Tropical Ecology **54**(2): 179-190, 2013 ISSN 0564-3295

www.tropecol.com

Tree diversity of tropical dry evergreen forests dominated by single or mixed species on the Coromandel coast of India

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Abstract: We investigated tree diversity of single- and mixed species-dominated tropical dry evergreen forests on the Coromandel coast of peninsular India and compared these forests with other monodominant forests of the tropical world. For this we established three 1- ha plots one each in three monodominant sites (Suryanpet- SP; Velleripet- VP; S. Pudhoor- SPD) and a 1- ha plot in a mixed species dominant site (Chinna Kumatti- CK). All trees ≥ 10 cm girth at breast height were enumerated. Dominance of a single species in the monodominant sites did not affect total tree diversity of these sites. Tree species richness totaled 56 species in four forests and ranged from 18 (at VP site) to 27 species ha^{-1} (at CK site). Tree density ranged from 771 (SP site) to 1285 trees ha^{-1} (CK site). Among the monodominant sites, *Tricalysia sphaerocarpa* formed 72 % of the forest stand density at SPD, *Strychnos nux-vomica* 67 % at VP and *Dimorphocalyx glabellus* accounted for 60.8 % of the total density at SP. A literature survey on the monodominant forests across the tropics revealed that a single tree species could account for 50 to 100 % of stand density in Asian, 58 to 100 % in African and 51 to 91 % in Neotropical forests. The monodominant tree species mostly belonged to Caesalpiniaceae in Africa and Neotropics, and Dipterocarpaceae and Lauraceae in Asia, while Rubiaceae, Loganiaceae and Euphorbiaceae contributed the monodominant species on our sites. As tropical dry evergreen forests of peninsular India still remain understudied, the need for conservation of both mono- and mixed species forests is emphasized.

Resumen: Investigamos la diversidad arbórea de los bosques tropicales secos perennifolios monodominados o de dominancia mixta en la costa de Coromandel de la India peninsular y comparamos estos bosques con otros bosques monodominados del mundo tropical. Para ello, establecimos tres parcelas de 1 ha en cada uno de tres sitios monodominados (Suryanpet- SP; Velleripet- VP; S.Pudhoor- SPD) y una parcela de 1-ha en un sitio de dominancia mixta (Chinna Kumatti- CK). Todos los árboles ≥ 10 cm perímetro a la altura del pecho fueron enumerados. La dominancia de una sola especie en los sitios monodominados no afectó la diversidad total de árboles de estos sitios. La riqueza arbórea total fue de 56 especies en cuatro bosques y fluctuó entre 18 (en el sitio VP) y 27 especies ha^{-1} (sitio CK). La densidad de árboles varió de 771 (sitio SP) a 1285 árboles ha^{-1} (sitio CK). Entre los sitios monodominados, *Tricalysia sphaerocarpa* contribuyó con 72 % de la densidad del rodal forestal en SPD, *Strychnos nux-vomica* con 67 % en VP y *Dimorphocalyx glabellus* representó 60.8% de la densidad total en SP. Una revisión de la literatura sobre bosques monodominados en todas las regiones tropicales mostró que una sola especie puede representar de 50 a 100 % de la densidad del rodal en bosques asiáticos, 58 a 100% en los africanos y 51 a 91 % en los neotropicales. Las especies arbóreas monodominantes pertenecieron principalmente a las Caesalpiniaceae en África y el Neotrópico, y a las Dipterocarpaceae y Lauraceae en Asia, mientras que las Rubiaceae, Loganiaceae y Euphorbiaceae contribuyeron con las especies monodominantes en nuestros sitios. Como los bosques tropicales secos perennifolios de la India peninsular todavía están poco estudiados, se

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enfatiza la necesidad de conservar tanto los bosques de dominancia única como los bosques de dominancia mixta.

Resumo: Investigou-se a diversidade arbórea de florestas tropicais secas sempreverdes dominadas por espécies únicas ou mistas na península costeira de Coromandel e compararam-se estas florestas com outras florestas mono-dominantes do mundo tropical. Para este estudo estabelecemos três talhões de 1 ha um em cada uma das estações por espécies mono-dominantes (Suryanpet- SP; Velleripet- VP; S.Pudhoor- SPD) e um talhão de 1 ha numa estação dominada por espécies mistas (Chinna Kumatti- CK). Todas as árvores com perímetros de troncos ≥ 10 cm ao nível do peito foram enumeradas. A dominância de uma única espécie em estações mono-dominantes não afectou a diversidade arbórea total destas estações. A riqueza arbórea total foi de 56 espécies nas quatro florestas e variaram entre 18 (estação VP) e as 27 espécies ha^{-1} (na estação CK). Entre os locais mono-dominantes a *Tricalysia sphaerocarpa* formou 72 % da densidade da parcela em SPD, sendo de 67 % para à *Strychnos nux-vomica* em VP cabendo à *Dimorphocalyx glabellus* 60,8 % da densidade total em SP. Uma análise à literatura sobre as florestas mono-dominantes ao longo do mundo tropical revelou que as espécies singulares podem ser responsáveis por 50 a 100 % da densidade das parcelas florestais na Ásia, 58 a 100 % em África e 51 a 91 % nas florestas Neotropicais. A maior parte das espécies mono-dominantes pertencem principalmente às Caesalpiniaceae em África e nos Neotrópicos, e às Dipterocarpaceae and Lauraceae na Ásia enquanto que as Rubiaceae, Loganiaceae and Euphorbiaceae contribuem para as espécies mono-dominantes nas nossas estações. Como as florestas tropicais secas sempreverdes da Índia peninsular continuam pouco estudadas, dá-se enfâse para a necessidade da conservação das espécies mono e mistas.

