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COMPOSITION, POPULATION STRUCTURE AND DISTRIBUTION OF DIPTEROCARPS IN A TROPICAL EVERGREEN FOREST AT VARAGALAIAR, ANAMALAIS, WESTERN GHATS, SOUTH INDIA

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AYYAPPAN, N. & PARTHASARATHY, N. 2001. Composition, population structure and distribution of dipterocarps in a tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, south India. The diversity, density, basal area, population structure and spatial distribution of all dipterocarps (≥ 10 cm dbh) was investigated in a 30-ha permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, south India. Dipterocarpaceae in our site was represented by three species, *Dipterocarpus indicus, Hopea parviflora* and *Vateria indica*. These contributed 2% of tree species richness, 6.8% of stand density and 18.3% of stand basal area. The density of dipterocarps in each hectare of the present study site varied greatly, ranging from 7 to 62 trees with a mean density of 31 trees ha^{-1}. *Dipterocarpus indicus* was the most abundant species accounting for 59% of dipterocarp density. Of the 51 tree families encountered in the 30-ha plot, dipterocarp species ranked first in basal area because of their greater girth frequency in the larger girth classes. Population structures of the three dipterocarp species obtained based on the number of individuals in each diameter class displayed a greater proportion of individuals in the lower size class. Spatial patterns of all dipterocarp species and their three stem sizes analysed at 1 ha, 0.5 ha and 0.25 ha scales revealed that individuals were dispersed both in clumped and uniform patterns, except *V. indica* which was randomly distributed in one subplot at the 1-ha scale.

Key words: Dipterocarpaceae - permanent plot - Western Ghats - evergreen forest - stand structure - tree dispersion - dipterocarp domain

AYYAPPAN, N. & PARTHASARATHY, N. 2001. Kandungan, struktur populasi dan taburan dipterokarpa di hutan malar hijau tropika di Varagalaiar, Anamalais, Ghats Barat, selatan India. Kepelbagaian, kepadatan, luas pangkal, struktur populasi dan taburan ruang kesemua dipterokarpa (≥ 10 cm dbh) dikaji di petak kekal 30 hektar di hutan malar hijau tropika di Varagalaiar, Anamalais, Ghats Barat, selatan India. Dipterocarpaceae di tapak yang dikaji diwakili oleh tiga spesies iaitu *Dipterocarpus indicus, Hopea parviflora* dan *Vateria indica*. Ini menyumbangkan sebanyak 2% daripada kekayaan spesies pokok, 6.8% kepadatan dirian dan 18.3% luas pangkal dirian. Kepadatan dipterokarpa di dalam setiap hektar tapak kajian ini sangat berubah-ubah, berjulat daripada 7 hingga 62 pokok dengan kepadatan min sebanyak 31 pokok setiap hektar. *Dipterocarpus indicus* merupakan spesies yang paling banyak iaitu 59% daripada kepadatan dipterokarpa. Daripada 51 famili pokok yang diperoleh di petak 30 hektar, spesies dipterokarpa menduduki tempat pertama dari segi luas pangkal kerana kekerapan lilitnya yang lebih banyak dalam kelas lilit yang lebih besar. Struktur populasi ketiga-tiga spesies dipterokarpa yang diperoleh berdasarkan bilangan pokok dalam setiap

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kelas garis pusat menunjukkan bilangan pokok yang lebih banyak bagi kelas saiz yang lebih kecil. Corak ruang bagi kesemua spesies dipterokarpa dan tiga saiz batangnya dianalisis pada skala 1 ha, 0.5 ha dan 0.25 ha menunjukkan bahawa pokok-pokok berselerak dalam corak berumpun dan corak seragam, kecuali *V. indica* yang disebarkan secara rawak di dalam satu petak kecil pada skala 1 hektar.

Introduction

The family dominance of Dipterocarpaceae is characteristic of all rain forests in Malaysia, Borneo and Sumatra and many seasonal forests from India to Philippines (Ashton 1982, Whitmore 1984, Richards 1996). The island of Borneo shows the highest dipterocarp diversity – 267 species with 59% endemicity (Ashton 1982). About 90% of the species are confined to the Indo-Malaysian region. In India, Dipterocarpaceae is represented by seven species (four genera) in north-east India (Rao *et al.* 1961) and 11 species (three genera) in Andaman archipelago. *Shorea robusta* occurs in large tracts of the central Indian dry deciduous forest and Gangetic plains. The Western Ghats of south India are the westernmost limit of dipterocarp domain and are represented by 13 species from four genera (*Dipterocarpus, Hopea, Vateria* and *Vatica*) (Ramesh *et al.* 1996).

