NATURE OF SECONDARY SUCCESSION IN THE ABANDONED *EUCALYPTUS* PLANTATIONS OF NEYYAR (KERALA) IN PENINSULAR INDIA

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GEORGE, S.J., KUMAR, B. MOHAN & RAJIV, G.R. 1993. Nature of secondary succession in the abandoned *Eucalyptus* plantations of Neyyar (Kerala) in Peninsular India. Vegetation structure and floristic composition of a 15- *y* - old secondary forest in an abandoned *Eucalyptus tereticornis* plantation of the Western Ghats (Peninsular India) was analyzed specifically addressing the following questions : (i) Does the stand show a lower floristic diversity than an adjacent mature forest? (ii) Does the young stand display vertical stratification and tree-girth distribution characteristic of uneven-aged forests under similar eco-climatic conditions? and, iii) Whether the pattern of abundance can be linked to the vital attributes of the species? Height and girth of all trees (≥15 *cm* girth at breast height (GBH)) in one hectare were recorded for phytosociological analyses. Density related diversity indexes were calculated and profiles of 80 x 10 *m* strip transects at two locations were made to describe stand physiognomy. Seven hundred and twenty-seven individuals belonging to 23 different species (≥15 *cm* GBH) were recorded from the sampling area. The average basal area for the stand was 12.77 m^2 ha^{-1}. Six species (*E. tereticornis, Olea dioica, Aporusa lindleyana, Symplocos spicata, Terminalia paniculata* and *Macaranga peltata*) had importance value indexes greater than or equal to 20. Few ruderal species were present at the site. Diversity index values were comparable with those of a mature forest stand of the Western Ghats. Girth class frequency distribution showed an inverse 'J' shaped curve and the height-diameter relationships showed equitable distribution of trees on either side of a reference line : h = 100.d, suggesting the forest has adequate regeneration and the *E. tereticornis* overstorey has not influenced forest development. The current suite of species includes many with light weight, wind dispersed seeds and a mix of shade tolerant and intolerant species. The abundance of evergreen heliophytes with deciduous species suggests eventual development into a semi evergreen forest type. The present state of the stand may be characterized as a "pre-equilibrium" stage in forest development.

Key words: *Eucalyptus* - India - phytosociology - secondary succession

GEORGE, S.J., KUMAR, B. MOHAN & RAJIV, G.R. 1993. Keadaan sesaran sekunder di ladang *Eucalyptus* yang ditinggalkan di Neyyar (Kerala) di Semenanjung India. Struktur tumbuhan dan komposisi flora hutan sekunder berusia 15 tahun di ladang *Eucalyptus tereticornis* yang ditinggalkan di Ghats Barat (Semenanjung India) telah dikaji untuk menjawab soalan-soalan berikut : (i) Adakah dirian tersebut menunjukkan kepelbagaian flora yang rendah dari hutan matang yang bersebelahan? (ii) Adakah dirian muda tersebut mempamirkan ciri-ciri penstrataan tegak dan taburan lilit pokok hutan-hutan tak seumur dibawah keadaan ekoiklim yang sama? (iii) Samada corak berlebihan dapat dikaitkan dengan sifat-sifat penting spesies tersebut? Ketinggian dan lilit semua pokok (≥15*cm* pada paras dada) dalam 1 hektar dicatitkan untuk analisis fitisisiologi. Petunjuk kepelbagaian yang berhubung dengan ketumpatan telah dikira dan profil-profil transek jalur 80 × 10 *m* pada dua

lokasi digunakan untuk menerangkan fisionomi dirian. Tujuh ratus dua puluh tujuh individu dari 23 spesies berlainan (≥ 15 *cm* GBH) telah direkodkan dari kawasan sampel. Purata luas pangkal dirian tersebut ialah 12.77 m^2 ha^1. Enam spesies (*E. tereticornis, Olea dioica, Aporusa lindleyana, Symplocos spicata, Terminalia paniculata* dan *Macaranga peltata*) mempunyai petunjuk nilai kepentingan yang lebih besar atau bersamaan dengan 20. Hanya sedikit spesies tumbuhan belukar terdapat di tapak tersebut. Nilai-nilai petunjuk kepelbagaian adalah setanding dengan apa yang didapati dalam dirian hutan matang di Ghats Barat. Taburan frekuansi kelas lilit menunjukkan lengkungan bentuk 'J' songsang dan perhubungan ketinggian- diameter menunjukkan taburan yang sama pada kedua-dua belah garis rujukan: h = 100.d, mencadangkan hutan mempunyai pemulihan yang mencukupi dan tingkat atas *E. tereticornis* tidak mempengaruhi perkembangan hutan. Jenis-jenis yang terdapat sekarang terdiri dari spesies yang mempunyai biji benih yang ringan yang disebarkan oleh angin dan campuran jenis-jenis yang tahan dan juga tidak tahan terhadap cahaya. Kedapatan kerofit malar hijau dan spesies meluruh dengan banyaknya menunjukkan perkembangan untuk menjadi hutan jenis separa malar hijau. Keadaan dirian sekarang boleh dicirikan sebagai peringkat 'pra-keseimbangan' perkembangan hutan.