Key words: Conservation, monodominance, species richness, stand structure, tree density, tropical forest.

Introduction

Tropical forests provide many goods and ecosystem services such as species conservation, prevention of soil erosion, and preservation of habitat for plants and animals (Armenteras *et al.* 2009; Li *et al.* 2003; Wang 2003). The current scale of deforestation and the large areas of degraded land in tropical regions underscore the urgent need for intervention to restore and protect biodiversity, ecological functioning and the supply of goods and services used by poor rural communities (Cayuela *et al.* 2006; Lamb *et al.* 2005). Global biodiversity is declining rapidly due to habitat destruction, over exploitation, pollution and species introduction caused by humans in the name of development and modernization (Pragasan & Parthasarathy 2010). As a result, most of the natural forests occur in fragments and in degraded forms causing a lot of spatial and temporal variation in species richness, composition and productivity at local and regional levels. Human disturbances often lead to altered environmental conditions, which influence the process that can both augment and erode species diversity in a forest community (Sapkota *et al.* 2010).

Tropical forests commonly consist of many different tree species. Nevertheless, forests dominated by one or only a few species are also found on all tropical continents in a variety of environments (Peh *et al.* 2011; Richards 1996). The low-diversity situation in such forests may, in some cases be explicable in terms of regeneration after large-scale disturbance or edaphic limitations (Grubb *et al.* 1994; Parolin *et al.* 2002). However, typically species-diverse areas can sometimes also include areas (from one to several thousand hectares) dominated by a single tree species; this is called classical monodominance (Peh 2009). Monodominance has been defined as ≥ 60 % of total trees belonging to the same species, although 80 % - 100 % dominance by a single species could be attained in such systems (Connell & Lowman 1989; Hart 1985; Hart *et al.* 1989). Monodominant forests have been reported from Asian (Whitmore 1984), African (Beard 1946; Connell & Lowman 1989; Johnston 1992; Milliken & Ratter 1989) and Neotropical regions (Davis & Richards 1934; Hart

1995; Hart *et al.* 1989; Isaacs *et al.* 1996; Nascimento & Proctor 1997). The monodominant forests which grow in similar environmental conditions as their adjacent high-diversity forests are apparently not formed by major edaphic differences or recent disturbance (Peh *et al.* 2011). According to Connell & Lowman (1989), the tree species richness of the monodominant and mixed forest types is generally similar, except for the presence or absence of the monodominant species. Examples of classical monodominant species in south-east Asia and Neotropics are *Shorea albida* (Anderson 1961) and *Peltogyne gracilipes* (Villela & Proctor 2002), respectively. According to Torti *et al.* (2001) a slow rate of leaf litter decomposition may affect soil nutrient cycling and availability, and create soil condition favorable to some mono-dominant species. Several studies have pointed out that soil parameters between classical mono-dominant forests and their adjacent mixed forests are not significantly different (Conway 1992; Hart 1985; Henkel 2003; Nascimento & Proctor 1997; Peh *et al.* 2011). Torti *et al.* (2001) also reported a suit of life history traits necessary for gaining recruitment advantages over other species to attain monodominance: a high canopy density that casts deep shade to out-compete light-demanding species, slow leaf litter decomposition that creates a physical barrier caused by the accumulation of leaf materials, thereby preventing the establish-ment of small seeded species, shade tolerant saplings that enable survival and growth in the shade created by parent trees, ballistic dispersal that promotes gregarious habits for replacing individuals of other species, and large seeds which contain enough resources to pass through the deep litter layers and enable survival at low light levels.

The tropical dry evergreen forests, distributed along the Coromandel coast constitute one of the rare forest types in the Indian sub-continent. They occur as patches and are short-statured, largely three-layered, tree-dominated evergreen forests with a sparse and patchy ground flora (Partha-sarathy *et al.* 2008). The increasing demand for land for human-related activities has increased the stress on these forests over the years. Specific threats include pressure from increasing human population bordering the forest patches, which leads to shrinkage in forest area, increasing forest resource extraction and grazing pressure. The main objective of the present study was to investigate tree species richness and structure of tropical dry evergreen forests dominated by single species in three sites and mixed species in one site.