In Southeast Asia, dipterocarps generally form a high proportion of the emergent and main canopy strata of forests (Manokaran *et al.* 1991). In Peninsular Malaysia, Symington (1943) surveyed 3200 ha of lowland and hill dipterocarp forests in 1930, of which 30% (16 trees or more per hectare) of trees ≥ 30 cm dbh (diameter at breast height) and basal area of 55.5% are dipterocarps. Poore (1968) found 28% of trees and 43% of basal area for trees ≥ 29 cm dbh are dipterocarps in a 21 ha of lowland dipterocarp forest in Jengka. The Dipterocarpaceae has received greater attention in the enumeration of dipterocarp-rich forests of Southeast Asia (Proctor *et al.* 1983, Kochummen *et al.* 1990, Manokaran & Kochummen 1990, Manokaran *et al.* 1991, Newbery *et al.* 1992, Newbery *et al.* 1996 (from Malaysia); Kartawinata *et al.* 1981, Riswan 1987, Sist 1996 (from Indonesia)). However, data on dipterocarp composition and their contribution to forest stand density and basal area in dipterocarp species-poor forests are lacking, especially from the western domain of dipterocarps, the Western Ghats of India. Recent quantitative ecological inventories of trees in the tropical evergreen forests of the Western Ghats in which dipterocarps formed a part of the forest stand include a 3.12-ha permanent plot at Uppangala (Pascal & Pelissier 1996, Elouard *et al.* 1997, Pascal *et al.* 1998) and three 1-ha plots along the elevational gradients in Agumbe.

The present paper is part of a tree diversity inventory and monitoring in a 30-ha permanent plot in the tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats. The 30-ha inventory yielded 13 393 trees of ≥ 10 cm dbh with a mean of 446 trees ha^{-1} (Ayyappan & Parthasarathy 1999). Of the 51 families represented in the 30-ha plot, Dipterocarpaceae took up 9% of the total family importance value index (based on Mori *et al.* 1983) and ranked second to Euphorbiaceae in family dominance. Although the predominant upper storey species of Dipterocarpaceae have low diversity (three species) and density of stems (7%), they contributed a greater basal area (19%) when compared to the much diverse and abundant families like Euphorbiaceae (19 species, 28% of stand density and 14% basal area), Meliaceae (9 species, 13% stand density and 4% basal area) and Clusiaceae (6 species, 8% stand density and 9.5%

basal area). The upper storey species play a vital role in the establishment of climax species promoting cyclic replacement of species in the growth and maintenance cycle of forest rather than succession (Whitmore 1984). The prime objective of this paper is to present the results related to dipterocarp diversity, density, dispersion patterns and their contribution to forest stand in a large-scale forest reserve of the Indian Western Ghats. The data generated on dipterocarps and the further investigation of their population biology would be useful in forest ecology and in the management and conservation of species *per se*.

Materials and methods

Study site

The study was conducted in a tropical evergreen forest at Varagalaiar, within the Indira Gandhi National Park and Wildlife Sanctuary, near Topslip, Anamalais, Western Ghats, south India (Figure 1). The Anamalais is one of the most important centres of biodiversity and endemism in India (Nair 1991). It is located in Coimbatore district of Tamil Nadu (10° 12'–10° 54' N, 76° 44'–76° 58' E) and covers a total area of 95 860 ha, with 84 149 ha comprising the wildlife sanctuary and 11 711 ha forming the protected national park.

