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Quantitative Structure and Composition of Tropical Forests of Mudumalai Wildlife Sanctuary, Western Ghats, India

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ABSTRACT: The present study deals with the assessment of quantitative structure and floristic composition of tropical forests of Mudumalai Wildlife Sanctuary, Western Ghats, India. Forest structure was analyzed across girth classes and height intervals. Altogether 156 tree species were analyzed. Vegetation type-wise Importance Value Index, Shannon-Weiner index, Simpson index, Margalef's index and Pielou Index were calculated. The tree stand density varies from 112-406.8 ha^{-1} with the average basal area of 26.25m^2/ha^{-1}. Shannon-Weiner Index (H') ranges from 3.94-4.90. The Simpson Index of dominance varies from 0.86-0.94. The Margalef Species Richness Index varies from 4.61-8.31.The population density of tree species across girth class intervals shows that 65.4% and 36.4% of individuals belong to 30-60 cm gbh. Tree distribution by height class intervals shows that around 28.7% of individuals are in the height class of 20-25m, followed by 24.4% in the height of 15-20m, whereas 3.37% of individuals are in the height class of >30m.

KEY WORDS: Tropical forests, structure, composition, Mudumalai, India.

INTRODUCTION

The structure and composition of tropical deciduous forests undergo changes with the length of wet period, amount of rainfall, latitude and altitude and impacts of human and livestock activities. As a result there is a great deal of spatial and temporal variation in species richness, composition and productivity across these forests. On account of their economic exploitation, tropical deciduous forests are the most threatened ecosystems in India. An increasing interest in the development and management of natural forests has given rise to the need to understand the community structure and ecosystem stability (Anitha et al., 2007).

The present study is an attempt to record structural composition of four main forest types in Mudumalai Wildlife Sanctuary, Western Ghats, Tamil Nadu, India. This outcome would be useful for formulating appropriate conservation strategies.

Nilgiri Biosphere Reserve (NBR) within Western Ghats is the first established Biosphere Reserve in India with rich repository of biological diversity (3203 sq. km). Out of 2100 species of flowering plants endemic to peninsular India, about 818 are found in the Nilgiris and adjoining areas (Mohanan and Balakrishnan, 1991). Dry forests cover major portion of the NBR and are one of the most threatened habitats due continuous human disturbances. Mudumalai Wildlife Sanctuary, on the central part of the NBR, primarily dominated by deciduous forests has been a point of interests for the ecologists for the long term studies. In accordance with the International effort of large scale permanent plots, Indian Institute of Science and Smithsonian Tropical Research Institute (STRI) established a 50 ha plot in Mudumalai Wildlife Sanctuary for studying dry forests dynamics in 1988 (Sukumar et al., 1992; Joshi et al., 1997; Condit et al., 2000; Plotkin, 2000). The fire frequency in the sanctuary has been studied by Kodandapani et al. (2004). The flora of the sanctuary was prepared by Sharma (1977) and Suresh et al. (1996). Except these studies, the detailed assessment of vegetation composition and other structural attributes has not been studied so far in the whole sanctuary. This basic lack of information hampered the conservation prioritization of the area from various threats (Sudhakar and Reddy, 2005).

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MATERIALS AND METHODS

Study area

The Mudumalai wildlife sanctuary lies on the northern and north-western side of the Nilgiris (Blue

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Fig. 1. Location map of the study area.

Mountains), Tamil Nadu, in between 11°32'-11°43'N latitudes, 76°22'-76°45'E longitudes (Fig. 1) and covers an area of 321 sq.km. The terrain is undulating with elevation going from 440 m to 1260 m (above MSL). There is a distinct rainfall gradient from east to west varying from 600 mm to 1800 mm respectively. Geologically, the rocks are of peninsular gneiss. The soils are black sandy loam and red heavy loam. Because of both topographical and climatic variations, the site is considered as unique in its distribution of species composition and biodiversity. There are four main types of vegetation viz., tropical moist deciduous, tropical dry deciduous, tropical riverine (riparian) and southern tropical thorny scrub (Champion and Seth, 1968) prevails in the sanctuary. The fauna consists of diverse wildlife population which includes elephant, gaur, tiger, leopard, wild dog, deer etc. with varied avifauna and reptiles.

