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Tree Species Diversity and Population Structure in the Tropical Forests of North Central Eastern Ghats, India

Dumpa PREMAVANI, Maradana TARAKESWARA NAIDU*, Malleboyina VENKAIAH

*Department of Botany, Andhra University, Visakhapatnam, India; premavani.d@gmail.com, tarakeswaranaidu@gmail.com (*corresponding author), venkaiah_botany@rediffmail.com*

Abstract

The tree species diversity and population structure were studied in four stands of the tropical forests in the north-central Eastern Ghats, based on tree inventories conducted on four 1-ha plots. In the four independent plots, two 5 x 1000 m transects were established and all trees with ≥ 15 cm girth at breast height were enumerated. The density, frequency, basal area and IVI along with diversity indices viz. Shannon index, species richness, equitability and species dominance were computed to see the variation in tree community. A total of 92 species representing 73 genera under 40 families of angiosperms were recorded. Tree species richness was as low as 34 species per hectare plot in Geddapalli to as high as 48 species in Koruturu. Tree density ranged from 360 stems per hectare in plot Geddapalli to 526 stems in plot Chintapalli and that of total basal area from 16.31 m^2 ha^{-1} in Koruturu to 31.15 m^2 ha^{-1} in Chintapalli. The number of species and stems decreased from the smaller to the largest girth classes. The tree inventories of the study area when compared to those of the other tropical forests showed great differences in density and basal area. This may probably be due to differences in geography and annual rainfall patterns. The information on tree species structure and function can provide baseline information for conservation of the biodiversity.

Keywords: diversity index, dominance, girth class, population structure, tree basal area

Introduction

Tropical forests are the most complex of all the terrestrial ecosystems. They provide many goods and ecosystem services, such as prevention of soil erosion and preservation of habitats for plants and animals (Anbarashan and Parthasarathy, 2013). Although tropical forests occupy only 7% of the earth's land surface (Wilson, 1988), they harbors about two thirds of all biological populations (Hughes *et al*., 1997). Phytogeographically, these forests are characterized by a large biological diversity and enriched with economically important species (Hare *et al*., 1997). On a global basis, 52% of total forests are tropical and over 42% of tropical forests have been classified as dry forests (Holdridge, 1967) and these currently are disappearing at an alarming rate, ranging between 0.8-2% per year (May and Stumpf, 2000; Sagar *et al*., 2003). Many tropical forests are under great anthropogenic pressure and require management interventions to maintain the overall biodiversity, productivity and sustainability (Kumar *et al*., 2006). Trees from the major structural and functional basis of tropical forest ecosystems can serve as robust indicators of changes and stresses at the landscape scale (Sahu *et al*., 2012b). Plant diversity inventories in tropical forests have mostly been concentrated on tree species than other life forms, because tree species diversity is an important aspect of forest ecosystem diversity and also fundamental to total tropical forest biodiversity (Rennols and Laumonier, 2000). They provide resources and habitat structure for almost all other species and form the major biotic component in the forest ecosystem.

Eastern Ghats are a long chain of broken hills and elevated plateaus, running along the east coast of India in the states of Orissa, Andhra Pradesh, Tamil Nadu and Karnataka. The topography and varied climate promoted luxurious growth of plants and diverse forests with a number of invaluable medicinal plant species (Rawat, 1997; Sahu *et al*., 2012a). Certain wild crop relatives have been reported from these tracts, giving these landscapes special conservation value as sources of novel genes for future crops. This rich biodiversity is being utilized by the inhabitants of the region for medicine, food (wild edible), fodder, fuel, timber, making agricultural tools, religious and other purposes. As the Eastern Ghats constitute important catchments of the peninsula and natural resource, they are

threatened due to anthropogenic disturbances, such as indiscriminate collection of fodder, fuel species, extraction of timber and minerals from the forests besides the shifting cultivation (Reddy *et al*., 2008). Several authors have studied the flora and stressed the need for better conservation of the Eastern Ghats.