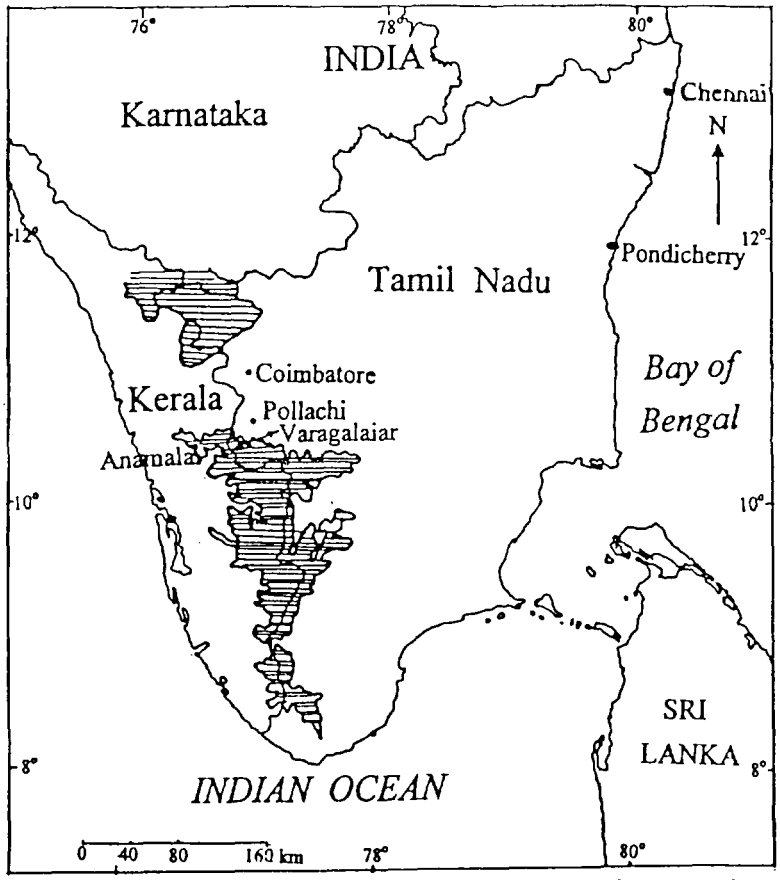

Figure 1. Location map of Varagalaiar study site in the Anamalais, Western Ghats, India

The Varagalaiar study site (elevation 600–660 m asl) receives rain from the south-west monsoon from June to September and the north-east monsoon from October to December. The mean annual rainfall is 1468 mm (recorded at Topslip, located 27 km away from Varagalaiar) for a period of 23 years and 103 rainy days per year for the same period. South of 16° N, the Western Ghats are made up of archean rocks of the Precambrian shield and the formations are granitic gneiss.

The site harbours a tropical evergreen forest. Besides the dipterocarps, the upper storey is dominated by evergreen species like *Calophyllum polyanthum, Diospyros buxifolia, D. sylvatica, Holigarna beddomei, Mesua ferrea, Palaquium ellipticum, Poeciloneuron indicum* and *Polyalthia fragrans,* with a few deciduous species such as *Bombax ceiba, Terminalia bellirica* and *Tetrameles nudiflora.* The middle storey is dominated by *Aglaia elaeagnoidea, Dimocarpus longan, Knema attenuata, Margaritaria indica, Myristica dactyloides, Reinwardtiodendron anamallayanum,* etc., and the lower storey by *Baccaurea courtallensis, Croton malabaricus, Drypetes longifolia, Orophea erythrocarpa, Phoebe lanceolata,* etc.

Anthropic interference in our study site, which also affects dipterocarps, includes fuel wood collection, removal of poles and illegal collection of white resin from *Vateria indica.* For honey collection, lofty trees are pegged with wooden footholds, which subsequently cause infestation by stem borers, leading to tree mortality. In the natural setting, bark of *V. indica* and *Hopea parviflora* is stripped off and eaten by wild elephants as laxative.

Field methods

A 600 m long and 500 m wide, rectangular permanent plot (30 ha) was established during 1997–1998. The 30-ha plot was divided into 30 1-ha subplots (100 × 100 m^2) and further subgridded into 10 × 10 m^2 quadrats as workable units. All trees ≥ 10 cm dbh were identified, tagged and their girth measured at 1.3 m from the ground or above the protuberances, in the first census. Voucher collections were made and deposited in the herbarium of Salim Ali School of Ecology, Pondicherry University. A total of 24 trees well within the 30-ha area, missed in the initial census, were tagged, identified, measured for their girth and added to the database during the recensus between January 1999 to March 1999. In addition to the 149 species enumerated in the 30-ha plot during the first census (Ayyappan & Parthasarathy 1999), four species, which were wrongly identified, were added to the list in the recensus.

