TREE DIVERSITY AND POPULATION STRUCTURE IN A LOWLAND TROPICAL RAINFOREST IN THE EASTERN HIMALAYA, INDIA

PANNA DEB, R. C. SUNDRIYAL* AND UMA SHANKAR**

G.B. Pant Institute of Himalayan Environment and Development, North East Unit, Itanagar (Arunachal Pradesh).

Introduction

The world vegetation cover under natural forests has been depleting fast and is being replaced by secondary forests or is being denuded completely (Whitmore, 1990). The large scale loss of primary forests, particularly in lowland tropical areas, has been observed at a time when knowledge on their structure and dynamics is woefully inadequate (Hubell and Foster, 1992; Maguran, 2004). The lowland rainforests are the most 'species rich terrestrial ecosystems' in the tropics of Southeast Asia (Whitmore, 1996). They are widely distributed from Myanmar to the pacific islands and extend to continental Asia from Thailand to south China and to northeast India. The northeastern region of India, which is a global hotspot of biodiversity, has the tropical rainforests farthest from the equator (Myers *et al.*, 2000; Proctor *et al.*, 1998). Unfortunately, anthropogenic interference and infrastructural developments during last few decades have seen a major transformation of once pristine landscapes in this region, which highlights the need to undertake ecological studies in pristine patches in remaining rainforest areas (IIRS, 2002; Chettri *et al.*, 2005). A 'Gap analysis exercise' conducted by the WWF's Ecoregion Based Conservation Programme (ERBC) identified many unexplored regions of high significance in the northeastern region of India (Anon., 1995; Chauhan *et al.*, 1996). The famous Namdapha National Park in the eastern Arunachal Pradesh also falls in this category (Deb and Sundriyal, 2005). The park is amongst the most diverse and largest relict patches of rainforests in the region falling in the Indo-Burma mega-hotspot of biodiversity that is also considered an Eastern Asiatic Regional Centre of high diversity and Endemism (Anon., 1995). The management of the park, however, is constrained because of lack of information on the structural and functional aspects of the diverse primary forest stands. To date the park remains unexplored except for a preliminary floristic study (Chauhan *et al.*, 1996). Considering this a detailed investigation was made to analyze its tree species composition, diversity and population structure in the undisturbed tropical lowland forest communities of the Namdapha National Park with a view that such an information would be helpful to planners and managers for conservation of the rich biodiversity of the area, which can act as gene pool reservoir in the coming years.

Study Area

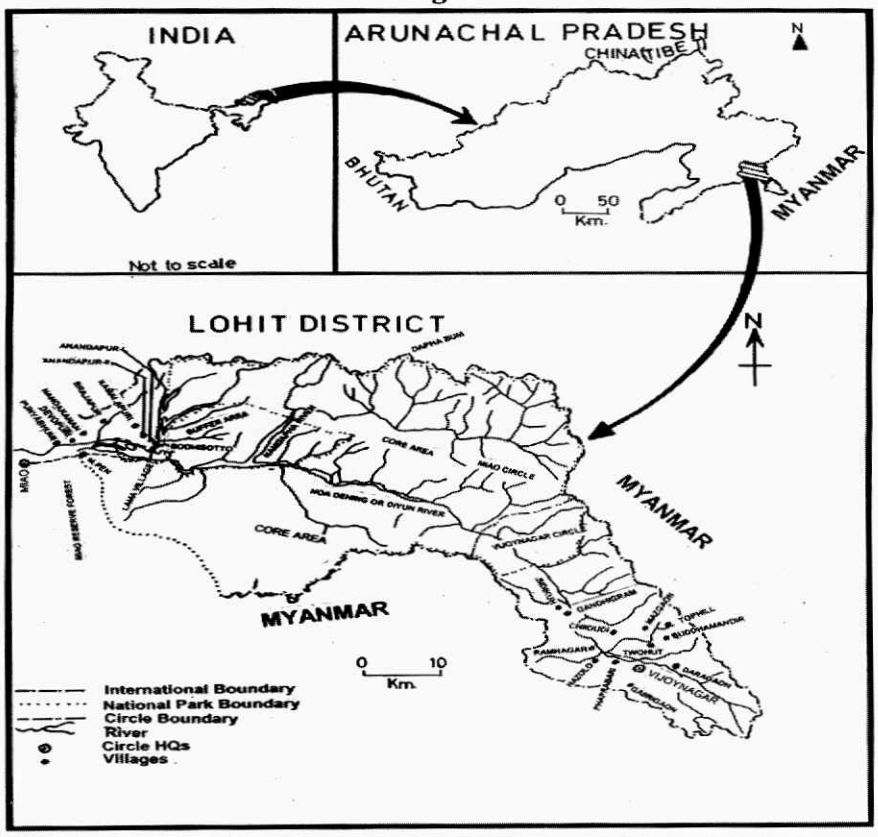
The Namdapha National Park (27°23´ to 27°39´ N and 96°15' to 96°58´ E) is located in the Changlang District, Arunachal Pradesh. To the south and east, the park is bordered by Myanmar, while the northern side has a common boundary with the Kamlang Wildlife Sanctuary of Lohit district in the north. The total area of the park is 1985.245 km^2, consisting of 1807.82 km^2 in core zone and 177.425 km^2 in buffer zone. Noa Dehing is the main river of the park. Namdapha is probably the only protected area in the world encompassing as great variation in altitude as 200 to 4,571 m. Biogeographically, the area falls under the Eastern Himalayan zone of India, which covers the Paleartic and the Indo-Malayan realms (Rodgers and Panwar, 1988).

The study area exhibits tropical climate having typical monsoon pattern with rainy season extending from May to September. The period from October to November, December to February, and March to April represents autumn, winter and spring seasons, respectively. The rainfall, average temperature and relative humidity for Namdapha National Park are presented in Fig. 1. The area receives an average annual rainfall of 2500-3000 mm of which nearly 85% is received during the monsoon season. At times the rainy months prolongs up to 9 month in a year. Occasional showers during off season are also not uncommon in this part of the country. Humidity remains very high throughout the year.

Geologically, the park area is of recent origin and owes its formation to the upheaval of the Himalaya in the Pleiocene period of the tertiary age (Chauhan *et al.*, 1996). Soils are characterized by a loamy surface layer of considerable depth and texture, with colour varying from yellowish to reddish and pH acidic. A deep layer of sandy loam, rich in vegetative matter, supports best growth of dipterocarp forests in the lower and gentle slopes of

*G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora, Uttarakhand
**Department of Botany, North-Eastern Hill University, Shillong, Meghalaya (India)

Fig. 1



Location map of Namdapha National Park, Arunachal Pradesh, India

the area. Freshwater alluvium on flat lands along stream banks supports leguminous trees. The soil characteristics of the study sites are given in Table 1.