Introduction

Directional vegetation changes over time after disturbances have interested many ecologists (see reviews by Horn 1974, Bazzaz & Pickett 1980, Whitmore 1983). Immediately following disturbance, typically there is a pulse of recruitment under conditions of little or no competition, and after the initial pulse, recruitment slows down. During a disturbance, however, depending on the magnitude and intensity, many of the predisturbance species survive, either through soil seed bank or through advance regeneration (Denslow 1987, Halpern 1989). Colonizers also invade the site through seed rain (Whitmore 1983), and interactions of their life-history traits and disturbance determine subsequent shifts in dominance (Halpern 1989).

Although a substantial number of studies on secondary succession have been reported from the neo-tropics, African and Malayan regions (Ross 1954, Richards 1955, Ashton 1964, Uhl *et al.* 1982, Brokaw 1982, Oldeman 1983, Bazzaz 1984, Whitmore 1984, Whittaker *et al.* 1989), few successional studies have been published from the Indian tropics. Ramakrishnan and his colleagues (Ramakrishnan *et al.* 1981, Toky & Ramakrishnan 1983, Shukla & Ramakrishnan 1984, Rao & Ramakrishnan 1987) analyzed secondary succession in abandoned swidden agricultural fields of northeastern India. They found that ruderal species predominated the scene during the early stages followed by bamboo (*Dendrocalamus hamiltonii*) in the 10-20*y* fallow period. Pascal (1988) observed that cessation of logging and protection of forests stimulate growth of evergreen and deciduous heliophytes in the openings in Western Ghats and soon the formation will evolve towards an evergreen forest. Barring these, no published reports are readily available from the Indian tropics on secondary succession.

In the present study we analyzed the vegetation structure and floristics of a *Eucalyptus tereticornis* stand abandoned after clear-felling to determine the pattern of vegetation development after clear-felling. Forestry operations of the past few

decades have focused heavily on afforestation/reforestation programmes involving the fast-growing Australian species, *Eucalyptus* (FAO 1985). Often these man-made forests were established after clear-felling dense natural forests under the garb of increasing productivity. The prevailing dogma relating to succession in *Eucalyptus* stand is that nothing ever grows under a eucalypts over-storey (Stein 1952), probably due to allelopathy or the detrimental biochemical interactions due to the release of organic compounds into the environment (Story 1967, Fisher 1981).

Several authors, however, have reported herb and shrub layer development in plantations having a standing crop of *Eucalyptus* (Qureshi 1967, Burdon & Chilvers 1977, Mathur & Soni 1980, Mathur & Jain 1983, Rajvanshi *et al.*, 1987, Pande *et al.* 1988). These are data from short-term studies of the ground flora of managed eucalypt plantations (snap-shots of the understorey initiation stages) and do not offer scope for understanding successional trends.

Low tree diversity reported in these studies and also the low niche specialization characteristic of the plants typical of younger stands (Odum 1969) lead us to predict a low floristic diversity and low equitability for the abandoned *E. tereticornis* stand of Neyyar. Furthermore, contrary to the generally held inhibitory role (Connell & Slatyer 1977) of *Eucalyptus* on successional development, we hypothesized that the present vegetation will eventually give rise to a stable community similar to the tropical moist deciduous vegetation native to the area, considered a pre-stage of the southern tropical semi-evergreen forest (Champion & Seth 1968, Pascal 1988), in view of the high rainfall availability and the consequent leaching of the potential inhibitors.

Our objectives were to characterize the vegetation structure and to compare the successional community with a native moist tropical forest. The particular questions of interest were :

i) Do the *Eucalyptus* plantations after 15*y* of abandonment and in the absence of major disturbances during vegetation development represent a lower floristic diversity compared to the moist deciduous forests of the Western Ghats?
ii) Do these 15-*y*-old stands display the vertical stratification and tree-girth distribution of uneven-aged moist deciduous forests?
iii) Can species abundance be linked to their life-history traits?

Materials and methods

Study area

The study area is in the Western Ghats, a mountain range running along the western fringe of the Indian peninsula, in the Neyyar Wildlife Sanctuary of Kerala State (8° 17' N and 8° 53' N latitudes; 76° 48'E and 77° 17'E longitudes). The tract is contiguous with a stretch of moist tropical forests. *E. tereticornis* was planted in this area during 1964 and 1965 and was clear-felled in 1975 (total area: 111.48 *ha*). The plantation was abandoned and incorporated into the

Neyyar Wildlife Sanctuary consequent to the implementation of the Wildlife Act of 1972. Most of the area of the abandoned eucalypt plantation is situated in an island in the Neyyar reservoir (Figure 1). Eucalypts in this area are all of coppice origin.

