Comparative analysis of tree diversity and dispersion in the tropical lowland rainforests of Agumbe, Central Western Ghats, India.

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COMPARATIVE ANALYSIS OF TREE DIVERSITY AND DISPERSION IN THE TROPICAL LOWLAND EVERGREEN FOREST OF AGUMBE, CENTRAL WESTERN GHATS, INDIA

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ABSTRACT

The diversity, density and dispersion of tree species were investigated in the tropical lowland evergreen forest of Agumbe, central Western Ghats, India. The Agumbe region receives the highest rainfall in the Western Ghats complex. Three 1-hectare plots, in the upper (650 m) and lower altitudes (100 m and 200 m), were censused for all trees ≥10 cm gbh. Altogether 3202 live stems were encountered, representing 125 species in 92 genera and 42 families. Species richness was greatest in the lower most plot (100 m) with 71 species, and lowest (56) in the upper plot. There was a progressive decrease in species richness with increasing altitude. The number of families was greatest (34 and 33) in the lower altitudes and least (23) in the upper most plot. Plots at lower altitudes contained greater proportion of large trees and emergent species. Altitude and tree density were positively correlated, whereas species richness and basal area negatively correlated. The observed spatial patterns were strongly influenced by density and altitude. Of the 125 species only 15 species were common to the three plots. Species composition varied continuously with altitude, as shown by a detrended correspondence analysis using data from thirty 100 m x 10 m subplots. The results indicate the existence of two discrete vegetation zones; the one at higher altitude being totally evergreen and the other at lower altitude had a considerable proportion of deciduous trees.

Keywords: Agumbe, altitudinal variation, monodominance, stand density, tree diversity, tropical lowland evergreen forest.

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INTRODUCTION

Changes in community structure of tropical lowland evergreen forests with altitude have been well documented (Grubb *et al.*, 1963; Grubb, 1971; van Steenis, 1972; Lieberman *et al.*, 1985, 1996; Ohsawa *et al.*, 1985; Proctor *et al.*, 1988; Ohsawa, 1991; Richards, 1996). The changes in community type with increasing altitudes are also accompanied with changes in structure, stratification, stature, species diversity, species dominance, basal area and other plant community attributes. The reasons that have been attributed to explain the observed effect are changes in temperature (Ohsawa *et al.*, 1985; Ohsawa, 1991), slope (Hallé *et al.*, 1978), light intensities (Brown, 1919), soil conditions (Grubb, 1971; Lieberman *et al.*, 1985, 1996; Heaney and Proctor, 1989), wind (Hartshorn and Peralta, 1988), *Massenerhebung effect* (Grubb *et al.*, 1963; Grubb, 1971; Proctor *et al.*, 1988) and other environmental factors (Proctor *et al.*, 1983; Lieberman *et al.*, 1985, 1996).

In the present study we provide information on the tree community in the tropical lowland evergreen forests of Agumbe, central Western Ghats. The aims of the study were: to determine the diversity and density of trees and to study the effect of altitude on diversity, density, species composition and spatial patterns.

Study area

Location

The present study was carried out in the tropical lowland evergreen forests of Someshvar reserve forest between 13°30'48" and 13°31'00"N lat. and 75°03'21" and 75°06'00" E long. in South Canara district of Karnataka state, south India (Fig. 1a and b). This region is popularly known as the Agumbe region, though Agumbe town lies north of Someshvar reserve forest. Champion and Seth (1968) have classified these forests as 'West coastal tropical evergreen forests'. These forests are the last few remaining patches of tropical lowland evergreen forests in the Western Ghats complex. The other important feature is the presence of such a community at a low altitude as compared with other parts of the Western Ghats.

Climate

The climate in the whole of the Indian peninsula is governed by the monsoon regime. The monsoons correspond to seasonal winds blowing from the Indian Ocean to Asia in summer, the southwest monsoon, and from Asia to the Indian Ocean in winter, the northeast monsoon. The monsoon reaches Agumbe around 1st June. Pascal (1988) has shown the high regularity of the monsoons in the Western Ghats. Precipitation is greatest in the latitude of Agumbe, exceeding 4000 mm near the coast, increasing steadily and rapidly towards the interior. Agumbe (650 m alt.) receives a mean annual rainfall between 7300 - 7600 mm spread over 128 days. The maximum rainfall recorded was 12,918 mm in 1946. The Ghats, although not very high (650 m alt.) and only 40 km from the coast, have a considerable influence: precipitation increases from 5900 to 7500 mm in 6 km. The decrease over the plateau is also rapid from 7500 to 4000 mm in 15 km (Pascal, 1988). The rains last almost up to November. During the wet season there is almost continuous cloud cover and high humidity. The dry period lasts for nearly four months. The mean annual temperature at Agumbe is 22°C. In Agumbe during the dry season, high velocity winds from the northeast corresponding to dry trade winds are noticeable. The mechanism is reversed only in May or June, during the southwest monsoon. In October the direction is reversed once again. The winds are never very violent in these regions. Wind velocities of 20-60 kmh^{-1} are exceptional, but are noticeable from October to end of January and again in July and August. The average values are generally between 3.8 and 8.8 km h^{-1}.