In peninsular India, quantitative phytodiversity related inventories from the forests of Eastern Ghats are very few. Some studies related to Eastern Ghats of Tamil Nadu (Kadavul and Parthasarathy, 1999a, b; Jayakumar *et al*., 2002; Natarajan *et al*., 2004; Pitchairamu *et al*., 2008; Pragasan and Parthasarathy, 2010); Orissa (Reddy *et al*., 2007; Sahu *et al*., 2012a, b; Sahu *et al*., 2007; Dash *et al*., 2009), Andhra Pradesh (Rawat, 1997; Reddy *et al*., 2008; Reddy and Ugle, 2008; Rao *et al*., 2011) are available. Such studies about Eastern Ghats are very few in the state of Andhra Pradesh, though it has major tracts of Eastern Ghats. Therefore, the present study was conceived to compare the species diversity, density and stand structure of the four plots of north-central Eastern Ghats, in the West Godavari district of Andhra Pradesh.

Material and methods

Study area

The study was carried out in four forest stands in the tropical dry deciduous forests (Champion and Seth, 1968) located in West Godavari district, Andhra Pradesh and the plots are 330 km south- west of Visakhapatnam city. They include Chintapalli (CP), Puliramudugudem (PG), Koruturu (KT) and Geddapalli (GP). The West Godavari district is located between the northern latitudes of 16°-15' and 17°- 30' and eastern longitudes of 80°- 50' and 81°- 55' bound on the north by Khammam district, on the south by Bay of Bengal and a small part of Krishna district, on the east by the river Godavari and on the west by Krishna district. The elevation measures about 450 m above the mean sea level. Geological formation of the region consists in chiefly crystalline metamorphic rocks. Soil of north central Eastern Ghats is loamy, black, lateritic and alluvial. Lateritic soils are the common type along the deciduous forests in the area. There are three distinct seasons in a year: winter (November to February), summer (March to June) and rainy season (July to October). The maximum temperature ranges between 28.0 – 46.2 °C and minimum temperature ranges between 12.9 – 27.0 °C. The maximum rainfall is 1300 mm per annum during south-west monsoon period. Similar pattern of temperature and rainfall prevails throughout the year for all the four studied plots. The relative humidity varied between 70 – 88%.

Field methods

For determination of biodiversity, the methodology prescribed by the National Bioresource Development Board, Department of Biotechnology, Government of India was followed. In all the four study plots, two belts transects of size 5 x 1000 m (totaling 1 ha) were randomly laid during the calendar years 2007 – 2009 and all live trees with ≥15 cm girth at breast height (gbh) were enumerated. The height of trees was measured using a clinometer. Depending on the shape of the forest stand, these transects were sub-divided into fifty 5 x 20 m quadrats. The representative taxa were collected and identified with the help of regional floras (Gamble and Fischer, 1915-1935; Rao *et al*., 1986) and preserved into herbarium. The voucher specimens were deposited in the Botany Department Herbarium (BDH), Department of Botany, Andhra University, Visakhapatnam.

Data analysis

Based on the individuals recorded in the discrete plot samples, vegetation data were quantitatively analysed for basal area, relative density, relative frequency and relative dominance.

The importance value index of tree species was determined as the sum of relative frequency, relative density and relative dominance (Curtis and McIntosh, 1950).

The data collected were also used to compute community indices like species diversity (H') of different tree species; it was calculated using the Shannon- Weiner Index (Shannon and Weiner, 1963):

$$H' = -\Sigma (ni/N)/ n(ni/N),$$

where, Pi = ni/N, which denotes the importance probability of each species in a population, ni= importance of value of species and N is the total number of individuals of all species in that vegetation type.

Species dominance (Cd) was calculated following Simpson (Simpson, 1949):

$$Cd = \Sigma (ni/N)^2,$$

where, ni and N are the same as those for Shannon-Weiner information function.

Equitability of evenness refers to the degree of relative dominance of each species in that area. It was calculated according to Pielou (1966) as:

$$\text{Evenness (e)} = H'/\log S$$

where, H'= Shannon index, S = number of species.

Species richness was determined by Margalef index (1968) as:

$$d = S_1/\log N$$

where, S is the number of species and N is the number of individuals.

