Plant Diversity and Distribution Pattern in Tropical Dry Deciduous Forest of Eastern Ghats, India

Durai Sanjay Gandhi and Somaiah Sundarapandian

Abstract Vegetation of a tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats, India was analyzed by laying 30 square plots (1 ha). A total of 210 plant species (75 trees and herbs, 27 shrubs and 33 climbers) were enumerated. Species richness ranged 35–84/ha. The number of tree, shrub, herb and climber species in plots varied from 7–28/ha, 5–14/0.125 ha, 10–36/50 m^2 and 3–23/0.125 ha respectively. The basal area of trees ranged 7.23–43.05 m^2/ha. Shannon's index ranged from 0.716 to 2.343 for tree species. *Albizia amara* was the dominant tree species except for plot nos. 24 and 25, where *Chloroxylon swietenia* was dominant. In shrub community, *Lantana camara* and *Clausena heptaphylla* were the dominant species. *Sida cordifolia* and *Ageratum conyzoides* were the most abundant species in the herbaceous community. In climbers, *Pterolobium hexapetalum* was the dominant species. The dominance of ruderal weeds and exotics in the understory indicates that this forest is under the threat of anthropogenic pressure although it has been declared as a reserve forest. The present study reveals that differences in microclimate, level and kind of anthropogenic perturbation, and edaphic characteristics among the plots could be the reason for the significant spatial variation in species richness and density among the plots even though they are located within 10 km radius. However, this forest ecosystem restores rich flora similar to other tropical dry forests in India and elsewhere. To impede the plant invasion, timely measures are to be adopted to eliminate invasive species in order to retain and conserve the native diversity.

Keywords Eastern Ghats · Biodiversity · Tropical forest · Anthropogenic disturbance · Vegetation structure · Species composition

D. S. Gandhi · S. Sundarapandian (✉)
Department of Ecology and Environmental Sciences, Pondicherry University, Puducherry 605014, India
e-mail: smspandian65@gmail.com

N. Roy et al. (eds.), *Socio-economic and Eco-biological Dimensions in Resource use and Conservation*, Environmental Science and Engineering,
https://doi.org/10.1007/978-3-030-32463-6_8

1 Introduction

Tropical forests are biodiversity-rich centres on earth and harbour approximately two-thirds of all living organisms (Hughes et al. 1997) including 96% of tree species (Poorter et al. 2015). The tropical forest biome comprises of diverse ecosystems between Tropic of Cancer and Tropic of Capricorn and spans across the Americas, Asia, Africa and Australia, and has the richest biodiversity with a unique environment. According to Miles et al. (2006), dry deciduous forest covers 6% (1,048,700 km^2) of the tropics. Around 40% of the earth's subtropical area is occupied by open or closed forest and of which 42% are tropical dry deciduous forest, 33% are moist forest and 25% are wet forest (Murphy and Lugo 1986). About 54.2% of the world's tropical dry forests are in South America and the rest are equally distributed in North and Central America, Eurasia, Africa, Southeast Asia and Australasia (Miles et al. 2006). In southeast Asia, 30% of forests in the mainland are classified as dry forest (Blackie et al. 2014).

Tropical forests of Asia, especially Eastern and Western Ghats are under threat owing to human activities and are consequently, being replaced by inferior species (Bahuguna 1999). Tropical rain forests are extensively studied compared to dry forests (Losos and Leigh 2004). Although tropical dry deciduous forests are highly degraded and converted to other land uses, they had little attraction among the researchers and the general public (Bullock et al. 1995; Rundel et al. 1995). Tropical dry deciduous forests are rich in economically important species and are known to provide high potential timber revenue (Mohapatra and Tewari 2005). Hence, there is a growing interest on dry forests in the recent past (Miles et al. 2006). Dry deciduous forests are one of the most exploited ecosystems in the world (Murphy and Lugo 1986; Janzen 1988; Gentry 1992), as they are more prone to fire in the dry season (Giriraj et al. 2010). Documentation of biodiversity patterns is essential to prioritize areas for conservation programmes (Villasenor et al. 2007). Information on structure and composition of tropical dry deciduous forests is needed to conserve and restore these threatened ecosystems. The quantitative floristic analysis of the forest provides the necessary information for future planning and management (Phillips et al. 2003).

India, being a mega-diverse country, covers about 2% of the global forest area and is one of the richest repositories due to the presence of different types of vegetation and they hold unique flora and fauna. Tropical forest in India occupies 86% of the total forest cover (Singh and Singh 1988), of which 54% are dry deciduous, 37% are moist deciduous and the remaining is wet-/semi-evergreen (Kaul and Sharma 1971). The Eastern Ghats are a fragmented hill-chain, starting from Odisha to Tamil Nadu. Studies exploring the structure and composition of forests in Eastern Ghats of Tamil Nadu are limited (Kadavul and Parthasarathy 1999a, b, 2000; Chittibabu and Parthasarathy 2000a, b, 2001; Jayakumar et al. 2002; Pragasan and Parthasarathy 2010; Muthumperumal and Parthasarathy 2013; Sundarapandian et al. 2015). However, studies on plant diversity in tropical dry deciduous forest Sathanur reserve forest is almost nil except for preliminary result output of us (Gandhi and Sundarapandian 2014a, b). Hence present study is intended to study the vegetation structure and

species composition of the tropical dry deciduous forest at Sathanur reserve forest of Eastern Ghats. Furthermore, an attempt was also made to understand the factors responsible for spatial variation in plant diversity.

2 Materials and Methods

2.1 Study Area

Sathanur reserve forest (longitude 78°51′10″ and latitude 12°4′48″), a part of Chennakesava hills, Tamil Nadu, India, spread over 870 ha (Fig. 1) was chosen for the present study belonging to a part of Eastern Ghats, India. The Eastern Ghats experience heavy pressure due to illegal logging, collection of fodder, fuelwood, medicinal plants, etc. and thereby are losing its vegetation at an alarming rate (Jayakumar et al. 2002). The vegetation of this region is dry deciduous forest type (Type 7/CI of Champion and Seth 1968) based on the Champion and Seth (1968) classification of Indian forests.

Sathanur Reserve forest receives a bimodal pattern of rainfall, with maximum rain during north-east monsoon (September–December) and very less and inconsistent rainfall during the south-west monsoon (May–July). The average annual rainfall for 44 years (1972–2015) was 965.49 mm and mean monthly maximum temperatures ranged between 28 and 37 °C while mean monthly minimum temperatures varied from 19.6 to 26.8 °C (Fig. 2). The major soil types in the district are red loam and

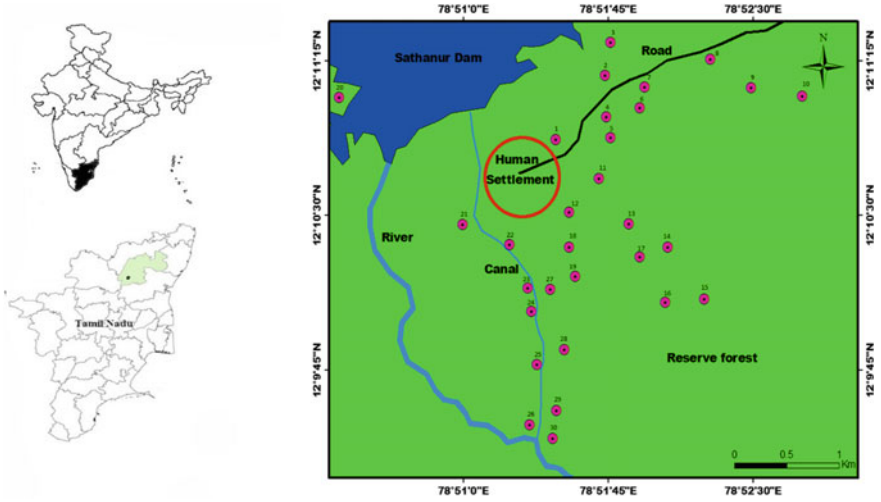

Fig. 1 Location of 30 one-hectare study plots (indicated by pink dots with numbers) in the Sathanur reserve forest of Eastern Ghats, India

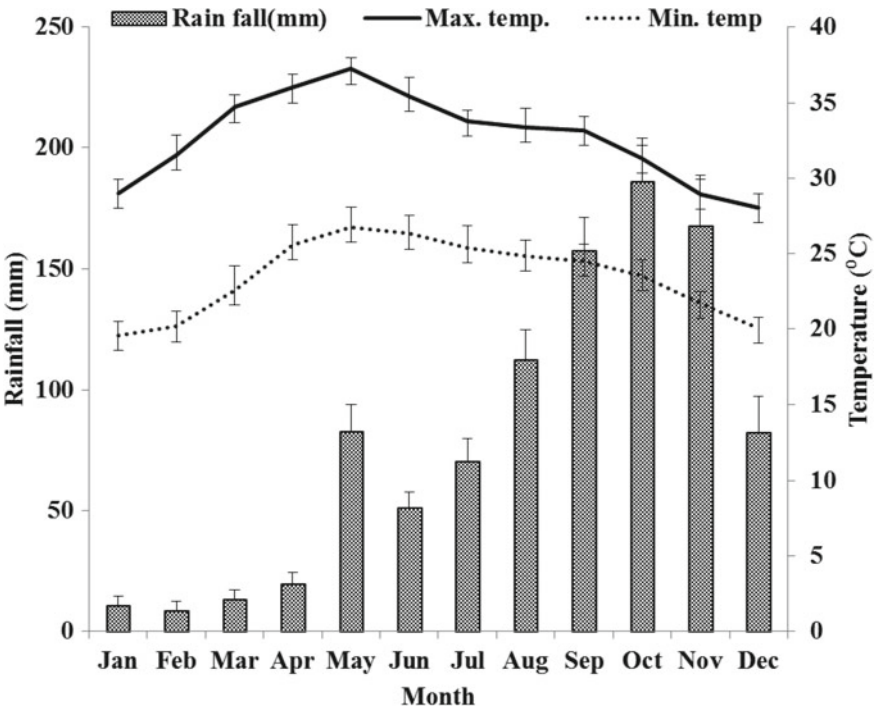

Fig. 2 Mean monthly rainfall (44 years) and temperature (study period) of the Sathanur reserve forest, Eastern Ghats

black soil and the red loam soil is predominantly found in Sathanur reserve forest (NADP 2008). The texture of the soil was sandy loam in most of the plots while the plots near to the rivulet were sandier than the other study sites. However, pebbles are abundant in the soil in most of the plots.

2.2 Vegetation Analysis

Thirty square plots of 1 ha each were laid approximately at 500 m intervals in the Sathanur reserve forests during the period of November 2013 to February 2015 (Fig. 1) which were further sub-gridded into 10 m × 10 m size (100 m^2) quadrats as easy, workable units. All the individual plants with ≥10 cm GBH were enumerated and their girth were measured at 1.37 m from the ground level. In multi-stemmed trees, GBHs were measured separately, after which basal area was calculated and summed up. Within each plot, 50 quadrats of 5 m × 5 m were laid in a systematic sampling method to enumerate shrubs and climbers. Similarly, fifty quadrats of 1 m × 1 m each were laid for herbs in each 1 ha plot and studied during October and November (peak growth period). Shrubs and herbs, the diameter was measured

at 3 cm above the ground of each individual using vernier caliper. Plant specimens were collected and identified with confirmation of taxonomist using floras (Gamble and Fischer 1987; Matthew 1991). The cut stems were enumerated in all the plots and the disturbance index was computed based on the number of cut stems divided by the total number of stems including cut stems (Rao et al. 1990). The vegetation data collected in each plot was analyzed for analytical and synthetic quantitative characteristics. The diversity indices were computed using the freely downloadable PAST 3.1 program (version 3.1; Øyvind Hammer, Natural History Museum, University of Oslo). Importance value index (IVI) was the sum of the values of relative frequency, relative density, and relative basal area (Curtis and McIntosh 1950). The abundance to frequency (A/F) ratio for different species was determined by following Whitford (1949). The ratio indicates regular (<0.025), random (0.025–0.050), and contagious (>0.050) distribution pattern.

Some plots (plot nos. 1–10) in the present study were laid near roads, human settlement or the agricultural fields which are more vulnerable to human exploitation. Although the study area is a reserve forest, locals frequently cut trees and collect firewood, lop branches and graze their cattle. Illegal selective cutting of *Chloroxylon swietenia* for fencing, agricultural tools and other domestic purposes and *Albizia amara* for firewood are quite frequent in this forest. Plots 11–20 are relatively less disturbed than the other plots. Study plots (plot nos. 21–30) were laid on both the sides of a rivulet from Ponnaiyar river. In general, the plots near the rivulet are also subjected to human disturbances. These plots had a rocky terrain. People regularly use the rivulet for day to day activities. In addition, it also serves as a source of drinking water for cattle and hence, these plots are also under high anthropogenic pressures. Soil moisture and pH values showed wide variation among the study plots. Soil pH ranged from 5.9 to 7.1 and the moisture content ranged from 1.28 to 24.0%. The mean soil bulk density value of the three layers ranged from 1.21 to 1.82 g/m^3. Coarse fragment (>2 mm size) fraction in the soil showed wide variations (33.9% of samples contain coarse fractions in all the three depths; 10.2% samples contain coarse fractions in surface (0–10 cm) and middle (10–20 cm) layers; 15.3% samples contain coarse fractions in middle and bottom layers (20–30 cm); 6.7% samples have coarse fractions only in the bottom layer) among the plots, samples and depths. However, 33.9% of the samples collected did not have any coarse fragment (Gandhi 2016; Gandhi and Sundarapandian 2017).

3 Results

3.1 Species Richness and Diversity

A total of 210 plant species belonging to 163 genera and 63 families were enumerated from 30 one-hectare plots in the tropical dry deciduous forest of Sathanur

reserve forest, Eastern Ghats. Among these, trees and herbs formed the major proportion represented by 75 (35.71%) species each followed by climbers (15.71%) and shrubs (12.86%). The total species richness of study plots ranged from a minimum of 35 species/ha to a maximum of 84 species/ha with a mean of 61.5 ± 2.5 species/ha (Table 1). Among different life-forms, the species richness varied from 7 to 28 species/ha for trees; 10–36 species/50 m^2 for herbs; 5–14 species/0.125 ha for shrubs and 3–23 species/0.125 ha for climbers. We encountered a total of 17,525 tree stems (≥10 cm GBH) from 30 one-hectare study plots. The density ranged from 336 stems/ha to 1075 stems/ha with a mean of 584 ± 38 stems/ha. For climbers and shrubs, it ranged from 9–252 individuals/0.125 ha and 247–969 individuals/0.125 ha respectively. The density of understory species varied considerably from 875 to 6567 individuals per 50 m^2. The total basal area registered by trees across the study plots was 561.3 m^2/ha and on individual plot, their basal area ranged from 7.2 to 43.1 m^2/ha, with a mean of 18.7 ± 1.5 m^2/ha. Similarly, for shrubs and climbers, it ranged from 0.16 m^2/ha to 0.8 m^2/ha and 0.06 m^2/ha to 3.3 m^2/ha respectively. The mean basal area for herbs in the study plots was 3.95 ± 0.3 m^2 per 50 m^2 and it ranged from 0.95 to 6.6 m^2 per 50 m^2. The diversity index, Shannon value ranged from 0.72–2.3 for tree species; 0.81–1.9 for shrubs; 1.16–2.8 for herbs and 0.24–2.8 for climbers (Table 2). Dominance index of tree species ranged from 0.14 to 0.7 with a mean of 0.4. Fisher's alpha index ranged from 1.25–6.36 for trees, 0.75–2.86 for shrubs, 1.23–5.4 for herbs and 0.76–8.1 for climbers.