Materials and methods

Study area

The present study was carried out in four tropical dry evergreen forests, Suryanpet (SP), Velleripet (VP), S. Pudhoor (SPD) and Chinna Kumatti (CK) on the Coromandel coast of southern India. The multi-species dominant CK site (N 11º 50' 71" and E 79º 70' 67") is located 61 km south of Puducherry and constitutes a three-layered forest with an average height of 8 m. Among the four forests, this is the least disturbed forest covering a total area of 2.42 ha. *Glycosmis mauritiana, Drypetes sepiaria* and *Memecylon umbellatum* are the dominant tree species. Each of the other three sites was dominated by a site-specific single species. SP (N 11º 73' 40" and E 79º 63' 89") is located 43 km south of Puducherry, and the forest area covers 2.5 ha. The soil is red ferralitic, and the forest is dominated by small tree species *Dimorphocalyx glabellus.* Agricultural fields of paddy, sugarcane and cashew plantation surround this site. SPD (N 11º 66 '91"and E 79º 69' 56") is located 40 km south of Puducherry and the forest area covers 8.64 ha, but more than 5 ha of the forest area has been cleared for pond and temple construction. The soil is red ferralitic and the forest is dominated by the wild coffee tree species, *Tricalysia sphaerocarpa.* VP (N 11º 73' 85" and E 79º 69' 45") is located 25 km west of Villupuram district of Tamil Nadu and constitutes a two-layered forest with an average height of 8 m. It is a disturbed forest, covering a total area of 2 ha. *Strychnos nux-vomica* is the predominant tree species. Fire wood collection and letting cattle and goats for grazing and browsing and convention of a portion of forest for road and temple construction etc., are the major disturbance factors in the three disturbed sites.

Twenty-year (1990 to 2010) climate data of Coromandel sites, available from the nearest station, Puducherry, reveal a mean annual tempe-rature of 29.5 ºC and the mean annual rainfall of 1,141 mm. The mean number of rainy days in the annual cycle is 55.5. The mean monthly temperatures range from 25 ºC to 34 ºC for the same period. The climate is tropical dissymmetric with the bulk of the rainfall occurring in the northeast monsoon during October- December. The vegetation of this region is described as tropical dry evergreen forest (type 7/CI of Champion & Seth 1968; Parthasarathy *et al.* 2008; Venkateswaran & Parthasarathy 2003) which is short-statured, 2- to 3-layered, characterized by an abundance of trees and lianas, with sparse ground flora and no distinct shrub layer.

Methodology

Four 1-ha plots (100 m × 100 m), one in each site were established and each plot was subdivided into one hundred 10 m × 10 m quadrats. All trees ≥ 10 cm girth at breast height (gbh at 1.3 m) were measured. For multi-stemmed trees, bole girth was measured separately, basal area calculated and summed. Site disturbance scores were determined based on the extent of anthropogenic activities such as fire wood collection, other resource removal, impact of temple visitors, grazing by cattle and goats, temple construction and the cultural attachment of the local people. The qualitative assessment of various types of disturbance was ranked as rare (1), occasional (2) or frequent (3). The sum of all the scores for each site provides overall ranking of human disturbance. High rank reveals a high level of anthropogenic disturbance and low ranks express low disturbance.

Data analysis

Species diversity indices, Shannon (which combines species richness and evenness into a single value) and Simpson (which gives more weight to the abundance of the most common species) were computed following Magurran (2004) (Shannon, $H' = -\sum pi \ln pi$, where, pi is the proportion of i^{th} species; Simpson, $D = 1-\sum ni (ni-1)/N (N-1)$, where, ni is the proportion of i^{th} species and N is the total density). Species-area curve was raised based on species increment by sequential arrangement of every 0.1 ha area. Bray-Curtis cluster analysis, based on abundance of tree species was performed using Biodiversity Pro (version 2).

Results

Species richness and diversity

A total of 56 tree species (≥ 10 cm gbh) that belonged to 50 genera and 28 families were recorded in the four forests (Table 1). Although 72 % and 60 % of stems in sites SPD and SP were occupied by their respective monodominant species *Tricalysia sphaerocarpa* and *Dimorphocalyx glabellus,* these sites also accommodated low to moderate density of other species too. Thus, the monodominance of one species, in at least these two sites did not affect their total tree diversity.

Table 1. Consolidated details of inventory of tree diversity (for stems ≥ 10 cm gbh) in four tropical dry evergreen forest sites Chinna Kumatti (CK), S. Pudhoor (SPD), Suryanpet (SP) and Velleripet (VP) on the Coromandel coast of India.