Structural composition was analysed by comparing the distribution of tree height and diameter classes.

Results

Floristic composition and species richness

A total of 1789 stems with ≥ 15 cm gbh were recorded within four 1 ha plots, representing 92 species belonging to 73 genera under 40 families. Of these, 27 families comprise 41 genera, 46 species and 526 individuals were recorded in plot CP; 28 families contributing 43 genera, 46 species and 447 individuals represented in plot PG, whereas 25 families comprising 41 genera, 48 species and 456 individuals reported in plot KT and 21 families represented 30 genera, 34 species with 360 individuals in plot GP (Tab. 1). With

regard to the number of species found within families, Papilionaceae and Mimosaceae were the most diverse families in the samples, each being represented by seven species; they were followed by Rubiaceae (6 species), Combretaceae and Euphorbiaceae (5 species each), Annonaceae, Moraceae, Rutaceae and Verbenaceae (4 species each), Apocynaceae, Caesalpiniaceae, Ebenaceae, Meliaceae (3 species each), Anacardiaceae, Bignoniaceae, Bombacaceae, Burseraceae, Loganiaceae, Sapindaceae and Ulmaceae (2 species each) and 19 families were represented only by single species.

Tab. 1. Number of taxa, diversity indices and structural characteristics of four 1-ha plots in the North-central Eastern Ghats

Variables	CP	PG	KT	GP
Number of species	46	46	48	34
Number of genera	41	43	41	30
Number of families	27	28	25	21
Density	526	447	456	360
Basal area m^2 ha^{-1}	31.16	23.36	16.32	17.04
Shannon_H	3.55	3.47	3.48	3.32
Simpson_1-D	0.96	0.97	0.95	0.96
Evenness_e	0.76	0.71	0.68	0.81
Margalef	7.18	7.37	7.68	5.61
Elevation	316	185	88	334
Latitude	17° 19' 446"	17° 15' 181"	17° 26' 014"	17° 20' 124"
Longitude	81° 28' 293"	81° 25' 875"	81° 32' 081"	81° 28' 836"

The mean tree density is 447 stems for 1 ha and density ranges from 360 – 526 stem ha^{-1}. The stand density is more for plot CP and less for plot GP. Basal area ranged between 16.32 m^2 ha^{-1} – 31.16 m^2 ha^{-1} and mean basal area was 22 m^2 ha^{-1}. Basal area is more voluminous in plot CP and less voluminous in plot GP.

Tree girth class-wise density is more for 31-60 cm gbh class interval, with 32.9%, while the class interval <30 cm accounted for 20%, girth interval between 91-120 cm accounted 15.09% and less abundance is for class interval >120 cm, with 12.5%. The stand structure based on girth frequency of species has a greater number of trees in lower size class particularly in plot CP and plot KT compared to plot PG and plot GP (Tab. 2). Stem density across girth classes in all the study plots decreased from the smallest to the largest trees, except in first girth class (<30 girth class). Tree girth class-wise basal area is more for >120 cm class represents 51 m^2 ha^{-1} and less for <30 cm girth intervals with 1.64% m^2 ha^{-1}.

The mean tree height is 18.5 m with the high ranging between 2-20 m. Tree distribution by height intervals shows that around 22% of individuals are in <5 m, about 60% of individuals fall in 5-10 m height interval and only 14% of individuals are contributed by 11-15 m interval, while >15 m tree species are very few and constitute about 2.9% of total individuals (Tab. 3).

Importance value index (IVI) and diversity

The IVI values of the 92 species varied considerably (Tab. 4). The IVI of the top ten tree species contributed by 76.5%, 48%, 44.4% and 51.7% of total IVI values respectively for plots CP, PG, KT and GP. *Cleistanthus collinus* is the dominant species in plot CP (IVI 105.34) accounting for 35.1% of total IVI. The co-dominant species is *Dalbergia paniculalta* (IVI 17.26) accounting for 5.7% of total IVI. The other species with IVI values greater than 10 include *Xylia xylocarpa*, *Terminalia alata*, *Ficus religiosa*, *Schleichera oleosa*, *Grewia tiliaefolia*, *Ficus benghalensis* and *Terminalia bellirica*; these accounted for 3.5 – 5.6% of total IVI.