Methods

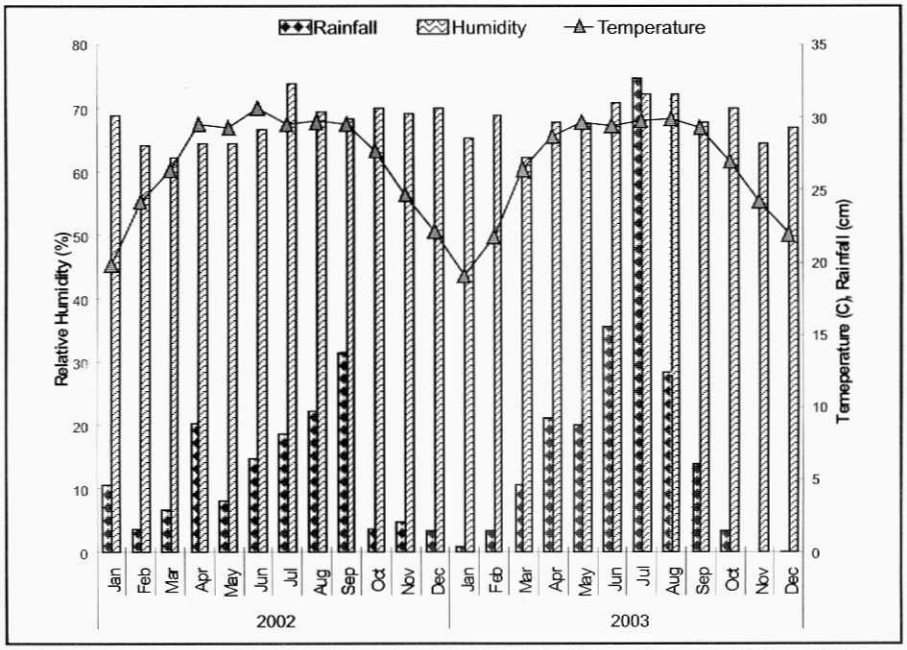
Two stands in south bank tropical wet evergreen (*Dipterocarpus*) forest type (*Altingia*-mixed species stand and *Shorea-Dipterocarp* stand) and one in riverine semi evergreen forest (*Albizia* stand) (Kaul and Haridasan, 1987) were selected for assessing species composition, association, diversity and tree population structure in the buffer zone area of Namdapha National Park. In each stand 20 m wide and 50 m long transects (0.1 ha) were laid starting 50 m inside the forest trail to avoid any outside interference. Each transect was further sub-divided to four 25x10 m quadrates for detailed study. The transects were placed randomly at different locations using grid maps to cover most of the species under different canopy covers. A total of 12, 10 and 18 transects were studied in the *Altingia*-mixed species, *Shorea-Dipterocarp* and *Albizia* stands, respectively. The transects were laid along a gentle gradient between 300-600 m elevation amsl. All individuals $\geqslant$ 10 cm dbh (diameter at breast height, i.e. 1.3 m above ground) were enumerated as trees, marked with an aluminum tag and their location in the plot to the nearest meter was mapped (Sundriyal *et al.*, 1994; Sundriyal and Sharma, 1996; Uma Shankar, 2001). Voucher specimen of all species were collected and identified at State Forest Research Institute, Itanagar and Botanical Survey of India, Itanagar. Individuals with buttresses or other irregularities at breast height were measured just above the buttresses. The species richness was simply the number of species per unit area (Whittaker, 1975). Tree species falling in different quadrates were added to present a cumulative species area curve for the tree layers in different forest stands. The dominance-diversity curve was plotted to assess species niche separation and partitioning of community resources using IVI for trees (Whittaker, 1975; Kent and Coker, 1994). The data were analyzed for density and basal area of each species (Curtis and McIntosh, 1950). The importance value index (IVI) of each species was computed by summing up the relative density, relative frequency and relative dominance (Sundriyal and Sharma, 1996). The Shannon and Wiener diversity index (Shannon and Wiener, 1963) was calculated following Maguran (2004).

$$H=-\sum pi \ln pi$$

Where, pi is the proportion of the ith species and the number of individuals of all the species (ni/N).

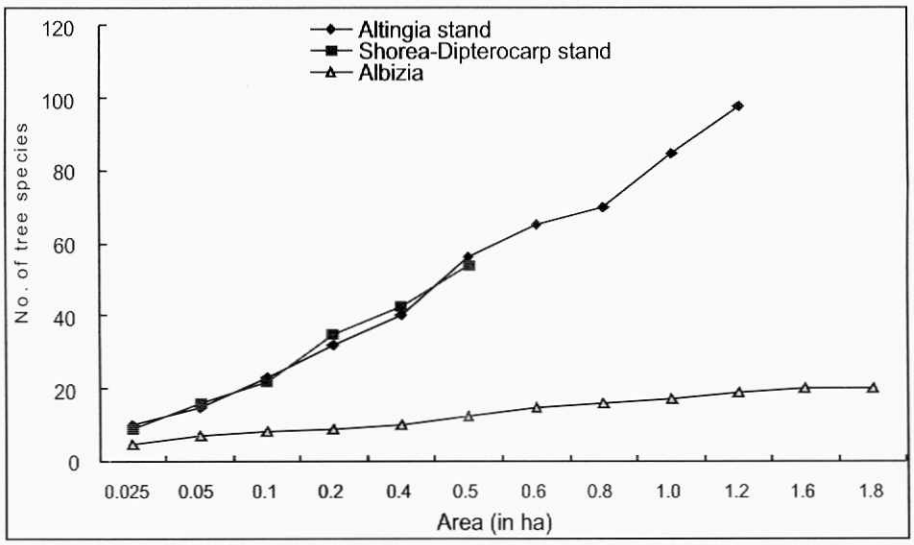
Simpson's index (Simpson, 1949) measured the concentration of dominance (CD):

Fig. 2



Climatic condition at Namdapha National Park (Deban Range) during 2002 and 2003.

Fig. 3



Species-area curve showing cumulative increase in number of tree species with >10 cm dbh in the three studied stands of Namdapha National Park, Arunachal Pradesh

$$CD = \sum pi^2$$

Where, *pi* is the same for the Shannon-Weiner information function.

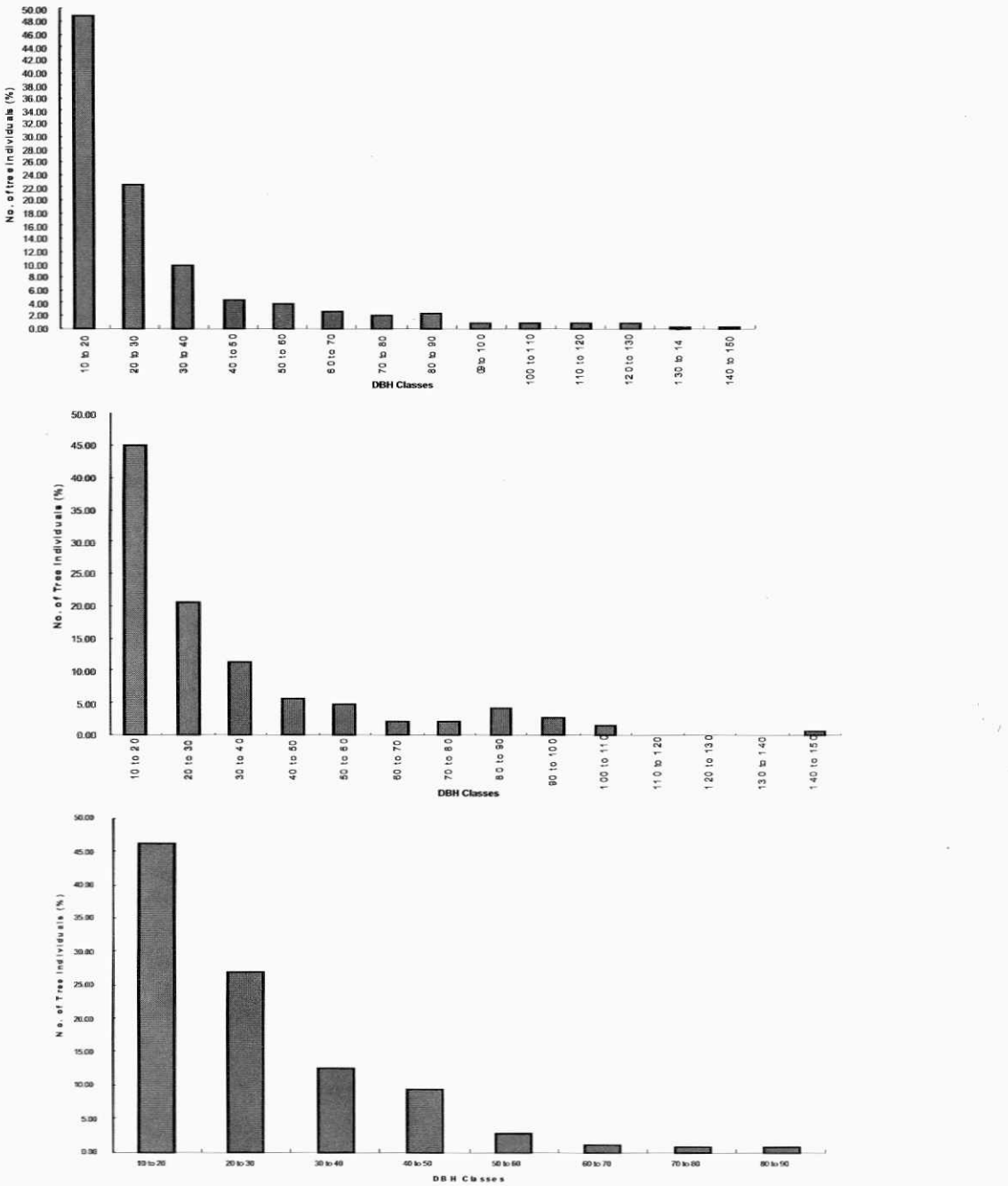
The dbh of all trees was measured for interpreting population structure (Sundriyal *et al.*, 1994; Sundriyal and Sharma, 1996). Based on tree diameter at breast height, individual tree species were separated into 8 classes (10-20, 21-30,.....>150 cm). The density in each diameter class in each stand was presented by adding seedling and saplings of important species and all other species for each stand.