Site selection

A preliminary survey carried out towards the end of April 1996 revealed the existence of two forest types, one on the upper reaches of the Ghats (300-650 m alt.), dominated by *Poeciloneuron indicum* and the other on the lower reaches of the Ghats (100-200 m and 200-300 m alt.), along the chosen slope. One-hectare plots were established in each of the forest types at altitudes of 650, 200 and 100 m (Fig. 1b). The location of each individual plot was based on the availability of relatively flat terrain and other

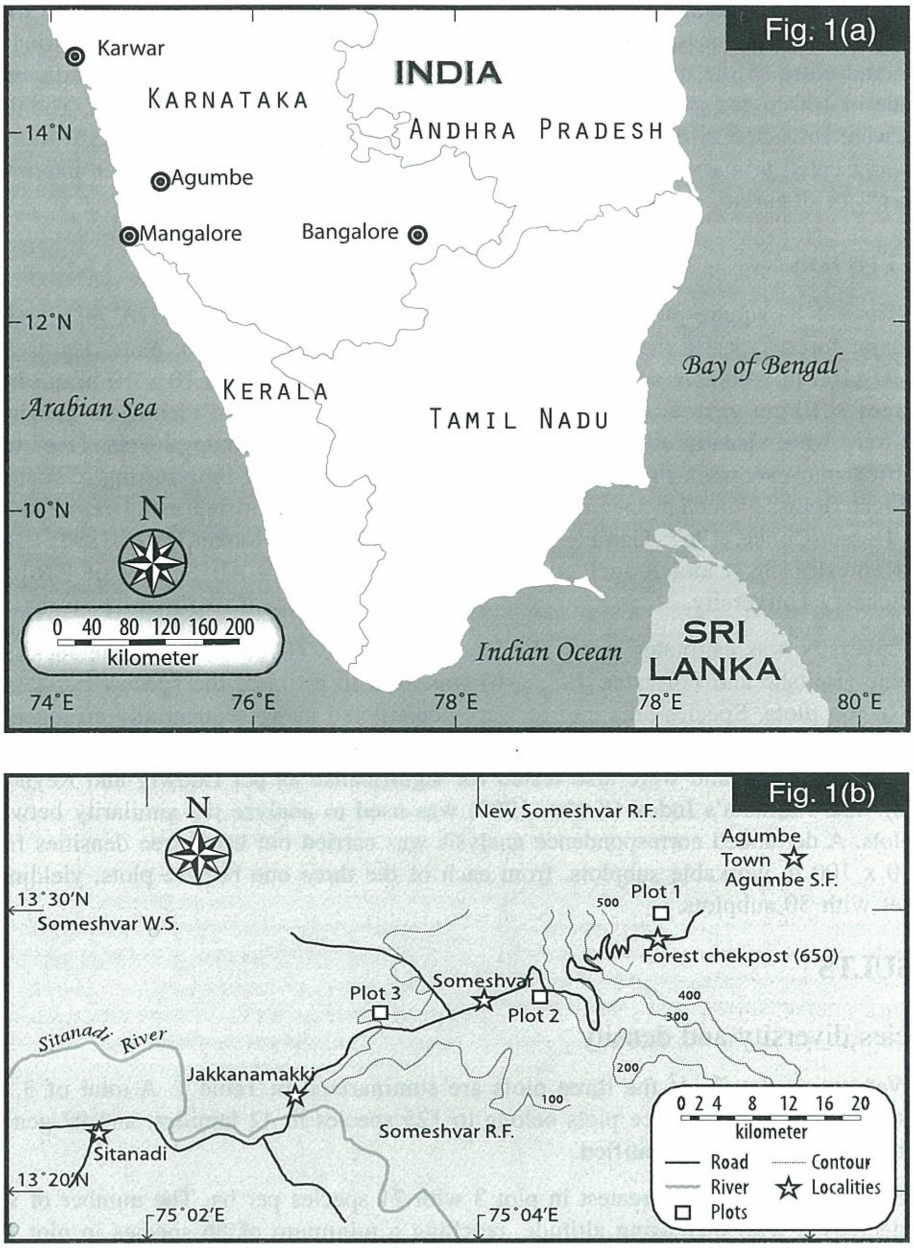

Figure 1. (a) Locality map of Agumbe in Karnataka state of south India; (b) Distribution of study plots near Agumbe (plot 1) and Someshvar towns (plots 2 and 3).

logistic conveniences. The linear distance between each of the plots is approximately 1.5 km. Plot 1 is situated on hilltop at an altitude of 650 m and at the Agumbe forest check-post, 2 km from Agumbe town. Plot 2 is situated at an altitude of 200 m along the slope and close to the nearby town, Someshvar. Plot 3 is located at the foothills at an altitude of 100 m and about 1 km away from Someshvar and towards Sitanadi. The three plots were subjected to different levels of human pressure. Plot 1 was the least disturbed and represented primary forest, Plot 2 the most and Plot 3 was subjected to an intermediate level of disturbance.

METHODS

Three 1 ha square plots were established in the month of May 1996, representing the major forest types in the study area. Each of the three one hectare plots was divided into 10 x100 m workable subplots, which were further divided into 10 x 10 m quadrats. All trees ≥ 10 cm girth at breast height (gbh) were measured and identified. Height of adult trees were visually estimated to assign them to different canopy levels. Trees were classified into evergreen or deciduous based on field notes and by referring to regional and local floras. Voucher specimens were collected and identified using regional and local floras (Cooke, 1967; Gamble and Fischer, 1915-1935; Hooker, 1872-1897; Pascal and Ramesh, 1987) and lodged in the herbarium of Salim Ali School of Ecology, Pondicherry University.

Diversity was estimated using the Shannon's index (Krebs, 1989). The Jackknife estimate (Heltshe and Forrester, 1983a, b) was used to estimate the species richness in each of the plots. Species-area curves were constructed using sequentially arranged 10 100 m subplots. Spatial patterns of tree species with ≥25 individuals were arrived at using variance: mean and were also tested for significance as per Ludwig and Reynolds (1988). The Morisita's Index (Krebs, 1989) was used to analyze the similarity between the plots. A detrended correspondence analysis was carried out using tree densities from the 10 x 100 m workable subplots, from each of the three one hectare plots, yielding a dataset with 30 subplots.