3.2 Species Composition

Among 75 tree species enumerated, *Albizia amara* was the most dominant tree species represented by 9871 individuals which is almost 56% of the total stems enumerated from 30 one-hectare study plots (Table 3). The other dominant tree species in the study plots were *Chloroxylon swietenia* (3171 individuals), *Azadirachta indica* (553 individuals), *Pongamia pinnata* (477 individuals) and *Acacia catechu* (442 individuals).

The top five species together comprised 82.8% of the total tree species' density (Table 3). In contrast, 32 species including *Strychnos nux-vomica*, *Gmelina asiatica* and *Cassia fistula* were represented by <10 individuals and four species viz. *Borassus flabellifer*, *Cordia monoica*, *Dalbergia oliveri*, and *Delonix elata* were represented by just one individual across the study plots. *Lantana camara* (4661), *Clausena heptaphylla* (3970) and *Tarenna asiatica* (3186) were the predominant shrub species encountered across the study plots. These three species together contributed to 81% of the total shrub species density. However, 11 species among 27 were represented by <10 individuals and four species viz. *Allophylus serratus*, *Cadaba fruticosa*, *Grewia abutilifolia* and *Ziziphus rugosa* were represented by a single individual in all the study plots. The herbaceous community of the study plots was dominated by *Sida cordifolia* (22,038 individuals), *Ageratum conyzoides* (13,510 individuals) and *Sida acuta* (9245 individuals). Among 75 species, two species including

Table 1 Summary of plant diversity inventory carried out in 30 one-hectare plots of tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats (T—tree, S—shrub, H—herb, C—climbers)

Plot No.	Species richness					Individuals				Basal area (m^2/ha)			
	T[a]	S[b]	H[c]	C[b]	Total	T	S	H	C	T	S	H	C
1	17	12	29	11	69	821	595	3294	78	8.4	0.65	6.53	1.37
2	11	10	23	10	54	797	620	3104	53	17.4	0.60	4.36	0.51
3	12	12	32	14	70	937	575	3234	52	18.6	0.70	3.99	0.42
4	11	10	33	10	64	1075	515	3499	55	24.9	0.61	3.62	0.59
5	17	8	28	21	74	864	481	2581	114	19.5	0.53	2.35	1.40
6	12	10	23	10	55	1000	467	3946	32	19.6	0.34	3.35	0.39
7	21	9	36	11	77	797	247	4514	33	25.1	0.41	5.71	0.87
8	7	9	29	10	55	336	340	2791	64	14.7	0.41	3.03	0.42
9	11	13	33	12	69	438	267	2658	58	9.8	0.52	3.00	1.85
10	21	9	34	10	74	438	333	2961	73	20.7	0.43	2.68	1.15
11	25	11	26	10	72	612	423	3274	86	25.6	0.16	2.63	1.41
12	16	9	29	11	65	456	408	3521	71	10.3	0.33	3.64	1.03
13	28	5	28	10	71	512	358	3065	70	43.1	0.25	3.38	1.41
14	20	13	28	23	84	406	329	4474	130	19.9	0.45	3.81	3.28
15	18	14	28	16	76	435	969	2960	184	30.3	0.80	2.76	0.52

(continued)

Table 1 (continued)

Plot No.	Species richness					Individuals				Basal area (m^2/ha)			
	T[a]	S[b]	H[c]	C[b]	Total	T	S	H	C	T	S	H	C
16	21	14	17	21	73	726	873	875	199	29.4	0.40	0.95	1.03
17	26	10	31	13	80	622	344	6258	97	26.0	0.45	6.41	1.26
18	27	9	21	9	66	561	349	4062	51	15.1	0.44	4.48	0.52
19	24	8	33	13	78	400	481	2595	52	17.9	0.39	2.45	1.39
20	20	6	23	9	58	746	424	4649	53	31.4	0.70	6.28	1.60
21	21	8	22	10	61	449	863	2779	252	24.5	0.36	1.94	0.63
22	12	5	15	3	35	414	589	4185	38	11.3	0.38	3.94	0.20
23	12	8	17	5	42	484	572	5104	50	14.0	0.39	6.59	0.06
24	24	6	11	5	46	500	344	5392	9	8.8	0.31	3.43	0.29
25	25	9	14	3	51	629	290	6567	16	7.2	0.31	4.07	0.45
26	26	7	12	5	50	425	385	3932	43	11.7	0.19	4.39	0.70
27	18	9	16	3	46	373	383	2539	20	11.1	0.17	4.52	1.32
28	15	6	17	4	42	367	521	3789	62	12.9	0.32	5.67	0.30
29	22	6	13	3	44	525	578	3092	20	19.7	0.27	3.88	1.09
30	17	8	10	8	43	380	671	4228	21	12.7	0.24	4.56	0.81

[a]No./ha
[b]No./1250 m^2
[c]No./50 m^2

Table 2 Diversity indices of four dynamic plant life forms in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats (T—tree, S—shrub, H—herb, C—climbers)

Plot No.	Dominance index				Shannon's index				Fisher alpha			
	T	S	H	C	T	S	H	C	T	S	H	C
1	0.41	0.32	0.15	0.21	1.49	1.37	2.33	1.97	4.04	2.13	4.38	3.49
2	0.56	0.30	0.14	0.17	0.85	1.37	2.28	2.04	1.81	1.69	3.37	3.65
3	0.62	0.26	0.13	0.10	0.77	1.58	2.48	2.48	1.94	2.15	4.39	6.29
4	0.68	0.29	0.12	0.22	0.72	1.43	2.49	1.93	1.71	1.76	5.04	3.58
5	0.35	0.32	0.11	0.10	1.52	1.38	2.51	2.69	3.00	1.57	4.93	7.56
6	0.66	0.22	0.19	0.11	0.74	1.71	2.08	2.26	1.92	1.58	3.24	4.99
7	0.29	0.23	0.10	0.14	1.80	1.73	2.61	2.21	3.95	1.83	5.34	6.30
8	0.59	0.24	0.13	0.28	0.89	1.62	2.42	1.75	1.25	1.70	4.51	3.32
9	0.35	0.25	0.10	0.26	1.28	1.72	2.80	1.89	2.05	2.86	5.31	4.59
10	0.32	0.23	0.13	0.15	1.56	1.65	2.64	2.07	4.60	1.71	5.39	3.14
11	0.27	0.37	0.21	0.32	1.87	1.32	1.90	1.60	5.24	2.07	2.19	3.11
12	0.37	0.34	0.34	0.22	1.32	1.40	1.27	1.92	3.23	1.63	1.32	3.64
13	0.27	0.61	0.47	0.28	2.03	0.81	1.16	1.77	6.36	0.82	1.69	3.19
14	0.36	0.33	0.09	0.09	1.60	1.48	2.70	2.80	4.41	2.70	5.33	8.11
15	0.36	0.23	0.20	0.36	1.62	1.78	2.12	1.75	3.79	2.32	3.15	4.21
16	0.46	0.25	0.16	0.26	1.01	1.74	2.30	2.15	3.03	2.37	3.85	5.93

(continued)

Table 2 (continued)

Plot No.	Dominance index				Shannon's index				Fisher alpha			
	T	S	H	C	T	S	H	C	T	S	H	C
17	0.57	0.30	0.34	0.23	1.14	1.66	1.71	1.84	5.75	1.93	4.25	4.04
18	0.25	0.17	0.18	0.27	2.03	1.95	2.02	1.72	5.92	1.69	2.90	3.17
19	0.17	0.30	0.34	0.12	2.21	1.46	1.42	2.31	5.61	1.36	1.23	5.56
20	0.34	0.34	0.28	0.48	1.48	1.28	1.53	1.27	3.78	1.22	1.96	2.08
21	0.36	0.27	0.47	0.27	1.72	1.38	1.26	1.65	4.57	0.75	1.53	2.93
22	0.63	0.21	0.20	0.90	0.89	1.69	1.84	0.24	2.31	1.32	1.74	0.76
23	0.43	0.23	0.17	0.59	1.17	1.60	2.18	0.88	2.69	1.03	3.26	1.38
24	0.13	0.28	0.21	0.23	2.34	1.54	1.97	1.52	4.98	1.76	2.28	4.63
25	0.18	0.25	0.21	0.37	2.07	1.60	1.83	1.04	4.69	1.22	2.29	1.09
26	0.36	0.29	0.25	0.49	1.68	1.59	1.95	1.02	6.11	1.65	4.26	1.47
27	0.56	0.28	0.10	0.67	1.15	1.50	2.64	0.61	3.95	0.95	3.99	0.98
28	0.48	0.39	0.13	0.76	1.18	1.28	2.45	0.52	3.15	0.93	4.28	0.96
29	0.18	0.42	0.10	0.44	2.19	1.15	2.49	0.93	4.65	0.99	2.99	0.98
30	0.40	0.37	0.15	0.24	1.51	1.28	2.27	1.68	3.65	1.28	4.33	4.72

Table 3 Life form abundance in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

Name of the species	Family	Abundance/30 ha	Mean ± SE
Tree			
Albizia amara (Roxb.) Boivin	Mimosaceae	9871	329.03 ± 35.9
Chloroxylon swietenia DC.	Flindersiaceae	3171	105.70 ± 17.0
Azadirachta indica A. Juss.	Meliaceae	553	18.43 ± 3.18
Pongamia pinnata (L.) Pierre	Fabaceae	477	15.90 ± 4.57
Acacia catechu (L. f.) Willd.	Mimosaceae	442	14.73 ± 4.59
Atalantia monophylla (L.) Correa	Rutaceae	311	10.37 ± 2.85
Canthium dicoccum (Gaertn.) Teijsm and Binn.	Rubiaceae	268	8.93 ± 2.71
Gyrocarpus jacquini Roxb.	Hernandiaceae	262	8.73 ± 3.10
Diospyros ebenum Koen.	Ebenaceae	231	7.70 ± 2.84
Wrightia tinctoria (Roxb.) R.Br.	Apocynaceae	190	6.33 ± 1.31
Drypetes sepiaria (W. and A.) Pax and Hoffm.	Euphorbiaceae	164	5.47 ± 1.47
Ziziphus mauritiana Lam.	Rhamnaceae	156	5.20 ± 1.48
Diospyros ferrea (Willd.) Bakh.	Ebenaceae	155	5.17 ± 3.20
Dichrostachys cinerea (L.) W. andA.	Mimosaceae	154	5.13 ± 2.83
Cassia siamea Lam.	Caesalpiniaceae	103	3.43 ± 2.00
Alangium salvifolium (L. f.) Wang.	Alangiaceae	85	2.83 ± 1.18
Sapindus emarginatus Vahl.	Sapindaceae	73	2.43 ± 1.19
Cleistanthus collinus (Roxb.) Benth.	Euphorbiaceae	67	2.23 ± 1.04
Dalbergia paniculata Roxb.	Fabaceae	53	1.77 ± 0.64
Prosopis juliflora (Sw.) DC.	Mimosaceae	53	1.77 ± 0.83
Syzygium cumini (L.) Skeels	Myrtaceae	50	1.67 ± 0.78
Diospyros montana Roxb.	Ebenaceae	47	1.57 ± 0.71
Moringa concanensis Nimmo	Moringaceae	44	1.47 ± 0.70
Albizia lebbeck (L.) Benth.	Mimosaceae	36	1.20 ± 0.39
Bauhinia racemosa Lam.	Caesalpiniaceae	34	1.13 ± 0.44
Acacia leucophloea Roxb.	Mimosaceae	31	1.03 ± 0.56
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	30	1.00 ± 0.55
Vitex trifolia L.	Lamiaceae	29	0.97 ± 0.51
Erythroxylum monogynum Roxb.	Erythroxylaceae	28	0.93 ± 0.50
Ficus benghalensis L.	Moraceae	27	0.90 ± 0.26

(continued)

Table 3 (continued)

Name of the species	Family	Abundance/30 ha	Mean ± SE
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	27	0.90 ± 0.80
Ailanthus excelsa Roxb.	Simaroubaceae	22	0.73 ± 0.67
Mallotus philippensis (Lam.) Müll. Arg.	Euphorbiaceae	22	0.73 ± 0.42
Premna serratifolia L.	Lamiaceae	17	0.57 ± 0.50
Strychnos potatorum L.	Strychnaceae	17	0.57 ± 0.47
Cassia roxburghii DC.	Caesalpiniaceae	16	0.53 ± 0.53
Pavetta indica L.	Rubiaceae	16	0.53 ± 0.50
Garcinia spicata Hook. f.	Rubiaceae	15	0.50 ± 0.31
Crataeva magna (Lour.) DC.	Capparaceae	14	0.47 ± 0.34
Dolichandrone falcata (Wall. ex DC.) Seem	Bignoniaceae	14	0.47 ± 0.26
Butea monosperma (Lam.) Taub.	Fabaceae	12	0.40 ± 0.18
Delonix regia (Boj. Ex Hook.) Rafin	Fabaceae	12	0.40 ± 0.40
Grewia tiliaefolia Vahl.	Tiliaceae	12	0.40 ± 0.18
Strychnos nux-vomica L.	Strychnaceae	9	0.30 ± 0.27
Tamarindus indica L.	Caesalpiniaceae	9	0.30 ± 0.11
Gmelina asiatica L.	Verbenaceae	8	0.27 ± 0.23
Rhus mysorensis G. Don	Anacardiaceae	8	0.27 ± 0.14
Terminalia arjuna (Roxb. Ex Dc.) W. and A.	Combretaceae	6	0.20 ± 0.12
Tricalysia sphaerocarpa (Dalzell ex Hook.f.) Gamble	Rubiaceae	6	0.20 ± 0.20
Cassia didymobotrya Fresn.	Caesalpiniaceae	5	0.17 ± 0.11
Ixora pavetta Andr.	Rubiaceae	5	0.17 ± 0.14
Acacia nilotica (L.) Willd. ex Delile	Mimosaceae	4	0.13 ± 0.10
Dalbergia sissoo Roxb. ex DC.	Fabaceae	4	0.13 ± 0.10
Eucalyptus tereticornis Smith	Myrtaceae	4	0.13 ± 0.13
Aglaia elaeagnoidea (A. Juss.) Benth.	Meliaceae	3	0.10 ± 0.07
Cassia fistula L.	Caesalpiniaceae	3	0.10 ± 0.07
Ficus glomerata Roxb.	Moraceae	3	0.10 ± 0.10
Gardenia resinifera Roth.	Rubiaceae	3	0.10 ± 0.06
Givotia moluccana (L.) Sreem.	Euphorbiaceae	3	0.10 ± 0.07

(continued)

Table 3 (continued)