	Mixed species dominant		Mono species dominant		
Variables	CK	SPD	SP	VP	Total
Species richness	27	25	26	18	57
Number of families	20	13	20	14	29
Number of genera	27	22	26	18	50
Stand density (stems ha^{-1})	1285	1145	771	1144	4345
Stand basal area (m^2 ha^{-1})	36.7	17.74	32.55	47.84	
Diversity indices					
Shannon	2.2	1.3	2.13	1.24	2.11
Simpson	0.14	0.53	0.38	0.47	3.15
Density of large trees (ghb 210 cm)	16	8	11	8	43
Disturbance score	7	23	28	19	

However, site VP was species-poor. Among the four sites tree species richness was highest (27 species ha^{-1}) in the mixed species dominant site CK and lowest (18 species ha^{-1}) in VP and intermediate (25 and 26 species ha^{-1}) in SPD and SP, respectively. Four species were common to all the sites. The species diversity indices varied across the sites (Table 1). SP scored a high value of Shannon and Simpson indices and CK scored low value of Simpson index.

Family diversity

The 29 plant families varied in their contribution towards tree taxa diversity (genera and species) and stand density across the four forests (Table 2). SP and CK had similar family diversity of 20 families each, and the other two forests (SPD and VP) had 13 and 14 families, respectively. The Rubiaceae (represented by five genera and five

Table 2. Family diversity and density (stems ha^{-1}), arranged in decreasing order of total tree abundance in four tropical dry evergreen forest sites at CK, SPD, SP and VP.

Family	Species richness				Density				Total density
	CK	SPD	SP	VP	CK	SPD	SP	VP	
Rubiaceae	3	5	2	1	29	869	19	1	918
Rutaceae	3	4	2	3	465	82	98	139	784
Loganiaceae				1				768	768
Euphorbiaceae	2	2	2	1	182	3	470	3	658
Melastomataceae	1	1	1		245	18	14		277
Sterculiaceae	1	2	1		119	121	15		255
Sapindaceae	1		1	1	98		17	86	201
Meliaceae	1	1	3	1	4	7	38	57	106
Clusiaceae	1		1		77		28		105
Ebenaceae	1		1	1	7		15	41	63
Myrtaceae	1		1		18		14		32
Arecaceae	1		1	1	7		5	16	28
Moraceae	3	2	2	1	5	6	7	6	24
Papilionaceae	1	2	1		6	13	2		21
Caesalpiniaceae	1	1	1		1	7	9		17
Verbenaceae	1		1	1	3		2	10	15
Mimosaceae		2		3		10		12	22
Cordiaceae		1	1	1		3	5	1	9
Capparaceae	1		1		4		4		8
Anacardiaceae	1	1			6	1			7
Barringtoniaceae			1				6		6
Oleaceae		1				5			5
Alangiaceae			1	1			2	2	4
Celastraceae	1				3				3
Ochnaceae	1				2				2
Bignoniaceae				1				1	1
Burseraceae	1				1				1
Fabaceae			1				1		1
Total	27	25	26	18	1282	1145	771	1143	4341

species) was taxonomically diverse and constituted the most speciose family, followed by Rutaceae (with four genera and four species). Four families Rubiaceae, Rutaceae, Loganiaceae and Euphorbiaceae were the top four families that contributed to maximum tree density. The Bignoniaceae, Burseraceae and Fabaceae were represented by single species and single individuals in the forests.

Stand density and basal area

There were 4,345 individuals of trees in four forests, and the density ranged from 771 trees ha^{-1} in SP to 1,285 trees ha^{-1} in CK (Table 3). SPD and VP had moderate stand densities. The basal area of individual sites ranged between 17.74 and 47.84 m^2 ha^{-1} in SPD and VP, respectively.

Species-area curve

The number of species in all sites increased steeply initially, but gradually up to 0.5 ha and later the species increment was minimal (Fig. 1). The species-area curve for each site captured about 50 % of species at the 0.2 ha scale and 100 % at the 0.8 ha scale in the three monodominant sites, and

Table 3. Species density of trees (≥ 10 cm gbh) in 1 ha plots of CK, SPD, SP and VP tropical dry evergreen forest sites on the Coromandel coast of India, arranged in decreasing order of their total abundance.