RESULTS

Species diversity and density

Vegetation details of the three plots are summarized in Table 1. A total of 3,202 stems inventoried in the three plots belong to 125 species in 42 families, and 92 genera, of which 6 remained unidentified.

Species richness was greatest in plot 3 with 71 species per ha. The number of species decreased with increasing altitude, reaching a minimum of 56 species in plot 1 at 650 m (78.87% of the 100 m value). Species richness and altitude were negatively correlated ($t = -0.334$, $p < 0.05$). The number of species at different girth classes in the three plots did not vary significantly (ANOVA, $F_{2,21} = 0.298$, $f_{crit} = 3.446$, $p<0.05$), but decreased with increasing altitude (Fig. 2a, b and c). Shannon's index reached its maximum in the lower plot of the gradient, plot 3 at 100 m (Table1) and there was a progressive reduction in diversity with increase in altitude.

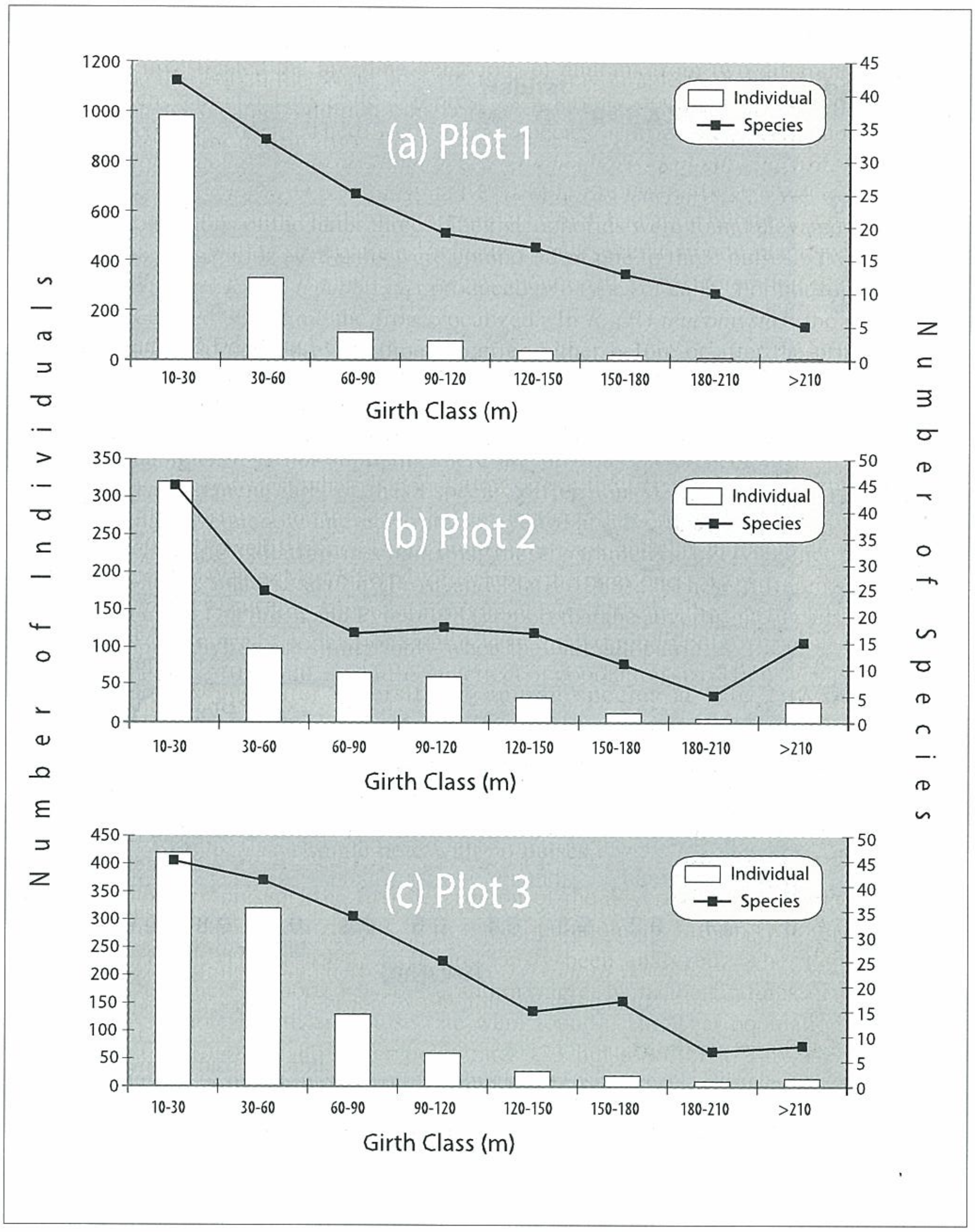

Figure 2. Girth class distribution of species and individuals of plots 1, 2 and 3 in Agumbe, central Western Ghats, India.