Name of the species	Family	Abundance/30 ha	Mean ± SE
Holoptelea integrifolia (Roxb.) Planch.	Ulmaceae	3	0.10 ± 0.07
Kleinhovia hospita L.	Sterculiaceae	3	0.10 ± 0.07
Manilkara hexandra (Roxb.) Dubard	Sapotaceae	3	0.10 ± 0.07
Annona squamosa L.	Annonaceae	2	0.07 ± 0.05
Commiphora caudata Engl.	Burseraceae	2	0.07 ± 0.07
Dalbergia lanceolaria L.	Fabaceae	2	0.07 ± 0.05
Drypetes deplanchei (Brongn. and Gris) Merr.	Euphorbiaceae	2	0.07 ± 0.07
Ficus hispida L. f.	Moraceae	2	0.07 ± 0.05
Murraya koenigii (L.) Spreng.	Rutaceae	2	0.07 ± 0.05
Parkinsonia aculeata L.	Fabaceae	2	0.07 ± 0.05
Pisonia sechellarum F. Friedmann	Nyctaginaceae	2	0.07 ± 0.07
Pithecellobium dulce (Roxb.) Benth.	Fabaceae	2	0.07 ± 0.05
Borassus flabellifer L.	Arecaceae	1	0.03 ± 0.03
Cordia monoica Roxb.	Boraginaceae	1	0.03 ± 0.03
Dalbergia oliveri Gamble ex Prain.	Fabaceae	1	0.03 ± 0.03
Delonix elata (L.) Gamble	Caesalpiniaceae	1	0.03 ± 0.03
Shrub			
Lantana camara L.	Verbenaceae	4661	155.37 ± 16.5
Clausena heptaphylla (Roxb.) Wight and Arn.	Rutaceae	3970	132.33 ± 14.7
Tarenna asiatica (L.) Kuntze ex K.Schum.	Rubiaceae	3186	106.20 ± 16.2
Canthium coromandelicum (Burm.f.) Alston	Rubiaceae	592	19.73 ± 4.48
Solanum nigrum L.	Solanaceae	471	15.70 ± 4.91
Barleria longiflora L. f.	Acanthaceae	415	13.83 ± 5.08
Opuntia stricta (Haw.) Haw.	Cactaceae	381	12.70 ± 2.93
Carmona retusa (Vahl) Masamune	Boraginaceae	302	10.07 ± 2.32
Dodonaea angustifolia L. f.	Sapindaceae	140	4.67 ± 2.60
Cassia auriculata L.	Caesalpiniaceae	108	3.60 ± 1.28
Catunaregam spinosa (Thunb.) Tirveng.	Rubiaceae	97	3.23 ± 1.65
Jatropha gossypifolia L.	Euphorbiaceae	66	2.20 ± 0.95

(continued)

Table 3 (continued)

Name of the species	Family	Abundance/30 ha	Mean ± SE
Securinega leucopyrus (Willd.) Muell.	Euphorbiaceae	64	2.13 ± 1.04
Flacourtia indica (Burm. f.) Merr.	Flacourtiaceae	42	1.40 ± 0.76
Ipomoea carnea Jacq.	Convolvulaceae	35	1.17 ± 0.69
Cassia hirsuta L.	Caesalpiniaceae	28	0.93 ± 0.58
Phyllanthus reticulatus Poir.	Euphorbiaceae	9	0.30 ± 0.19
Euphorbia antiquorum L	Euphorbiaceae	7	0.23 ± 0.18
Cassia alata L.	Caesalpiniaceae	5	0.17 ± 0.08
Calotropis gigantea (L.) R. Br.	Asclepiadaceae	4	0.13 ± 0.13
Carissa paucinervia A.DC.	Apocynaceae	3	0.10 ± 0.07
Crotalaria formosa Wight and Arn.	Fabaceae	2	0.07 ± 0.07
Solanum torvum Sw.	Solanaceae	2	0.07 ± 0.07
Allophylus serratus (Roxb.) Kurz	Sapindaceae	1	0.03 ± 0.03
Cadaba fruticosa (L.) Druce	Capparaceae	1	0.03 ± 0.03
Grewia abutilifolia Vent. ex Juss.	Tiliaceae	1	0.03 ± 0.03
Ziziphus rugosa Lam.	Rhamnaceae	1	0.03 ± 0.03
Herb			
Sida cordifolia L.	Malvaceae	22,038	734.60 ± 87.3
Ageratum conyzoides L.	Asteraceae	13,510	450.33 ± 89.2
Sida acuta Burm. f.	Malvaceae	9245	308.17 ± 142
Eragrostis tenella (L.) P. Beauv. ex Roem. and Schult.	Poaceae	8876	295.87 ± 85.5
Aristida hystrix L. f.	Poaceae	8649	288.30 ± 77.1
Aristida setacea Retz.	Poaceae	5497	183.23 ± 141
Evolvulus alsinoides L.	Convolvulaceae	4180	139.33 ± 30.9
Euphorbia hirta L.	Euphorbiaceae	3927	130.90 ± 29.1
Ocimum canum Sims	Lamiaceae	3074	102.47 ± 73.2
Mollugo pentaphylla L.	Molluginaceae	2587	86.23 ± 20.38
Sida cordata (Burm. f.) Borssum Waalkes	Malvaceae	2055	68.50 ± 31.75
Blepharis maderaspatensis (L.) B.Heyne ex Roth	Acanthaceae	2029	67.63 ± 19.23
Tephrosia purpurea (L.) Pers.	Papilionaceae	1930	64.33 ± 24.13
Bulbostylis densa (Wall.) Hand.-Mazz.	Cyperaceae	1856	61.87 ± 14.30
Leucas aspera (Willd.) Link.	Lamiaceae	1484	49.47 ± 7.26

(continued)

Table 3 (continued)

Name of the species	Family	Abundance/30 ha	Mean ± SE
Hybanthus enneaspermus (L.) F. Muell.	Violaceae	1417	47.23 ± 22.84
Cyrtococcum trigonum (Retz.) A.Camus	Poaceae	1229	40.97 ± 15.33
Brachiaria ramosa (L.) Stapf	Poaceae	1208	40.27 ± 19.41
Commelina paleata Hassk. Pl. Jungh.	Commelinaceae	1195	39.83 ± 14.21
Heteropogon contortus (L.) P.Beauv. ex. R. and Schu.	Poaceae	1159	38.63 ± 19.69
Andrographis paniculata (Burm. f.) W. ex Nees	Acanthaceae	1136	37.87 ± 18.58
Apluda mutica L.	Poaceae	1089	36.30 ± 16.68
Achyranthes aspera L.	Amaranthaceae	843	28.10 ± 9.57
Boerhaavia diffusa L.	Nyctaginaceae	672	22.40 ± 20.63
Vernonia cinerea (L.) Less.	Asteraceae	591	19.70 ± 5.25
Tragia involucrata L.	Euphorbiaceae	555	18.50 ± 17.92
Cyperus rotundus L.	Cyperaceae	533	17.77 ± 5.61
Acalypha indica L.	Euphorbiaceae	497	16.57 ± 8.53
Dipteracanthus patulus (Jacq.) Nees	Acanthaceae	466	15.53 ± 14.19
Perotis indica (L.) Kuntze	Poaceae	465	15.50 ± 7.82
Cynodon dactylon (L.) Pers.	Poaceae	416	13.87 ± 6.79
Leonotis nepetifolia (L.) R.Br.	Lamiaceae	407	13.57 ± 5.74
Anisomeles malabarica (L.) R. Br. ex Sims	Lamiaceae	341	11.37 ± 9.91
Parthenium hysterophorus L.	Asteraceae	341	11.37 ± 7.20
Paspalidium flavidum (Retz.) A.Camus	Poaceae	339	11.30 ± 5.78
Gomphrena decumbens C. Martius.	Amaranthaceae	320	10.67 ± 3.60
Indigofera astragalina DC.	Papilionaceae	311	10.37 ± 4.32
Spermacoce ocymoides Burm. f.	Rubiaceae	262	8.73 ± 4.90
Dipteracanthus prostratus (Poir.) Nees	Acanthaceae	259	8.63 ± 8.50
Rostellularia simplex Wight	Acanthaceae	256	8.53 ± 4.68
Corchorus acutangulus L.	Tiliaceae	255	8.50 ± 2.83
Cyperus tenuispica Steud.	Cyperaceae	233	7.77 ± 7.77
Sporobolus virginicus (L.) Kunth	Poaceae	212	7.07 ± 5.89

(continued)

Table 3 (continued)

Name of the species	Family	Abundance/30 ha	Mean ± SE
Desmodium triflorum (L.) DC.	Papilionaceae	181	6.03 ± 4.41
Crotalaria spectabilis Roth	Fabaceae	174	5.80 ± 3.71
Triumfetta rhomboidea Jacq.	Tiliaceae	169	5.63 ± 3.95
Hemidesmus indicus (L.) R. Br.	Asclepiadaceae	152	5.07 ± 4.73
Croton bonplandianus Baillon	Euphorbiaceae	142	4.73 ± 2.30
Asystasia gangetica (L). T. Anderson	Acanthaceae	119	3.97 ± 2.40
Pseudarthria viscida (L) Wight and Arn.	Papilionaceae	119	3.97 ± 2.55
Dactyloctenium aegyptium (L.) P. Beauv.	Poaceae	117	3.90 ± 1.52
Cleome viscosa L.	Capparaceae	111	3.70 ± 2.16
Commelina elegans Kunth	Commelinaceae	108	3.60 ± 1.26
Commelina benghalensis L.	Commelinaceae	96	3.20 ± 2.42
Phyllanthus amarus Schum. and Thonn.	Euphorbiaceae	90	3.00 ± 1.74
Anisomeles indica (L.) Kuntze	Lamiaceae	68	2.27 ± 2.27
Ocimum sanctum L.	Lamiaceae	58	1.93 ± 1.48
Tridax procumbens L	Asteraceae	56	1.87 ± 0.99
Aerva lanata (L.) Juss.	Amaranthaceae	39	1.30 ± 0.61
Chloris inflata Link.	Poaceae	25	0.83 ± 0.55
Datura metel L.	Solanaceae	24	0.80 ± 0.26
Mollugo nudicaulis Lam.	Molluginaceae	23	0.77 ± 0.50
Physalis minima L.	Solanaceae	21	0.70 ± 0.70
Tribulus terrestris L.	Zygophyllaceae	21	0.70 ± 0.70
Abutilon indicum (L.) Sweet	Malvaceae	12	0.40 ± 0.29
Spermacoce articularis L. f.	Rubiaceae	12	0.40 ± 0.40
Acanthospermum hispidum DC.	Asteraceae	8	0.27 ± 0.27
Commelina diffusa Burm.f.	Commelinaceae	8	0.27 ± 0.27
Barleria lupulina Lindl.	Acanthaceae	6	0.20 ± 0.15
Blepharis repens (Vahl) *Roth*	Acanthaceae	6	0.20 ± 0.20
Agave americana L.	Agavaceae	5	0.17 ± 0.11
Hyptis suaveolens (L.) Poit.	Lamiaceae	4	0.13 ± 0.13
Euphorbia thymifolia L.	Euphorbiaceae	2	0.07 ± 0.05
Alysicarpus monilifer (L.) DC.	Papilionaceae	1	0.03 ± 0.03
Amaranthus spinosus L.	Amaranthaceae	1	0.03 ± 0.03

(continued)

Table 3 (continued)

Name of the species	Family	Abundance/30 ha	Mean ± SE
Climber			
Pterolobium hexapetalum (Roth) Sant. and Wagh	Caesalpiniaceae	899	29.97 ± 6.70
Combretum albidum G. Don	Combretaceae	262	8.73 ± 1.90
Acacia caesia (L.) Willd.	Mimosaceae	157	5.23 ± 0.89
Leptadenia reticulata (Retz.) W. and A.	Asclepiadaceae	101	3.37 ± 0.61
Wattakaka volubilis (L. f.) Stapf	Asclepiadaceae	87	2.90 ± 0.65
Diplocyclos palmatus (L.) C. Jeffrey	Cucurbitaceae	70	2.33 ± 0.56
Reissantia indica (Willd.) N. Hallé	Celastraceae	69	2.30 ± 0.45
Ziziphus oenoplia (L.) Miller	Rhamnaceae	58	1.93 ± 0.57
Secamone emetica (Retz.) R. Br. ex Schult.	Asclepiadaceae	55	1.83 ± 0.30
Toddalia asiatica (L.) Lam.	Rutaceae	49	1.63 ± 0.27
Pachygone ovata (Poir.) Diels	Menispermaceae	42	1.40 ± 0.49
Hugonia mystax L.	Linaceae	31	1.03 ± 0.35
Strychnos minor Dennst.	Strychnaceae	29	0.97 ± 0.43
Capparis brevispina DC.	Capparaceae	27	0.90 ± 0.35
Cissus quadarngularis L.	Vitaceae	24	0.80 ± 0.29
Tiliacora acuminata (Lam.) HK. f. and Thoms.	Menispermaceae	22	0.73 ± 0.31
Cansjera rheedii J. F. Gmel.	Opiliaceae	21	0.70 ± 0.28
Plecospermum spinosum Trecur.	Moraceae	21	0.70 ± 0.23
Asparagus racemosus Willd.	Asparagaceae	19	0.63 ± 0.23
Cardiospermum halicacabum L.	Sapindaceae	18	0.60 ± 0.26
Ichnocarpus frutescens (L.) W. T. Aiton	Apocynaceae	16	0.53 ± 0.22
Coccinia grandis (L.) J. Voigt	Cucurbitaceae	12	0.40 ± 0.29
Derris ovalifolia (Wight and Arn.) Benth.	Fabaceae	12	0.40 ± 0.28
Premna latifolia Roxb.	Verbenaceae	11	0.37 ± 0.18
Jasminum angustifolium (L.) Willd.	Oleaceae	9	0.30 ± 0.30
Trichosanthes cucumerina L.	Cucurbitaceae	9	0.30 ± 0.17
Cissampelos pareira L.	Menispermaceae	3	0.10 ± 0.10
Ampelocissus tomentosa (B. Heyne and Roth) Planch.	Vitaceae	1	0.03 ± 0.03

(continued)

Table 3 (continued)

Name of the species	Family	Abundance/30 ha	Mean ± SE
Carissa spinarum L.	Apocynaceae	1	0.03 ± 0.03
Dioscorea bulbifera L.	Dioscoreaceae	1	0.03 ± 0.03
Maerua oblongifolia (Forssk.) A.Rich.	Capparaceae	1	0.03 ± 0.03
Pisonia aculeata L.	Nyctaginaceae	1	0.03 ± 0.03
Toxocarpus kleinii W. and A.	Apocynaceae	1	0.03 ± 0.03

Alysicarpus monilifer and *Amaranthus spinosus* were represented by single individual and seven species viz., *Acanthospermum hispidum*, *Agave americana*, *Barleria lupulina*, *Blepharis boerhaviifolia*, *Commelina diffusa*, *Euphorbia thymifolia* and *Hyptis suaveolens* were encountered with <10 individuals.