Species	CK	SPD	SP	VP	Total
Tricalysia sphaerocarpa (Dalz.) Gamble		826	15		841
Strychnos nux-vomica L.				768	768
Dimorphocalyx glabellus Thw.			469		469
Atalantia monophylla (L.) Correa	150	17	15	129	311
Memecylon umbellatum Burm.f.	245	18	14		277
Pterospermum canescens Roxb.	119	101	15		235
Drypetes sepiaria (Wight & Arn.) Pax & Hof.	182	1	1	3	187
Lepisanthes tetraphylla (Vahl.) Radlk.	98		17	86	201
Garcinia spicata (Wight & Arn.) J.D. Hook.	77		28		105
Azadirachta indica A. Juss.	4	7	31	57	99
Glycosmis mauritiana (Lam.) Yuich. Tanaka	306	56	83	6	451
Diospyros montana Roxb.			15	41	56
Syzygium cumini (L.) Skeels	18		14		32
Canthium dicoccum (Gaertn.) Teijsm. & Binn.	3	25			28
Borassus flabellifer L.	6		5	16	27
Ixora pavetta Andrews	15	12			27
Pterospermum xylocarpum (Gaertn.) Sant. & Wagh.		20			20
Cassia fistula L.		8	9		17
Albizia amara (Roxb.) Boivin		3		9	12
Ficus benghalensis L.	3	3		6	12
Benkara malabarica (Lam.) Tirven.	11				11
Premna latifolia L.				10	10
Pamburus missionis (Wight) Swingle	9				9
Bauhinia racemosa Lam.	1	7			8
Albizia lebbeck (L.) Benth.		7			7
Dalbergia paniculata Roxb.		5	2		7
Diospyros ferrea (Willd.) Bakh.	7				7
Lannea coromandelica (Houtt.) Merr.	6	1			7
Morinda coreia Buch. -Ham.		2	4	1	7
Pongamia pinnata (L.) Pierre	6		1		7
Barringtonia acutangula (L.) Gaertner			6		6
Walsura trifolia (A..Juss.) Harms			6		6
Chionanthus zeylanica L.		5			5
Chloroxylon swietenia DC.		5			5
Cordia obliqua Willd.			5		5
Ehretia pubescens Benth.		3		2	5
Ficus hispida L.f.			5		5
Alangium salvifolium (L.f.) Wangerin			2	2	4
Cadaba trifolia (Roxb.) Wight & Arn.		4	4		4
Clausena dentata (Willd.) Roemer				4	4
Pleiospermium alatum (Wight & Arn.) Swingle		4			4

Contd...

Table 3. Continued.

Species	CK	SPD	SP	VP	Total
Streblus asper Lour.	2		2		4
Tarenna asiatica (L.) Kuntze ex Schumann		4			4
Ficus amplissima J.E.Smith		3			3
Gmelina asiatica L.	3				3
Maytenus emarginata (Willd.) Ding Hou	3				3
Ochna obtusata DC.	3				3
Mallotus philippensis (Lam.) Muell.-Arg.	2				2
Prosopis juliflora (Sw.) DC.				2	2
Suregada angustifolia (Muell-Arg.) Airy Shaw		2			2
Vitex negundo L.			2		2
Acacia leucophloea (Roxb.) Willd.				1	1
Aglaia elaeagnoidea (Juss.) Benth.			1		1
Commiphora berryi (Arn.) Engl.	1				1
Dolichandrone falcata (DC.) Seemann				1	1
Ficus microcarpa L.f.	1				1
Total	1285	1145	771	1144	4345

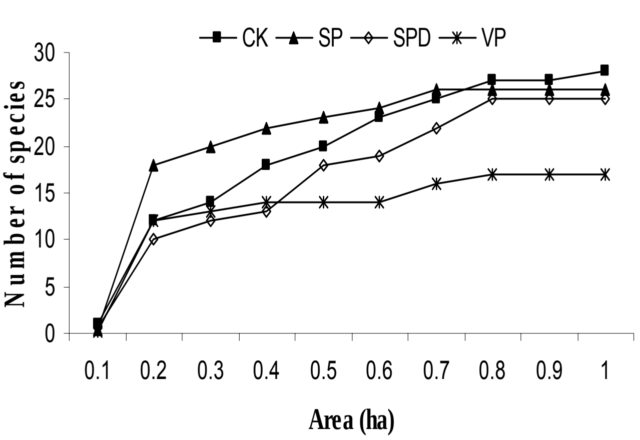

Fig. 1. Species-area curve for the four tropical dry evergreen forest sites CK, SPD, VP and SP.

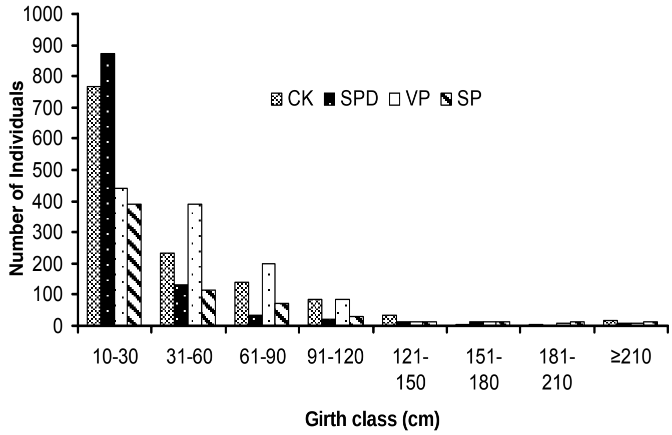

Fig. 2. Girth class distribution of trees in four tropical dry evergreen forest sites at CK, SPD, VP and SP.

then species increment was low with addition of just one to two species for every 0.1 ha in mixed species dominant site CK.