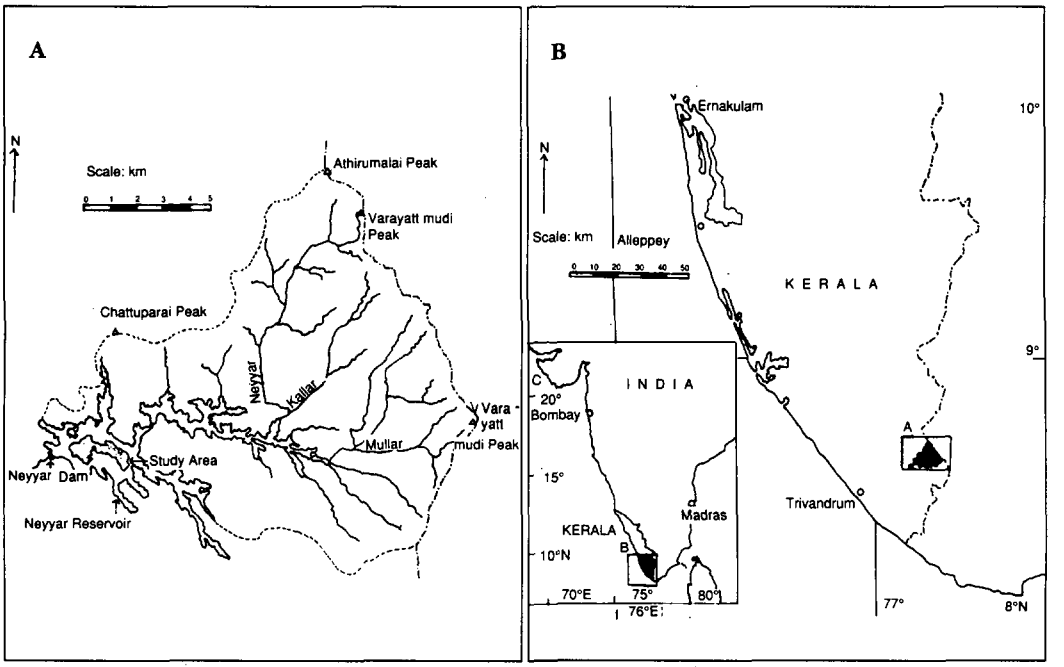

Figure 1. Map of Peninsular India showing the study area

The main forest type in and around the Neyyar Wildlife Sanctuary is the southern secondary moist deciduous type (3B/C2/2S1 of Champion & Seth, 1968). The dominant trees include: *Alstonia scholaris, Artocarpus hirsutus, Butea monosperma, Careya arborea, Cassia fistula, Dalbergia latifolia, Dalbergia paniculata, Emblica officinalis, Lannea coromandelica, Mangifera indica, Pterocarpus marsupium, Syzygium cumini, Terminalia bellirica, Terminalia paniculata, Toona ciliata, Tetrameles nudiflora, Trewia nudiflora* and *Xylia xylocarpa.*

The terrain is very rugged; soils are Inceptisols, and are of varying depths. The area is characteristically hot and humid with a mean annual precipitation of 2800 *mm.* The maximum mean daily temperature during the hottest month of March is about 35°*C* and mean daily minimum during the coldest month of January is about 16°*C.*

Methods

One hectare of forest, located on the island surrounded by waters of the Neyyar reservoir was enumerated in early 1990. The species-area curve for Neyyar

plateaued at around 2000 m^2 and 3500 m^2 respectively for the ≥15 *cm* GBH class (23 species) and <15 *cm* GBH class (44 species) indicating that our 1 *ha* sample was adequate to record the majority of tree species present in the sanctuary. One hundred 10 × 10 *m* quadrats were randomly established in the study area; height and girth at breast height (GBH) of all trees (≥15 *cm* GBH) were measured using a Suunto optical reading clinometer and a tape respectively. All herbs, shrubs and tree seedlings (< 15*cm* GBH) were counted and recorded by species. A detailed profile was drawn of a strip transect measuring 80 × 10*m* at two locations in the area by charting the position of the tree bases, their crown projections and the extent of the ground vegetation. For all charted trees, heights of the crown's top and bottom were recorded and a representation made with consideration to canopy architecture.