Results

Tree species richness, genera and families in forest stands

A comparative account of the three forest stands of the buffer zone area of Namdapha National Park is presented in Table 1. A total of 130 species varying in 75 genera and 44 families were recorded from all the three stands studied. Of these, *Altingia*-mixed species stand had 98 species in 54 genera and 31 families, *Shorea-Dipterocarp* stand comprised 54 species in 34 genera and 22 families and *Albizia* stand

Fig. 4

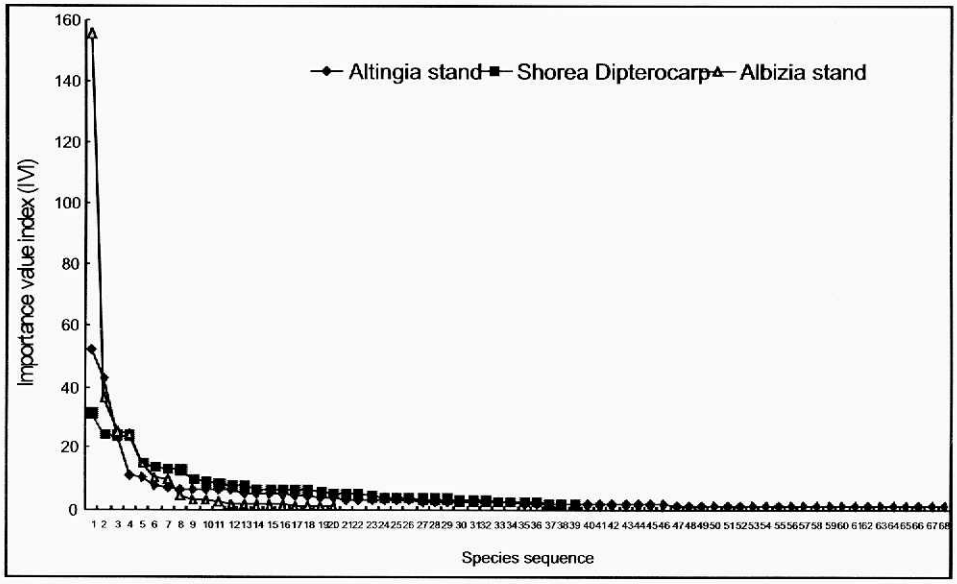


Diameter distribution of individuals >10 cm dbh in *Altingia*-mixed species stand (a) *Shorea-Dipterocarp* stand (b), and *Albizia* stand (c).

recorded 20 species in 19 genera and 15 families (Table 1). In *Altingia*-mixed species stand 11 families were represented by more than one genus and 21 by a single species. In *Shorea-Dipterocarp* stand 7 families included more than one genus while 16 had one genus. In *Albizia* stand, 3 families were represented by more than one genus and the remaining 12 by a single genus. Tree species rarity with greater number of singletons at a site, which contributed significantly to the stand diversity, seems to be an important characteristic of the evergreen forest stands.

In *Altingia*-mixed species stand, Euphorbiaceae had the maximum number of individuals (19.54%) of dbh >10 cm, followed by Meliaceae (9.72%) and Hamamelidaceae (8.50%) (Table 2). *Shorea-Dipterocarp* stand was dominated by the individuals belonging to Dipterocarpaceae (18.46%), Euphorbiaceae (17.44%) and Fagaceae

Fig. 5



Density-dominance curve for the tree layer (>10 cm dbh) of three stands of the buffer zone of Namdapha National Park

(6.67%). Leguminosae (74.65%) was the dominant family in the *Albizia* stand, followed by Verbenaceae (8.54%) and Bombacaceae (7.49%). Including seedlings and saplings together with mature trees showed dominance of Lauraceae and Euphorbiaceae in the *Altingia*-mixed species stand, Dipterocarpaceae and Euphorbiaceae in the *Shorea-Dipterocarp* stand, and Leguminosae in the *Albizia* stand (Table 2).

Tree species density, basal area and dominance

Overall stand tree density (dbh >10 cm) was highest in the *Altingia*-mixed forest stand (418 trees ha^{-1}), followed by the *Shorea-Dipterocarp* stand (390 trees ha^{-1}), and minimum in the *Albizia* stand (245 trees ha^{-1}) (Table 3). However, the basal area was highest in the *Shorea-Dipterocarp* stand (49.7 m^2 ha^{-1}) followed by the *Altingia*-mixed stand (45.5 m^2 ha^{-1}) and minimum in the *Albizia* stand (18.3 m^2 ha^{-1}) (Table 3). *Altingia excelsa, Terminalia myriocarpa and Albizia procera* recorded highest basal area in the *Altingia*-mixed species, *Shorea-Dipterocap*, and *Albizia* stands, respectively (Table 1). The data showed that the differences in mean tree density and basal area were low between two lowland tropical evergreen forests stands, it however varied markedly between lowland tropical evergreen and semi-evergreen stands.

The *Altingia*-mixed species stand was dominated by *Altingia excelsa* (35 trees ha^{-1}), *Dipterocarpus retususs* (18 trees ha^{-1}) and *Ostodes paniculata* (63 trees ha^{-1}) (Table 1). The *Shorea-Dipterocarp* stand was dominated by *Dipterocarpus retusus* (40 trees ha^{-1}) and *Shorea assamica* (36 trees ha^{-1}). The *Albizia* stand was dominated by *Albizia procera* (126.2 trees ha^{-1}) (Table 3).