Data collection

We conducted phytosociological studies during Nov, 2004-Feb, 2006. The data has collected from ninety randomly selected quadrats of 0.1 ha size with a sampling intensity of 0.03%. In each of the plot, all the trees were identified at species level, counted individuals and measured its height (hypsometer) and GBH (Girth at Breast Height, 1.3 m) using a tape. One quadrat of 10 x 10 m was laid within 0.1 ha quadrat for recording number of tree saplings, tree seedlings, shrubs, herbs and climbers. Herbarium specimens were prepared and identified with the help of floras and confirmed with the specimens deposited at Botanical Survey of India, Coimbatore. The spatial location (latitude, longitude and altitude) of each quadrat was collected using a Global Positioning System (GPS). Care has been taken to cover different elevation, slope, aspects, drainage density, rainfall and temperature gradients to study overall spectrum of tree species diversity.

We considered mature trees as stems with >30 cm girth at breast height. All sampled plants were enumerated and analyzed in each sample plot.

Data analysis

The field data collected were analyzed for number of species, stand density (trees) per hectare, basal area per hectare, diversity using Shannon-Weiner index (Shannon and Weaver, 1949) and concentration of dominance following Simpson index (Simpson, 1949). Quantitative analysis of dominance and their relative values of frequency, density and basal area were calculated and summed to get Importance Value Index. Species richness index was computed using Margalef index (Margalef, 1958). The evenness index of the forest community was calculated following Pielou (Pielou, 1966). Similarity between the four forest types was determined using Sorenson's index of similarity (Sorenson, 1948). Population structure of tree species were analysed across fixed girth classes. Species and their corresponding individuals were proportionately analysed by height class intervals.

RESULTS

Composition

Altogether 90 sample plots of 0.1 hectare size were laid in all the vegetation types (moist deciduous-25, dry deciduous-36, Scrub-18 and Riparian-11) under study. Of the 498 species collected, 156 were trees, 90 were shrubs, and 214 were herbs and 61 climbers. The highest Shannon and Weiner index was observed for moist deciduous (4.90) followed by scrub (4.52), riparian (4.41) and dry deciduous (3.94) (Table 1). The high value of 4.90 in case of moist deciduous was probably due to the association of various species and contiguity of large patches. The highest Simpson Index of dominance was observed for Moist deciduous Forest (0.94) and Scrub (0.94) followed by Riparian (0.92) and Dry deciduous Forest (0.86). The Importance Value Index (IVI) was high for *Anogeissus latifolia*,

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Table 1. Consolidated details of species inventory in Mudumalai Wildlife Sanctuary.

Description	Dry Deciduous	Moist Deciduous	Scrub	Riparian	Total
No. of Sample Points	36	25	18	11	90
Area Sampled (ha)	1.08	0.75	0.54	0.33	2.7
No. of Tree Species	66	83	38	39	156
Density (stems/ha¯1)	406	407	169	113	274
Species Diversity Index H'	3.94	4.9	4.52	4.41	4.44
Simpson Index	0.86	0.94	0.94	0.92	0.92
Margalef Species Richness Index	6.28	8.31	4.61	5.61	6.2
Pielou Index of Evenness	0.06	0.059	0.12	0.11	0.09
Basal Area (m² /ha¯1)	24.61	49	6.12	25.3	26.2
No. of Shrub Species	45	33	34	15	90
No. of Herb Species	112	92	65	33	214
No. of Climber Species	28	35	17	10	61
Total Species (incl. Trees)	285	272	164	111	498
Similarity Index :					
Dry Deciduous	-	83.9	38.5	39.3	
Moist Deciduous	-	-	38.3	39.4	
Scrub	-	-		38.3	
Riparian	-	-	-	-	