Phytosociological analyses

The following parameters (Simpson 1949, Curtis & McIntosh 1950, Shannon & Weiner 1963, Pascal 1988) were calculated:

1. Density = number of individuals of the species 'i' in the sample plot;
2. Abundance = Total number of individuals/number of quadrats of occurrence;
3. Basal area = $GBH^2/4'PI'$;
4. Relative density = Number of individuals of a species × 100/number of individuals of all species;
5. Percentage frequency = Number of quadrats of occurrence × 100/Total number of quadrats studied;
6. Relative basal area = Basal area for the species × 100/Basal area for all species;
7. Importance value index = Relative density + Relative frequency + Relative basal area;
8. Simpson's floristic diversity index, $D = 1- [\sum_{i=1}^{S} (n_i/N)^2]$
   where, D = Simpson's index, s = total number of species, n_i = number of individuals of ith species, N = total number of individuals in the plot;
9. Shannon - Weiner's diversity index;

   $H' = 3.3219 (\log_{10}N-1/N \sum_{i=1}^{S} n_i \log_{10} n_i)$ where n_i = number of individuals of the species 'i', N = total number of individuals in the plot. Equitability (E) = H'/ H_{max}, where H_{max}, the maximum dispersion taking into account the number of species present in the plot, and $H_{max} = 3.3219 \log_{10}S$, where S is the total number of species.

Although several quantitative descriptions are available for characterizing species diversity, we used the Simpson's diversity index and Shannon-Wiener diversity index because of their popularity (Pascal 1988). Simpson's index may easily be interpreted in terms of probability and indicates the number of pairs of two different species per 100 pairs of trees taken at random. Shannon-Wiener diversity index indicates the distribution of observations among categories.

Equitability or evenness may be viewed as a measure of homogeneity of relative diversity and it gives the real distribution as compared to the maximum dispersion taking into account the number of species present in the plot.

Results

Floristic composition and species diversity

Fifteen years after abandonment, 727 individuals (GBH $\geq$ 15*cm*) belonging to 23 different species occurred in the 1 *ha* study area (Table 1). *Eucalyptus tereticornis* had the highest density (235 individuals per hectare) and accounted for about 32% of the trees. Invading species such as *Aporusa lindleyana, Symplocos spicata, Terminalia paniculata, Olea dioica* and *Macaranga peltata* had comparatively high densities. About 25% of the species were, however, represented only once or twice. *E. tereticornis* also had the highest abundance (2.4 individuals per quadrat), and was reported from 98% of the quadrats.

The basal area of the stand was 12.77 m^2 ha^1, 26% made up of *E. tereticornis.* Six of the 23 species had an importance value index (IVI) of 20 and above. They were as follows: *E. tereticornis, O. dioica, A. lindleyana, S. spicata, T. paniculata* and *Mangifera indica.* Myrtaceae, Euphorbiaceae, Combretaceae, Anacardiaceae, Symplacaceae and Oleaceae, in the decreasing order, had the largest six Family importance values (range: 20.37 to 80.55). *O. dioica, A. lindleyana, Careya arborea, M. peltata* and *Smilax zeylanica* incidentally had the highest occurrences in the <15 *cm* GBH category with percentage frequencies around 50% (data not shown). Ruderal species like *Chromolaena odorata* and *Lantana camara* had comparatively lower percentage frequencies (<20).

In the old growth moist deciduous forest stands of Trichur Forest Division (10° 28' to 10° 45' N; 76° 05' to 76° 30'E) in the Western Ghats, on a lateritic substrate, 21 species in the $\geq$30 *cm* GBH class were present over a five-hectare sampling unit, spread over a geographical area of 328 km^2. However, the total density was less than 300 trees per hectare (Table 2).

The Simpson's diversity index for the secondary stand was 0.85 indicating that 85 of the 100 random pairs of trees will include two different species. The density based Shannon-Weiner diversity index (H') was 3.38, again suggesting a relatively high degree of variability (H_{max} :4.52). The moist deciduous forests of Trichur exhibited similar values of H' (3.52; $H_{max:}$:4.39) and Simpson's index (0.87: $\geq$30 *cm* GBH). The high equitability or evenness index also indicates destribution of individuals among a larger number of species (0.75 and 0.80 respectively for Neyyar and Trichur).

Vegetation structure

Physiognomically, the stand can be described as having three strata. Stand height was around 18*m* (Figure 2). The first stratum ranged between 12 and 18*m.*

Table 1. Structural attributes of vegetation in the abandoned *Eucalyptus* stand of Neyyar Wildlite Sanctuary (GBH≥15 *cm*)