Species area curve

The tree species accumulation curve drawn for different stands showed that the species accumulation increased linearly with increasing area of the sampling in lowland tropical evergreen forest stands (*Altingia*-mixed species stand and *Shorea-Dipterocarp* stand) and a asymptote was not reached in any of the two studied evergreen stands (Fig. 2). Contrarily, the riverine semi evergreen forest stand (*Albizia* stand) showed asymptotic pattern from 6000 m^2 area onwards.

Tree species diversity and concentration of dominance

The Shannon-Weiner diversity index value was highest for the *Altingia-mixed* species stand (3.85), followed by *Shorea-Dipterocarp* stand (3.55), and minimum in *Albizia* stand (1.71) (Table 1). The Concentration of Dominance (CD) was 0.044 in *Altingia-mixed* stand, 0.042 in the *Shorea-Dipterocarp* stand and 0.305 in *Albizia* stand, which shows that many species shared dominance in first two stands, but only a few in the latter stand (Table 1).

Population structure

The distribution of individuals in different dbh classes varied with stands. In *Altingia*-mixed species stand, of the total 418 tree individuals ha^{-1} with dbh $\geqslant$ 10 cm, 49% tree individuals were recorded in dbh

Table 1

Comparative account for the three forest stands in the study area of Namdapha National Park, Arunachal Pradesh.

Parameters	Forest stands		
	Altingia-mixed species	*Shorea-Dipterocarp*	*Albizia*
Location	Hornbill area	Gibbonsland area	Lankai area
Elevational range	300-600	350-400	350-400
Forest type	South Bank Tropical Wet Evergreen (*Dipterocarpus*) Forest	South Bank Tropical Wet Evergreen (*Dipterocarpus*) Forest	Riverine Semi –Evergreen Forest
Sampled area (ha)	1.2	1.0	1.8
Biotic pressure	Nil	Low	Moderate
Number of tree species	98	54	20
Density ha^{-1}			
Trees	418	390	245
Total basal area ($m^2 ha^{-1}$)	45.47	49.68	18.29
Tree species diversity	3.85	3.55	1.71
Concentration of dominance	0.044	0.042	0.31
Species with highest basal area ($m^2 ha^{-1}$)	*Altingia excelsa* (17.58)	*Terminalia myriocarpa* (8.09)	*Albizia procera* (13.0)
Dominant family	Euphorbiaceae	Dipterocarpaceae	Leguminosae
Dominant tree species	*Altingia excelsa*, *Dipterocarpus macrocarpus*, *Ostodes paniculata*	*Dipterocarpus macrocarpus*, *Shorea assamica*, *Ostodes paniculata*	*Albizia procera*, *Dalbergia pinnata*, *Bombax ceiba*
Emergent species	*Altingia excelsa*, *Dipterocarpus macrocarpus*	*Dipterocarpus macrocarpus*, *Shorea assamica*	*Albizia procera*, *Bombax ceiba*
Dominant shrub	*Strobilanthus* sp.	*Strobilanthus* sp.	*Citrus medica*
Trees with buttresses*	69 (14%)	40 (20.51%)	2 (0.45%)
Most buttressed tree	*Altingia excelsa* (55%)	*Dipterocarpus macrocarpus* (20%)	*Bombax ceiba* (100%)
Deciduous trees (%)	6	3	80
Soil:			
Soil texture	Sandy loam	Sandy loam	Loamy sand
N (%)	0.37±0.09	0.1±0.014	0.2
P (%)	0.23±0.02	0.21±0.014	0.19±0.02
C (%)	2.69±1	0.98±0.14	1.11±0.11

*Above 50 cm from ground

All the forest types forms the sub-types of tropical lowland rainforest.

The South bank tropical wet evergreen (*Dipterocarpus*) forest and the riverine semi evergreen forest (Kaul and Haridasan 1987) corresponds to the Assam valley tropical wet evergreen forest (1B/C1) in the classification of Champion and Seth (1968).

Table 2

Dominant families at the three study sites in tree (>10 cm dbh) and regeneration layers (<10 cm dbh) based on their contribution to total density at three stands in Namdapha National Park, Arunachal Pradesh

	Altingia-mixed species stand		*Shorea-Dipterocarp* stand		*Albizia* stand	
Family	dbh >10 cm	dbh <10 cm	dbh >10 cm	dbh <10 cm	dbh >10 cm	dbh <10 cm
Bombacaceae	0	0	0	0	7.49	5.77
Combretaceae	0.41	0.047	4.1	0	1.69	0
Dipterocarpaceae	4.86	1.63	18.46	33.58	0	0
Euphorbiaceae	19.54	4.61	17.44	4.48	3.54	13.33
Fagaceae	2.42	1.87	6.67	10.69	0	0
Hamamelidaceae	8.5	0	1.54	0.12	0	0
Lauraceae	4.04	39.99	4.1	3.24	0.34	0.72
Leeaceae	2.23	0.14	4.62	1.12	0	0
Leguminosae	0.41	2.18	0	4.15	74.65	10.81
Magnoliaceae	5.26	1.24	3.59	0.12	0.68	0
Meliaceae	9.72	7.99	4.1	5.27	0.34	3.6
Myrtaceae	4.86	3.81	3.08	4.12	0	0
Rubiaceae	2.43	7.31	3.08	6.94	0	0
Verbenaceae	0.4	1.26	0.51	0	8.54	3.6
Unidentified	21.66	1.74	16.92	3.88	0.68	0
Other families	13.61	25.544	11.78	22.26	2.03	62.1

Table 3

Tree density (ha^{-1}), basal area ($m^2 ha^{-1}$) and importance value index (IVI) in the three studied forest stands of Namdapha National Park, Arunachal Pradesh.

