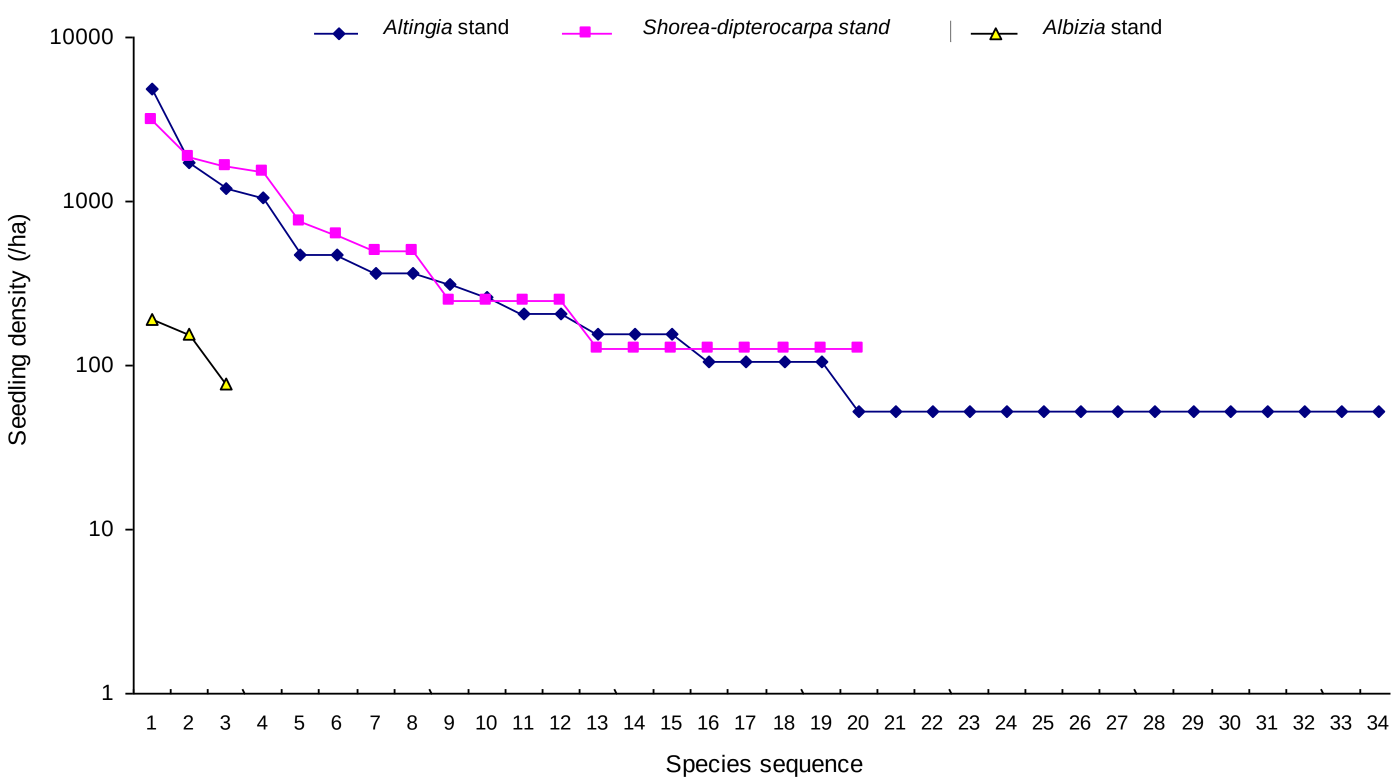


Figure 6. Density-Dominance curve for the saplings (<31.4 cm CBH and height > 20 cm) (top graph) and seedlings (< 20 cm) (lower graph) for *Altingia* mixed, *Shorea-Dipterocarp* and *Albizia* stands.

Table 10. Comparison of Sorensen's similarity index of tree, sapling, seedling and herb components in the three forest stands.

Stands	Trees	Saplings	Seedlings	Herbs
*Altingia-m*ixed species stand and *Shorea-Dipterocarp* stand	28.19	33.33	14	96.96
Altingia Mixed stand and *Albizia* stand	4.35	4.17	0	0
Shorea-Dipterocarp stand and *Albizia* stand	11.94	6.67	0	0

Euphorbiaceae, Fagaceae and Leguminosae are combined together, it exhibited a high number of species and reveals that the forest comprises the attributes of lowland evergreen tropical rainforests (Whitmore, 1998; Proctor et al., 1998).