Pterolobium hexapetalum (899 individuals) was the predominant climber species across the study plots followed by *Combretum albidum* (262 individuals) and *Acacia caesia* (157 individuals). The top five climber species comprised 70.41% of the total liana density across the study plots. Six species including *Ampelocissus tomentosa*, *Carissa spinarum*, *Dioscorea bulbifera*, *Maerua oblongifolia*, *Pisonia aculeata* and *Toxocarpus kleinii* were represented by mono individuals and three species such as *Cissampelos pareira*, *Jasminum angustifolium* and *Trichosanthes cucumerina* were represented by less than ten individuals. Alien invasive species such as *Lantana camara* (100%) and *Ageratum conyzoides* (93%) were the most commonly distributed and dominant species in shrub and herbaceous communities. Another exotic invasive species *Prosopis juliflora* was also recorded in 43% of plots.

3.3 Importance Value Index and Family Diversity

Albizia amara was the predominant tree species with regard to IVI value across all the 30 one-hectare study plots followed by *Chloroxylon swietenia* and *Acacia catechu* (Tables 4, 5, 6 and 7). Among shrub species, *Lantana camara*, *Clausena heptaphylla* and *Tarenna asiatica* scored greater IVI values, whereas *Sida cordifolia*, *Ageratum conyzoides* and *Sida acuta* were among the predominant herb species in terms of IVI values. *Pterolobium hexapetalum* registered the highest IVI values among climber species followed by *Combretum albidum* and *Acacia caesia*.

Euphorbiaceae was the most speciose plant family across the study plots represented by 17 species followed by Fabaceae and Poaceae with 13 species each (Table 8). Plant families such as Euphorbiaceae and Fabaceae were represented in all the four life-forms studied. However, 24 families were represented by just one species in the present study.

Table 4 Importance value index of top ten tree species in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

Name of the species	Plot number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Albizia amara (Roxb.) Bavi	12.2	21.9	213.6	216.7	152.4	26.6	139.4	222.9	17.6	132.3	134.7	150.0	124.0	153.2	164.7
Chloroxylon swietenia DC.	141.2	55.7	6.1	39.3	4.6	49.5	38.5	29.8	75.5	6.6	59.2	87.3	11.3	19.9	0.0
Azadirachta indica A.Juss	15.6	8.4	6.0	22.1	0.0	13.5	22.6	22.3	4.6	47.7	2.3	6.5	1.9	5.4	17.8
Pongamia pinnata (L.) Pierre	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	0.0	13.3	3.2	4.4	43.7	40.0
Acacia catechu (L. f.) Willd.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	28.1	23.3	18.2	15.2	3.2	4.8	8.7
Gyrocarpus jacquini Roxb.	3.3	5.3	3.7	0.8	35.6	4.5	0.0	0.0	0.0	1.4	6.9	5.6	3.8	1.1	0.0
Atalantia monophylla (L.) Correa	0.7	0.0	0.6	0.7	0.6	0.0	18.4	1.0	2.4	5.7	17.6	0.9	6.1	4.7	1.7
Wrightia tinctoria (Roxb.) R.Br.	0.9	0.0	5.7	3.9	1.8	6.8	1.3	17.6	4.3	0.6	2.7	5.3	3.4	1.6	3.6
Diospyros ebenum Koen.	2.0	0.0	2.5	1.7	0.0	0.0	17.3	0.0	6.6	6.6	0.8	0.0	14.1	18.6	7.7
Drypetes sepiaria (W. and A.) Pax and Hoffm.	0.0	0.9	1.3	1.4	3.5	3.7	2.7	0.0	1.0	1.2	1.3	0.0	3.5	0.0	0.0

(continued)

Table 4 (continued)

Name of the species	Plot number														
	16	17	18	19	20	21	22	13	24	25	26	27	28	29	30
Albizia amara (Roxb.) Bavi	147.8	29.6	117.3	74.2	139.5	163.7	215.8	183.6	14.8	3.3	164.5	2.5	183.7	81.3	28.2
Chloroxylon swietenia DC.	26.8	24.8	21.2	17.2	76.8	2.3	26.5	72.9	62.3	97.9	17.2	26.3	42.4	16.2	35.6
Azadirachta indica A.Juss	15.0	2.2	21.8	32.5	14.9	2.8	18.4	6.6	12.2	0.7	0.9	1.5	0.8	24.3	0.0
Pongamia pinnata (L.) Pierre	1.4	0.0	2.7	22.6	3.7	39.3	0.0	0.0	1.6	0.0	47.8	0.0	24.1	62.1	6.8
Acacia catechu (L. f.) Willd.	0.0	14.4	1.8	8.3	25.2	0.0	0.0	0.0	5.9	5.2	3.6	5.7	0.0	0.0	2.4
Gyrocarpus jacquini Roxb.	42.9	3.3	1.2	1.3	3.3	7.6	8.3	0.0	1.7	1.0	1.7	9.3	2.4	2.4	7.9
Atalantia monophylla (L.) Correa	0.0	13.2	12.1	0.0	6.8	4.2	0.0	1.5	16.5	24.6	4.4	1.9	0.9	0.0	3.3
Wrightia tinctoria (Roxb.) R.Br.	2.6	0.7	0.0	3.5	3.9	1.4	0.0	9.3	0.0	0.0	8.8	12.4	27.8	0.8	7.3
Diospyros ebenum Koen.	3.5	1.6	31.1	0.0	0.0	5.7	1.0	3.3	0.0	0.0	3.6	1.5	0.0	5.6	2.2
Drypetes sepiaria (W. and A.) Pax and Hoffm.	1.4	2.5	5.8	0.0	0.6	7.7	5.6	13.0	11.2	48.5	0.8	2.1	4.0	0.0	7.6

Table 5 Importance value index of top ten shrub species in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

Name of the species	Plot number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Lantana camara L.	38.3	86.0	95.6	93.6	38.5	26.5	59.1	108.6	18.5	57.7	43.0	62.4	55.7	129.8	61.3
Clausena heptaphylla (Roxb.) W. and A.	62.7	72.8	75.5	56.5	94.4	63.5	62.5	75.1	86.6	95.0	58.5	118.4	72.9	94.7	48.4
Tarenna asiatica (L.) Alston.	106.2	50.7	52.7	53.7	73.9	115.1	91.1	58.8	108.9	65.4	145.8	36.8	107.6	29.7	116.4
Canthium coromandelicum (Burm.f.) Alston.	26.1	4.7	8.3	11.4	16.7	0.0	8.6	8.6	28.7	25.7	30.4	0.0	61.7	4.8	12.3
Opuntia stricta Haw.		11.3	5.5	38.0	2.6	15.4	11.2	0.0	3.4	16.4	4.8	13.8	0.0	4.3	0.0
Solanum nigrum L.	9.7	54.2	5.1	2.1	0.0	3.2	0.0	5.2	0.0	5.1	0.0	0.0	0.0	15.2	24.9
Barleria longiflora L.f.	2.4	0.0	4.8	3.0	2.7	0.0	0.0	0.0	0.0	1.9	6.9	36.6	0.0	1.5	5.5
Carmona retusa (Vahl) Masam.	10.1	2.4	36.2	14.1	13.6	48.1	11.4	12.0	18.4	31.5	0.0	25.3	0.0	6.4	3.1
Cassia auriculata L.	0.0	16.5	4.6	0.0	0.0	1.5	5.0	2.4	13.9	1.4	0.0	3.2	0.0	0.0	0.0
Dodonaea angustifolia L. f.	1.7	0.8	7.2	24.4	48.3	23.7	0.0	1.9	1.3	0.0	0.0	0.0	2.1	0.0	2.7

(continued)

Table 5 (continued)

Name of the species	Plot number														
	16	17	18	19	20	21	22	13	24	25	26	27	28	29	30
Lantana camara L.	54.3	112.7	70.7	84.2	91.2	66.5	205.1	141.3	110.7	38.4	103.1	135.0	45.7	141.8	97.3
Clausena heptaphylla (Roxb.) W. and A.	136.7	53.6	62.5	49.8	82.3	164.3	46.0	47.5	79.6	142.9	50.2	63.9	161.8	75.9	93.6
Tarenna asiatica (L.) Alston.	80.4	22.9	51.4	41.2	56.4	27.9	12.7	61.7	52.1	14.2	37.4	42.9	37.8	50.7	32.1
Canthium coromandelicum (Burm.f.) Alston.	0.0	23.6	34.9	28.7	0.0	17.6	0.0	1.0	0.0	30.7	31.4	5.9	0.0	3.2	4.6
Opuntia stricta Haw.	6.7	6.2	0.0	20.5	14.4	13.5	11.5	5.3	16.7	32.7	39.4	9.7	28.2	5.9	9.6
Solanum nigrum L.	0.9	17.6	18.6	0.0	0.0	0.0	24.7	38.5	0.0	0.0	0.0	20.3	0.0	22.6	25.6
Barleria longiflora L.f.	6.1	0.0	13.0	73.3	37.1	0.0	0.0	0.0	15.5	20.9	35.2	0.0	8.3	0.0	0.0
Carmona retusa (Vahl) Masam.	3.1	0.0	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.2	0.0	5.4
Cassia auriculata L.	1.2	5.3	20.7	0.0	0.0	0.0	0.0	3.4	0.0	1.6	0.0	12.9	0.0	0.0	31.8
Dodonaea angustifolia L. f.	0.0	0.0	0.0	0.0	0.0	6.9	0.0	0.0	0.0	2.6	0.0	0.0	0.0	0.0	0.0

Table 6 Importance value index of top ten herb species in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

Name of the species	Plot number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Sida cordifolia L.	86.2	6.3	73.7	53.7	63.4	57.8	34.6	60.4	64.5	53.6	58.2	29.7	99.7	25.3	53.6
Ageratum conyzoides L.	19.8	28.9	27.5	24.4	7.8	75.5	43.5	39.1	35.6	16.5	70.3	43.8	65.4	52.5	39.0
Sida acuta Burm. f.	27.4	21.4	1.0	11.0	2.5	3.0	1.2	1.5	8.6	0.0	16.3	63.2	16.6	31.3	8.7
Aristida hystrix L.f.	0.9	0.0	18.1	0.5	0.0	5.4	14.3	15.4	3.4	7.1	2.5	0.7	0.0	6.0	1.0
Eragrostis tenella (L.) Beauv.	9.0	4.6	1.1	7.2	17.8	0.0	1.5	0.0	0.0	0.0	17.5	2.7	4.4	8.6	11.5
Evolvulus alsinoides L.	17.3	50.1	35.4	11.0	3.1	18.0	21.7	13.1	10.7	48.1	19.5	15.0	15.9	11.0	36.1
Euphorbia hirta L.	15.6	17.6	26.1	7.4	0.0	14.1	14.4	10.5	2.2	16.0	15.0	14.0	2.2	12.7	33.8
Aristida setacea Retz.	0.0	1.3	0.4	0.0	0.0	26.8	0.0	0.0	0.0	11.1	0.0	0.0	0.5	0.7	7.2
Blepharis maderaspatensis (L.) Roth	0.9	10.4	22.1	55.5	0.0	19.2	1.7	21.7	13.7	21.8	3.2	32.2	3.9	0.0	37.6
Ocimum canum Sims	3.5	0.0	2.0	7.6	1.3	1.8	3.5	9.4	0.0	0.0	4.0	1.6	11.2	7.8	6.2

(continued)

Table 6 (continued)

Name of the species	Plot number														
	16	17	18	19	20	21	22	13	24	25	26	27	28	29	30
Sida cordifolia L.	0.0	38.4	2.8	33.5	108.7	66.2	117.7	113.3	38.0	0.0	40.1	146.7	109.2	70.8	0.0
Ageratum conyzoides L.	0.0	9.1	2.8	22.9	39.1	18.1	0.0	17.3	127.9	10.6	10.9	22.4	34.0	62.7	32.4
Sida acuta Burm. f.	0.0	135.3	0.0	4.6	0.0	10.3	3.9	0.6	0.0	0.0	169.1	1.1	6.9	33.0	0.0
Aristida hystrix L.f.	0.0	0.0	101.3	4.0	3.7	62.8	56.0	43.9	27.8	56.9	0.0	20.6	31.2	21.5	56.2
Eragrostis tenella (L.) Beauv.	0.0	9.0	24.5	6.0	0.0	29.7	68.2	47.0	93.1	5.2	20.5	27.9	57.4	58.2	0.0
Evolvulus alsinoides L.	11.7	9.3	12.8	65.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Euphorbia hirta L.	2.0	6.7	33.2	28.0	23.2	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0
Aristida setacea Retz.	0.0	0.0	1.9	4.7	4.3	3.0	0.0	8.3	0.0	163.2	9.9	16.7	2.0	9.1	0.0
Blepharis maderaspatensis (L.) Roth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ocimum canum Sims	15.6	0.3	0.0	2.7	5.0	0.5	1.3	5.3	0.8	3.7	6.6	0.0	0.0	0.9	121.9

Table 7 Importance value index of top ten climber species in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

Name of the species	Plot number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pterolobium hexapetalum (Roth) Santapau and Wagh	119.5	138.5	102.8	154.6	101.0	0.0	81.2	140.7	15.0	62.1	158.6	151.3	70.0	105.8	44.5
Combretum albidum G. Don	12.1	30.5	20.6	22.0	52.1	25.2	71.1	31.8	165.9	85.6	26.4	28.9	16.0	25.9	140.0
Acacia caesia (L.) Willd	18.5	0.0	23.1	26.5	17.8	30.9	28.4	22.3	11.3	25.7	17.9	19.8	29.3	0.0	13.1
Leptadenia reticulata (Retz.) W. et Arn	11.2	16.5	6.1	10.1	7.8	27.0	17.3	23.2	5.8	26.6	19.8	26.4	13.7	9.1	20.9
Wattakaka volubilis (L.f.) Stapf	7.6	0.0	0.0	16.5	7.8	27.6	18.1	9.7	8.3	14.1	16.8	6.7	11.4	21.9	21.6
Ziziphus oenoplia (L.) Miller	27.1	12.2	0.0	0.0	4.0	50.7	16.4	31.7	0.0	51.5	11.7	22.2	11.2	15.2	0.0
Diplocyclos palmatus (L.) C. Jeffrey	10.0	0.0	9.9	17.5	7.3	35.0	8.8	9.6	8.8	8.6	11.2	8.0	17.9	15.6	9.9
Reissantia indica (Willd.) N. Hallé	6.7	8.3	0.0	19.6	4.2	26.5	29.8	14.6	15.5	12.4	16.1	18.3	4.1	9.1	0.0
Secamone emetica (Retz.) R. Br.	7.3	25.3	12.3	6.8	4.3	11.7	11.3	6.6	11.2	5.0	8.3	8.9	8.4	5.4	0.0

(continued)

Table 7 (continued)

Name of the species	Plot number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Toddalia asiatica (L.) Lam.	5.5	14.0	0.0	9.6	6.8	23.9	9.0	9.9	11.8	8.4	13.1	6.1	2.8	8.3	0.0

Name of the species	Plot number														
	16	17	18	19	20	21	22	13	24	25	26	27	28	29	30
Pterolobium hexapetalum (Roth) Santapau and Wagh	65.0	137.2	45.8	106.4	37.4	154.9	104.0	144.6	184.5	10.3	117.2	186.0	265.9	140.8	81.7
Combretum albidum G.Don	151.1	13.6	83.9	27.7	15.0	44.1	0.0	53.2	10.4	278.6	0.0	15.8	16.6	0.0	0.0
Acacia caesia (L.) Willd	0.0	41.3	19.3	96.5	247.6	0.0	63.5	102.2	32.5	11.1	0.0	27.5	0.0	132.5	139.8
Leptadenia reticulata (Retz.) W. and A.	12.7	46.1	20.6	0.0	0.0	0.0	0.0	0.0	25.9	0.0	27.0	0.0	0.0	0.0	0.0
Wattakaka volubilis (L.f.) Stapf	4.6	11.5	13.5	3.0	0.0	29.8	0.0	0.0	9.2	0.0	39.3	0.0	0.0	0.0	10.3