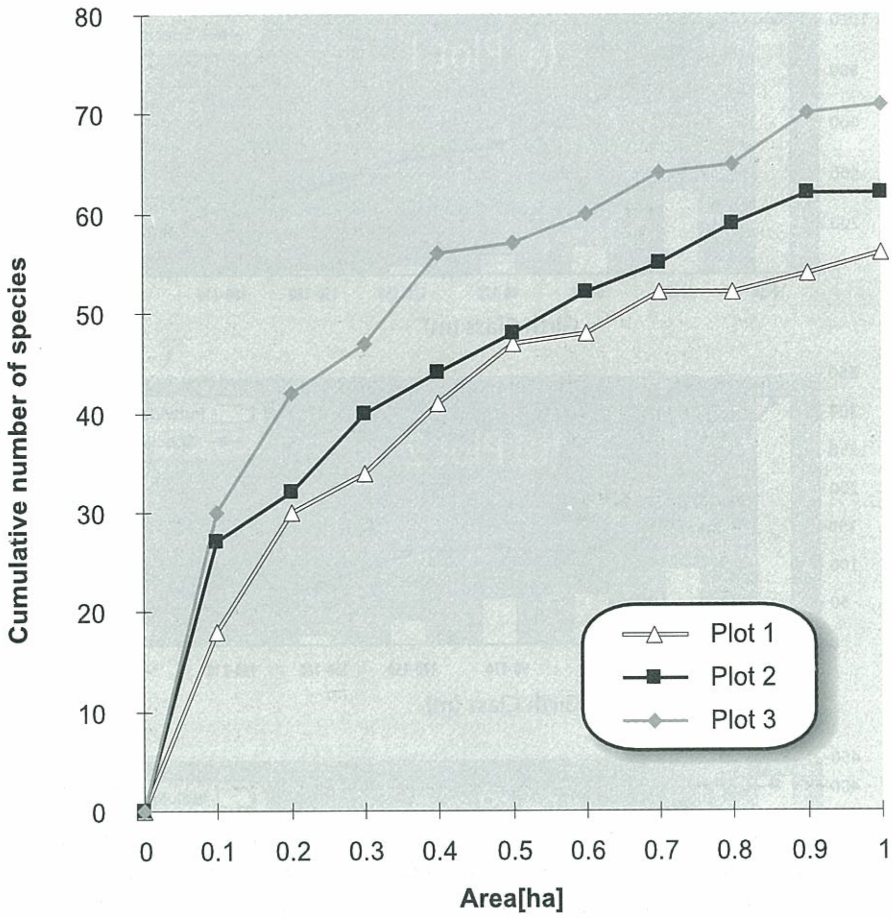

Figure 3. Species accumulation curve for the three plots in Agumbe.

The species-area curves for all the three plots did not reach an asymptote on a one-hectare scale (Fig. 3). The jackknife estimate of species richness for plot 1, 2 and 3 was 58.62 to 71.20, 69.1 to 86.07 and 79.13 to 96.85 respectively.

Density decreased along the gradient from 1576 in plot 1 to 1001 in plot 3. The lowest density was encountered in plot 2, at 200 m (Table 1). The decrease in density was positively correlated with altitude ($t = 0.267$, $p < 0.1$).

Table 1. Tree inventory results of three study plots in the tropical lowland evergreen forest of Agumbe, central Western Ghats, India.

Variable	Plot 1	Plot 2	Plot 3
Altitude(m)	650	200	100
Number of stems	1576	625	1001
Number of species	56	62	71
Number of families	23	33	34
Basal area (m^2ha^{-1})	35.41	38.20	36.39
Stratification			
Emergents & Top canopy species (32-35 m)	39.3%	41.9%	44.3%
Middle canopy species (20-25 m)	30.4%	27.4%	32.9%
Lower canopy species (10-12m)	23.2%	25.8%	21.4%
Undergrowth species (≤ 5 m)	7.1%	4.8%	1.4%
Number of unique species	27	19	30
Diversity Index(species)			
Shannon (H')	0.992	1.458	1.746
Evenness			
E(H')	0.561	0.814	0.797
Diversity Index(families)			
Shannon(H')	1.241	1.449	1.439
E(H')	0.912	0.954	0.939

The low evenness on the hilltop, plot 1 (Table 1) reflects the predominance of *Poeciloneuron indicum* (Clusiaceae), which comprised 49% of all individuals encountered. The dominant species in plot 2 are *Dimocarpus longan* (9.3%), *Knema attenuata* (9.3%), *Nothopegia beddomei* (8.7%), *Diospyros paniculata* (8.5%), *Ehretia laevis* (7.4%) and *Vateria indica* (7.4%) which comprised 50.72% of the stand. The dominant species in plot 3 were *Hopea parviflora* (9.9%), *Ixora brachiata* (9.1%), *Humboldtia brunonis* (8.3%), and *Nothopegia beddomei* (7%) that comprised 34.3% of all stems.

Family- level diversity

Family-level richness did not vary from the pattern followed by species richness. The number of families reached a maximum of 34 in the lowermost plot and a minimum value of 23 in plot 1 (Table 1).

At the family level the accumulation curve of all three plots (Fig. 4) were found to be asymptotic at one hectare. The dominant families in plot 1 were Clusiaceae, Dipterocarpaceae, Euphorbiaceae and Lauraceae contributing 44.7% of the stand. Anacardiaceae, Dipterocarpaceae, Ebenaceae and Myrtaceae (27.4% of the stand), and Anacardiaceae, Ebenaceae and Lauraceae (25% of the stand) ere dominant in plots 2 and 3 respectively.