Species	Density ha^{-1}	Relative density	Abundance	%Frequency	Basal area m^2ha^{-1}	Relative basal area	Importance value Index
**Eucalyptus tereticornis*	235	32.3	2.4	98	3.43	26.9	79.3
Aporusa lindleyana	63	8.7	1.3	50	0.83	6.5	25.4
Symplocos spicata	74	10.2	1.8	42	0.46	3.6	22.4
Terminalia paniculata	62	8.5	1.4	45	0.59	4.6	22.4
Olea dioica	60	8.3	1.2	51	0.20	1.6	20.3
Macaranga peltata	54	7.4	1.2	44	0.44	3.4	20.0
Careya arborea	36	5.0	1.2	30	0.71	5.6	16.7
Pterocarpus marsupium	37	5.1	1.4	27	0.58	4.5	15.2
Artocarpus hirsutus	14	1.9	1.0	14	1.14	8.9	13.7
Mangifera indica	9	1.2	1.1	8	1.31	10.3	13.1
Hydnocarpus laurifolia	19	2.6	1.1	18	0.24	1.9	8.2
Buchanania lanceolata	13	1.8	1.1	12	0.39	3.1	7.3
Emblica officinalis	18	2.5	1.1	17	0.14	1.1	7.1
Albizia odoratissima	2	0.3	1.0	2	0.63	4.9	5.6
Bridelia crenulata	5	0.7	1.3	4	0.37	2.9	4.4
Terminalia bellirica	6	0.8	1.0	6	0.28	2.2	4.4
Albizia procera	4	0.6	1.0	4	0.34	2.7	4.0
Vitex altissima	2	0.3	1.0	2	0.25	2.0	2.6
**Anacardium occidentale*	4	0.6	1.0	4	0.15	1.2	2.5
Tabernaemontana dichotoma	6	0.8	1.2	3	0.05	0.4	2.2
Elaeocarpus glandulosa	1	0.1	1.0	1	0.17	1.3	1.7
Ficus callosa	2	0.3	1.0	2	0.06	0.5	1.2
**Psidium guajava*	1	0.1	1.0	1	0.01	0.1	0.4
TOTAL	727			485	12.77		

*exotics

Table 2. Structural attributes of trees with ≥30 *cm* GBH in the moist deciduous forests of Trichur Division (from Narayanan 1988, reproduced with permission)

Species	Density ha^{-1}	Relative density	Basal area (m^2 ha^{-1})	Relative basal area	Importance value Index
Xylia xylocarpa	72.41	24.09	4.0601	33.61	67.41
Terminalia paniculata	30.22	11.24	2.0072	17.67	37.29
Grewia tiliaefolia	16.99	5.75	1.0495	9.19	23.10
Wrightia tinctoria	61.08	14.36	0.2588	1.31	21.45
Lagerstroemia microcarpa	13.67	4.46	1.7275	9.56	16.32
Holarrhena antidysenterica	25.85	8.34	0.0376	0.25	14.94
Dillenia pentagyna	12.89	4.30	0.8116	6.46	11.49
Bombax spp.	11.06	4.61	0.1641	2.22	9.78
Albizia odoratissima	1.84	0.44	0.0765	0.58	6.42
Tectona grandis	4.86	1.18	0.6712	3.04	5.61
Dalbergia sissoides	3.10	1.19	0.3062	2.68	5.55
Tetrameles nudiflora	3.61	1.37	0.7442	5.52	4.95
Stereospermum colais	5.38	1.61	0.0582	0.86	4.95
Melia dubia	3.70	1.81	2.3050	5.10	4.29
Terminalia bellirica	3.09	0.85	0.4301	2.03	4.14
T. crenulata	4.62	1.24	0.2853	2.01	3.69
Alstonia scholaris	6.76	2.27	0.0252	0.34	3.24
Lannea coromandelica	6.03	1.86	0.1329	0.86	2.82
Pterocarpus marsupium	3.79	1.35	0.1309	1.53	1.98
Haldina cordifolia	5.56	1.33	0.1999	1.08	1.50
Radermachera xylocarpa	1.83	0.63	0.0286	0.59	1.08
Total	298.34		15.5106		