The tree density of *Shorea-Dipterocarp* and Altingia-mixed stand (390 and 418 tree ha^{-1} respectively) is within the range of 300 to 700 tree ha^{-1} for tropical rainforests (Richards, 1996). The total tree basal area (45 to 49 m^2 ha^{-1}) was also within the range recorded for tropical forests of south-east Asia (25.2 to 67.4 m^2 ha^{-1}) (Newbery et al., 1992; Swamy et al., 2000), however our values were lower than forests of Silent Valley (Singh et al., 1981), Southeast Asian rainforests (Proctor et al., 1998; Manokaran and LaFrankie, 1990; Newbery et al., 1992), Peninsular forests (Manokaran and LaFrankie, 1990), Malaysian rainforest (Proctor et al., 1983; Sist and Saridan, 1998) and neotropical forests (Knab-Vispo et al., 1999; Zent and Zent, 2004).

An analysis of the IVI of species can be used to recognize the dominance pattern of different species in a community (Parthasarathy and Karthikeyan, 1997). A. excelsa dominated the Altingia-mixed species stand, while *O. paniculata*, *D. macrocarpus*, *T. hodgsonii*, *Dysoxylum procerum* were co-dominant species in this stand. In *Shorea-Dipterocarp* stand, *Dipterocarpus macrocarpus* was the most dominant followed by *Shorea assamica*, *Terminalia myriocarpa*, *A. excelsa*, *D. grandiflora*, *C. tribuloides*. At Albizia stand, *A. procera* was the dominant species all through the riverine area.

As many as 91, 83 and 85% species in three studies stands, respectively, had fewer than 10 individuals, while 35, 22 and 50% species had ≤ 2 individual ha^{-1} thus showing high species rarity. For tropical rainforests tree species rarity is a common feature (Whitmore, 1998). Species rarity also underlines the need to conserve such forests as reserves. At Western Ghats nearly 60-63% species showed rarity at local level (Swamy et al., 2000). Our values of species rarity are higher than those of tropical forests of Malaysia (8%) (Poore, 1968), and similar to those of Peninsular region (40%) (Manokaran and Kochumnen, 1987) and South India (26 to 61%) (Parthsarathy and Karthikeyan, 1997).

With increasing DBH size the stem density decreased, which is perhaps an important characteristics of the primary forests where large trees, though very few in density, comprised considerable share of total basal cover. The differences in mean tree density and basal area were low between two stands of tropical evergreen forest. However, it varied markedly high between the evergreen and semi-evergreen stands.

The structural pattern of the different stands showed a heterogeneous distribution of trees and can be considered as one of the highly diverse forests in the Eastern Himalaya (Bhuyan, et al., 2003). The Shannon-Weiner diversity index is generally high for tropical forests, ranging from 0.81 to 4.1 for the Indian subcontinent (Bhuyan et al., 2003; Singh et al., 1984; Swamy et al., 2000). The diversity index values of the present study (1.71 to 3.85) are within the earlier reported range. Within studied stands, it was recorded higher for tropical evergreen stands than semi-evergreen stand. Our values are lower than those reported for young (H=5.06) and old (H=5.4) tropical forest stands of Barro Colorado Island, Panama (Knight, 1975).

The overall liana density was 53 individuals ha^{-1}, and nearly 8% trees carried them. *Buettneria aspera* was major contributor to the density and a few individuals could reach to >30 cm CBH at Altingia-mixed species stand. At Sabah, Malaysia, large numbers of lianas (range 833 to 929 individuals ha^{-1}) have been reported that are carried by 54 to 61% trees (Campbell et al., 1992), 391 to 440 lianas ha^{-1} are reported from Sarawak, Malaysia (Proctor et al., 1983; Newbery et al., 1992). For humid tropical forests of south India, 273 to 1015 lianas and climbers ha^{-1} were recorded and carried by 1 to 14% trees (Swamy et al., 2000). The high number of lianas in a forest stand is a reflection of the opening of canopy in the past (Newbery et al., 1992). In Namdapha National Park, the forest gaps were few and small which can explain the low density of liana at this site (Deb and Sundriyal, 2007). Climbers and lianas are conspicuous feature of almost all rainforest and compete actively with the trees for light and space.

Dominance-diversity has inverse relationship and if the dominance increases the diversity decreases (Maguran, 2004). The dominance-diversity figure for the tree layer in the Altingia-mixed species and the Shorea-Dipterocarp stand fits the Preston's log normal distribution, which reveals that the community niche space was substantially partitioned by large number of species (Sugihara, 1980). For Albizia stand figure represents the geometric series which corroborates the niche preemption hypothesis that is supposed to be commonly applicable for species poor stands with a dominance of one or few species only (Whittaker, 1975). The lognormal forms are common in mixed type of communities (Whittaker, 1975; Upreti et al., 1985). The concept of dominance plays an important part in theories on plant strategies and competition/ co-existence mechanisms.