Species	*Altingia*-mixed species stand			*Shorea-Dipterocarp* stand			*Albizia* stand		
	Density	TBA	IVI	Density	TBA	IVI	Density	TBA	IVI
1	2	3	4	5	6	7	8	9	10
Actinodaphne obovata (Nees) Bl.	-	-	-	6	0.405	6.3	-	-	-
Ailanthus grandis Prain	-	-	-	2	0.676	3.19	<1*	0.01	0.97
Alangium chinense (Lour) Harms	-	-	-	-	-	-	1	0.01	1.17
Albizia procera (Roxb.) Benth	-	-	-	-	-	-	126.±4.19	13.03	155.3
Altingia excelsa Noronha	35±2.23	17.58	51.72	6±1.41	5.432	15.1	-	-	-
Antidesma acuminatum Linn.	2.50±0.59	0.06	2.25	-	-	-	-	-	-
Aphania rubra (Roxb.) Radlk.	2.50	0.10	2.34	-	-	-	-	-	-
Aporosa dioica (Roxb.) Muell-Arg	1	0.01	1.01	8±2.83	0.145	4.97	-	-	-
Baccaurea ramiflora Lour	6±0.80	0.14	4	26±5.74	0.453	12.84	-	-	-
Beilschmiedia assamica Meissn.	2.50±0.59	0.04	1.07	-	-	-	-	-	-
Beilschmiedia sp.	1	0.01	2.14	-	-	-	-	-	-
Bischofia javanica Bl.	-	-	-	4	1.461	6.6	-	-	-
Bombax ceiba avet. Non Linn	-	-	-	-	-	-	18±1.21	1.21	25.05
Bridelia assamica Hk. f.	4±0.42	0.15	3.63	-	-	-	-	-	-
Callicarpa arborea Roxb.	-	-		2	0.172	2.18	2.51	0.17	2.74
Canarium strictum Roxb.	1	0.03	1.03	-	-	-	-	-	-
Capparis acutifolia (Hook. f. & Thomson) Jacobs.	-	-	-	2	0.283	2.4	-	-	-
Castanopsis indica (Roxb.) A. DC.	3±0.48	0.11	2.55	14±1.10	1.76	13.71	-	-	-
Castanopsis sp. 3	2	0.26	1.96	2	1.386	4.62	-	-	-
Castanopsis sp. 4	-	-	-	4	1.826	7.33	-	-	-
Castanopsis tribuloides (Smith) A. DC.	2.50±0.59	0.07	2.28	2	0.021	1.87	-	-	-
Cedrella toona Roxb. ex. Roth	2	1.05	3.49	-	-	-	-	-	-
Chisocheton paniculatus (Roxb.) Hiern.	12±2.46	0.74	6.74	2	0.066	1.96	-	-	-
Cinnamomum bejolghota (Buch-Ham) Sweet	5±0.48	0.72	5.08	-	-	-	-	-	-
Cinnamomum glaucescens (Nees) Meissn	2.50±0.59	0.52	3.27	-	-	-	-	-	-
Cinnamomum sp.	1	0.06	1.11	-	-	-	-	-	-
Cordia dichotoma Forst. f.	-	-	-	-	-	-	<1	0.01	0.97
Croton roxburghii Balakr.	1	0.01	1.01	-	-	-	-	-	-
Dalbergia pinnata (Lour.)Prain	-	-	-	-	-	-	31±2.18	0.67	36.67
Dalbergia sericia G. Don	-	-	-	-	-	-	24±3.21	0.59	24.19
Dillenia indica Linn.	-	-	-	2	0.211	2.25	-	-	-
Diospyros sp.	1	0.01	1.28	-	-	-	-	-	-
Dipterocarpus macrocarpus Vesque	18±9.43	2.31	10.3	40±14.74	4.996	24.26	-	-	-
Duabanga grandiflora (Roxb ex DC.) Walp.	2	1.41	5	6	3.571	10.04	-	-	-
Dysoxylum binectariferum Hk.f. et. Bedd.	10±1.12	0.53	5.89	-	-	-	-	-	-
Dysoxylum procerum Hiern	16±1.11	0.52	8.04	4	0.205	4.07	-	-	-
Dysoxylum sp.	-	-	-	10±4.24	1.193	7.6	-	-	-

Contd.....

1	2	3	4	5	6	7	8	9	10
Ehretia acuminata R. Br.	-	-	-	-	-	-	1	0.02	1.36
Elaeocarpus aristatus Roxb	2.50	0.14	3.19	12±2	0.579	8.19	-	-	-
Elaeocarpus sp.	1	0.02	1.03	-	-	-	-	-	-
Engelhardtia spicata Leschen ex Bl. Bigdr	-	-	-	-	-	-	1	0.06	1.43
Eriobotrya bengalensis Hk. f.	-	-	-	4	0.154	3.97	-	-	-
Erythrina stricta Roxb.	-	-	-	-	-	-	2±0.79	0.16	2.71
Euonymus sp. 1	2	0.06	1.32	-	-	-	-	-	-
Euonymus sp. 2	4±1.77	0.07	2.67	-	-	-	-	-	-
Ficus sp. 1	1	0.05	1.09	-	-	-	-	-	-
Ficus sp. 2	2.50±0.59	0.94	4.18	-	-	-	-	-	-
Ficus sp. 3	1	0.01	1.01	-	-	-	-	-	-
Glochidion lanceolarium (Roxb.) Voigt	-	-	-	-	-	-	9±0.61	0.16	10.28
Gmelina arborea Roxb.	-	-	-	-	-	18±2.40	0.38	15.06	
Grewia disperma. Roxb.	-	-	-	-	-	-	<1	0.01	1
Griffithianthus fuscus Merr.	2.50±0.59	0.07	2.27	10±4.24	0.289	5.78	-	-	-
Helicia robusta Wall ex Benn	-	-	-	4	0.127	2.6	-	–	-
Knema angustifolia (Roxb.) Warb.	2	0.02	1.23	-	-	-	-	-	-
Laportea pterostigma Wedd.	2.50	0.32	2.08	-	-	-	-	-	-
Lasianthus longicauda Hk. F.	2	0.02	1.23	-	-	-	-	-	-
Leea indica (Burn.f. &) Merr	9±1.11	0.13	6.29	18±3.46	0.239	9.04	-	-	-
Lindera latifolia Hk. f.	1	0.02	1.01	-	-	-	-	-	
Lindera sp.	-	-	-	8±1.15	0.183	6.37	-	-	-
Linociera macrophylla Wall. ex. DC	1	0.02	1.03	-	-	-	-		
Litsea monopetala (Roxb.) pers	-	-	-	-	-	-	1	0.14	1.89
Litsea salicifolia (Roxb. ex. Nees) Hk. f.	3	0.09	3.3	-	-	-	-	-	-
Litsea sp.	-	-	-	2	0.41	2.65	-	-	-
Macropanax dispermus (Bl.) O. Ktze	2	0.11	1.43	-	-	-	-	-	-
Maesa indica (Roxb.) Wall	-	-	-	-	-	-	1	0.01	1.16
Magnolia griffithii Hook.f.& Thomson	1	0.01	1.01	-	-	-	-	-	-
Magnolia sp. A	1	0.08	1.15	-	-	-	-	-	-
Magnolia sp. B	-	-	-	6±1.41	1.071	6.33	-	-	-
Melia dubia Cavv.	-	-	-	-	-	-	1	0.12	1.76
Meliacecae	1	0.02	1.03	-	-	-	-	-	-
Mesua ferrea Linn.	3±1.18	0.06	2.44	-	-	-	-	-	-
Michelia oblonga Wall. ex. Hk.f &Th.	2.50±0.59	0.97	3.51	2	0.286	2.4	-	-	-
Micromellum sp.	4±0.42	0.08	3.46	-	-	-	-	-	-
Miliusa roxburghiana (Wall) Hk.f & Th.	2.50	0.09	2.51	-	-	-	-	-	-
Milletia sp.	2	0.09	2.1	-	-	-	-	-	-
Murraya paniculata (Linn.) Jack	2	0.04	1.26	-	-	-	-	-	
Olea dentata Wall ex DC	1	0.04	1.08	-	-	-	-	-	
Ostodes paniculata Bl. Bigdr	63±3.68	1.63	23.55	30±7.21	0.699	13.05	-	-	-
Persea sp.	1	0.08	1.16	-	-	-	-		
Premna sp.	1	0.02	1.02	-	-	-	-	-	
Premna sp.2	1	0.07	1.12	-	-	-	-	-	
Pterospermum acerifolium Willd.	-	-	-	2	0.017	1.86	-	-	
Pterospermum lancifolium	1	0.01	1.01	-	-	-	-	-	
Pterygota alata (Roxb.) R. br.	2.50	0.04	1.48	-	-	-	-	-	
Quercus lamellosa Smith	1	0.01	1.01	-	-	-	-	-	

Contd.....