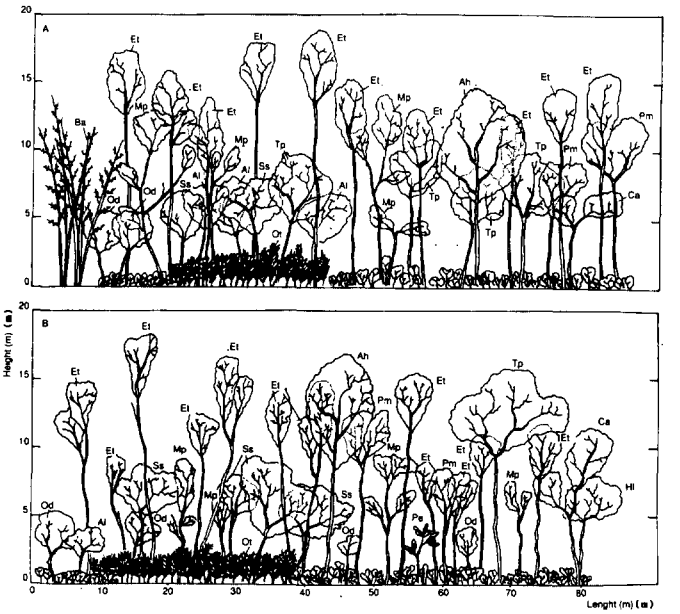

Figure 2. (A and B). Profile diagram of secondary successional forests at Neyyar (two locations). Species code: Ah- *Artocarpus hirsutus*, Al-*Aporusa lindleyana*, Ba-*Bambusa arundinacea*, Ca-*Careya arborea*, E_o-*Emblica officinalis* Et-*Eucalyptus tereticornis*, Hl-*Hydnocarpus laurifolia*, Mp-*Macaranga peltata*, Od-*Olea dioica*, Ot-*Ochlandra travancorica*, Pm-*Pterocarpus marsupium*, Ss-*Symplocos spicata*, Tp-*Terminalia paniculata*

Prominent species in this stratum were *Pterocarpus marsupium, Artocarpus hirsutus, E. tereticornis, T. paniculata* and *C. arborea.* The second stratum ranged between 5 and 12*m* and included *S. spicata, M. peltata* and *Hydnocarpus laurifolia.* The third stratum comprised *O. dioica* and *C. arborea.* Furthermore, height-diameter relationship of trees (Figure 3) indicates that there is an equitable distribution of trees on either side of the reference line: h = 100.d (Oldeman 1974).

Girth frequency distribution for the whole stand (Figure 4) and the set of the future followed an inverse 'J' shaped distribution implying a negative exponential relationship. However, strata 1, 11 and 111 did not follow any consistent pattern of girth distribution. It appears that distribution pattern of *S. spicata, A. lindleyana, H. laurifolia, O. dioica* and *M. peltata* also followed an inverse 'J' shaped curve (Figure 5). While *P. marsupium* and *T. paniculata* were represented in all girth classes except the 60-74 *cm* class and *E. tereticornis* dominated all girth classes except the >75 *cm* GBH class, *Vitex altissima, M. indica* and *Albizia procera* were seen only in the higher girth classes.

Discussion

Species associated with higher importance values in the secondary forest exhibit a diverse set of characteristics, some typical of early seral species, others

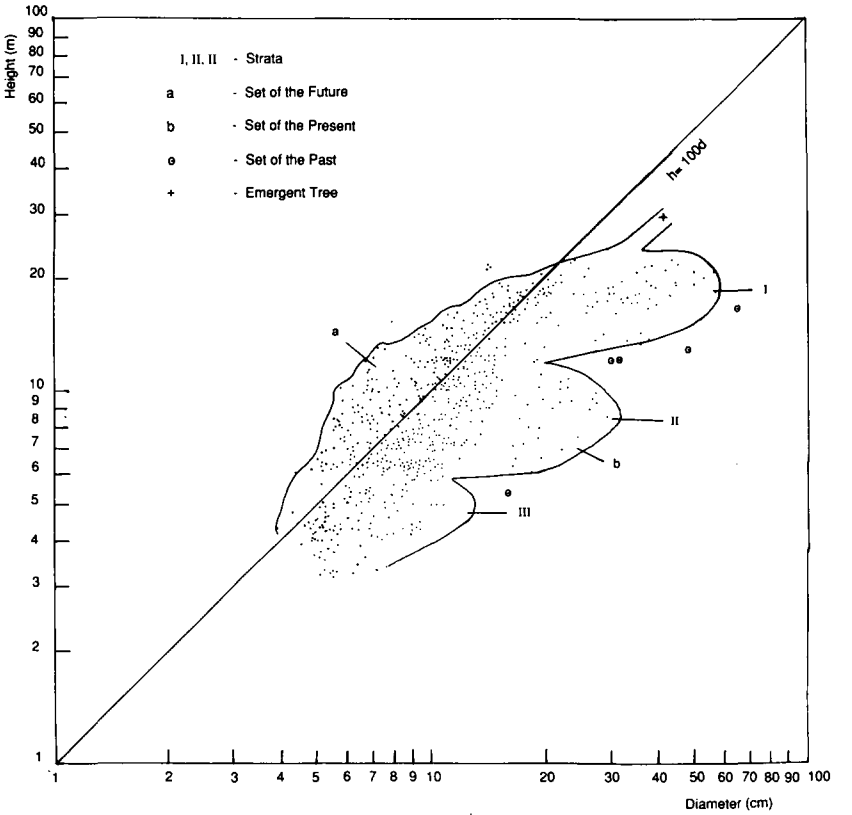

Figure 3. Height diameter relationships of secondary forests (GBH≥15*cm*) at Neyyar (h = height in *m*, d - diameter in *cm*; area = 1 *ha*; trees falling to the left of the line constitute the 'set of the future' and those falling to the right of the line constitute the 'set of the present'. Since the trees are equally distributed between the sets of the future and present, the regeneration is enough to restock the area. The set of the future will be gradually transferred into the set of the present, as the old trees die. Trees in the set of the future are not accumulating at any point in the graph implying that mature stratification has not occurred)