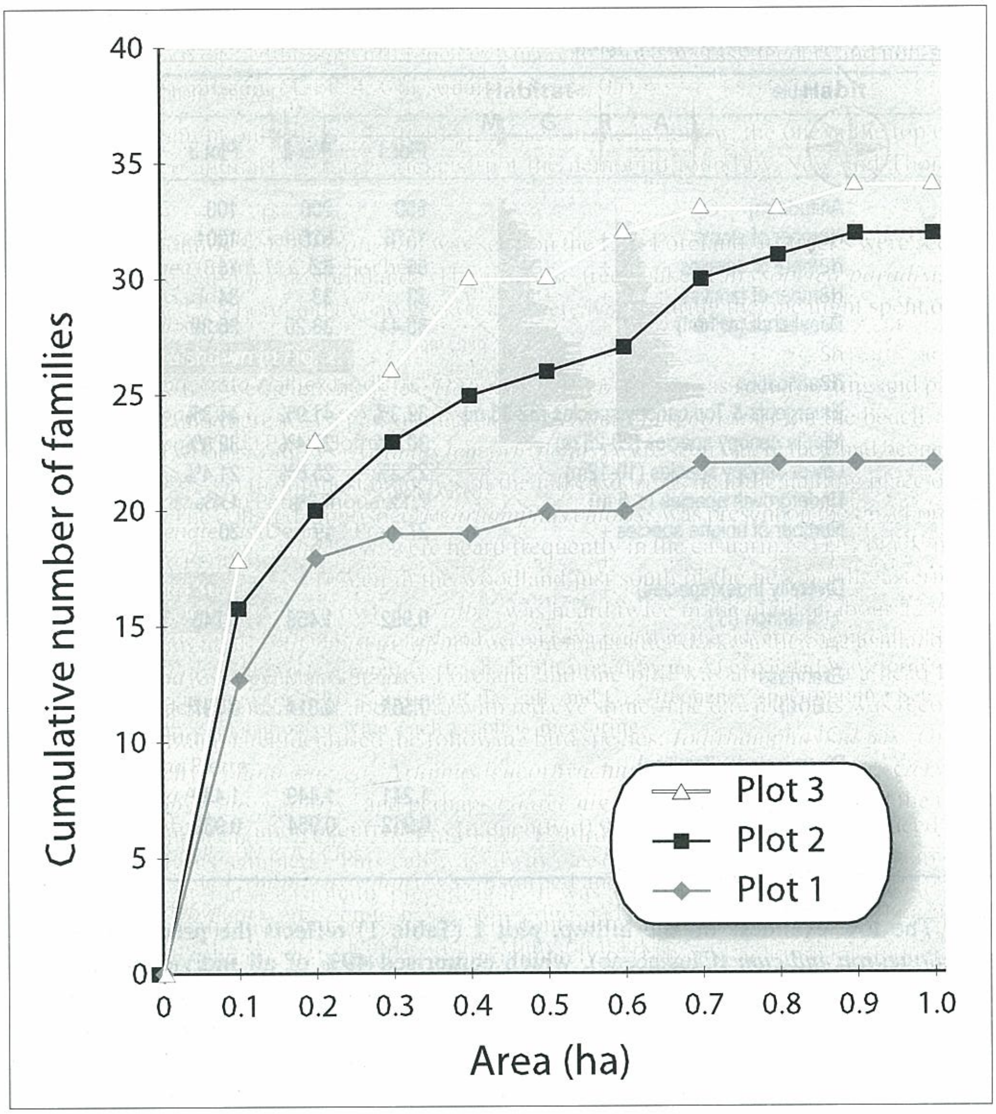

Figure 4. Family-level accumulation curve of the three plots in Agumbe.

Basal Area

Though the basal area was found to decrease with increasing altitudes from 36.39 m^2ha^{-1} in plot 3 to 35.41 m^2ha^{-1} in plot 1, there was no significant correlation between altitude and basal area. Moreover the basal area of the three plots did not show any considerable difference (ANOVA, $F_{2,27} = 0.248$, $F_{crit} = 3.354$, $p<0.05$). Maximum girths recorded, decreased with altitude from 100 to 650 m plot. The maximum girth attained by any single individual in plot 1 was 307 cm, *Ficus drupacea*, whereas in plot 2, 357 cm, *Hydnocarpus pentandra* and plot 3, 347 cm, an unidentified species, were recorded. The plot at intermediate altitude contained relatively more large trees. The absence of large trees is particularly noticeable in plot 1 (at 650 m alt.). The girth class distribution of individuals in each of the plots was the same, with reduced number of individuals in the larger girth classes (Fig. 2a, b and c).

Spatial patterns

The results of spatial patterns indicate substantial differences between the plots. In plot 1, 60% of the ten species examined were significantly aggregated, 40% of the 7 species and 38.5% of the 13 species were significantly aggregated on a 1 ha scale in plots 2 and 3 respectively (Table 2). A correlation of the observed spatial pattern of species, on 0.64 ha and 1 ha scale, and abundance of trees was found to be positively correlated ($r = 0.137$, $p < 0.05$)

Vertical stratification

Of the 71 species encountered in plot 3, 44.3% were emergents and species of the top canopy and 1.4% of the species formed the understorey. In plot 1, 33.9% and 7.1% of the 56 species made up the top canopy and understorey respectively (Table 1). With increase in altitude, there was a decrease in the number of emergent and top canopy species whereas there was an increase in the understorey component.

Similarity

Similarity between plots indicates that plots 2 and 3 were quite similar (Table 3). Of the 125 species that were encountered in the three plots only 4% were found in all three plots. 6.77% species were common to plot 1 and plot 2, 15.03% species to plot 3 and plot 2 and 4.72% species to plot 1 and plot 3 respectively. The number of new species found at each successive plot varied considerably. Nineteen and 27 species were found between plot 3 and plot 2, plot 2 and plot 1 respectively. The three plots differed significantly in their species composition with respect to the number of evergreen and deciduous species. Plot 1 at 650 m was totally composed of evergreen species (Fig. 5) where as plots at lower altitudes had significant proportion of deciduous species. The decrease in the number of deciduous trees was negatively correlated with altitude ($t = -0.779$, $p < 0.05$).