(continued)

Table 7 (continued)

Name of the species	Plot number														
	16	17	18	19	20	21	22	13	24	25	26	27	28	29	30
Ziziphus oenoplia (L.) Miller	25.0	0.0	13.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diplocyclos palmatus (L.) C. Jeffrey	3.4	10.9	4.6	0.0	0.0	0.0	0.0	0.0	13.3	0.0	24.0	0.0	0.0	26.7	0.0
Reissantia indica (Willd.) N. Hallé	7.0	14.4	16.8	0.0	0.0	0.0	0.0	0.0	6.6	0.0	17.4	0.0	0.0	0.0	0.0
Secamone emetica (Retz.) R. Br.	3.1	7.5	11.3	0.0	0.0	0.0	0.0	0.0	5.5	0.0	12.5	32.0	0.0	0.0	0.0
Toddalia asiatica (L.) Lam.	8.4	17.5	11.2	0.0	0.0	0.0	0.0	0.0	12.1	0.0	9.0	0.0	0.0	0.0	0.0

Table 8 Family-wise contribution of all life forms (tree, shrub, herb, lianas) in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats (T—tree, S—shrub, H—herb, C—climbers)

Name of the family	Species					Genus					Density				
	H	C	S	T	Total	H	C	S	T	Total	H	C	S	T	Total
Acanthaceae	8		1		9	5		1		6	4277		415		4692
Agavaceae	1				1	1				1	5				5
Alangiaceae				1	1				1	1				85	85
Amaranthaceae	4				4	4				4	1203				1203
Anacardiaceae				2	2				2	2				38	38
Annonaceae				1	1				1	1				2	2
Apocynaceae		2	1	1	4		2		1	3		2	3	190	195
Arecaceae				1	1				1	1				1	1
Asclepiadaceae	1	3	1		5	1	3	1		5	152	243	4		399
Asteraceae	5				5	5				5	14,506				14,506
Bignoniaceae				1	1				1	1				14	14
Boraginaceae			1	1	2			1	1	2			302	1	303
Burseraceae				1	1				1	1				2	2
Cactaceae			1		1			1		1			381		381
Caesalpiniaceae		1	3	7	11		1	1	2	4		899	141	171	1211
Capparaceae	1	2	1		4	1	2	1	1	5	111	28	1	14	29
Celastraceae		1			1		1			1		69			69
Combretaceae		1		2	3		1		1	2		262		33	295
Commelinaceae	4				4	1				1	1407				1407
Convolvulaceae	1		1		2	1		1		2	4180		35		4215

(continued)

Table 8 (continued)

Name of the family	Species					Genus					Density				
	H	C	S	T	Total	H	C	S	T	Total	H	C	S	T	Total
Cucurbitaceae		2			2		2			2		82			82
Cyperaceae	3				3	2				2	2622				2622
Dioscoreaceae		1			1		1			1		1			1
Ebenaceae				3	3				1	1				433	433
Erythroxylaceae				1	1				1	1				28	28
Euphorbiaceae	6	2	4	5	17	3	2	4	4	13	5213	25	146	258	5642
Fabaceae	1	2	1	9	13	1	2		6	9	174	169	2	565	910
Flacourtiaceae			1		1			1		1			42		42
Flindersiaceae				1	1				1	1				3171	3171
Hernandiaceae				1	1				1	1				262	262
Lamiaceae	7			1	8	5			1	6	5436			17	5453
Liliaceae		1			1		1			1		19			19
Linaceae		1			1		1			1		31			31
Loganiaceae		1			1		1			1		29			29
Malvaceae	4				4	2				2	33,350				33,350
Meliaceae				2	2				2	2				556	556
Menispermaceae		3			3		3			3		67			67
Mimosaceae				7	7				3	3				10,591	10,591
Molluginaceae	2				2	1				1	2610				2610
Moraceae		1		3	4		1		1	2		21		32	53
Moringaceae				1	1				1	1				44	44

(continued)

Table 8 (continued)

Name of the family	Species					Genus					Density				
	H	C	S	T	Total	H	C	S	T	Total	H	C	S	T	Total
Myrtaceae				2	2				2	2				54	54
Nyctaginaceae	1	1		1	3	1	1			2	672	1		2	675
Oleaceae		1			1		1			1		9			9
Opiliaceae		1			1		1			1		21			21
Papilionaceae	5				5	5				5	2542				2542
Poaceae	13				13	12				12	29,281				29,281
Rhamnaceae		1	1	1	3		1			1		58	1	156	215
Rubiaceae	2		3	6	11	1		2	6	9	274		3875	313	4462
Rutaceae		1	1	2	4		1	1	2	4		49	3970	313	4332
Sapindaceae		1	2	1	4		1	2	1	4		18	141	73	232
Sapotaceae				1	1				1	1				3	3
Simaroubaceae				1	1				1	1				22	22
Solanaceae	2		2		4	2		1		3	45		473		518
Sterculiaceae				1	1				1	1				3	3
Strychnaceae				2	2				1	1				26	26
Tiliaceae	2		1	1	4	2			1	3	424		1	12	437
Ulmaceae				1	1				1	1				3	3
Verbenaceae		1	1	2	4			1	2	3		11	4661	37	4709
Violaceae	1				1	1				1	1417				1417
Vitaceae		2			2		2			2		25			25
Zygophyllaceae	1				1	1				1	21				21

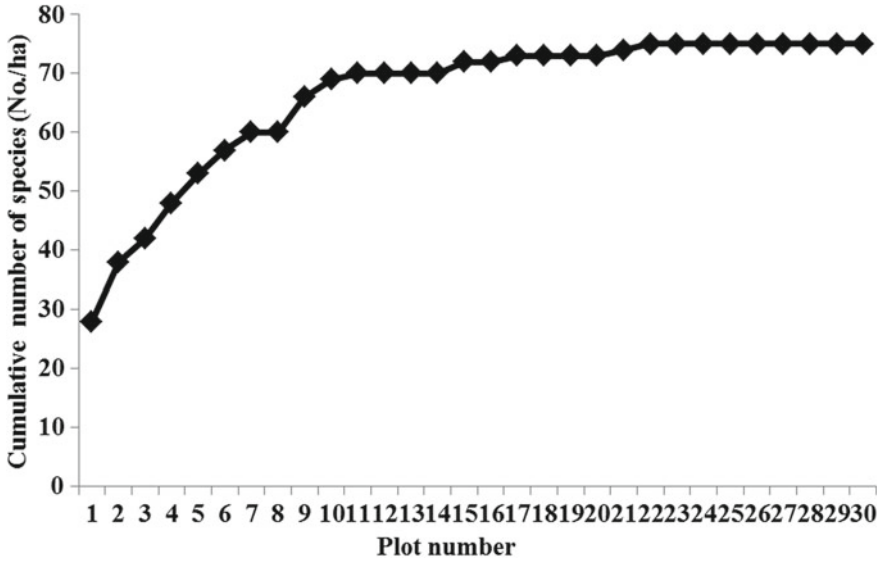

Fig. 3 Species-area curve of plant species (all life forms) in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

3.4 Species-Area Curve

Species-area curve for plant diversity of tropical dry deciduous forest of all life forms (trees, shrubs, herbs, climbers) of 30 one-hectare plots pooled data showed the number of species in all the plots increased initially, steeped up to 13 ha followed by gradual rise, until the sampling reached 23 ha after which, it flattened (Fig. 3). This indicates that sampling of 23 ha is sufficient to record the species richness of the study area. Hence, coverage of 30 ha sampling has been done in the present study exhibits the current status of Sathanur reserve forest.

3.5 Diameter Class Distribution

The density and species richness of trees decreased with increasing tree diameter class (DBH) across the study plots (Figs. 4 and 5). This pattern was also consistent with dominant tree species like *Albizia amara*, *Chloroxylon swietenia*, *Pongamia pinnata*, and *Azadirachta indica* which showed more or less similar trend in diameter class distribution (Fig. 6). Overall, the juvenile population of trees (3.2–10 cm DBH) contributed 50.3% of the total tree density, whereas, adult trees constituted 49.7%.

We screened all the multi-stemmed tree individuals in 30 one-hectare plots and observed a maximum of nine branches below 1.37 m height (Fig. 7). The presence of multiple stems was more prevalent among *Albizia amara* and *Pongamia pinnata*.

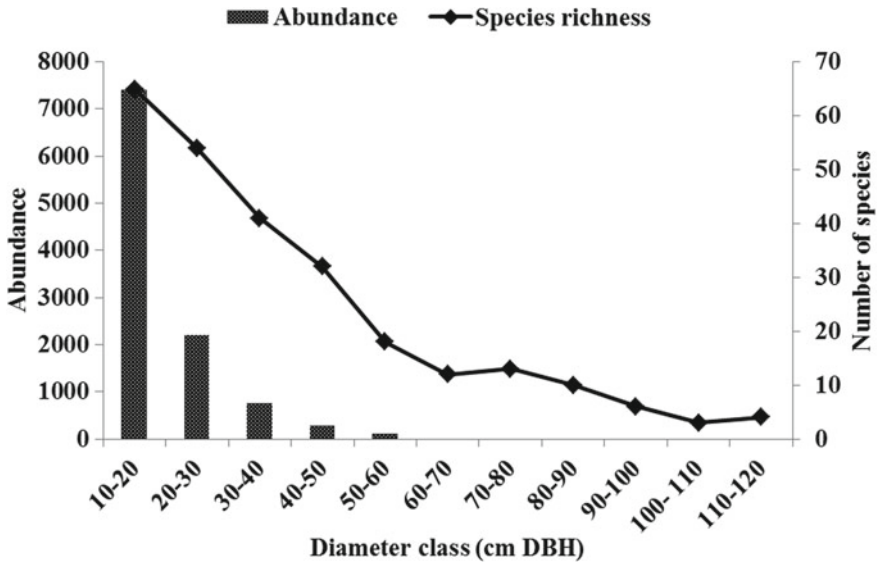

Fig. 4 Diameter class-wise distribution of species richness and abundance of trees in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

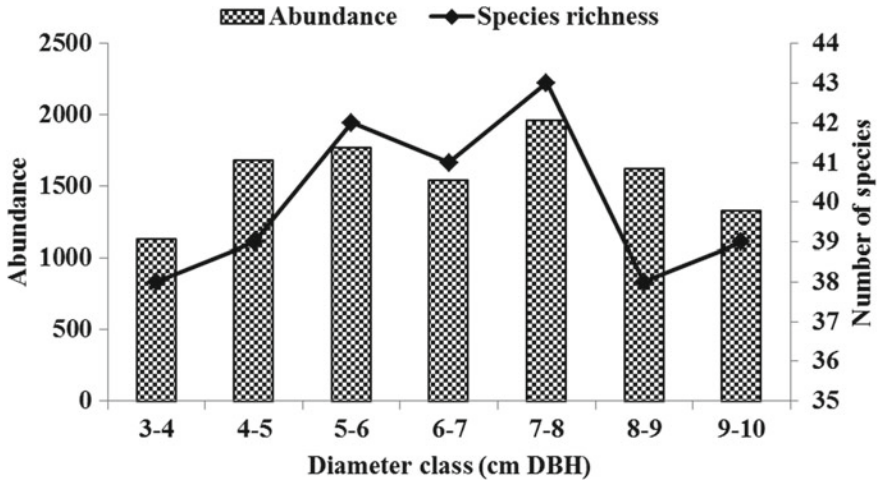

Fig. 5 Diameter class-wise distribution of species richness and density of juvenile population of tree species in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

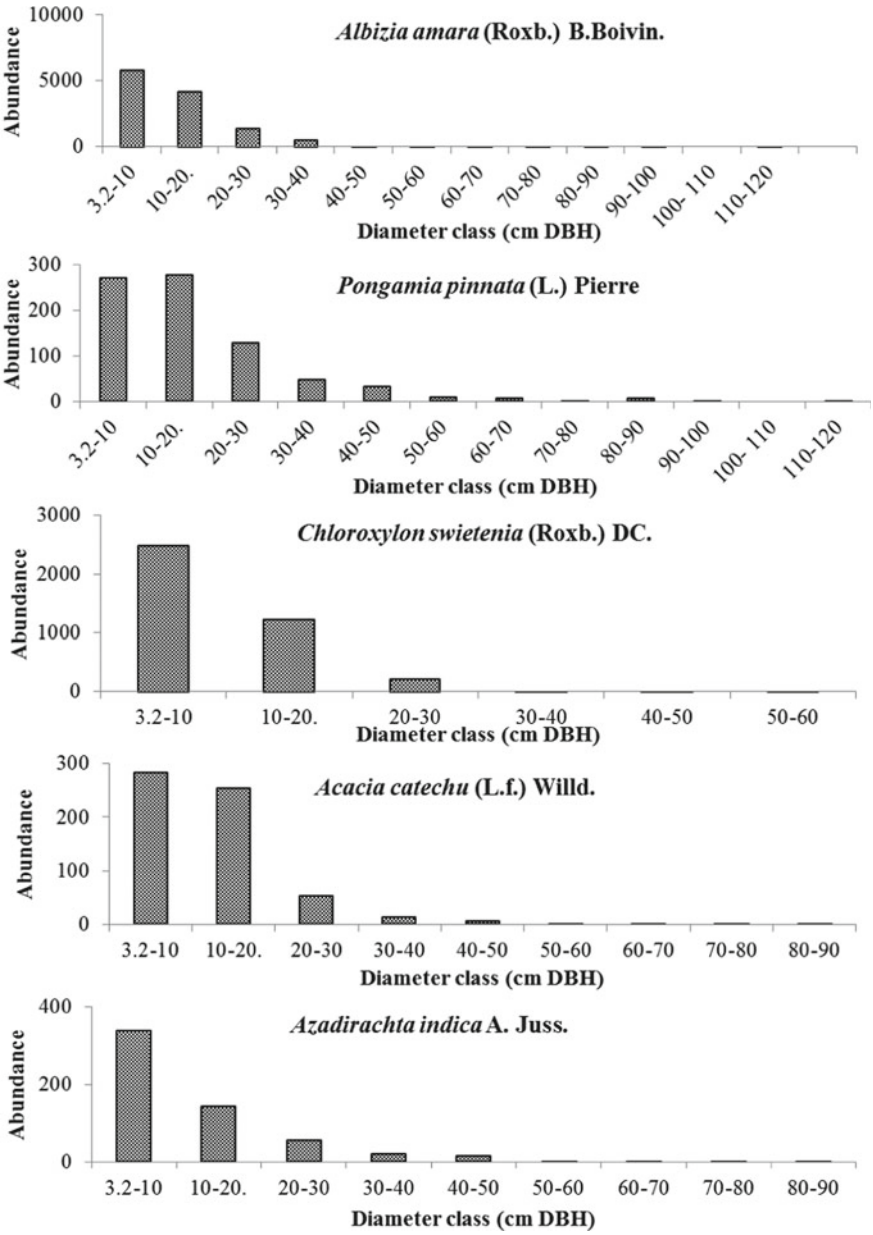

Fig. 6 Diameter class-wise distribution of dominant tree species in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

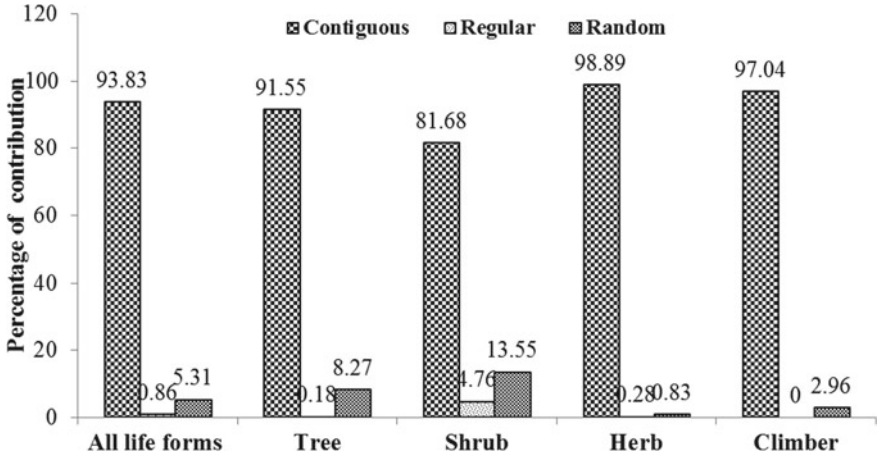

Fig. 7 Distribution patterns of species in a community in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

For calculating the disturbance index, we screened the presence of cut stems and damaged stems in each one-hectare study plot and found that a total of 1335 were removed from the base and 122 individuals were damaged. Disturbance index across the study plots ranged from 0.01 to 0.25 (Fig. 8). The most number of cut stems in the study plots belonged to *Albizia amara* and *Chloroxylon swietenia* followed by *Acacia catechu* and *Pongamia pinnata*.