more typical of mid-late successional species. A majority of the species now occupying the area are thus characterized by widely dispersed seeds (wind, birds and animals), varying degrees of shade tolerance and mechanisms of vegetative propagation. For instance, *A. lindleyana* (IVI: 25.4) exhibits shade tolerance and ornithochory; *S. spicata* (IVI: 22.4) is semi-tolerant, exhibits anemochory, and produces large quantities of seeds; *T. paniculata* (IVI: 22.4) is another tolerant species, having good coppicing power and widely dispersed small seeds (anemochory) capable of establishing at any time in the community; *O. dioica* (IVI: 20.0) requires an overstorey for establishment, besides it has good coppicing power and the seeds are also wind-dispersed. *M. peltata* has light weight seeds, good coppicing ability and is a strong light demander (Troup 1921). Many of these may be residual species (vegetatively reproducing and soil seed bank, *e.g. T. paniculata*) or rapidly establishing invaders from the nearby areas (seed rain,

e.g. A. lindleyana, M. peltata, etc.) and may persist into a mature forest. This highlights that species attributes such as shade tolerance, mechanism of dispersal and seed size and vegetative propagation strategies of the native species play an important role in deciding the dominant species groups of secondary forests.

Interestingly, evergreen and heliophilic components have a significant presence in the site (Table 1). Out of the six species having an IVI of 20 or more, four were evergreens (*A. lindleyana, O. dioica, S. spicata* and *M. peltata*). The sole deciduous component was *T. paniculata* apart from *E. tereticornis,* whereas Trichur Forest Division, probably as a result of edaphic modifications following disturbance (fire, grazing, and tree fall) is dominated by deciduous vegetation (Narayanan 1988). For instance, trees which contribute much of the stand basal area are deciduous components such as *Dillenia pentagyna, Grewia tiliaefolia, Lagerstroemia microcarpa, T. paniculata* and *X. xylocarpa* (Table 2). Pascal (1988) also observed that dry conditions arising from anthropogenic factors eliminate new species and favour enrichment of more resistant species such as *X. xylocarpa.* The presence of evergreen heliophytes at Neyyar probably points to its progression towards an evergreen forest (Pascal 1988).

Although explanations differ, the density based floristic diversity indexes showed similar values for both localities. Strict quantitative comparisons are, however, impossible because of the difference in lower limits for enumerations of the two sites. Nevertheless, for both locations the values reported are, lower than the Simpson's diversity indexes reported for other tropical forests; in other words, concentrations of dominance (cd) in the mature Trichur forests (cd = 0.13) and the Neyyar secondary forest (cd = 0.15) were higher than those for tropical forests elsewhere. According to Knight (1975) the mean cd value for the tropical forests of Panama was only 0.06. For Neyyar it can be attributed to the dominance of *E. tereticornis* in several of the girth classes (Figure 5).

As far as Trichur forests are concerned, species diversity ($\geq$30 *cm* GBH) might have decreased as postulated by Clebsch & Busing (1989) for old growth stands. Swaine & Hall (1983) also observed greater species diversity three years after clearance than that of an equal area of nearby mature forest. In the present study, however, species diversities in both situations were similar. Nevertheless, the number of individuals in the secondary forest was greater than that of a mature forest (727 and 298 respectively).

Stand physiognomy also was similar for Neyyar and Trichur forests. The forests of Trichur Division also have a three stratum structure according to Narayanan (1988). Height-diameter relationships (Figure 3) imply three vertical strata, 12 to 18*m*, 5 to 12 *m* and < 5*m* height for the secondary forests of Neyyar. All trees falling to the left of the line constitute the 'set of the future' and those falling to the right of the line constitute the 'set of the present' (Oldeman 1974). Besides, the equitable distribution of trees on either side of the reference line imply adequate regeneration potential of the secondary forests.

The inverse 'J' shaped girth class frequency distribution (Figure 4) indicates that younger floristic elements with lower girth are more abundant than older