Detrended correspondence analysis

A detrended correspondence analysis was carried out using 30 subplots from the three one-hectare plots. Only species which were found in more than two subplots were considered. The results indicate a strong floristic trend with altitude. Species composition varied continuously with altitude (Fig. 6). Based on floristic analysis, the change was gradual and two discrete vegetation zones were observed, one at higher altitudes (650 m alt.) and the other at lower altitudes (100-200 m). Plot 3 had the highest axis 1 scores and plot

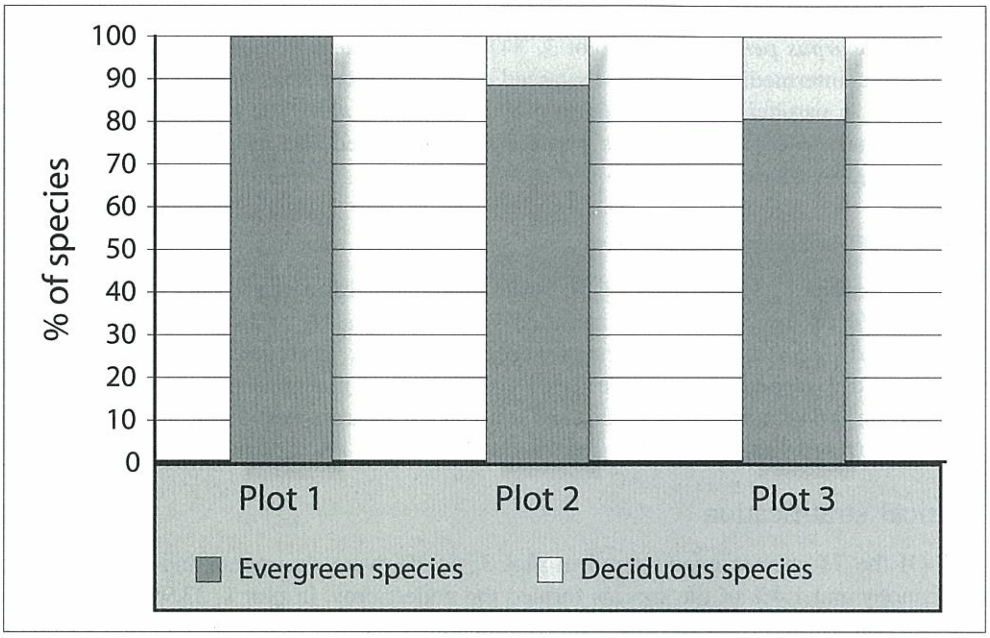

Figure 5. Percentage of evergreen and deciduous species in the three plots of Agumbe.

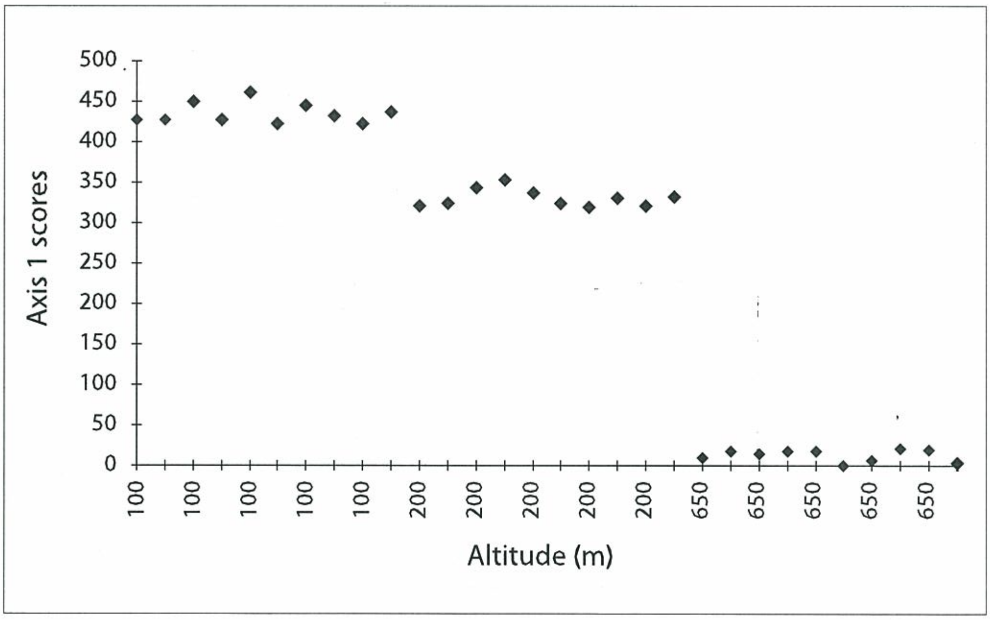

Figure 6. Axis 1 sample scores from the detrended correspondence analysis in relation to altitude in Agumbe, central Western Ghats, India.

Table 2. Dispersion patterns of all species ≥ 25 individuals in the three plots, Agumbe, Western Ghats.