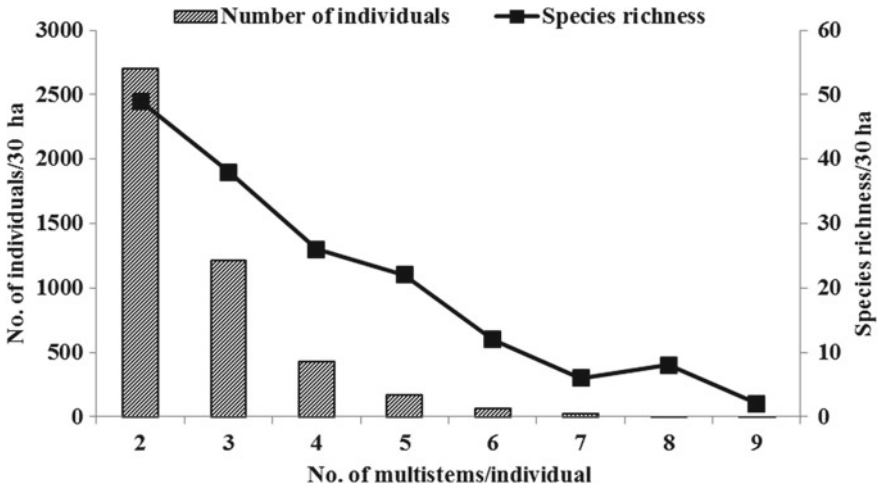

Fig. 8 Contribution of multi-stemmed trees to no. of individuals and species richness in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

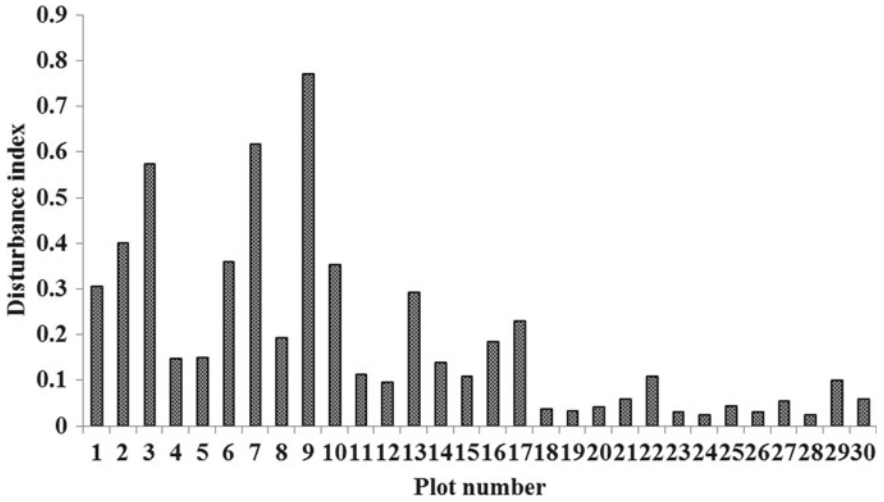

Fig. 9 Disturbance index of the study plots in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats

3.6 Distribution Pattern

The A/F ratio of species in plots indicates the species distribution patterns. Overall, 93.83% of species (of all life forms—trees, shrubs, herbs and climbers) showed contagious distribution, 5.31% showed a random distribution and 0.86% showed the regular distribution (Fig. 9). In tree community, 91.55% showed contiguous distribution, 8.27% showed random and 0.18% showed regular distribution patterns. In shrub community, 81.68% of shrub species showed the contiguous distribution while 13.55% showed random and 4.76% showed regular distribution patterns. Similarly, contiguous distribution was more common in herb (98.89%) and climber (97.02%) life forms.

4 Discussion

The plant species richness recorded from 30 (1 ha) plots in the tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats was 210, of which, trees and herbs occupied a significant proportion (35.71% species each) followed by lianas (15.71%) and shrubs (12.86%). The observed species richness in the present study plots (35–84 species/ha) is greater than those reported in a tropical dry deciduous forest of northern Eastern Ghats (18–55 species/ha; Devi and Behera 2003) and in line with the findings of Reddy et al. (2008a, b) and elsewhere (Hubbel 1979; Jimenez et al. 2016). However, total species richness encountered in this study is much lower than those values (173–218 species/ha) reported by Reddy et al. (2011) from tropical moist

deciduous forests of Eastern Ghats, Andhra Pradesh. Plant diversity is directly influenced by many factors including climate, topography, soil and natural/anthropogenic causes (Behera et al. 2016). All the 30 one-hectare study plots of Sathanur reserve forest are located within the radius of 10 km and an altitude ranging from 192 to 250 m, hence, the climate cum topography of study plots largely remain the same. The human disturbance varied considerably among the study plots due to closeness to the settlement, agricultural field and rivulet, roads and path intrusions. The plots located near to rivulet have more soil moisture and air humidity due to water flow. The plots laid along roadsides and near human settlements are subjected to anthropogenic pressure which has resulted in an increase in cut stems. Seepage from the agricultural land to forest area also increases soil moisture content in the study plots which are close to them. These microclimatic variations among the plots could be the reason for the significant spatial variation in species richness and density among the plots even though they are located within 10 km radius. The low species richness recorded in the present study compared to the Western Ghats and some regions of Eastern Ghats could be ascribed to low and erratic rainfall pattern, anthropogenic disturbances and extensive grazing.

Tree species richness is vital to tropical forest biodiversity because trees directly or indirectly support almost all other life forms (Huston 1994). Tree (for individuals $\geq$10 cm DBH) species richness recorded in the current study plots ranged 7–28 species/ha, which is much lower than previous studies conducted in other parts of Eastern Ghats, for example, Kadavul and Parthasarathy (1999a, b) reported 42 to 47 species/ha in Kalrayan hills and 33–50 species/ha in Shervarayan hills. Similarly, Chittibabu and Parthasarathy (2000a) encountered 26–54 species/ha in Kolli hills of Eastern Ghats. Reddy et al. (2008a) reported 60–69 species/ha in dry deciduous forests of Eastern Ghats. Premavani et al. (2014) estimated 34–48 species/ha in tropical dry forests of central Eastern Ghats. The relatively lower species richness values obtained in the present study when compared to the other studies (Palomino and Alvarez 2008; Powers et al. 2009; Rao et al. 2015; Naidu and Kumar 2016; Sahoo et al. 2017) could be attributed to the greater extent of anthropogenic activities prevailing in the study plots including stem cutting and stem removal in addition to low rainfall.

The species richness of climbers registered in this study (3–23 species/0.125 ha) is comparable to other areas of Eastern Ghats i.e., Kolli hills (2–17 species/ha; Chittibabu and Parthasarathy 2001), tropical dry deciduous forest of Srilankamalla wildlife sanctuary, Andhra Pradesh (6–27 species/ha; Mastan et al. 2015). However, the value obtained in the present study is lower than in tropical dry deciduous forest of Nallamalai–Seshachalam–Nigidi hills of Eastern Ghats (21–29 species/ha; Reddy et al. 2008a), in the Vindhyan tropical dry deciduous forest (37 species/ha; Sharma and Raghubanshi 2010) and in Mudumalai Wildlife Sanctuary, southern India (53 species/ha; Joseph et al. 2008). The species richness of climbers is comparable even though this study site has low species richness (includes all life forms) in general which could be attributed to anthropogenic perturbation as observed by Dewalt et al. (2000), Laurance et al. (2001) and Schnitzer and Bongers (2002). According to Gerwing and Uhl (2002) and Schnitzer et al. (2004), human activities including logging

create canopy gaps, which lead to more light exposure that subsequently results in the successful establishment of climbers and lianas.

The density of climbers enumerated in the present study was 569.6 individuals/ha (range: 9–252 individuals/0.125 ha). This value is comparable with other reports from tropical forest of Eastern Ghats such as Kolli hills (12.5–56 individuals/ha; Chittibabu and Parthasarathy 2001) and Bobiri forest reserve, Ghana (152–280 individuals/ha; Addo-Fordjour et al. 2009). The wide variations in the climber density among plots could be due to different levels of anthropogenic pressures associated with canopy opening and other microclimatic conditions. The low density of climbers in few plots observed in the present study may be due to selective tree felling as stated by Chittibabu and Parthasarathy (2000b).

Species richness of understory vegetation in 30 one-hectare plots in the tropical dry deciduous forest of Sathanur reserve forest was 102 (fifty 25 m^2 quadrats for shrubs and fifty 1 m^2 quadrats for herbs in each one-hectare plot). Comparatively, the value obtained in the present study is moderately higher than the other parts of Eastern Ghats and elsewhere (52 species/0.32 ha (eight hundred 4 m^2 quadrats) in tropical evergreen forest in the Kolli hills, Chittibabu and Parthasarathy (2000b); 84 species/4 ha in tropical dry deciduous forest in Odisha, Sahu et al. (2007); 32–93 species/0.05 ha (twenty 25 m^2 quadrats) in riparian environments of Atlantic forests in Rernambuco, Brazil, Gomes-Westphalen et al. (2012)). However, this is lower than several reports of tropical forests in India (155 species/1.2 ha (three thousand 4 m^2 quadrats in 30 ha plots) in tropical evergreen forest in Anamalais, Western Ghats, Annaselvam and Parthasarathy 1999; 170 species/3 ha (shrubs + herbs) in tropical dry deciduous forest in Nallamalai-Seshachalam-Nigidi hills of Eastern Ghats, Andhra Pradesh, Reddy et al. 2008a; 107 species/2.04 ha (shrubs + herbs) in tropical dry deciduous forest in Similipal biosphere reserve, Odisha, Reddy et al. 2008b; 269 species in tropical forest tract of Sileur-Maredumilli hills of north Eastern Ghats, Reddy et al. 2011). The wide variations in understory species richness may be influenced by various ecosystem processes like nutrient cycling, decomposition of organic matter, hydrological cycle, soil formation, species composition of overstory, canopy cover, light penetration, different levels of disturbances, etc., as suggested by Singh et al. (2014). Comparison of understory diversity is very difficult because of the variations in the area of sampling, size of quadrats, number of quadrats etc. as suggested by Chittibabu and Parthasarathy (2000a, b). However, the value recorded in the present study is well within the range (Annaselvam and Parthasarathy 1999). The population density of understory species (shrubs and herbs) varied considerably among the species as well as among the plots. In shrub community, the three dominant species occupy 81% of populations. *Lantana camara* population contributed 32% of shrub composition. In the herbaceous community, five dominant species were represented by 62,318 individuals (57%) in all the study sites. In the herbaceous community, annuals were more predominant than that of perennials. Similarly, annuals were more predominant in the herbaceous community in tropical evergreen forests of Anamalais, Western Ghats as observed by Annaselvam and Parthasarathy (1999). In contrast, perennials dominated the understory community in Amazonian rainforest (Poulsen and Balslev 1991). The prevalence of annuals in the herbaceous community

as observed in this study could be largely due to seasonal variation i.e. hot summer (herbaceous vegetation is completely dried off and rejuvenate in rainy season) and overgrazing. The shrub species richness is low in few study plots, owing to tree species dominance. The presence of *Lantana camara*, an alien weed, in all the studied plots indicates that it would have probably invaded the Sathanur reserve forest several years back and had successfully established itself (Behera and Misra 2006). The low density of herbaceous vegetation in the inner plots is because of low insulation on the forest floor as the canopy is closed.

The species diversity is dependent on the capability of species to adapt, which increases as the community becomes more stable. Species diversity is brought about by species interaction like competition as well as niche variation (Pianka 1966), which are prominently expressed in the tropical regions because of high temperature and humidity (Ojo and Ola-Adams 1996). Shannon's index is generally higher for tropical forests (Knight 1975), whereas in Indian forests, the reported range was 0.83–4.1 (Singh et al. 1981; Sundarapandian 1997). In the present study, Shannon's index value ranged from 0.716–2.343 for tree species; 0.812–1.948 for shrubs; 1.157–2.8 for herbs and 0.243–2.796 for climbers. It is very difficult to compare diversity indices due to variations in the sampling location and uneven plot dimensions. The greater dominance index could be due to the mono-species dominance exhibited by *Albizia amara* in this forest ecosystem.

The density of species is directly dependent on species richness (Denslow 1995; Condit et al. 1998). The extent of tree density contributes as much to the forest's functional diversity, ecological processes and ecosystem services (Gopalakrishna et al. 2015). The mean tree density of 584 stems/ha registered in the present study is closer to the Amazonian average (597 stems/ha; Lewis et al. 2004) and Bornean (Asia) average (602 stems/ha; Slik et al. 2010), and 28.8% higher than the tropical forest average (425 stems/ha; Lewis et al. 2013) of Africa. Similarly, the value recorded in the present study is in line with those reported by Pragasan and Parthasarathy (2010) in the southern Eastern Ghats (457 stems/ha); Reddy et al. (2008b) in Similipal biosphere reserve (568 stems/ha) and Sahu et al. (2007) who reported 591 stems/ha in tropical dry deciduous forest, Odisha. However, the mean tree stem density values in the present study are lower than the findings of Kadavul and Parthasarathy (1999a, b) who reported 815 stems/ha in Shervarayan hills of southern Eastern Ghats. Similarly, Reddy et al. (2008a, 2011) reported 735 stems/ha and 709 stems/ha respectively in the tropical dry deciduous forest, Andhra Pradesh. The observed tree species density in the present study is higher than the findings of Sahu et al. (2012), Premavani et al. (2014), and Sahu et al. (2016) with 443 stems/ha, 360–526 stems/ha and 479 stems/ha respectively in the northern Eastern Ghats. Similarly, low stand density was recorded from other tropical forests of the world: Brazil (420–777 stems/ha; Campbell et al. 1992), Costa Rica (448–617 stems/ha; Heaney and Proctor 1990) and Malaysia (250–500 stems/ha; Primack and Hall 1992). Therefore, the observed density of trees in the present study can be considered modest when compared to the similar forest types in the Indian Eastern Ghats. Tree density may be influenced by anthropogenic activities and soil properties.