Girth class distribution

Overall, no distinct difference in stem size class distribution was evident in the four forests. Girth class distribution consistently decreased with increasing size class of trees from 10 to 210 cm gbh, except for the greatest girth class ≥ 210 cm (Fig. 2). The lowest size class of 10 - 30 cm gbh was more abundant and formed 76.4 % of the total density in SPD, 59.6 % in CK, 50.4 % in SP and 38.3 % in site VP. Whereas the tree density of 31 - 60 cm gbh class was greater in VP and CK than in SPD and SP. The density of large trees (girth ≥ 210 cm) was 16 trees ha^{-1} in CK and 11 in SP and 8 each in SPD and VP.

Size class distribution of three monodominant tree species

Among the four studied sites, three sites exemplify monodominant forests, but the pre-dominant species varied across the three sites. *Tricalysia spaerocarpa* formed 72 % of the forest stand density with a basal area contribution of 5.91 m^2 ha^{-1} in SPD; *Strychnos nux-vomica* gained monodominance in VP occupying 67 % of the forest stand with a basal area of 21.75 m^2 ha^{-1} and *Dimorphocalyx glabellus* had a density of 60.8 % with a basal area of 4.71 m^2 ha^{-1} in site SP. *Dimorphocalyx glabellus* had 94 % of stems in the lower girth class category (10 - 30 cm) in SP. Whereas in SPD, 87 % of stems of *Tricalysia sphaerocarpa* belonged to this size class and in VP, *Strychnos nux-vomica* had 41% of the stems that belonged to 10 - 30 cm girth class (Fig. 3). Notably, among the three monodominant species, *Strychnos nux-vomica* had stem size class representation in all girth classes, while the stems of *Tricalysia sphaerocarpa* and *Dimorphocalyx glabellus* were skewed towards the lower size class (10 - 30 cm gbh).

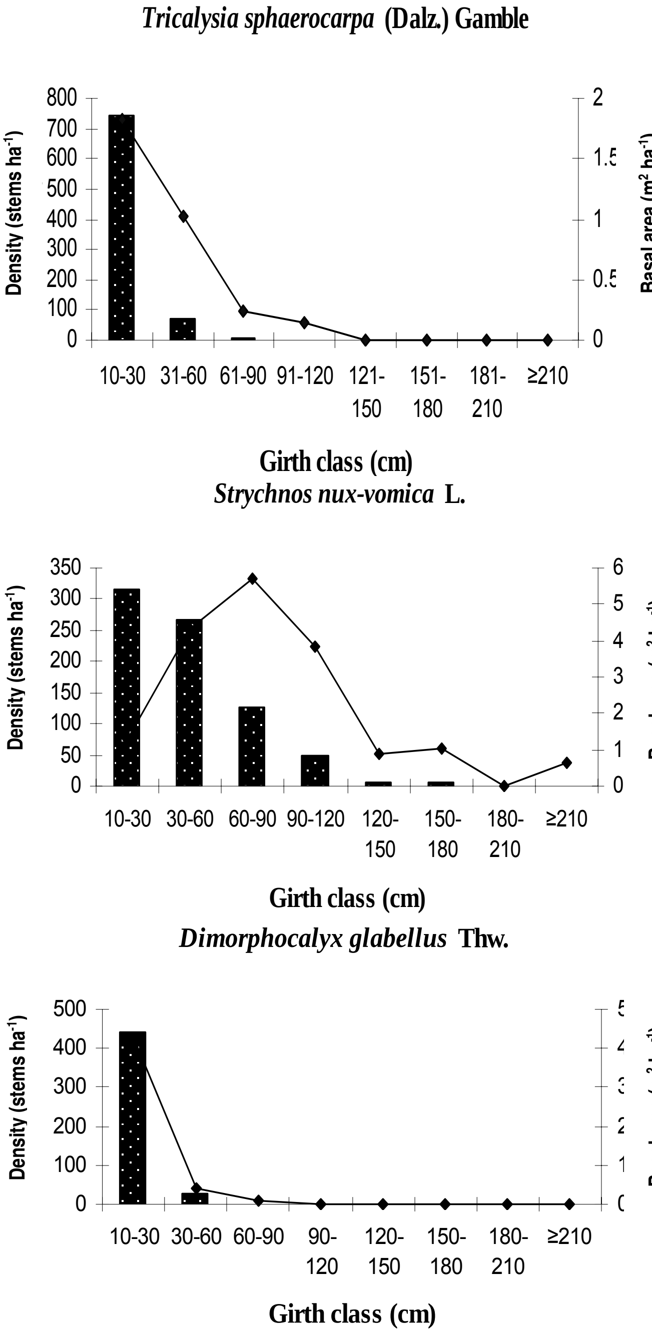

Fig. 3. Stem size class distribution of three monodominant tree species in three study sites at SPD, VL and SP.