		Variance /mean		
Area[ha]		O.16	0.64	1.0
Plot 1	*Casearia wynadensis*	0.8[r]	0.9[r]	1.3[c]
	Garcinia morella	1.6[r]	1.4[c]	1.2[r]
	Palaquium ellipticum	1.7[r]	1.5[c]	1.8[c]
	Pinanga dicksonii	11.5[c]	7.3[c]	5.2[c]
	Poeciloneuron indicum	1.4[r]	2.2[c]	2.0[c]
	Reinwardtiodendron anamallayanum	1.6[r]	1.7[c]	1.9[c]
	Alseodaphne semecarpifolia	1.2[r]	1.2[r]	1.2[r]
	Garcinia talbotii	1.9[r]	1.1[r]	1.1[r]
	Psychotria anamallayana	0. 7[r]	0.8[r]	1.0[r]
	Syzygium laetum	1.0[r]	1.8[c]	1.6[c]
Plot 2	*Dimocarpus longan*	1.2[r]	1.1[r]	1.0[r]
	Diospyros paniculata	0.9[r]	1.0[r]	1.2[r]
	Knema attenuata	0.9[r]	1.1[r]	1.2[r]
	Nothopegia beddomei	1.3[c]	1.3[c]	1.2[r]
	Vateria indica	0.7[r]	0.8[r]	0.9[r]
	Ehretia laevis	1.5[r]	2.0[c]	2.1[c]
	Polyalthia fragrans	1.0[r]	2.4[c]	2.5[c]
Plot 3	*Holigarna arnottiana*	2.1[c]	1.6[c]	1.6[c]
	Hopea parviflora	0.7[r]	1.0[r]	1.1[r]
	Hopea ponga	0.9[r]	1.6[c]	1.5[c]
	Humboldtia brunonis	--	3.7[c]	5.5[c]
	Nothopegia beddomei	1.6[r]	1.4 [c]	1.4[c]
	Artocarpus hirsutus	0.8[r]	0.9[r]	1.0[r]
	Diospyros paniculata	1.3[r]	1.4[r]	1.1[r]
	Knema attenuata	0.9[r]	1.0[r]	1.1[r]
	Madhuca neriifolia	0.9[r]	0.7 [r]	1.0[r]
	Memecylon terminale	0.9[r]	0.9[r]	1.0[r]
	Myristica malabarica	2.4 [c]	1.7 [c]	1.8[c]
	Cinnamomum verum	0.9[r]	1.0[r]	1.2[r]
	Ixora brachiata	1.5 [r]	1.1 [r]	1.2[r]

Note:
c= clumped; r= random; - = no individuals.

Table 3. Similarity between the three study plots of Agumbe, Western Ghats, as measured using the Morisita's index. Values in parentheses indicate the number of common species.

	Plot 1	Plot 2	Plot 3
Plot 1	1.00[56]	0.03[08]	0.02[20]
Plot 2		1.00[62]	0.36[06]
Plot3			1.00[71]

1 the least, due to their species composition, indicating change in species composition with altitude. The axis 1 scores of plot 2 and 3 were comparable, indicating that the two plots were similar in species composition. Heterogeneity in the three plots was noticed with considerable intraplot variation in axis 1 scores.

The eigenvalue for axis 1 was 0.85, indicating a strong floristic trend with altitude. However, eigenvalues of the other axis were lower and no further interpretable information was made available.

DISCUSSION

In the present study a total number of 125 tree species (≥ 10 cm gbh) were recorded. Forty species of lianas ≥5 cm gbh) were encounterd in the same 3 plots (Padaki and Parthasarathy, ms). The total species richness of the Agumbe region is expected to be ≈ 180 tree species. In the two other studies on a comparable 3 ha scale from medium and high elevation evergreen forest sites in Kalakad National Park, southern Western Ghats, 125 and 122 species were enumurated respectively for trees ≥30 cm gbh (Parthasarathy *et al.*, 1992). Ganesh *et al.*, (1996) recorded 90 species in 3.82 ha of Kakkachi area in southern Western Ghats. While Pascal and Pelissier (1996) in 3.12 ha have obtained 91 species in Uppangala forest of Coorg area, located south west of Agumbe, in the Western Ghats. The species richness of Agumbe forest is not only lower than many other sites of the Western Ghats but also of other tropical lowland forests (Prance *et al.,* 1976; Knight, 1975; Procter *et al.,* 1988; Campbell *et al.,* 1992; Duivenvoorden, 1996; Pascal and Pelisser, 1996). Although Agumbe receives high rainfall, exceeding 7000 mm annually, the observed species richness is low when compared to forests of Barro Colorado Island, Panama, which receives only 2670 mm of rain (Knight, 1975), and Manaus, Brazil which houses 179 species per ha that receives ≈ 2000 mm of rain (Prance *et al.*, 1976). Gentry's (1982) hypothesis of species richness and precipitation being positively correlated does not hold good in the case of Western Ghats. Clearly, precipitation is not the only reason for the observed species richness in the southern Indian context. Plot 3 had the maximum number of species. Species richness and altitude were negatively correlated, indicating that species richness decreased with increasing altitudes, plot 1 was 22.17% species-poor when compared to plot 3. Possibly edaphic factors and altitude play a vital role in determining the species richness in the Agumbe region.

The species-area curve of all the three plots clearly indicates that a sample size of 1 ha was insufficient to determine the species richness of the area. All the curves would probably reach an asymptote clearly with addition of another 0.5 ha. From the jackknife estimates and the species-area curves the existence of a few more species at each of the altitude is indicated. The high variance in the jackknife estimate indicates a high abundance of spatially rare species. At the family- level the accumulation curves for all the three plots were found to be asymptotic at a scale of one hectare, indicating that a sample size of 1 ha was sufficient to enumerate all the families in each of the plots; plot 1 clearly reaching an asymptote on a one hectare scale (Fig. 4). Therefore, the six unidentified species were not considered to belong to new families and were not included while constructing the curves.