Data analysis

The tree girth measurements were transformed into diameter to facilitate comparison with other studies. Families were ranked based on their contribution to species richness, density and basal area. The population structure of dipterocarps was based on the number of individuals in different diameter classes. The spatial patterns of dipterocarp species *per se* and their individuals in the three diameter classes of stems (*viz.* smaller stems (≥ 10 to < 30 cm dbh), medium-sized (≥ 30 to < 90 cm dbh) and larger stems (≥ 90 cm dbh)) were determined based on quadrat (10 × 10 m^2) count method, using standardised Morisita's index (Krebs 1989) at three different scales, tested with 95% confidence limits. Of the three scales tested two of them were square subplots of 0.25-ha (50 × 50 m^2) and 1-ha (100 × 100 m^2) area and one was a

rectangular subplot of 0.5-ha area (50 × 100 m^2). The subplots that contained single or no individual of dipterocarp species were omitted in this analysis.

Results

Dipterocarp diversity, density and basal area

There were three species of dipterocarps, namely, *Dipterocarpus indicus, V. indica* and *H. parviflora* (Table 1), representing three genera, contributing 2% of total tree species diversity (153 species) of the 30-ha study plot. The total stand density of trees ≥ 10 cm dbh in the study site was 13 417 trees, with a mean of 447 trees ha^{-1}. A total of 916 individuals of dipterocarps ≥ 10 cm dbh were enumerated in the 30-ha plot, which formed 6.8% of the total stand density. Of the 30 ha, 29 ha contained at least any two dipterocarp species and in only one hectare they were absent. Dipterocarp density in each hectare of the present study site varied greatly, ranging from 7 to 62 trees with a mean density of 31 trees ha^{-1}, contributing 2 to 13% of tree density in each hectare. Based on density, *D. indicus* ranked first, contributing 59% of dipterocarp density (18 trees ha^{-1}), followed by *V. indica* (33%, 10 trees ha^{-1}) and *H. parviflora* (9%, 3 trees ha^{-1}).

The basal area contribution of dipterocarps ranged from 2 to 16.5 m^2 ha^{-1}, with a mean stand basal area value of 6.61 m^2 ha^{-1}, which was 18.4% of the total stand basal area. The basal area contribution of each species of dipterocarps varied greatly. *Dipterocarpus indicus* alone accounted for 63% of the total basal area of dipterocarps.

Of the 51 families encountered in the 30-ha plot, Dipterocarpaceae ranked first in terms of its contribution to basal area, fourth in terms of density and fifteenth in species richness (Table 2).

Density based on diameter class and basal area

The population structure based on the mean number of trees per hectare of both non-dipterocarps and dipterocarps generally decreased with increasing diameter class

Table 1. Population density and basal area of three dipterocarp species and non-dipterocarps for trees ≥ 10 cm dbh in the 30-ha study plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India (standard deviation is provided in parentheses)

Species	Tree density		Basal area m^2 ha^{-1}
	Whole 30 ha plot	Mean ha^{-1} (SD)	(SD)
Dipterocarpus indicus	537	18 (13)	4.15 (2.82)
Vateria indica	294	10 (6.5)	1.92 (1.58)
Hopea parviflora	85	3 (2.8)	0.66 (0.66)
Dipterocarps	916	31 (16)	6.61 (3.6)
Non-dipterocarps	12 501	416 (97)	29.45 (4)

Table 2. The dominant families (with rank) of trees ≥ 10 cm dbh with their species richness, number of stems and basal area in the 30-ha permanent plot of tropical evergreen forest at Anamalais, Western Ghats, India

	Family name	Species richness	(rank)	Number of trees	(rank)	Basal area (m^2) ha^{-1}	(rank)
1	Euphorbiaceae	19	(1)	3786	(1)	4.9	(2)
2	Lauraceae	11	(2)	344	(11)	0.6	(17)
3	Meliaceae	9	(3)	1750	(2)	1.4	(4)
4	Moraceae	9	(4)	170	(15)	3.5	(8)
5	Clusiaceae	6	(5)	1038	(3)	3.5	(3)
6	Annonaceae	6	(6)	797	(5)	1.3	(9)
7	Flacourtiaceae	6	(7)	401	(9)	0.8	(14)
8	Anacardiaceae	5	(8)	231	(13)	0.8	(13)
9	Sapindaceae	5	(9)	586	(7)	1.6	(6)
10	Rutaceae	5	(10)	161	(16)	0.3	(18)
11	Rubiaceae	5	(11)	137	(18)	0.1	(22)
12	Sapotaceae	4	(12)	504	(8)	1.7	(5)
13	Ebenaceae	4	(13)	255	(12)	0.8	(16)
14	Sterculiaceae	4	(14)	37	(26)	0.2	(20)
15	Dipterocarpaceae	3	(15)	916	(4)	6.6	(1)
	Subtotal	95		11 113		28.1	
	Other 36 families	58		2 304		8.3	
	Total	153		13 417		36.5	