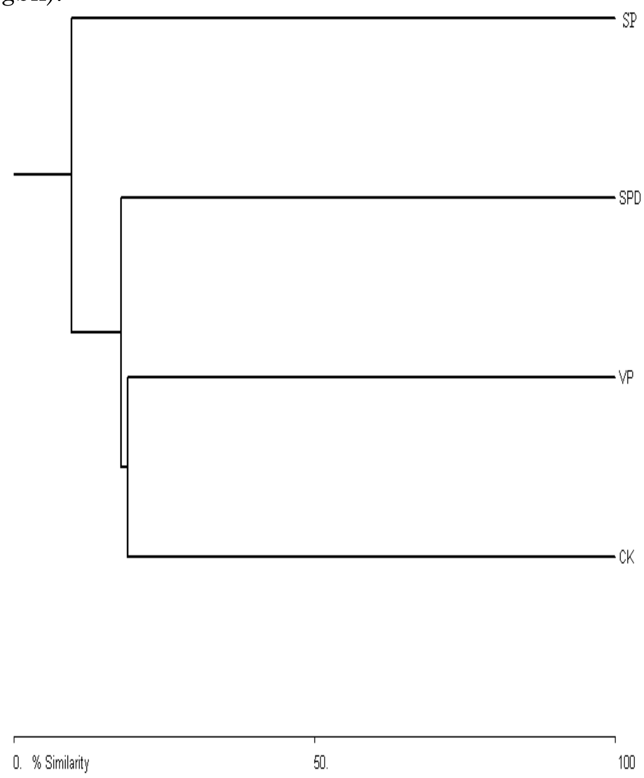

Fig. 4. Cluster analysis for species similarity in four tropical dry evergreen forest sites.

Bray-Curtis cluster analysis

The Bray-Curtis cluster analysis produced three distinct groups in which SP was quite distantly placed, VP and CK formed one group and SPD formed a distinct group (Fig. 4).

Discussion

Tricalysia sphaerocarpa, *Strychnos nux-vomica* and *Dimorphocalyx glabellus* constituted the top three dominant tree species in the presently studied sites which in turn formed monodominant stands in site SPD, VP and SP respectively. Whereas *Atalantia monophylla*, *Tricalysia sphaerocarpa* and *Garcinia spicata* were the top three abundant species in coastal mixed species-dominant sites (Venkateswaran & Parthasarathy 2003), and among these three species, the last two species were totally absent in the inland tropical dry evergreen forests (Mani & Parthasarathy 2005). In the inland sites, *Chloroxylon swetinia*, *Strychnos nux-vomica* and *Albizia amara* were among the top three species, but these species occurred in considerably low densities in coastal sites. *Memecylon umbellatum* and *Pterospermum canescens* were dominant in all the coastal and inland tropical dry evergreen sites (Mani & Parthasarathy 2005; Venkateswaran & Parthasarathy 2003). *Dimorphocalyx glabellus* and *Dolichandrone falcata* occurred only in the present study sites, and they were absent in the other previously studied tropical dry evergreen forests.

The Rubiaceae, Rutaceae and Moraceae were predominant plant families in the present study sites, while Rubiaceae, Ebenaceae and Sterculiaceae constituted predominant families in coastal tropical dry evergreen forests (Venkateswaran & Parthasarathy 2003) and Melastomataceae, Flindersiaceae, Sterculiaceae and Euphorbiaceae were dominant in inland tropical dry evergreen forests (Mani & Parthasarathy 2005). In contrast, Dipterocarpaceae dominated the seasonal dry evergreen forest of Thailand (Bunyavejchewin 1999).

Diameter distributions are commonly used to assess the disturbance effect within forests (Denslow 1995) and to direct trend in regeneration patterns (Poorter *et al.* 1996). Tree density in 10 - 30 cm size class was highest in SPD with 875 stems ha^{-1} (76.5 %) and lowest in VP with 439 stems ha^{-1} (38 %). Site CK stocked more density of large trees, which can be considered as an indicator of undisturbed old-growth forest, as also reported by Ramirez-Marcial *et al.* (2001) who showed a decrease in density and basal area with disturbance intensity and Smiet (1992) who correlated basal area with the rate of disturbance. Our study sites indicate that stem density declined with site disturbance score (Table 1).