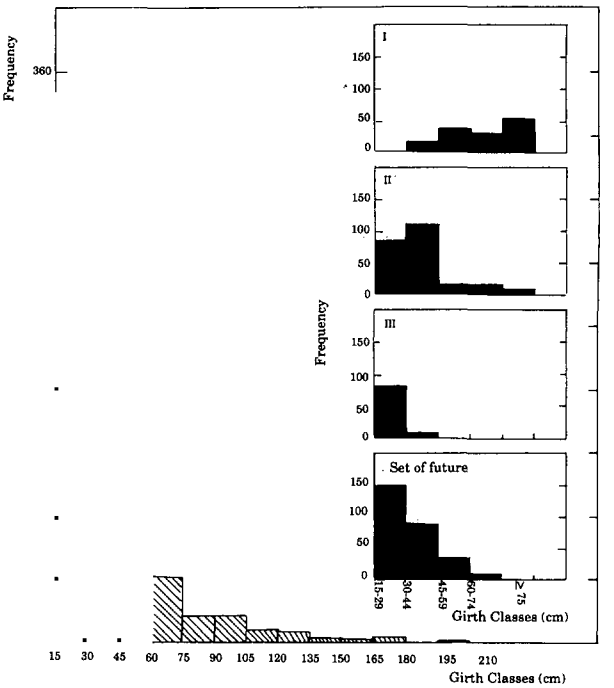

Figure 4. Girth class frequency distribution of secondary successional communities (GBH≥15*cm*) at Neyyar (1*ha*) (Inset: Girth class frequencies of the three strata and set of the future)

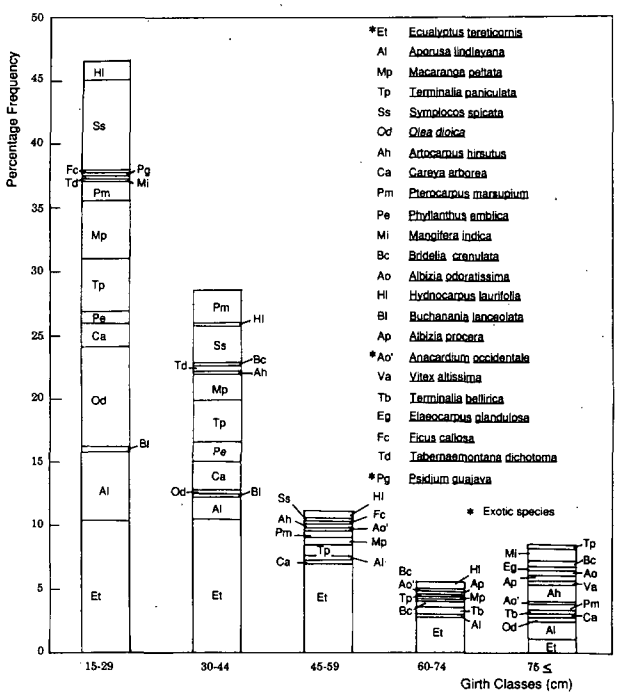

Figure 5. Tree-size histograms (GBH≥ 15*cm*) of species as percentages of grand total at Neyyar

individuals in the higher girth classes, which again suggests profuse regeneration. A similar inverse 'J' shaped tree girth distribution was reported by Narayanan (1988) for Trichur forests.

Fifteen years after abandonment, the eucalypt plantations of the Neyyar Wildlife Sanctuary has reached the 'pre-equilibrium' stage of the silvatic mosaic development (Oldeman 1990) characterized by vertical canopy closure and presence of early seral species (Figure 2). Furthermore, the species diversity values reported in the present study suggests the *E. tereticornis* overstorey does not exert any inhibitory influence on understorey vegetation development. Regarding this, Ewel (1983) has suggested that under high rainfall conditions of the tropics, the toxic chemicals are, perhaps, diluted and/or leached out, and thus the allelopathic effects are probably minimal in the tropics (see also, Rajvanshi *et al.* 1987). This hypothesis, in all probability, holds good for the high rainfall zones of the Western Ghats also. However, comparisons with natural gap regeneration within the native forest will only confirm this.

Vegetation development at Neyyar and possibly in other large openings in the moist deciduous forests of Western Ghats can, perhaps, be described as follows: (1) an accumulation of the early colonizers, characterized by widely dispersed seeds mostly heliophytes, immediately after abandonment; (2) a second wave of regeneration of mostly shade tolerant species, in all probability, occurring at a time of 10-15 *y* after abandonment, (3) a gradual decline in floristic richness as competition intensifies in a mature stand, with the eventual dominance of a few species as suggested by Langford and Buell (1969) for temperate forest ecosystems, and (4) eventual convergence of the system to an evergreen or semi-evergreen floristic composition as hypothesized by Pascal (1988).

Interpretation of the present study is limited because observations were made at only one point in time. Nevertheless, it may aid future assessments of secondary successional pathways for tropical vegetation. Further, as postulated in Egler's (1954) initial floristic model or succession, the present floristic composition may be used to predict future shifts in vegetation dynamics.

To sum up, floristic diversity and vegetation structure in the *E. tereticornis* plantations in the high rainfall zones of the Western Ghats 15 *y* after abandonment, were comparable to those of mature forests in the Western Ghats, although the nature of floristic elements differed. The colonizing species included both heliophilic evergreens and deciduous species and possessed several attributes which may facilitate their eventual dominance, and the stand might be evolving towards a semi-evergreen vegetation structure.

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