(Table 3). In the stand, the proportion of dipterocarp density and basal area increased from the smaller diameter class to the larger diameter class. Density, based on diameter class of all the three dipterocarp species, decreased with increasing size class (Table 4). Notably, the tree diameter of *H. parviflora* and *V. indica* did not exceed 140 cm diameter, probably indicating their growth limit. Only one tree (*D. indicus*, diameter 187 cm) represented the greatest diameter class limit of 190 cm. The basal area contribution of each diameter class of all dipterocarps showed a similar trend, which was a gradual increase in basal area with increasing diameter class, until a maximum value was attained (at 71–80 cm dbh class for *D. indicus*, 81–90 cm dbh class for *V. indica* and 111–120 cm dbh class for *H. parviflora*) and then a general decrease. The mean basal area contribution per tree of each species of the dipterocarps was almost the same: 0.23, 0.21 and 0.19 m^2 for *D. indicus*, *H. parviflora* and *V. indica* respectively.

Spatial patterns

All the three species of dipterocarps were dispersed either in clumped or uniform pattern at all the scales tested, except *V. indica* which was randomly distributed in one subplot at the 1-ha scale (Table 5). Individuals of *D. indicus* and *V. indica* were predominantly clumped than being uniform in dispersion at the 1- and 0.5-ha scales tested. *Hopea parviflora* was distributed uniformly in a greater number of subplots than being clumped and also in greater number of hectares (9 ha). This species had single

Table 3. Diameter class frequency distribution of non-dipterocarp and dipterocarp individuals and their basal area contribution in the 30-ha plot of Anamalais, Western Ghats, India

Diameter class (cm)	Mean trees ha^{-1} (SD)		Basal area m^2 ha^{-1} (SD)	
	Non-dipterocarps	Dipterocarps	Non-dipterocarps	Dipterocarps
10–20	224 (68)	9 (7)	3.24 (1.02)	0.13 (0.10)
21–30	78 (24)	5 (3)	3.28 (1.00)	0.20 (0.13)
31–40	42 (10)	4 (3)	3.62 (0.87)	0.32 (0.27)
41–50	29 (6)	2 (2)	4.09 (0.87)	0.35 (0.36)
51–60	19 (5)	3 (2)	3.92 (1.03)	0.57 (0.51)
61–70	11 (4)	2 (2)	3.27 (1.18)	0.48 (0.46)
71–80	6 (3)	2 (2)	2.30 (1.11)	0.89 (0.73)
81–90	3 (2)	1 (1)	1.56 (1.00)	0.69 (0.69)
≥90	5 (3)	3 (2)	4.06 (2.35)	2.98 (1.95)

Table 4. Diameter class-wise density and basal area of the three dipterocarp species recorded in the 30-ha plot of Varagalaiar, Anamalais, Western Ghats

Diameter class (cm)	Species					
	D. indicus		*V. indica*		*H. parviflora*	
	Density	Basal area (m^2)	Density	Basal area (m^2)	Density	Basal area (m^2)
10–20	136	2.2	94	1.3	25	0.4
21–30	84	3.7	41	1.8	13	0.5
31–40	65	5.6	35	2.9	14	1.2
41–50	46	6.5	21	3.0	6	0.8
51–60	49	10.8	26	5.5	4	0.8
61–70	30	9.1	14	4.1	4	1.2
71–80	43	17.0	21	8.2	4	1.5
81–90	19	9.5	17	9.0	4	2.1
91–100	25	15.7	11	7.0	3	1.9
101–110	14	11.1	6	4.8	3	2.3
111–120	8	7.4	5	4.7	4	3.7
121–130	4	4.4	1	1.1	0	0.0
131–140	7	9.0	2	2.5	1	1.3
141–150	3	4.7	0	0	0	0
151–160	2	3.3	0	0	0	0
161–170	1	1.8	0	0	0	0
171–180	0	0	0	0	0	0
181–190	1	2.8	0	0	0	0

individuals. On a 0.25-ha scale, all the species followed a similar trend, which was individuals exhibited a uniform distribution in the study area rather than being clumped.