Connell & Lowman (1989) and Hart *et al.* (1989) reported that low frequency of forest disturbance resulting in reduced rates of gap formation and a subsequent low abundance of shade-tolerant species may create a physical environment favorable to some monodominant species. Slow growth and poor seed dispersal capability of many species that sometimes attain monodominance also suggest that such communities have not experienced major disturbance events and are not merely older secondary forests (Connell & Lowman 1989). One general assumption regarding monodominant forests is that they have experienced little or no disturbance over long period of time (Connell & Lowman 1989; Hart *et al.* 1989), which can be called intrinsically monodominant. On the other hand, others have argued that a high frequency of small area disturbance may lead to monodominance (in which case it becomes a disturbance-derived monodominance), because the small gaps would be colonized by the previously suppressed offspring of the surrounding dominant species (Newbery *et al.* 2004). However, features such as an abundance of seedlings and juveniles in lower girth classes and seed dispersal by vertebrate fauna are likely to qualify the persistently monodominant species. In the present study, the monodominant tree species *Tricalysis sphaerocarpa* and *Strychnos nux-vomica* are vertebrate dispersed and also have abundant seedlings and saplings on the forest floor (pers. observ.); these features along with operating site disturbance seem to qualify three of our study sites (SP, SPD and VP) to be intrinsically monodominant forests.

Monodominant forests dominated by different tree species have been reported from various tropical forests. *Celaenodendron mexicanum* (Euphorbiaceae) in Mexico (Martijena & Bullock 1994), *Pentaclethra macroloba* (Mimosaceae) in Costa Rica (Lieberman *et al.* 1985), *Peltogyne gracilipes* (Caesalpiniaceae) in Maraca Island, Brazil (Nascimento & Proctor 1997), *Brachystegia laurentii* (Caesalpiniaceae) and *Gilbertiodendron dewevrei* (Caesalpiniaceae) in Yangambi, Congo (Germaine & Ervard 1956; Louis 1947). In tropical Asia, *Shorea albida* (Dipterocarpaceae) in Baram Sarawak (Connell & Lowman 1989), *Shorea curtissi* (Dipterocarpaceae) in Malaysia (Whitmore 1984), *Dryobalanops aromatica* (Dipterocarpaceae) in Sumatra (Whitmore 1984), *Eusideroxylon zwageri* (Lauraceae) in Borneo and *Poeciloneuron pauciflorum* (Clusiaceae) in Agumbe, India (Srinivas & Parthasarathy 2000), achieved monodominance. In many forests, the monodominant species mostly belonged to Caesalpiniaceae, especially in Africa, followed by the Neotropics. Members of Dipterocarpaceae, Lauraceae and Clusiaceae had monodominant species in various Asian forests. Rubiaceae, Loganiaceae and Euphorbiaceae also had monodominant species in the present study.

A comparison of tree density contribution reported in monodominant forests across the tropics reveals that the monodominant forests dominated by single tree species formed 50 to 100 % of stand density in Asian forests, 58 to 100 % in African forests (Gerard 1960; Hall & Swaine 1981) and 51 to 91 % in Neotropical forests (Beard 1946; Davis

& Richards 1934; Marimon *et al*. 2001). In Mexican forest, Martijena & Bullock (1994) reported that the dominance of *Celaenodendron mexicanum* was greater in large sized classes with more than 60 % of trees in the largest class belonging to one species. Whereas in the present study sites, the monodominant tree species *Tricalysia sphaerocarpa*, *Dimorphocalyx glabellus* and *Strychnos nux-vomica* had greater abundances (41 to 94 %) of individuals in the lower girth classes.

The quantitative inventory of tree species diversity revealed a considerable variation in the composition of dominant tree species and forest stand density in various tropical dry evergreen forest sites and also in other tropical forests of the world, mainly due to variation in biogeography and habitat disturbance (Mani & Parthasarathy 2006, 2009). Even though the monodominant and mixed species tropical dry evergreen forest sites are smaller in size ranging from 0.5 to 10 hectare or so, they hold moderate diversity and represent unique, less known and understudied forest type protected on religious grounds as temple forests, and, thus, gains significance from ecological and societal perspectives. Pither & Kellman (2002) also stated that even very small forest patches could play a role in the maintenance of regional diversity by augmenting regional populations (Turner & Corlett 1996) and, also providing habitat as well as food for plant and animal species. Being sacred groves, creating environmental awareness of the local people on the values of the studied forests, and making resource extraction and utilization at a minimal level, would serve as long-term conservation measures to sustain the sites and their resources.

Acknowledgement

The first author thanks Pondicherry University for financial support received through UGC University fellowship.

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(Received on 05.12.2011 and accepted after revisions, on 16.02.2012)