1	2	3	4	5	6	7	8	9	10
Quercus Semiserrata Roxb.	1	0.03	1.04	-	-	-	-	-	
Quercus sp.	-	-	-	4	0.172	2.69	-	-	
Saprosma ternatum Hk.f	10±0.63	0.09	6.02	12±5.66	0.132	5.97	-	-	
Saurauia cerea Griff. ex Dyer	1	0.01	1.01	-	-	-	-	-	
Schima wallichii (DC) Korth	7.50±2.20	1.78	7.24	2	1.661	5.17	-	-	-
Shorea assamica Dyer	2	0.24	1.7	32±3.06	5.718	23.66	-	-	-
Styrax serruletum Roxb	2.50	0.12	1.66	-	-	-	-	-	-
Styrax sp.	1	0.01	1	-	-	-	-	-	-
Syzygium cumini (Linn.)			6.01			3.06	-	-	-
Skeels	7±1.18	0.96		4	0.355				
Syzygium macrocarpum			5.18	-	-	-	-	-	-
(Roxb.) Balak.	13±7.07	0.53							
Syzygium sp.	-	-	-	8	0.174	3.72	-	-	-
Talauma hodgsonii Hk.f &			10.6			3.8			2.25
Th.	17.50±1.47	1.16		6	0.472		2	0.07	
Terminalia chebula Retz.	-	-	-	2	0.806	3.45	-	-	-
Terminalia myriocarpa			4.55			23.81			9.64
Heurck & Muell-Arg	2	1.20		14±4.62	8.087		4±0.39	1.03	
Unidentified	89±3.82	7.42	42.53	66±6.66	3.783	31.12	2	0.47	4.4
Total	418±13.62	45.47		390±12.97	49.68		245±28.28	18.33	

The number of unidentified species was 16 in *Shorea-Dipterocarp* stand
The number of unidentified species was 31 in *Altingia*-mixed species stand
Values <1 are not added in the total density in the Albizia stand

class 10-20 cm, 23% in 21-30 cm, 18% in 31-60 cm, and 10% in dbh class >60 cm. Similarly, in *Shorea-Dipterocarp* stand, of the total of 390 tree individual ha^{-1}, 45, 21, 22 and 13% tree individual were recorded in dbh classes 10-20 cm, 21-30 cm, 31-60 cm and >60 cm, respectively. With a total of 245 tree individuals ha^{-1} in *Albizia* stand, 46, 27, 25 and 2% individuals were recorded in dbh classes 10-30, 31-60 and >61 cm classes, respectively. Diameter distribution of important species in all the stands also showed similar pattern with a dominance of lower and medium girth classes.

Dominance-diversity curve

The dominance-diversity curves for *Altingia*-mixed species stand and *Shorea-Dipterocarp* stand fit the Preston's log normal situation, whereas the dominance-diversity curve for the tree layer of *Albizia* stand fit the geometric series (Fig. 3), which corroborates the niche preemption hypothesis.

Discussion

A total of 130 tree species in 75 genera and 44 families were recorded from the three studied 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). *Altingia excelsa*, *Ostodes paniculata*, *Dipterocarpus retusus*, *Shorea assamica*, *Terminalia myriocarpa*, *Duabanga grandiflora*, *Albizia procera*, *Dalbergia pinnata*, *Bombax ceiba* and *Dalbergia sericia* showed dominance at different *stands*. All these species are reported as dominating canopy elements for lowland forest areas in northeastern region (Kaul and Haridasan, 1987; Proctor *et al.*, 1998). On riverine areas leguminous species showed dominance and although they are considered to be seral in nature, their progression to climax does not take place (Mohan and Puri, 1955). The species richness of the studied stands are close to the floristic richness recorded in various parts of Western Ghats (another global hot spot of biodiversity), which varied from 17 species in 3.82 ha in Kalakad Mundanthurian Tiger Reserve (Ganesh *et al.*, 1996), 92 species in 3.12 ha in Kadamakal Reserve (Elouard *et al.*, 1997), 398 species in 75 ha in the entire length of hill chains of Western Ghats (Ghate *et al.*, 1988), and 66-118 species from three 0.3 ha plots at Veerapuli and Kalamalai forest reserve (Swamy *et al.*, 2000). The species richness for Amazonian forest is reported >275 species ha^{-1} (De Oliveira and Mori, 1999). For neotropical forests it was 133-187 species ha^{-1} (Zent and Zent, 2004). It was observed that the *Shorea-Dipterocarp* stand had a much well drained soil condition than the *Altingia*-mixed species stand. *Dipterocarpus retusus* had shown preference to such well drained soils along with a large variety of species (Rajkhowa, 1961). *Altingia excelsa* was recorded growing preferably in relatively flatter areas. *Albizia procera* and *Dalbergia* species showed a clear preference for sandy soil.

The enumerated tree species belonged to 44 families in the present study. It falls well within the range of 16-58 families found in the tropical forests (Swamy *et al.*, 2000; Parthasarathy and Karthikeyan, 1997). Our values are higher than those reported by

Proctor *et al.* (1998) for Haldibari area (36 families) of Namdapha National Park. The difference in family wise distribution may be attributed to heterogeneity in the habitats of the Namdapha National Park. When all individuals of tree species (seedling, sapling and adult trees) were combined together, Lauraceae, Dipterocarpaceae, Euphorbiaceae, Fagaceae and Leguminosae showed their clear cut dominance, which showed that the forest comprises the attributes of lowland evergreen tropical rain forests (Whitmore, 1990; Proctor *et al.*, 1998). The high frequencies of Euphorbiaceae, Dipterocarpaceae, Meliaceae, Magnoliaceae, Lauraceae in this study are in agreement with the forests of Kalimantan, Berau, where Dipterocarpaceae and Euphorbiaceae contributed 6-24% and 13-19%, respectively (Sist and Saridan, 1998; Wilkie *et al.*, 2004). Some of these families also comprise by far the largest group of trees. Our results are in contrary to Proctor *et al.* (1998) who showed low dominance of Euphorbiaceae from Haldibari area in the same park. Dominance of Dipterocarpaceae and Euphorbiaceae in the forest is interesting that suggest a healthy recruitment of medium to large trees of these families.

As many as 89, 45 and 17 species in three studies stands, respectively, had fewer than 10 individuals. A large number of species were represented with one or a few individuals only, thus showed rarity of such species. Similar reports are available for many tropical and rainforest areas (Whitmore, 1990). Woody species rarity with greater number of singletons at a site also underlines the need to preserve such areas of forests as single large reserve (Parthasarathy, 2001).

The tree density of *Shorea-Dipterocarp* and *Altingia*-mixed species stand (390-418 tree ha^{-1}) is well within the range of 300-700 tree ha^{-1} of tropical rain forests (Richards, 1996), and the total tree basal area of 45-49 $m^2 ha^{-1}$ for same stands was also within the range recorded for tropical forests of south-east Asia (25.2-67.4 $m^2 ha^{-1}$) (Swamy *et al.*, 2000), though it was lesser than the forests of Silent Valley (Singh *et al.* 1981). The density of stems with >10 cm dbh is reported between 283 to 739 ha^{-1} and the basal area between 25.2 to 57.0 $m^2 ha^{-1}$ for different Southeast Asian rainforests (Proctor *et al.*, 1983; Riswan, 1987; Wyatt-Smith, 1966; Manokaran and LaFrankie, 1990). Our values fall in the medium range to those reported above.

Analysis of IVI of a species can be used to recognize the pattern of association of dominant species in a community (Parthasarathy, 2001). *Altingia excelsa* dominated the *Altingia*-mixed species stand, while *Ostodes paniculata, Dipterocarpus macrocarpus, Talauma 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, Altingia excelsa, Duabanga grandiflora, Castanopsis tribuloides. Albizia procera* with the highest IVI was the most dominant species in the *Albizia stand* located in the riverine area. The comparative species dominance in any given stand is a function of tree (Keel and Prance, 1979) and past damage (Jacobs, 1987; Swamy *et al.*, 2000). The same could be true for *Albizia* stand in this investigation as the site observed annual floods with additional pressure of grazing. Stand I and stand II, however, did not show any symptoms of biotic pressure in the areas of sampling and therefore dominance of a few species could be attributed to evolution and colonization of these species in various stages of forest development. Varied environmental conditions also result in accumulation of diverse species in a forest stand (Richards, 1996).