Tectona grandis, Terminalia alata, Phyllanthus emblica and *Lagerstroemia microcarpa* in Dry deciduous forest and *Tectona grandis, Lagerstroemia microcarpa, Grewia tilifolia, Terminalia alata and Syzygium cumini* for moist deciduous forest followed by *Erythroxylum monogynum, Anogeissus latifolia, Albizia amara, Givotia rottleriformis* and *Acacia chundra* in case of Scrub (which is compositionally similar to southern tropical thorny scrub) and *Mangifera indica, Syzygium cumini, Terminalia arjuna, Erythrina variegata, Schleichera oleosa* for riparian forest (Table 2). The highest Margalef index was observed for moist deciduous forest (8.31) followed by dry deciduous (6.28), riparian (5.61) and scrub (4.61).The Evenness index (Pielou) was highest for scrub (0.12) followed by riparian (0.11), dry deciduous forest (0.06) and moist deciduous forest (0.05).

Forest Structure

A total of 322 individual trees per hectare having girth of > 30 cm GBH were found in the study area (range 113-407) and a mean basal area was 26.2 m^2/ha^{-1}. Basal area was ranging from 6.12 m^2/ha^{-1} (scrub) to 49.0 m^2/ha^{-1} (moist deciduous). The distribution of the basal area across the forest types, using gbh class intervals reveals the dominance of small stemmed individuals in the plots (Table 3). The density of moist deciduous forests and dry deciduous is 407 and 406 respectively which is within the range of 276 – 905 stems/ ha^{-1} reported in the tropics (Prasad et al., 2007; Reddy et al., 2007).

Population density of tree species across girth class interval shows that around 65.4% of species and 36.4% of individuals belong to 30-60 cm gbh (Table 3). The overall population structure indicates that study area represents typical mature stands.

The mean tree height is 15 m with a height range from 1 to 35 m. Tree distribution by height class intervals shows that around 28.7% of individuals are in the height class of 20-25 m, followed by 24.2% in the height of 15-20 m. Whereas 3.37% of individuals are in the height class of >30 m (Table 4). Tree species in scrub type show tendency towards shorter stature (86.0% of individuals are with less than 5m height) than trees in moist deciduous (9.5%) and dry deciduous (7.5).

DISCUSSION

The main vegetation types encountered in Mudumalai Sanctuary can be grouped into four formations, i.e. moist deciduous, dry deciduous, riparian and scrub. Both species richness and diversity differed among the four types.

The moist deciduous forest represents a transitional type from dry deciduous to semi-evergreen vegetation. It harbours a much larger set of species extensively shared with other vegetation types. It has fairly highest level of diversity and occurs mostly in Benne Range, where rainfall is comparatively more. The high stems and basal area per hectare were observed for moist deciduous forest followed by dry deciduous forest.

The number of tree species (156) recorded in the present study was found to be higher than the number of species reported by several workers in the different tropical forests (Chowdhury et al., 2000; Fox et al., 1997; Kadavul and Parthasarathy, 1999; Khera et al., 2001; Pande, 1999; Uma Shanker, 2001; Sahu et al., 2007 (91 species); Reddy et al., 2008 (137 species) and lower than the value reported by Prasad et al., 2007 and Reddy et al., 2007 in different forest types.)

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Table 2. Ecological dominance of top ten species (based on IVI) in different vegetation types.