Top ten tree species including *Albizia amara* and *Chloroxylon swietenia* dominated the entire stand, contributing to 90.01% of the total individuals. Tree density differences among the plots could be due to the efficiency of seed dispersal and its establishment as well as resource exploitation levels by locals as suggested by Kadavul and Parthasarathy (1999a). Nevertheless, mono-dominance of species like *Albizia amara* in all the study plots shows their inherent ability to thrive in varied environmental conditions and in disturbed areas.

The mean basal area of tree community was 18.71 m^2/ha in dry deciduous forests of Sathanur reserve forest that is modest when compared to the dry tropical forest in Vindhyan hills (Jha and Singh 1990). The value (7.22–43.05 m^2/ha) obtained in the present study is well within the range of tropical dry forests in other parts of India (range 7–23.2 m^2/ha, Jha and Singh 1990; mean 29.0 m^2/ha, Reddy and Ugle 2008; range 8.15–41.17 m^2/ha, Sahu et al. 2008; range 8.6–26.9 m^2/ha, Reddy et al. 2008a; range 30–39 m^2/ha, Reddy et al. 2011; 6.86 m^2/ha, Sahu et al. 2012; range 12.98–33.3 m^2/ha with mean of 25.82 m^2/ha, Naidu and Kumar 2016) and elsewhere (Murphy and Lugo 1986; Lieberman and Lieberman 1987; Campbell et al. 1992). However, our mean value is less than the pantropical mean of 32 m^2/ha (Dawkins 1959), Amazonian average (29 m^2/ha; Lewis et al. 2004), Bornean (Asia) average (37.1 m^2/ha; Slik et al. 2010), African average (31.5 m^2/ha; Lewis et al. 2013) and other forests of Eastern Ghats (Kadavul and Parthasarathy 1999a, b). Similarly, the mean value recorded in the present study is lower than mean basal area values reported by several others in tropical forests of Western Ghats (Singh et al. 1981; Sundarapandian and Swamy 2000). The wide variations in the basal area among the 30 one-hectare plots obtained in the present study indicate that these plots were subjected to different levels of anthropogenic pressure. Exceptionally few plots have high values of the basal area, which indicates that those plots have more mature trees whereas, in some plots that had low basal area, there were many juveniles and very few mature trees. This is probably due to greater biotic disturbances in the area as suggested by Thakur (2015).

A total of 63 families were observed in this tropical dry deciduous forest. The most speciose families are Euphorbiaceae and Poaceae, followed by Fabaceae and Rubiaceae. Interestingly, similar findings were reported by Pragasan and Parthasarathy (2010) in tropical deciduous forests of the Eastern Ghats, where Euphorbiaceae, Rubiaceae and Moraceae were the most dominant families. Borah et al. (2016) also found that Euphorbiaceae was the dominant family in tropical forests of Barak Valley, Assam. Several others also observed the similar results (Ifo et al. 2016; Naidu and Kumar 2016). Hence, it can be noted that there is a similarity in family composition of forests in tropical environments.

Diameter class frequency exhibited an L-shaped curve for the trees and the data is in line with many other reports from Eastern and Western Ghats (Sundarapandian 1997; Kadavul and Parthasarathy 1999a). This is the typical characteristic of a tropical forest. The DBH size class distribution showed a decline in the number of individuals from lower class to higher class, indicating expanding population. The stem density decreased with increase in diameter class of trees as observed in the present study, which is in agreement with other reports (Lieberman et al. 1985; Swaine et al. 1987;

Campbell et al. 1992; Swamy et al. 2000; Sundarapandian and Karoor 2013). This type of distribution indicates that this forest has a good potential for regeneration. Species richness also decreased with increase in diameter class. A similar trend was exhibited by the dominant species. Greater proportion (81.9%) of stems belonged to lower diameter class (≥3.2 cm −<10 cm). This is so because of growth of coppices from illegal cutting of adult stems for firewood and domestic purposes. This is the same case with many other dry forests where lower diameter class individuals are more in number. The greater density of low diameter class individuals is primarily due to open canopy (Manokaran and La Frankie 1990).

A/F ratios indicate species distribution patterns in a community. According to Odum (1971), generally, contagious distribution is the most common pattern in nature; while random distribution is restricted to very homogeneous microclimates and regular distribution prevails where competition among the population exists. Species distribution patterns vary due to differences in microclimate, habitat heterogeneity, dispersal ability and allelopathy (Kandari et al. 2011). Understanding the distribution patterns would be useful to develop management strategies in these forests that are under pressure.

Human activities and cattle grazing in forest ecosystems have changed the diversity, structure and functions of ecosystems (Sundarapandian and Swamy 2000; Swamy et al. 2000; Sundarapandian and Karoor 2013; Sundarapandian et al. 2015). The effect of anthropogenic disturbances on forest features would be plot-specific (Htun et al. 2011). Some plots (plot nos. 1–10) in the present study are near roads, human settlements or the agricultural fields which are easily accessible to human exploitation. The tree species richness was found to be low in these plots (plot nos. 1–10 except for 1, 7 and 10) compared to other study plots while shrub and herb species richness are observed to be more in these plots. The lower number of tree species may be due to several kinds of anthropogenic perturbations. Although the study area is a reserve forest, localites frequently cut trees and collect firewood, lop branches and graze their cattle. Illegal selective cutting of *Chloroxylon swietenia* for fencing, agricultural tools and other domestic purposes and *Albizia amara* for firewood are quite frequent in this forest. This kind of selective cutting may result in coppicing of those species which could affect forest species composition and stand structure. This has resulted in more density of both species in the plots near to the road, agriculture field and settlements which enhance the tree density in these plots. Due to greater tree density in these plots, the density of the herbaceous community is comparatively low here. Study plots (plot no. 21–30) are located on both sides of the rivulet. In general, the plots near the rivulet also have lower species richness; this could also be attributed to human disturbance and edaphic factors. The study area has a rocky terrain that would alter the structure of the forests. People regularly use the rivulet for day to day activities. In addition to that, this is a source of drinking water for cattle and hence, these plots were also under high anthropogenic pressures. The present study reveals that the edaphic variations and anthropogenic disturbance alter the microclimate among the plots which could be the reason for the significant spatial variation in species richness and density among the plots even though they are located within 10 km radius.

Anthropogenic perturbation in tropical dry deciduous forests of Sathanur Reserve forests creates niche space for ruderal weeds and alien invasive species to colonize and establish. Ruderal weeds and alien invasive species were the dominant understory community in all the study plots. Herbaceous community population in the study plots were dominated by native ruderal species like *Sida cordifolia*, *Sida cordata* and *Sida acuta*. Generally, these native ruderal species occur abundantly in the first year of the fallow-land of agroecosystems, wastelands subjected to frequent disturbances, adjacent to roads and rivulet, and moderately shaded and open areas of forests. The greater density of these ruderal weeds implied that these study plots are still under a certain level of disturbance. Alien invasive plants, *Lantana camara* and *Ageratum conyzoides* were observed in 100% and 93% of plots respectively. In addition to that, another exotic invasive species *Prosopis juliflora* was also registered in 43% of plots. This successful colonization and establishment of alien invasion revealed that these study plots are either under disturbance or have canopy opening. Many studies have confirmed that the natural or anthropogenic perturbations pave way for a conducive environment for the establishment of invasive plants (Whitmore and Burslem 1996; Sundarapandian 1997; Sundarapandian and Karoor 2013). In shrub community, 32.18% of the population is contributed by exotic invasive species. Similarly, in the herbaceous community, exotic invasive species contribution is 13.33%. The present study reveals that the understory vegetation of tropical dry deciduous forest at Sathanur Reserve forest is dominated by ruderal weeds and exotics. It indicates that this forest is under the threat of anthropogenic pressure even though it has been declared as a reserve forest. However, this forest ecosystem restores rich flora similar to other tropical dry forests of the Eastern Ghats and central India. To impede the plant invasion, timely measures are to be adopted to eliminate invasive species in order to retain and conserve the native diversity.

Acknowledgements DSG thankfully acknowledges the fellowship provided by University Grants Commission (UGC), Government of India. We thank the Tamil Nadu Forest Department for permission and help to complete the field work. We are also thankful to Prof. N. Parthasarathy, Department of Ecology and Environmental Sciences, Pondicherry University, India for his help in identification of plants. We express our profound thanks to Mr. Pragash, Department of Earth Sciences, Pondicherry University for helping me in the preparation of study area map.

References

Addo-Fordjour P, Anning AK, Larbi JA, Akyeampong S (2009) Liana species richness, abundance and relationship with trees in the Bobiri forest reserve, Ghana: impact of management systems. For Ecol Manag 157:1822–1828

Annaselvam J, Parthasarathy N (1999) Inventories of understory plants in a tropical evergreen forest in the Anamalais, Western Ghats, India. Ecotropica 5:197–211

Bahuguna VK (1999) Forest fire prevention and control strategies in India. Int For Fire News 20:5–9

Behera SK, Misra MK (2006) Floristic and structure of the herbaceous vegetation of four recovering forest stands in the Eastern Ghats of India. Biodivers Conserv 15:2263–2285

Behera SK, Suresh K, Rao BN, Manoja K, Manorama K (2016) Soil nutrient status and leaf nutrient norms in oil palm (*Elaeis guineensis* Jacq) plantations grown in the west coastal area of India. Commun Soil Sci Plant Anal 47:255–262

Blackie R, Baldauf C, Gautier D, Gumbo D, Kassa H, Parthasarathy N, Paumgarten F, Sola P, Pulla S, Waeber P, Sunderland T (2014) Tropical dry forests: the state of global knowledge and recommendations for future research. Discussion Paper, CIFOR, Bogor, Indonesia. http://www.cifor.org/publications/pdf_files/WPapers/DPBlackie1401.pdf

Borah N, Rabha D, Athokpam FD (2016) Tree species diversity in tropical forests of Barak valley in Assam, India. Trop Plant Res 3(1):1–9

Bullock SH, Mooney HA, Medina E (1995) Seasonally dry tropical forests. Cambridge University Press, New York

Campbell DG, Stone JL, Rosas AJ (1992) A comparison of the phytosociology and dynamics of three floodplain (Varzea) forests of known ages, Rio Jurua, western Brazilian Amazon. Bot J Linn Soc 108:213–237

Champion HG, Seth SK (1968) A revised survey of the forest types of India. Govt of India Press, New Delhi, India 404pp

Chittibabu CV, Parthasarathy N (2000a) Understory plant diversity in a tropical evergreen forest in Kolli hills, Eastern Ghats, India. Ecotropica 6:129–140

Chittibabu CV, Parthasarathy N (2000b) Attenuated tree species diversity in human-impacted tropical evergreen forest sites at Kolli hills, Eastern Ghats, India. Biodivers Conserv 9:1493–1519

Chittibabu CV, Parthasarathy N (2001) Liana diversity and host relationship in a tropical evergreen forest in the Indian Eastern Ghats. Ecol Res 16:519–529

Condit R, Sukumar R, Hubbell SP, Foster RB (1998) Predicting population trends from size distributions: a direct test in a tropical tree community. Am Nat 152:495–509

Curtis JT, McIntosh RP (1950) The interrelations of certain analytic and synthetic phytosociological characters. Ecology 31:434–455

Dawkins HC (1959) The volume increment of natural tropical high-forest and limitations of improvements. Empire Rev 38:175–180

Denslow JS (1995) Disturbance and diversity in tropical rain forests: the density effect. Ecol Appl 5:962–968

Devi U, Behera N (2003) Assessment of plant diversity in response to forest degradation in a tropical dry deciduous forest of Eastern Ghats in Orissa. J Trop For Sci 15(1):147–163

Dewalt SJ, Schnitzer SA, Denslow JS (2000) Density and diversity of lianas along a chronosequence in a central Panamanian lowland forest. J Trop Ecol 16:1–19

Gamble JS, Fischer CEC (1987) Flora of presidency of Madras, vols 1–3. Bishen Singh Mahendra Pal Singh, Dehra Dun, 2017pp

Gandhi DS, Sundarapandian SM (2014a) Inventory of trees in tropical dry deciduous forests of Tiruvannamalai district, Tamil Nadu, India. Biodiversitas 15(2):169–179

Gandhi DS, Sundarapandian SM (2014b) Diversity and distribution pattern of understory vegetation in tropical dry forests of Sathanur Reserve forest in Eastern Ghats, India. Int J Sci Nat 5(3):452–461

Gandhi S (2016) Large-scale carbon stock assessment in tropical dry deciduous forest of Sathanur reserve forest, Eastern Ghats, India. Doctoral dissertation, Pondicherry University, Puducherry, pp 1–152

Gandhi DS, Sundarapandian SM (2017) Soil carbon stock assessment in tropical dry deciduous forest of Sathanur reserve forest of Eastern Ghats, India. J Sustain For. https://doi.org/10.1080/10549811.2017.1308870

Gentry AH (1992) Tropical forest biodiversity distributional patterns and their conservational significance. Oikos 63:19–28

Gerwing JJ, Uhl C (2002) Pre-logging liana cutting reduces liana regeneration in logging gaps in the eastern Brazilian Amazon. Ecol Appl 12:1642–1651

Gomes-Westphalen JS, Linse-Silva ACB, Soares de Araujo F (2012) Who is who in the understory: the contribution of resident and transitory groups of species to plant richness in forest assemblages. Rev Biol Trop 60(3):1025–1040

Giriraj A, Babar S, Jentsch A, Sudhakar S, Murthy MSR (2010) Tracking fires in India using advanced along track scanning radiometer (A)ATSR Data. Remote Sens 2(2):591–610

Gopalakrishna SP, Kaonga ML, Somashekar RK, Suresh HS, Suresh R (2015) Tree diversity in the tropical dry forest of Bannerghatta National Park in Eastern Ghats, Southern India. Eur J Ecol 1(2):12–27

Heaney A, Proctor J (1990) Preliminary studies on forest structure and floristics on Volcan Barva, Costa Rica. J Trop Ecol 6:307–320

Htun NZ, Mizoue N, Yoshida S (2011) Tree species composition and diversity at different levels of disturbance in Popa Mountain Park, Myanmar. Biotropica 43(5):597–603

Hubbel SP (1979) Tree dispersion, abundance and diversity in a tropical dry forest. Science 203:1299–1309

Hughes JB, Daily GC, Ehrlich PR (1997) Population diversity: its extent and extinction. Science 278:689–692

Huston MA (1994) Biological diversity: the coexistence of species in changing landscapes. Cambridge University Press, Cambridge