In the present study the species area curve showed that asymptote was not reached for the evergreen forest up to 1.7 ha, the riverine forest, however, reached asymptote from an area of 6000 m^2 onwards though a total of 1.8 ha area was sampled. The data showed that the diversity of evergreen forest could be much higher if we further increase the area of sampling. The Shannon-Weiner diversity index is generally high for tropical forests, ranging from 0.81-4.1 for the Indian subcontinent (Singh *et al.*, 1981; Parthasarathy, 2001; Swamy *et al.*, 2000; Bhuyan *et al.*, 2003). The diversity index values of the present study (H=1.71 to 3.85) fall within the reported range for above and other tropical forests. It was recorded higher for tropical evergreen stands than the semi-evergreen stand. However, these values are markedly low than those reported for young (H=5.06) and old (H=5.4) tropical forest stands of Barro Colorado Island, Panama (Knight, 1975).

The dbh class structure for different species occurring in different forest type showed the dominance of middle to lower diameter classes depicting a reverse j-shaped structure, which denotes an evolving or expanding population (Parthasarathy, 2001). The number of species and individual decreased with increasing diameter. Similar findings are reported for other tropical rainforests as well (Whitmore, 1990). Discontinuous distributions for trees have been observed for many tropical tree species (Itow and Mueller-Dombois, 1988). Dominance-diversity has inverse relationship, if the dominance increases the diversity decreases (Maguran, 2004). The dominance-diversity curves for

the tree layer in the *Altingia*-mixed species and the *Shorea-Dipterocarp* stand fits the Preston's log normal distribution, whereas for *Albizia stand* represents the geometric series which corroborates the niche preemption hypothesis (Whittaker, 1975).

Namdapha comprises the maximum area under any National Park in the north eastern region of India. It comprises 21% of the total area of all the protected area network of Arunanchal Pradesh state. The park is also identified as a Tiger reserve, which further converses of its importance. The lowland tropical rainforests of Namdapha which occurs at the northernmost limit of the rainforest formation that occurs farthest from the equator are one of the largest relict patches of *Dipterocarpus* forests in entire India that form a huge genetic reservoir of diverse species (Proctor *et al.*, 1998). As these forests have features of rainforests with diversity at par with many similar forests in other areas, all efforts are required to protect such stands from any kind of anthropogenic pressure. Therefore a strong scientific plan is desired for the long term and sustained conservation of Namdapha National Park, which would have larger implications not only for the state of Arunachal Pradesh but for whole of the northeastern region.

Acknowledgements

This study was funded by the Ministry of Environment and Forests, Government of India, New Delhi under the Biosphere Reserve Programme. The authors acknowledge the help and support of the Director, G.B. Pant Institute of Himalayan Environment and Development; PCCF and Additional PCCF (Wildlife and Biodiversity), Department of Forests and Wildlife, Government of Arunachal Pradesh for permitting to work in Namdapha; and Field Director, Research Officer and the Technical and Administrative Staff of Namdapha National Park for field level assistance. Dr. K. Haridasan, State Forest Research Institute and the scientists of the Botanical Survey of India, Itanagar are thanked for help in identification of plant specimens. Mr. A. Mossang, Mr. D. Bora and Mr. B. Ali extended immense help during the field work.

SUMMARY

The tropical rainforests in the northeast India are least investigated despite of their high diversity and being located at the northern most limit of the rainforests that occur farthest from the equator. The lowland tropical rainforests at Namdapha National Park, Arunachal Pradesh (Eastern Himalaya) was investigated for tree species diversity, population structure and species richness with reference to three distinct canopy covers, *viz.* an *Altingia*-mixed species stand, *Shorea-Dipterocarp* stand, and an *Albizia* stand. A total of 1053 trees covering 130 species in 44 families were recorded at ≥ 10 cm dbh, while 34526 individuals covering 104 species in 44 families were enumerated at <10 cm dbh. The tree species richness for three inventoried stands varied from 98, 54 and 20 species in ≥ 10 cm dbh with overall density of 418, 390 and 245 trees ha^{-1} for the three stands respectively. Lauraceae, Dipterocarpaceae, Euphorbiaceae, Fagaceae and Leguminosae dominated the flora; thus the forest exhibited typical attributes of lowland evergreen tropical rainforests.

Keywords: Lowland Tropical Rain Forests, Namdapha National Park, Species diversity, Tree structure, Conservation, Northeast India.

पूर्वी हिमालय प्रदेश, भारत के निम्नभूमि उष्ण वर्षा पोषित वनों की वृक्ष विविधता और संख्या संरचना

पन्ना देव, आर. सी. सुन्दरियाल व उमा शंकर

सारांश

अधिक वृक्ष विविधता और वर्षा वनों की दूरतम उत्तरी सीमा पर अवस्थित होने के बावजूद जो विषुवत रेखा से सबसे ज्यादा दूर पड़ती है, उत्तर पूर्वी भारत के उष्णदेशीय वर्षा वन सबसे कम अन्वेषित किए गए हैं। नामदाफा राष्ट्रीय उपवन, अरूणाचल प्रदेश (पूर्वी हिमालय भू-भाग) के निम्नभूमि उष्णदेशीय वर्षा वनों का तीन वितान आवरणों अर्थात *एल्टिंगिया* मिश्र जाति वन, *शोरिया-डिप्टेरोकार्प* वन और *एल्बिजिया* वन के सन्दर्भ में वृक्ष जाति विविधता संख्या संरचना और पादप जाति सम्पन्नता विचार से अन्वेषण किया गया। ≥ 10 सेमी वक्षोच्चता पर व्यास पर 44 कुलों की 130 जातियों के कुल 1053 वृक्ष मिले जबकि < 10 सेमी वक्षोचता पर व्यास के 44 कुलों की 104 जातियों के 34526 वृक्ष मिले। तालिका बनाए तीनों वनों में वृक्ष जातियों की सम्पन्नता ≥ 10 सेमी वक्षोच्चता पर व्यास में 98, 54 और 20 जातियां तथा समग्र विविधता 418, 390 और 245 वृक्ष प्रति हेक्टेयर तीनों वृक्ष संनिधियों में क्रमशः रही। पेड़-पौधों में लौरेसी, डिप्टेरोकार्पेसी (गुर्जन कुल) युफोर्बियो (सुधी कुल) फगेसी और लेग्युमिनोसी (शिशि कुल) कुलो की बहुलता रही अतः इस वन ने निम्नभूमि सदाहरित उष्ण वर्षा वनों की प्रारूपिक विशेषताएं ही प्रदर्शित की।

References

Anon. (1995). *Centers for plant diversity*: A guide and strategy for their conservation. WWF and IUCN. IUCN Publication Unit, Cambridge, UK.

Bhuyan, P., M. L. Khan and R. S. Tripathi (2003). Tree diversity and population structure in undisturbed and human-impacted stands of tropical wet evergreen forests in Arunachal Pradesh, Eastern Himalayas, India. *Biodiversity and Conservation*, **12:** 1753-1773.

Chauhan, A. S., K. P. Singh and D. K. Singh (1996). *A contribution to the flora of Namdapha, Arunachal Pradesh*. Botanical Survey of India, Calcutta, India.

Chettri, N., D. C. Deb, E. Sharma and R. Jackson (2005). The relationship between bird community and habitat: A study

along a trekking corridor in the Sikkim Himalaya. *Mountain Research and Development,* **25** (3): 235-243.