Plant Species	Relative Density	Relative Frequency	Relative Dominance	IVI
		Dry Deciduous		
Anogeissus latifolia	35.2	14.4	30.8	80.4
Tectona grandis	19.8	11.52	33.9	65.3
Terminalia alata	15.1	10.7	13	38.8
Phyllanthus emblica	1.92	5.76	0.84	8.51
Lagerstroemia microcarpa	1.98	4.9	1.31	8.23
Shorea roxburghii	3.22	3.7	1.02	7.94
Dalbergia latifolia	1.23	4.12	2.53	7.88
Radermachera xylocarpa	1.57	2.06	2.57	6.2
Ziziphus xylopyrus	1.98	3.29	0.47	5.75
Buchanania lanzan	1.03	3.29	0.56	4.88
		Moist Deciduous		
Tectona grandis	14.6	7.35	21.1	43.0
Lagerstroemia microcarpa	11.4	6.53	15.2	33.2
Grewia tiliifolia	8.26	6.94	9.37	24.6
Terminalia alata	8.55	6.12	8.96	23.6
Syzygium cumini	7.28	6.12	8.47	21.9
Anogeissus latifolia	7.28	4.08	3.62	15.0
Radermachera xylocarpa	4.03	2.45	5.66	12.1
Schleichera oleosa	2.65	3.67	4.96	11.3
Cassia fistula	5.21	3.67	0.41	9.3
Bambusa arundinacea	5.51	2.04	0.4	7.94
		Scrub		
Erythroxylum monogynum	22.7	11.65	7.04	41.4
Anogeissus latifolia	12.8	8.74	13.1	34.6
Albizia amara	8.55	7.77	11.4	27.7
Givotia rottleriformis	2.3	4.85	15.6	22.8
Acacia chundra	5.92	8.74	5.28	19.9
Chloroxylon swietenia	6.58	3.88	4.69	15.1
Butea monosperma	3.29	3.88	4.23	11.4
Bauhinia racemosa	3.95	3.88	1.82	9.65
Diospyros montana	2.96	1.94	4.5	9.4
Cassia fistula	3.62	2.91	2.04	8.57
		Riparian		
Mangifera indica	18.5	9.23	32.4	60.1
Syzygium cumini	15.3	10.8	17	43.1
Terminalia arjuna	8.87	4.62	15.8	29.3
Erythrina variegata	6.45	1.54	6.31	14.3
Schleichera oleosa	3.23	4.62	4.45	12.3
Ficus benghalensis	2.42	3.08	4.53	10.0
Diospyros assimilis	1.61	3.08	5.19	9.88
Pongamia pinnata	3.23	4.62	1.29	9.13
Schefflera venulosa	1.61	3.08	2.17	6.86
Trema orientalis	3.23	3.08	0.47	6.77

Table 3. Population density of tree species across girth class intervals.

GBH	Dry Deciduous		Moist Deciduous		Riparian		Scrub	
Class	Species	Individuals	Species	Individuals	Species	Individuals	Species	Individuals
<30	34	85	36	75	-	-	9	22
30-60	48	607	48	238	24	31	26	183
60-90	28	372	38	198	13	20	17	69
90-120	18	184	21	106	6	9	6	11
120-150	12	97	28	170	7	17	8	10
150-180	8	59	20	98	10	14	2	3
180-210	8	32	14	56	6	9	3	3
210-240	6	16	12	43	4	5	1	1
240-270	3	7	8	16	2	3	1	1
270-300	-	-	6	10	3	8	-	-
>300	2	2	5	7	4	7	1	1
Total	66	1461	83	1017	39	124	38	304

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Table 4. Height Class wise proportion of tree individuals in Mudumalai Wildlife Sanctuary.

Height Class	Overall vegetation		Dry Deciduous	Moist Deciduous	Riparian	Scrub
	species	% of Individuals	% of Individuals	% of Individuals	% of Individuals	% of Individuals
<5m	40	8.4	7.5	9.5	2.42	86
5-10	76	18.2	18.8	12.3	12.9	14
10-15	28	3.61	4.9	1.97	0.81	-
15-20	75	24.2	30.5	16	15.3	-
20-25	76	28.7	28.5	32.4	25.8	-
25-30	47	13.5	8.6	22.4	24.2	-
>30	31	3.37	1.3	5.31	18.5	-
Total	156	100	100	100	100	100

The high basal area in moist deciduous forest type indicates resource utilization and canopy closure of tree species. The girth class interval analysis gives the scenario of the forest stand structure as more number of species are under GBH of 30-60 cm. A low diversity was recorded in all the three forest types in the girth class > 150 cms indicating the low population of mature trees, giving impression of ongoing seral stages within forest types. The height of species relies greatly upon the climate, edaphic conditions and anthropogenic factors. In case of scrub, around 86% of tree individuals are represented in less than 5 m height class followed by 14% in 5-10 m. It means tree species in scrub shows tendency towards short stature.