Tab. 2. Girth class-wise population density of tree species (≥15 cm gbh) in four 1-ha plots

Gbh m^2 ha^{-1} (cm)	Plot				Individuals	% of Individuals
	CP	PG	KT	GP		
<30	112	94	92	59	357	19.95
31-60	167	134	180	109	590	32.97
61-90	87	92	72	97	348	19.45
91-120	65	71	68	66	270	15.09
>120	95	56	44	29	224	12.52
Total	526	447	456	360	1789	100

Tab. 3. Height class-wise proportion of tree individuals in four 1-ha plots

Height	Plot				Individuals	% of Individuals
	CP	PG	KT	GP		
≤ 5m	126	106	107	59	398	22.24
6-10 m	308	246	289	238	1081	60.42
11-15m	71	78	49	59	257	14.36
> 15 m	21	17	11	4	53	2.96
Total	526	447	456	360	1789	100

In plot PG, *Dalbergia paniculata* was the dominant species (IVI 24.15) which contributed with 8% of total IVI. *Tamarindus indica* was the co-domonant species (IVI 20.11) accounting for 6.7% of total IVI. The other species with IVI greater than 10 include *Haldinia cordifolia*, *Anogeissus acuinata*, *Terminalia alata*, *Chloroxylon swietenia*, *Lannea coromandelica* and *Strychnos nux-vomica*, which accounted for 4 – 6% of the total IVI.

In the plot KT, *Cleistanthus collinus*, *Dalbergia paniculata*, *Terminalia alata*, *Schleichera oleosa*, *Anogeissus latifolia* and *Albizia odoratissima* had IVI values greater than 10. *Cleistanthus collinus* had the largest IVI, with a value of 21.52, accounting for 7.1% of total IVI, followed by *Dalbergia paniculata* with IVI - 18.9 accounting for 6.3% of the total IVI. The IVI of the other four species ranged between 10.67-17.21, accounting for 3.5 – 5.7% of total IVI.

In the plot GP, species with IVI greater than 10 include *Anogeissus latifolia*, *Xylia xylocarpa*, *Ficus religiosa*, *Bombax ceiba*, *Anogeissus acuminata*, *Terminalia alata*, *Albizia odoratissima*, *Lannea coromandelica*, *Alangium salvifolium* and *Albizia lebeck* accounted for above 50% of total IVI. *Anogeissus latifolia* is the dominant species with 19.11 IVI, accounted for 6.3% of the total IVI. *Xylia xylocarpa* is the co-dominant with 18.11 IVI, accounted for 6% of the total IVI.

Diversity of tree species in the study plots calculated using the Shannon-Weiner diversity index (H') showed values of 3.55, 3.47, 3.48 and 3.32 for the plots of CP, PG, KT and GP respectively. The values for Simpson's index were 0.96, 0.97, 0.95 and 0.96 for the plots of CP, PG, KT and GP respectively. Pielou's evenness index of tree communities at CP, PG, KT and GP plots showed values of 0.76, 0.71, 0.68 and 0.81 respectively. The Margalef species