Curtis, J. T. and R. P. Mcintosh (1950). The inter-relations of certain analytic and synthetic phytosociological characters. *Ecology,* **32:** 434-455.

De Oliveira, A. A. and S. A. Mori (1999). A Central Amazonian terra firme forest I. High tree species richness on poor soils. *Biodiversity and Conservation,* **8**: 1219-1244.

Deb, P. and R. C. Sundriyal (2005). Status review of Namdapha National Park, India: Need for strengthening community-conservation linkages. *Indian Journal of Forestry,* **28** (1): 89-100.

Elouard, C., J. P. Pascal, R. Pelissier, B. R Ramesh, M. Durand, S. Aravavajy, M. A. Moravie and C. Gimaret-Capenter (1997). Monitoring the structure and dynamics of a dense moist evergreen forest in the Western Ghats (Kodagu district, Karnataka, India). *Tropical Ecology*, **38:**193-214.

Ganesh, T., R. Ganesan, M. S. Devy, P. Davidarand and K. S. Bawa (1996). Assessment of plant biodiversity at a mid elevation evergreen forest of Kalakad-Mundanthurai Tiger Reserve, Western Ghats, India. *Current Science,* **71:** 379-392.

Ghate, U., N. V. Joshi and M. Gadgil (1988). On the patterns of tree diversity in the Western Ghats of India. *Current Science*, **75:** 594-603.

Hubbell, S. P. and R. B. Foster (1992). Short term population dynamics of a neotropical forest: why ecological research matters to tropical conservation and management. *Oikos*, **63:** 48-61.

IIRS. (2002). *Biodiversity Characterization at Landscape Level in North East India Using Satellite Remote Sensing and Geographic Information System*. Indian Institute of Remote Sensing, Dehradun, 296 pp.

Itow, S. and D. Mueller-Dombois (1988). Population structure, stand-level dieback and recovery of *Scalesia pedunculata* in the Galapagos Islands. *Ecol. Res.*, **3:** 333-339.

Jacobs, M. (1987). *The Tropical Rainforest*. Springer-Verlag, New York.

Kaul, R. N. and K. Haridasan (1987). Forest types of Arunachal Pradesh, A preliminary study. *Journal of Economic and Taxonomic Botany,* **9:** 379-389.

Keel, S. H. K. and G. T. Prance (1979). Studies of the vegetation of a white-sand black-water igapo (Rio Negro, Brazil). *Acta Amazonica,* **9:** 645-655.

Kent, M. and P. Coker (1994). *Vegetation description and analysis*, A practical approach. International Book Distributor, Dehradun, India, 355 pp.

Knight, D. H. (1975). A phytosociological analysis of species rich tropical forest on Barro Colorado Island, Panama. *Ecological Monograph*, **45:** 259-284.

Maguran, A. E. (2004). *Measuring Biological Diversity assessment*. Blackwell Publishing Company, 256

Manokaran, N. and Jr. Jv. Lafrankie (1990). Stand structure of Pasoh forest reserve, a lowland rainforest in peninsular Malaysia. *Journal of Tropical Forest Science,* **3:** 14-24.

Mohan, N. P. and G. S. Puri (1955). The Himalayan conifers III- The succession of forest communities in oak-conifer forests of the Bashahr Himalayas. *Indian Forester*, **181**: 465-711.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. Da Fonseca and J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature*, **403:** 853-858.

Parthasarathy, N. and R. Karthikeyan (1997). Biodiversity and population density of woody species in a tropical evergreen forest in Courtallum Reserve, Western Ghats, India. *Tropical Ecology,* **38 (2)**: 297-306.

Parthasarathy, N. (2001). Changes in forest composition and structure in three sites of tropical evergreen forest around Sengaltheri, Western Ghats. *Current Science*, **80 (3):** 389-393.

Proctor, J., J. M. Anderson, P. Chai and H. W. Vallack (1983). Ecological studies of four contrasting lowland rainforest types of Gunung Mulu N, **76:** 320-340 pp.

Proctor, J., K. Haridasan and G. W. Smith (1998). How far does the lowland evergreen tropical rainforest go. *Global Ecology and Biogeography Letters,* **7:** 141-146.

Rajkhowa, S. (1961). The Upper Assam (*Dipterocarpus-Mesua*) forests and their regeneration. *Indian Forester,* **87 (7):** 406-425.

Richards, P. W. (1996). *The tropical rain forest* (2nd edn). Cambridge University press.\

Riswan, S. (1987). Structure and floristic composition of a mixed dipterocarp forest, Lempake, East Kalimantan. *In: proceedings of the third round table conference on dipterocarps* (A. Kostermans ed), 435-458 pp. Samarinda, Indonesia.

Rodgers, W. A. and H. S. Panwar (1988). *Planning a wildlife protected area network in India,* Wildlife Institute of India, Dehradun.

Shannon, C. E. and W. Wiener (1963). *The mathematical theory of communities*. University of Illinois press, Urbana, Illinois, 117 pp.

Simpson, E. M. (1949). Measurement of Biodiversity. *Nature*, **163:** 668.

Singh, J. S., S. P. Singh, A. K. Saxena and Y. S. Rawat (1981). The Silent valley forest ecosystem and possible impact of proposed hydroelectric project. Report on the Silent valley study, Ecology Research Circle, Kumaun University,

Nainital, India.

Sist, P. and A. Saridan (1998). Description of the primary lowland forest of Berau. *In: Silvicultural Research in a lowland mixed Dipterocarp Forest of East Kalimantan* (Bertault J. and K. Kadir eds.), Contribution of STREK project, CIRAD-foret, 435-457 pp., Indonesia.

Sundriyal, R. C., E. Sharma, L. K. Rai and S. C. Rai (1994). Tree structure, regeneration and woody biomass removal in a subtropical forest of Mamlay Watershed in Sikkim Himalaya. *Vegetatio,* **113:** 53-63.

Sundriyal, R. C. and E. Sharma (1996). Anthropogenic pressure on tree structure and biomass in temperate forest of Mamlay Watershed in Sikkim. *Forest Ecology and Management,* **81:** 113-134.

Swamy, P. S., S. M. Sundrapandian, P. Chandrasekar and S. Chandrasekaran (2000). Plant species diversity and tree population structure of humid tropical forest in Tamil Nadu, India. *Biodiversity and Conservation*, **9:** 1643-1669.

Uma Shankar (2001). A case of high tree diversity in a sal (*Shorea robusta*)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science*, **81 (7):** 776-805.

Whitmore, T. C. (1990). *An Introduction to Tropical Rainforests*. Clarendon Press, Oxford.

Whitmore, T. C. (1996). A review of some aspects of tropical rainforest seedling ecology with suggestions for further enquiry. In: *Ecology of Tropical Forest Tree Seedlings*, (M.D. Swaine, ed.). 3-39 pp. UNESCO/Parthenon, Paris/Canforth.

Whittaker, R. H. (1975). *Communities and Ecosystems*, New York, MacMillan.

Wilkie, P., G. Argent, E. Cambell and A. Saridan (2004). The diversity of 15 ha of lowland mixed dipterocarp forest, Central Kalimantan. *Biodiversity and Conservation*, **13:** 695-708.

Wyatt-Smith, J. (1966). Ecological studies on Malayan forests 1. Malayan Forestry Department Research Pamphlet **52.**

Zent, E L. and S. Zent (2004). Floristic composition, structure and diversity of four forests in the Siera Maigualida, Venezuelan Guayana. *Biodiversity and Conservation,* **13** (13): 2453-2483.