Species wise analysis shows *Anogeissus latifolia*, is found to be one of the ecologically dominant species contributing high IVI in dry deciduous, moist deciduous and scrub types. This indicates a wide range of growth and adaptability of *Anogeissus latifolia* through out the Sanctuary.

It was observed that some of the species confined themselves to a particular vegetation type. These species are unique in nature that they were not found in any other vegetation types. This may be due to their adaptation to particular micro climatic conditions and specific ecological niche, outside their adaptability zone the viability of these species is less and hence act as "*preferential species (habitat specialist)*", limiting their population to a particular type. Of the top ten predominant species of riparian forest, i.e. *Mangifera indica, Terminalia arjuna, Diospyros assimilis, Pongamia pinnata* and *Schefflera venulosa, Trema orientalis* are preferential species. *Erythroxylum monogynum* is preferential species of scrub.

Simultaneously about 13 species (8%) were found to be common to all the four vegetation types and thrive for cosmopolitan distribution of their population. These species may be termed as "*companion species*", which survive in any type of community without showing special affinities for association. Probably these species have high ecological amplitude. The companion species are *Acacia ferrugenia, Anogeissus latifolia, Bambusa arundinacea, Bauhinia racemosa, Butea monosperma, Cassia fistula, Cassine glauca, Diospyros montana, Ficus benghalensis, Kydia calycina, Schleichera oleosa, Terminalia alata* and *Ziziphus xylopyrus*.

Similarity index reveals that 83.9 % of floristic composition of dry deciduous forest is similar with moist deciduous forest. Comparatively a similarity of 38.3% was observed between riparian and scrub. In overall sampling, single individuals (singletons) represented 45 (29%) species and doubletons with 33 species (21%).

CONCLUSION

Quantitative structure and floristic composition of tree species have been studied. Vegetation is an integral component of ecosystem, which indicates the effects of changing environmental conditions in an obvious and easily measurable manner. Thus, careful analysis of vegetation types is used as a means of evaluating useful information about other components of the ecosystems.

Presence of high species diversity and richness indicates uniqueness and potentiality of Mudumalai wildlife sanctuary for conservation of ecosystem in totality. The problem of recurrent forest fire is observed, which must be checked.

According to IUCN Categories for Protected areas, Mudumalai wildlife sanctuary falls under category 4 (Habitat/Species management area), so conservation of habitat / species should be of highest priority (http://www.kerala.com/wiki).

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印度西高止山脈莫都馬賴野生動物保護區內熱帶森林之植物組成與評估量化後的林分結構

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摘　　要

本研究主要探討位於印度西高止山脈 (Western Ghats of India) 莫都馬賴野生動物保護區 (Mudumalai Wildlife Sanctuary) 內熱帶森林之植物組成與評估量化後的林分結構。林分結構的量化是透過胸高樹圍 (G.B.H., Girth Breast Height) 與樹高分級的方式進行。分析計算當地 156 個樹種之重要值 (IVI, Importance Value Index)、Shannon 指數 (Shannon-Weiner index)、辛普森指數 (Simpson index)、Margalef 物種豐富度指數 (Margalef Species Richness Index) 與均勻度指數 (Pielou index)。結果顯示林分密度的範圍介於每公頃 112-406.8 棵，平均林分胸高斷面積為 26.25 m^2/ha。物種歧異度方面，Shannon 指數範圍介於 3.94-4.90 之間，辛普森優勢度指數範圍介於 0.86-0.94 之間。Margalef 物種豐富度指數範圍則在 4.61-8.31 之間。關於林分結構量化方面，約 65.4%及 36.4%的林木屬於胸高樹圍徑級 30-60 cm。在樹高分級部份，約 28.7%的林木高度介於 20-25 m 之間；24.4%的林木高度介於 15-20 m 之間；僅有 3.37%的林木高度大於 30 m。

關鍵詞：熱帶林、結構、成份、莫都馬賴 (Mudumalai)、印度。

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