Tab. 4. Top ten IVI of the tree species in four 1-ha plots

Species	CP	PG	KT	GP
Alangium salvifolium	–	–	–	11.32
Albizia lebeck	–	–	–	10.73
Albizia odoratissima	–	–	10.67	14.16
Anogeissus acuminata	–	15.66	12.8	16.81
Anogeissus latifolia	–	–	–	19.11
Bombax ceiba	9.92	–	9.58	17.8
Chloroxylon swietenia	–	13.98		–
Cleistanthus collinus	**105.34***	–	**21.52***	–
Dalbergia paniculata	17.26	**24.15***	18.99	–
Ficus benghalensis	10.88	–	–	–
Ficus religiosa	16.26	13.98	–	17.85
Grewia tiliaefolia	12.16	–	–	–
Haldinia cordifolia	–	17.94	9.45	–
Lannea coromandelica	–	11.81	9.89	12.7
Polyalthia cearsoides	–	8.04	–	–
Sapindus emarginatus	–	7.56	–	–
Schleichera oleosa	13.00	–	13.84	–
Semecarpus anacardium	–	–	9.29	–
Strychnos nux-vomica	–	10.78	–	–
Tamarindus indica	–	20.11	–	–
Terminalia alata	16.78	–	17.21	16.72
Terminalia bellirica	10.73	–	–	–
Xylia xylocarpa	17.04	–	–	**18.11***
Subtotal (10 species)	229.37	144.01	133.24	155.31
Remaining species	70.63	155.99	166.76	144.69
Grand total	300	300	300	300

*Highest IVI in each plot

richness index is 7.18, 7.37, 7.68 and 5.61 for plots of CP, PG, KT and GP respectively (Tab. 1).

Discussion

The tree species richness varied among the four plots. There are 92 species enumerated in the 4 ha of the north central Eastern Ghats. Species richness ranges between 34-48 stems ha^{-1}. Species richness is higher for plot CP, with 48 species, while GP has least diversity, with 34 species. These study plots are compared with that of tropical dry deciduous forests of Eastern Ghats, southern Andhra Pradesh, which represents 18 – 86 tree species in 3 ha (Reddy *et al*., 2008), Niyamgiri hill ranges of Orissa with 22-29 species in 0.6 ha (Sahu *et al*., 2012b), Similipal Biosphere Reserve harbouring 76-121 species in 8.48 ha (Reddy *et al*., 2007), Khokham Wildlife Sanctuary comprising 11-17 tree species in 2 ha (Pant and Samant, 2012), inland forests and coastal forests of peninsular India with 19-35 and 21-28 tree species respectively in 5 ha each (Mani and Parthasarathy, 2006), tropical dry evergreen forests of Coromandel coast of India harbouring 18-27 species in 4 ha (Anbarashan and Parthasarathy, 2013), tropical dry deciduous forests of western India contributed 18-37 species in 3 ha (Kumar *et al*., 2010), *Kaan* forests in the central Westrn Ghats harbouring 28-53 species in 3 ha (Ganuga *et al*., 2013).

The present study enumerated the presence of 1789 individuals in 4 ha^{-1} study plots. These results were compared with tropical dry deciduous forests of Eastern Ghats, Southern Andhra Pradesh (1541- 3 ha^{-1} – Reddy *et al*., 2008), Similipal Biosphere Reserve (4819- 8.48 ha^{-1} – Reddy *et al*., 2007), *Kaan* forests of central Western Ghats (1925- 3 ha^{-1} – Ganuga *et al*., 2013), Boudh district of Orissa (2364- 4 ha^{-1} – Sahu *et al*., 2007), Malayagiri hill ranges of Eastern Ghats (1063- 2 ha^{-1} – Sahu *et al*., 2012a), Inland and coastal dry evergreen forests (4676- 10 ha^{-1} – Mani and Parthasarathy, 2006), tropical dry deciduous forests of Western India (1724- 3 ha^{-1} – Kumar *et al*., 2010), reserved forests of southern Eastern Ghasts of Andhra Pradesh (3078- 5 ha^{-1} – Rao *et al*., 2011), tropical dry evergreen forests of Coromandel coast of India (4345- 4 ha^{-1} – Anbarashan and Parthasarathy, 2013).

Girth class-wise frequency population structure of trees in four study plots are in conformity with other forest stands in tropical forests such as Shervarayan hills (Kadavul and Parthasarathy, 1999a), Kalarayan hills (Kadavul and Parthasarathy, 1999b), sacred groves of the Jaintia hills (Upadhaya *et al*., 2003), Malayagiri hill ranges of Eastern Ghats (Sahu *et al*., 2012a) and Cerros de Amotape Cordillera, Peru (Palomino and Alvarez, 2005). Species richness and density decreased with the increasing tree size classes in all four plots, as the middle class stems 61-90 cm contributed with 33% of total density, whereas the largest size >120 cm comprised 12.5%. The trend of decreasing diversity with increasing girth class is similar to that observed by Paijmans (1970) in New Guinea.