The similarity index (Sorensen, 1948) was also assessed to understand the commonality of species occurrence between different stands. The difference in species similarity among different forest stands may be due to the varied microclimate, habitat conditions and soil factors which may support different species composition in studied forests

Implications for management

The tropical forests of the world are increasingly being affected by human activities (Proctor et al., 1983; Newbery et al., 1992; Swamy et al., 2000). Therefore, an investigation of such forests for analysis of different components of biodiversity and their quantification has high implications for forest management. This study presented data from Namdapha National Park, Northeast India and revealed that the lowland tropical evergreen forests were highly diverse and well comparable to other similar forests of the globe. These forests comprised a large number of species that were rare at local level, however they contributed significantly to the stand diversity. On the contrary, the diversity of lowland tropical semi-evergreen forest was low, most species had successional status. All forests, however, showed an evolving population. The information on these forests has high implications for conservation, As most of the forests surrounding Namdapha National park are depleting fast because of community pressure, logging, and habitat alteration (Deb and Sundriyal, 2005). the management planning for the park must take into account the rich diversity of the buffer zone comprising best timber and other utility tree species including dipterocarp species. Availability of such species may attract community attention in near future; therefore maximum vigil is required at this site so as to avoid any outside disturbance. This highlights the need to investigate community resource dependency and their linkages with the park so as to improve the management of such primary forest stands everlastingly. It is also reported that a few weed species are invading at the park boundary, particularly nearby the Albizia stand. It is expected that such proliferation of alien weed species may extend to the other parts of the park in near future when resources in the nearby forests are depleted. Such kind of perturbation in the ecosystem may result in alteration of the structure of the biological community and proliferation of noxious weeds (Ramakrishnan, 1992). Therefore, assessing patterns of vegetation cover, species accumulation, richness and diversity, commonness and rarity, plant family expression, forests diameter class structure, and tree, shrub and herb composition are key parameters to determine ecosystem stability, and such information is useful in management as well as restore the health of bioresources in forest stands. This calls for further analysis of broad patterns of species distribution across different vegetation covers and landscapes types in biodiversity rich areas. Since the information on biodiversity characterization is meager in northeast India, particularly in protected areas (Proctor et al., 1998; Bhuyan et al., 2003; Nath et al., 2005), it is suggested that more and more area be investigated as it will open now intricacies of biodiversity in the area.

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Appendix I. Importance Value Index (IVI) of tree species in the three studies forest stands at the buffer zone area of Namdapha National Park, Arunachal Pradesh.

Species	*Altingia*-mixed species stand	*Shorea-Dipterocarp* stand	*Albizia* stand
Altingia excelsa Noronha	51.72	15.10	-
Ostodes paniculata Bl. Bigdr	23.55	13.05	-
Talauma hodgsonii Hk.f & Th.	10.60	3.80	2.25
Dipterocarpus macrocarpus Vesque	10.30	24.26	-
Dysoxylum procerum Hiern	8.04	4.07	-
Schima wallichii (DC) Korth	7.24	5.17	-
Chisocheton paniculatus (Roxb.) Hiern.	6.74	1.96	-
Leea indica (Burn.f. &) Merr	6.29	9.04	-
Saprosma ternatum Hk.f	6.02	5.97	-
Syzygium cumini (Linn.) Skeels	6.01	3.06	-
Dysoxylum binectariferum Hk.f. et. Bedd.	5.89	-	-
Syzygium macrocarpum (Roxb.) Balak.	5.18	-	-
Cinnamomum bejolghota (Buch-Ham) Sweet	5.08	-	-
Duabanga grandiflora (Roxb ex DC.) Walp.	5.00	10.04	-
Terminalia myriocarpa Heurck & Muell-Arg	4.55	23.81	9.64
Ficus sp. 2	4.18	-	-
Baccaurea ramiflora Lour	4.00	12.84	-
Bridelia assamica Hk. f.	3.63	-	-
Michelia oblonga Wall. ex. Hk.f &Th.	3.51	2.40	-
Cedrella toona Roxb. ex. Roth	3.49	-	-
Micromellum sp.	3.46	-	-
Litsea salicifolia (Roxb. ex. Nees) Hk. f.	3.30	-	-
Cinnamomum glaucescens (Nees) Meissn	3.27	-	-
Elaeocarpus aristatus Roxb	3.19	8.19	-
Euonymus sp. 2	2.67	-	-
Castanopsis indica (Roxb.) A. DC.	2.55	13.71	-
Miliusa roxburghiana (Wall) Hk.f & Th.	2.51	-	-
Mesua ferrea Linn.	2.44	-	-
Aphania rubra (Roxb.) Radlk.	2.34	-	-
Castanopsis tribuloides (Smith) A. DC.	2.28	1.87	-
Griffithianthus fuscus Merr.	2.27	5.78	-
Antidesma acuminatum Linn.	2.25	-	-
Beilschmiedia sp.	2.14	-	-
Milletia sp.	2.10	-	-
Laportea pterostigma Wedd.	2.08	-	-
Castanopsis sp. 3	1.96	4.62	-
Shorea assamica Dyer	1.70	23.66	-
Styrax serruletum Roxb	1.66	-	-
Pterygota alata (Roxb.) R. br.	1.48	-	-
Macropanax dispermus (Bl.) O. Ktze	1.43	-	-
Euonymus sp. 1	1.32	-	-
Diospyros sp.	1.28	-	-
Murraya paniculata (Linn.) Jack	1.26	-	-
Knema angustifolia (Roxb.) Warb.	1.23	-	-
Lasianthus longicauda Hk. F.	1.23	-	-
Persea sp.	1.16	-	-
Magnolia sp. A	1.15	-	-
Premna sp.2	1.12	-	-