Spatial distribution of individuals based on three different size classes of all the dipterocarps revealed that they were not randomly distributed at any of the scales tested (Table 6). On the 1-ha scale, *H. parviflora* displayed only a uniform distribution for all the three size classes. Small- (≥ 10 to < 30 cm dbh) and medium-sized (≥ 30 to < 90 cm dbh) stems of *D. indicus* and *H. parviflora* exhibited clumped pattern of individuals at the 0.5- and 0.25-ha scales tested. Individuals of small- and medium-

Table 5. Spatial patterns of the three dipterocarp species tested at 1, 0.5 and 0.25 ha scales (based on standardised Morisita's index) in the 30-ha area of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats (numbers indicate the subplots in which such pattern prevailed)

Species	Dispersion pattern								
	Clumped			Uniform			Random		
	1 ha	0.5 ha	0.25 ha	1 ha	0.5 ha	0.25 ha	1 ha	0.5 ha	0.25 ha
D. indicus	18	48	35	9	2	47	-	-	-
H. parviflora	1	20	2	16	19	19	-	-	-
V. indica	16	46	22	10	7	25	1	-	-

Table 6. Spatial dispersion of smaller stems (≥ 10 to < 30 cm dbh class) medium sized (≥ 30 to < 90 cm dbh class) and larger stems (≥ 90 cm dbh class) of the three dipterocarp species at 1, 0.5 and 0.25 hectare scales (based on standardised Morisita's index) in the 30-ha plot at Varagalaiar, Anamalais, Western Ghats (numbers indicate the subplots in which such pattern prevailed)

Species	dbh class (cm)	Dispersion pattern								
		Clumped			Uniform			Random		
		1 ha	0.5 ha	0.25 ha	1 ha	0.5 ha	0.25 ha	1 ha	0.5 ha	0.25 ha
	≥ 10 < 30	12	43	48	12	-	-	-	-	-
D. indicus	≥ 30 < 90	9	43	59	16	-	-	-	-	-
	≥ 90	-	17	14	18	-	-	-	-	-
	≥ 10 < 30	-	9	8	9	-	-	-	-	-
H. parviflora	≥ 30 < 90	-	7	7	9	-	-	-	-	-
	≥ 90	-	-	-	2	-	-	-	-	-
	≥ 10 < 30	10	11	11	13	20	22	-	-	-
V. indica	≥ 30 < 90	5	18	7	18	24	28	-	-	-
	≥ 90	-	-	-	7	5	2	-	-	-

sized classes of *V. indica* displayed both (largely) uniform and clumped pattern of dispersion at the 0.5- and 0.25-ha scales tested. The larger size classes (≥ 90 cm dbh) of *H. parviflora* and *V. indica* showed no clumped pattern of distribution at all the scales tested. Trees of *D. indicus* on the 1-ha scale, was uniformly distributed and at the lower scales of 0.5- and 0.25-ha they were clumped.

Discussion

The Western Ghats form one of the most important biogeographical zones in peninsular India and are the westernmost limit of the dipterocarp domain. The three species of dipterocarp encountered in the study area (representing three genera) accounted for 23% of the total 13 dipterocarp species (in four genera) reported from the Western Ghats (Ramesh *et al.* 1996). Except for *V. chinensis*, the other 12 species reported from the Western Ghats are endemic to the Western Ghats area (Ramesh *et al.* 1996). Unfortunately *V. chinensis* has not been relocated from its distribution area after its century-old collection. The dipterocarp diversity of our site was 5 to 15 times lower compared to the dipterocarp forests of Malaysia and Kalimantan

(Table 7). The tropical evergreen forest at Uppangala, Western Ghats, contains two additional species of dipterocarps (Pascal & Pelissier 1996), besides the three species enumerated in our site.