Ifo SA, Moutsambote JM, Koubouana F, Yoka J, Ndzai SF, Bouetou-Kadilamio LNO, Mampouya H, Jourdain C, Bocko Y, Mantota AB, Mbemba M, Mouanga-Sokath D, Odende R, Mondzali LR, Wenina YEM, Ouissika BC, Joel LJ (2016) Tree species diversity, richness, and similarity in intact and degraded forest in the tropical rainforest of the Congo basin: case of the forest of Likouala in the republic of Congo. Int J For Res 2:1–12

Janzen DH (1988) Tropical dry forests—the most endangered major tropical ecosystem. In: Wilson EO (ed) Biodiversity. National Academy of Sciences, Smithsonian Institution, Washington, USA, pp 130–137

Jayakumar S, Arockiasamy DIS, Britto J (2002) Forest type mapping and vegetation analysis in part of Kolli hills, Eastern Ghats of Tamil Nadu. Trop Ecol 43(2):345–349

Jha CS, Singh JS (1990) Composition and dynamics of dry tropical forest in relation to soil texture. J Veg Sci 1:609–614

Jimenez JU, Fabrega J, Mora D, Tejedor N, Sánchez M (2016) Composition, diversity, and tree structure of a tropical moist forest in Gamboa, colon, Panama. Air Soil Water Res 9:29–34

Joseph S, Reddy CS, Pattanaik C, Sudhakar S (2008) Distribution of plant communities along climatic and topographic gradients in Mudumalai Wildlife Sanctuary (southern India). Biol Lett 45:29–41

Kadavul K, Parthasarathy N (1999a) Structure and composition of woody species in tropical semi-evergreen forest of Kalrayan hills, Eastern Ghats, India. Trop Ecol 40:77–90

Kadavul K, Parthasarathy N (1999b) Plant biodiversity and conservation of tropical semi-evergreen forest in the Shervarayan hills of Eastern Ghats, India. Biodivers Conserv 8:421–439

Kadavul K, Parthasarathy N (2000) Regeneration patterns of woody species in tropical semi-evergreen forest of Shervarayan hills, Eastern Ghats, India. Int J Ecol Environ Sci 26:37–48

Kandari LS, Rao KS, Maikhuri RK, Kharkwal G, Kala KC, Payal CP (2011) Distribution pattern and conservation of threatened medicinal and aromatic plants of Central Himalaya, India. J For Res 22:403–408

Kaul ON, Sharma DC (1971) Forest type statistics. Indian For 97:435–436

Knight DHA (1975) Phytosociological analysis of species rich tropical forest on Barro Colorado Island, Panama. Ecol Monogr 45:259–284

Laurance WF, Pérez-Salicrup D, Delamônica P, Fearnside PM, D'Angelo S, Jerozolinski A, Pohl L, Lovejoy TE (2001) Rain forest fragmentation and the structure of Amazonian liana communities. Ecology 82:105–116

Lewis SL, Sonke B, Sunderland T, Begne SK, Lopez-Gonzalez G, van der Heijden GMF, Phillips OL, Affum-Baffoe K, Baker TR, Banin L, Bastin J-F, Beeckman H, Boeckx P, Bogaert J, De Canniere C, Chezeaux E, Clark CJ, Collins M, Djagbletey G, Djuikouo MNK, Droissart V, Doucet J-L, Ewango CEN, Fauset S, Feldpausch TR, Foli EG, Gillet J-F, Hamilton AC, Harris DJ, Hart TB, de Haulleville T, Hladik A, Hufkens K, Huygens D, Jeanmart P, Jeffery KJ, Kearsley E, Leal ME, Lloyd J, Lovett JC, Makana J-R, Malhi Y, Marshall AR, Ojo L, Peh KS-H, Pickavance G, Poulsen JR, Reitsma JM, Sheil D, Simo M, Steppe K, Taedoumg HE, Talbot J, Taplin JRD, Taylor D, Thomas SC, Toirambe B, Verbeeck H, Vleminckx J, White LJT, Willcock S, Woell H, Zemagho L (2013) Above-ground biomass and structure of 260 African tropical forests. Philos Trans R Soc B 368:1–17

Lewis SL, Phillips OL, Sheil D, Vinceti B, Baker TR, Brown S, Graham AW, Higuchi N, Hilbert DW, Laurance WF, Lejoly J (2004) Tropical forest tree mortality, recruitment and turnover rates: calculation, interpretation and comparison when census intervals vary. J Ecol 92:929–944

Lieberman D, Lieberman M (1987) Forest tree growth and dynamics at La Selva, Costa Rica (1969–1982). J Trop Ecol 3:347–369

Lieberman D, Lieberman M, Hartshorn G, Peralta R (1985) Growth rates and age-size relationships of tropical wet forest trees in Costa Rica. J Trop Ecol 1:97–109

Losos EC, Leigh EG Jr (eds) (2004) Tropical forest diversity and dynamism: findings from a large-scale plot network. University of Chicago Press, Chicago

Manokaran N, La Frankie JVJ (1990) Stand structure of Pasoh forest reserve, a lowland rain forest Peninsular Malaysia. J Trop For Sci 3:14–24

Mastan T, Parveen NS, Reddy MS (2015) Liana species inventory in a tropical forest of Sri Lankamalla wildlife sanctuary, Andhra Pradesh, India. J Environ Res Dev 1024–1030

Matthew KM (1991) An excursion flora of Central Tamil Nadu. Oxford and IBH Publishing Co., Pvt. Ltd., New Delhi, India

Miles L, Newton AC, DeFries RS, Ravilious C, May I, Blyth S, Kapos V, Gordon JE (2006) A global overview of the conservation status of tropical dry forests. J Biogeogr 33(3):491–505

Mohapatra AK, Tewari DD (2005) Importance of non-timber forest products in the economic valuation of dry deciduous forests of India. For Poli Econ 7(3):455–467

Murphy PG, Lugo AE (1986) Ecology of tropical dry forest. Annu Rev Ecol Syst 17:67–88

Muthumperumal C, Parthasarathy N (2013) Diversity, distribution and resource values of woody climbers in tropical forests of southern Eastern Ghats, India. J For Res 24:365–374

NADP (2008) Proceedings of the meeting conducted for the formulation of national agricultural development programme (2008–2009 to 2011–2012) in Tiruvannamalai district of Tamil Nadu India, pp 1–247

Naidu MT, Kumar OA (2016) Tree diversity, stand structure and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. J Asia-Pacif Biodivers 9:328–334. https://doi.org/10.1016/j.japb.2016.03.019

Odum EP (1971) Fundamentals of ecology, 3rd edn. WB Saunders, Philadelphia, p 574

Ojo LO, Ola-Adams BA (1996) Measurement of tree diversity in the Nigerian rainforest. Biodivers Conserv 5:1253–1270

Palomino RL, Alvarez SIP (2009) Structural patterns and floristics of a seasonally dry forest in Reserva Ecologica chaparri, Lambayeque, Peru. Trop Ecol 50:305–314

Phillips OL, Martinez RV, Vargas PN, Monteagudo AL, Zans MC, Sanchez WG, Cruz AP, Timana M, Yali-Halla Rose S (2003) Efficient plot based floristic assessment of tropical forests. J Trop Ecol 19:629–645

Pianka ER (1966) Latitudinal gradients in species diversity: a review of concepts. Am Nat 100:33–46

Poorter L, van der Sande MT, Thompson J, Arets EJMM, Alarcón A, Álvarez-Sánchez J, Ascarrunz N, Balvanera P, Barajas-Guzmán G, Boit A, Bongers F, Carvalho FA, Casanoves F, Cornejo-Tenorio G, Costa FRC, de Castilho CV, Duivenvoorden JF, Dutrieux LP, Enquist BJ, Fernández-Méndez F, Finegan B, Gormley LHL, Healey JR, Hoosbeek MR, Ibarra-Manríquez G, Junqueira AB, Levis C, Licona JC, Lisboa LS, Magnusson WE, Martínez-Ramos M, Martínez-Yrizar A, Martorano LG, Maskell LC, Mazzei L, Meave JA, Mora F, Muñoz R, Nytch C, Pansonato MP, Parr TW, Paz H, Pérez-García EA, Rentería LY, Rodríguez-Velazquez J, Rozendaal DMA, Ruschel AR, Sakschewski B, Salgado-Negret B, Schietti J, Simões M, Sinclair FL, Souza PF, Souza FC, Stropp J, Ter Steege H, Swenson NG, Thonicke K, Toledo M, Uriarte M, van der Hout P, Walker P, Zamora N, Pena-Claros M (2015) Diversity enhances carbon storage in tropical forests. Glob Ecol Biogeogr 1–15

Poulsen AD, Balslev H (1991) Abundance and cover of ground herbs in the Amazonian rainforest. J Veg Sci 2:315–322

Powers JS, Becknell JM, Irving J, Perez-Aviles D (2009) Diversity and structure of regenerating tropical dry forests in Costa Rica: geographic patterns and environmental drivers. For Ecol Manag 276:88–95. https://doi.org/10.1016/j.foreco.2008.10.036

Pragasan AL, Parthasarathy N (2010) Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. Flora 205:728–737

Premavani D, Naidu DT, Venkaiah M (2014) Tree species diversity and population structure in the tropical forests of north central Eastern Ghats, India. Not Sci Biol 6(4):448–453

Primack RB, Hall P (1992) Biodiversity and forest change in Malaysian Borneo. Bioscience 42:829–837

Rao P, Barik SK, Pandey HN, Tripathi RS (1990) Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. Vegetation 88:151–162

Rao DS, Murty PP, Kumar OA (2015) Tree Species diversity and distribution patterns in tropical forests of Vizianagaram District, Andhra Pradesh, India. Eur J Environ Ecol 2(2):78–95

Reddy CS, Ugle P (2008) Tree species diversity and distribution patterns in tropical forest of Eastern Ghats, India: a case study Forestry Ecology Division, National Remote Sensing Agency, Balanagar, Hyderabad 500037, India. Life Sci J 4:87–93

Reddy CS, Babar AS, Giriraj KN, Reddy K, Rao T (2008a) Structure and floristic composition of tree diversity in tropical dry deciduous forest of Eastern Ghats, Southern Andhra Pradesh, India. Asian J Sci Res 1:57–64

Reddy CS, Pattanaik C, Mohapatra A, Biswal AK (2008b) Phytosociological observation on tree diversity of tropical forest of Similipal biosphere reserve, Orissa, India. Taiwania 52(4):352–359

Reddy CS, Babar S, Amarnath G, Pattanaik C (2011) Structure and floristic composition of tree stand in tropical forest in the Eastern Ghats of northern Andhra Pradesh, India. J For Res 22(4):491–500

Rundel PW, Boonpragob K, Mooney HA, Medina E (1995) Dry forest ecosystems of Thailand. Seasonally dry tropical forests. Cambridge University Press, pp 9–34

Sahoo T, Panda TP, Acharya L (2017) Structure, composition and diversity of tree species in tropical moist deciduous forests of Eastern India: a case study of Nayagarh Forest Division. J For Res, Odisha. https://doi.org/10.1007/s11676-017-0408-5

Sahu SC, Dhal NK, Reddy CS, Pattanaik C, Brahmam M (2007) Phytosociological study of tropical dry deciduous forest of Boudh district, Orissa, India. Res J For 1:66–72

Sahu SC, Dhal NK, Mohanty RC (2012) Tree species diversity, distribution and population structure in a tropical dry deciduous forest of Malyagiri Hill ranges, Eastern Ghats, India. Trop Ecol 53(2):163–168

Sahu PK, Sagar R, Singh JS (2008) Tropical forest structure and diversity in relation to altitude and disturbance in a Biosphere Reserve in central India. Appl Veg Sci 11:461–470

Sahu SC, Suresh HS, Ravindranath NH (2016) Forest structure, composition and above ground biomass of tree community in tropical dry forests of Eastern Ghats, India. Not Sci Biol 8(1):125–133

Schnitzer SA, Bongers F (2002) The ecology of lianas and their role in forests. Trend Ecol Evol 17:223–230

Schnitzer SA, Parren MPE, Bongers F (2004) Recruitment of lianas into logging gaps and the effects of pre-harvest climber cutting in a lowland forest in Cameroon. For Ecol Manag 190:87–98

Sharma GP, Raghubanshi AS (2010) *Lantana camara* L. invasion and impact on herb layer diversity and soil properties in a dry deciduous forest of India. Appl Ecol Environ Res 9(3):253–264

Singh KP, Singh JS (1988) Certain structural and functional aspects of dry tropical forests and savanna. Int J Ecol Environ Sci 14:31–45

Singh JS, Singh SP, Saxena AK, Ravat YS (1981) The forest vegetation of Silent Valley. In: Chadwick AC, Sutton SL (eds) Tropical rain-forest: the Leeds symposium. Leeds Philosophical and Literary Society, USA. ISBN-13: 9780950192130

Singh V, Gupta SR, Singh N (2014) Vegetation composition, species diversity and soil carbon storage in tropical dry deciduous forests of southern Haryana. Indian J Sci 7(18):28–39

Slik JWF, Aiba SI, Brearley FQ, Cannon CH, Forshed O, Kitayama K, Nagamasu H, Nilus R, Payne J, Paoli G, Poulsen AD, Raes N, Sheil D, Sidiyasa K, Suzuki E, van Valkenburg JLCH (2010) Environmental correlates of tree biomass, basal area, wood specific gravity and stem density gradients in Borneo's tropical forests. Glob Ecol Biogeogr 19:50–60

Sundarapandian SM (1997) Ecological studies on forest ecosystems at Kodayar in Western Ghats of Tamil Nadu. PhD thesis submitted to Madurai Kamaraj University, Madurai, p 133

Sundarapandian SM, Karoor PJ (2013) Edge effects on plant diversity in tropical forest ecosystems at Periyar Wildlife sanctuary in the Western Ghats of India. J For Res 24(3):403–418

Sundarapandian SM, Swamy PS (2000) Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. J Trop For Sci 12:104–123

Sundarapandian SM, Naveenkumar J, Arunkumar KS (2015) Tree diversity in tropical forest in the Jvadihills in the Eastern Ghats, India. J Glob Ecol Environ 3(4):272–288

Swaine MD, Lieberman D, Putz FE (1987) The dynamics of tree populations in tropical forest: a review. J Trop Ecol 3:359–366

Swamy PS, Sundarapandian SM, Chandrasekar P, Chandrasekaran S (2000) Plant species diversity and tree population structure of a humid tropical forest in Tamil Nadu, India. Biodivers Conserv 9:1643–1669

Thakur AS (2015) Floristic composition, life-forms and biological spectrum of tropical dry deciduous forest in Sagar District, Madhya Pradesh, India. Trop Plant Res 2(2):112–119

Villasenor JL, Maeda P, Rosell JA, Ortiz E (2007) Plant families as predictors of plant biodiversity in Mexico. Divers Distrib J 13(6):871–876

Whitmore TC, Burslem DFR (1996) Major disturbances in tropical rainforests. In: Newberg DM, Prins HHT, Brown ND (eds) Dynamics of tropical communities. Blackwell Science, UK, pp 549–565

Whitford PB (1949) Distributions of woodland plants in relation to succession and clonal growth. Ecology 30:199–208