Appendix I. Contd.

Cinnamomum sp.	1.11	-	-
Ficus sp. 1	1.09	-	-
Olea dentata Wall ex DC	1.08		-
Beilschmiedia assamica Meissn.	1.07	-	-
Quercus Semiserrata Roxb.	1.04	-	-
Canarium strictum Roxb.	1.03	-	-
Elaeocarpus sp.	1.03	-	-
Linociera macrophylla Wall. ex. DC	1.03	-	-
Meliacecae	1.03	-	-
Premna sp.	1.02	-	-
Aporosa dioica (Roxb.) Muell-Arg	1.01	4.97	-
Croton roxburghii Balakr.	1.01	-	-
Ficus sp. 3	1.01	-	-
Lindera latifolia Hk. f.	1.01	-	-
Magnolia griffithii Hook.f.& Thomson	1.01	-	-
Pterospermum lancifolium	1.01	-	-
Quercus lamellosa Smith	1.01	-	-
Saurauia cerea Griff. ex Dyer	1.01	-	-
Styrax sp.	1.00	-	-
Actinodaphne obovata (Nees) Bl.	-	6.30	-
Ailanthus grandis Prain	-	3.19	0.97
Alangium *chinense* (Lour) Harms	-	-	1.17
Albizia procera (Roxb.) Benth	-	-	155.30
Bischofia javanica Bl.	-	6.60	-
Bombax ceiba avet. non Linn	-	-	25.05
Callicarpa arborea Roxb.	-	2.18	2.74
Capparis acutifolia (Hook. f. & Thomson) Jacobs.	-	2.40	-
Castanopsis sp. 4	-	7.33	-
Cordia dichotoma Forst. f.	-	-	0.97
Dalbergia pinnata (Lour.)Prain	-	-	36.67
Dalbergia sericia G. Don	-	-	24.19
Dillenia indica Linn.	-	2.25	-
Dysoxylum sp.	-	7.60	-
Ehretia acuminata R. Br.	-	-	1.36
Engelhardtia spicata Leschen ex Bl. Bigdr	-	-	1.43
Eriobotrya bengalensis Hk. f.	-	3.97	-
Erythrina stricta Roxb.	-	-	2.71
Glochidion lanceolarium (Roxb.) Voigt	-	-	10.28
Gmelina arborea Roxb.		-	15.06
Grewia disperma. Roxb.	-	-	1.00
Helicia robusta Wall ex Benn	-	2.60	-
Lindera sp.	-	6.37	-
Litsea monopetala (Roxb.) pers	-	-	1.89
Litsea sp.	-	2.65	-
Maesa indica (Roxb.) Wall	-	-	1.16
Magnolia sp. B	-	6.33	-
Melia dubia Cavv.	-	-	1.76
Pterospermum acerifolium Willd.	-	1.86	-
Quercus sp.	-	2.69	-
Syzygium sp.	-	3.72	-

Appendix I. Contd.

Terminalia chebula Retz.	-	3.45	-
Unidentified*	42.53	31.12	4.40