The mean density of dipterocarp trees ≥ 10 cm dbh and their proportion to plot density recorded in this study were about 2 to 4 times lower compared to the dipterocarp forests of Malaysia and Kalimantan and also that of Uppangala, Western Ghats (Table 7). The proportion of dipterocarp trees ≥ 30 cm dbh in our site was 17 trees per ha (13.6%), which was equal to the median dipterocarp frequency of 16 trees or more per ha in the lowland and hill dipterocarp forests of Malaysia (Symington 1943), and lower to that at Pasoh where dipterocarps are represented by 22% (about 20 trees ha^{-1}) of all trees over 30 cm dbh (Manokaran *et al.* 1991).

In the study area, the mean stand basal area (36.06 m^2 ha^{-1}) was greater than the one in the lowland dipterocarp forests of Malaysia (25.2 m^2 ha^{-1} at Pasoh (Manokaran & La Frankie 1990), 26.3 m^2 ha^{-1} at Danum Valley (Newbery *et al.* 1992)) and also the lowland dipterocarp forests of Kalimantan (28.1 to 33.96 m^2 ha^{-1} on a 4-ha scale in Berau (Sist 1996), 29.7 m^2 ha^{-1} in Wanariset (Kartawinata *et al.* 1981), 33.7 m^2 ha^{-1} in Lempake (Riswan 1987)), but lower than that of 37.8 m^2 ha^{-1} in Sepilok, Sabah (Nicholson 1965). The mean basal area of dipterocarps per ha in our study site (6.61 m^2 ha^{-1}) was about 2–3 times lower than those of Kalimantan forest

Table 7. Comparison of number of dipterocarp species and their proportion to density and basal area in various dipterocarp forests of Asia

Forest type and location	Plot size (ha)	Tree size class	No. of dipterocarp species (cm dbh)	Dipterocarp density (trees ha^{-1}) ≥ 10 cm dbh	Density as proportion to plot density	Dipterocarp basal area as % of total basal area	Source
India							
• Evergreen forest, Anamalais, Western Ghats	30	≥ 10	3	31	6.8	19.00	Present study
• Evergreen forest, Uppangala, Western Ghats	3.12	≥ 10	3	-	21	42.00	Pascal & Pelissier (1996)
Malaysia							
• Lowland dipterocarp forest, Pasoh	50	≥ 1	30	62	9.33	24.38	Manokaran *et al.* (1991)
• Lowland dipterocarp forest, Pasoh	8	≥ 10	26	52	9.53	31.03	Manokaran (1988)
• Lowland dipterocarp forest, Sungai Menyala Forest Reserve	2	≥ 10	16	72	15.11	38.45	Manokaran (1988)
• Hill dipterocarp forest, Bukit Lagong Forest Reserve	2	≥ 10	15	57	11.53	30.55	Manokaran (1988)
Kalimantan, Indonesia							
• Lowland dipterocarp forest, Berau	4		49	141	25.3	53.50	Sist (1996)
(Plot 1, 2 and 3)	4	≥ 10	50	114	20.6	44.00	
	4		40	114	24.5	47.20	
• Lowland dipterocarp forest, Wanariset	1.6	≥ 10	14	52	16.0	55.00	Kartawinata *et al.* (1981)

(14.89 m^2 ha^{-1} (Sist 1996)) and Uppangala, Western Ghats (16.75 m^2 ha^{-1} (Pascal & Pelissier 1996)), and closer to that of Malaysia (6.89 m^2 ha^{-1} (Manokaran *et al.* 1991)). The greater basal area relative to the density of dipterocarps (7% trees ha^{-1}) in our site indicated that the dipterocarps dominated the larger diameter classes and this was in conformity with other dipterocarp forests.

Spatial patterns of all dipterocarp species and their three stem size classes exhibited both clumped and uniform patterns at the scales tested (Tables 5 & 6), while random pattern was very rare at our site. According to Armesto *et al.* (1986), random patterns are exhibited by species that are subjected to frequent large scale disturbances. In the 1-ha scale especially, the predominantly clumped dispersion of *D. indicus* and *V. indica* may be attributed to their greater number of individuals, as opposed to *H. parviflora*, which was largely uniform in distribution (Table 5).

In essence, the diversity of dipterocarps at our study site was poorer than that in the Southeast Asian forests. However, as upper storey species, the dipterocarps dominated the evergreen forest of Varagalaiar, and hence this forest can be considered as a low-elevation dipterocarp forest and part of the westernmost dipterocarp forest of Asia. Demographic studies of these species would be possible in subsequent inventories, as all individuals are permanently tagged and such monitoring would provide further data useful for forest management and conservation.

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