The basal area is used as one of the important aspects for studying the forest vegetation structure in most of the studies (Mani and Parthasarathy, 2006). The mean basal area obtained in the present study is 22 m^2 ha^1, as it ranges between 16.32- 31.16 m^2 ha^{-1}; with this value, is greater than the one for tropical forests of Hainan Island, with 17.04-21.11 m^2 ha^{-1} (Meng *et al*., 2011), Niyamgiri hill range of Eastern Ghats constituted 3.16- 10.04 m^2 ha^{-1} (Sahu *et al*., 2012a), Cerros de Amotape Cordillera, Peru comprised 2.31- 22.79 m^2 ha^{-1} (Palomino and Alvarez, 2005), tropical forests of southern Eastern Ghats harboring 5.6- 24.4 m^2 ha^{-1} (Pragasan and Parthasarathy, 2010). This value is closer of near reserved forests of southern Eastern Ghats of Andhra Pradesh has 10.5- 31.7 (Rao *et al*., 2011), tropical dry deciduous forests of Eastern Ghats, Southern Andhra

Pradesh with 8.55- 34.39 m^2 ha^{-1} (Reddy *et al*., 2008), but lower than that of 61.32- 70.93 m^2 ha^{-1} for Niyamgiri hill ranges of Orissa (Dash *et al*., 2009), sacred groves of Jaintia hills contributed 57.46- 77.44 m^2 ha^{-1} (Upadhaya *et al*., 2003), fan-palm dominated forests of east coast peninsular Malaysia with 25.3- 48.6 m^2 ha^{-1} (Nizam *et al*., 2013). The basal area and vertical structure of a forest is difficult to summarize as these depend heavily upon climate and prevailing edaphic factors.

The Shannon-Weiner varied among all plots is 3.55, 3.47, 3.48 and 3.32, which are compared with other findings of lowland forests of Cameroon, 3.9- 4.12 (Gonmadje *et al*., 2011), in Niyamgiri hill ranges of Orissa, 3.84- 4.86 (Dash *et al*., 2009), in tropical dry evergreen forests of Coromandel coast of India, 1.24- 2.4 (Anbarashan and Parthasarathy, 2013), in inland and costal tropical dry evergreen forests, 1.29- 2.44 (Mani and Parthasarathy, 2006), in the tropical semi evergreen forests in the Shervarayan hills, 2.37- 3.072 (Kadavul and Parthasarathy, 1999a), in tropical dry deciduous forests of southern Andhra Pradesh, 4.11- 4.89 (Reddy *et al*., 2008) and tropical dry deciduous forests of Boudh district of Orissa, 4.51 (Sahu *et al*., 2007). The evenness index in the present study sites were within the range for tropical forests, between 0.64-1.34 (Lalfakwma *et al*., 2009; Sahu *et al*., 2012a). The dominance index values obtained in the current study ranges between 0.95-0.97, which are close to the value of tropics (Reddy *et al*., 2007).

Conclusion

Tropical dry deciduous forests are a critical repository of India's biodiversity and are threatened due to wide spread of habitat destruction. Plant diversity inventories in tropical forests have mostly been concentrated on tree species than other life-forms, because tree species diversity is an important aspect of forest ecosystem diversity and also fundamental for total tropical forest biodiversity. The present quantitative inventory of tree species diversity revealed considerable variation in the composition of dominant species and stand density in various forest areas. The IVI values have helped to understand the ecological significance of the tree species in community structure. The present study clearly established the fact that the tree diversity in tropical forests of Eastern Ghats varied greatly from location to location, mainly due to variation in biogeography and habitat disturbance. Most of the species present in these communities are used for fuel, fodder, making agricultural tools, house building and miscellaneous purposes. During the surveys, it has been observed that use-pressure on species along with heavy grazing is responsible for habitat degradation, poor regeneration and population depletion of the tree species.

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