The basal area of all the three plots is similar to Dawkins's (1959) estimate of average basal area for tropical lowland evergreen forests, which is about 36 m^2ha^{-1} for trees ≥

30 cm gbh. The observed basal area is similar to those reported from the Indian subcontinent (Rai and Proctor, 1986; Pascal, 1988; Swamy and Proctor, 1994; Pascal and Pelissier, 1996; Parthasarathy and Karthikeyan, 1997). The maximum basal area was recorded in plot 2 and the minimum in plot 1. The decrease in basal area seems to be compensated by increase in density. With increase in density the incidence of thin stem plants was also found to increase. This is clearly visible in plot 1 where 47% of the stand was made up of plants with girths ≤ 20 cm, when compared to 42% and 26% in plots 2 and 3 respectively. The observed variation in basal area between plots is due to the low number of large trees at higher altitudes.

Spatial patterns of trees were the same as those exhibited in any other tropical forest, mainly aggregated and a few randomly dispersed trees. Janzen (1970) and Connell (1971) suggested that adult trees in tropical evergreen forests may be uniformly spaced and this enabling the maintenance of high levels of diversity. Numerous studies carried out in the tropics have revealed that trees are more commonly aggregated or randomly dispersed than being uniformly dispersed (Hubbell, 1979; Thorington *et al.,* 1982; Forman and Hahn, 1980; Strasberg, 1996). There was no single species that was uniformly dispersed in any of the three plots, on any scale of measurement. There was significant variation in the dispersion patterns between plots. The result of a correlation between the observed spatial patterns and abundance of tree species has shown that species tend to aggregate at high abundance. This phenomenon was well noticed on higher scales of measurement and on the lowest scale of measurement, species were more often randomly dispersed. As increasing densities were positively correlated with altitude, the aggregation of species appears to be strongly influenced by altitude. This is well noticed in plot 1, which had the highest density and highest proportion of species that are aggregated when compared to plots 2 and 3.

With increase in altitude the following changes were observed, reduced species richness, increase in undergrowth component, reduced number of large trees, increased densities and change in spatial pattern from random to aggregated dispersion. The observed changes in vegetation are similar to those previously reported (Grubb *et al.,* 1963; Grubb, 1971; van Steenis, 1972; Lieberman *et al.,* 1985, 1996; Ohsawa *et al.,* 1985; Proctor *et al.,* 1988; Hartshorn and Peralta, 1988; Heaney and Proctor, 1989; Ohsawa, 1991). Hallé *et al.* (1978) suggested that on slopes the crowns of the emergents are arranged in a step-like fashion or over lap like tiles due to the combined effect of gravity and one-sided incidence of light explaining the greater floristic richness of forests on slopes, rather than hilltops. In the Western Ghats, wind is a highly discriminatory factor in facies linked to exposure. So it plays an important role in the crest region such as uprooting of trees in the upper regions of the slope (Pascal, 1988). In the upper reaches of the Ghats high velocity winds are largely encountered during the dry season. This could be one of the possible reasons for the observed low diversity on the upper reaches of the slope. The other possible reason for the observed low species richness of the plots at higher altitudes could be edaphic factor.

With increase in altitude the number of dominant species reduced and monodominant *Poeciloneuron indicum* forests were encountered on the hilltops. Similar monodominant forests have been observed in the forests of Malaysia and Guyana (Johnston and Gillman,

1995) and in Mexico (Martijena and Bullock, 1994). The occurrence of such forests has been attributed to poor soil conditions and increased reproductive pressures (Whitmore, 1984), successional stages (Hart, 1990) and altitude (Ohsawa *et al.*, 1985). In the Agumbe region the reasons attributed for the occurrence of such gregarious *Poeciloneuron indicum* forests are felling of *P.indicum* poles in the past (Rai and Proctor, 1986) and high levels of iron and alumina in the soil (Pascal, 1988). It has been speculated that the reason for monodominance of *P.indicum* is due to edaphic factors. Higher densities at higher altitudes provide a better resistance against strong winds (Lorence and Sussman, 1988). In our present site strong winds are predominant and play a vital role in the crest region (Pascal, 1988). Wind is an important factor in this region and the reduced heights of trees at higher altitudes is due to the drying effect brought about by high velocity winds. The observed increase in the undergrowth component with increase in altitude could be due to the altitudinal difference between the plots as suggested by Ohsawa *et al.* (1985).

The ordination indicates that the species composition varied continuously with altitude, the change was gradual and two discrete vegetation zones were detected, one at higher altitudes and the other at lower altitudes. The plot at higher altitudes representing the primary forest and plots at lower altitude representing secondary forest formations. The change was gradual between 100-200 m, but the change between 200-650 m was sudden and abrupt. We believe that with inclusion of a few more plots this change would be more gradual, but still forming a discrete vegetation zone at higher altitudes. The formation of the two discrete zones is better reflected when the results of the similarity analysis and ordination are juxtaposed. Both reflect the similarity in species composition between plots 2 and 3 as compared with plot 1. Apart from changes in species composition there was a gradual and complete replacement of deciduous species by evergreen species with increase in altitude. Plot 1 was totally composed of evergreen species. The main reasons for these observed changes are rainfall, edaphic factors and duration of the dry period.

Grubb (1971) has attributed the observed changes in vegetation to soil conditions. Similarly Lieberman *et al.* (1996) indicated that nitrogen is the most likely limiting factor at higher altitudes. They further observed that forest structure was strongly influenced by landform position and tall dense forests occurred on sloping landforms due to adequate drainage. Ohsawa (1991) and Ohsawa *et al.* (1985) have suggested that the observed changes in vegetation with altitude are due to the low temperature at higher altitudes which limits the formation of organic matter thereby inhibiting the formation of tall forests. It is speculated that the observed changes in vegetation with altitude in the Agumbe region is due to the combined effect of wind, duration of the dry season, changes in landforms and soils conditions.

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