Research Article

Assessment of tree species diversity and above-ground biomass in two disturbed tropical dry evergreen forests of Coromandel coast of India

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Abstract

The tree diversity and carbon stock of all woody plants were determined in two-hectare square plots (100 m x 100 m), established in Suryanpet (SP) and Velleripet (VP) as tropical dry evergreen forest (TDEF) sites on the Coromandel coast of peninsular India. All trees ≥ 10 cm girth at breast height measured at 1.3 m from the rooting point were enumerated. A total of 35 tree species (≥ 10 cm gbh) belonging to 34 genera and 23 families were recorded in tropical dry evergreen forests. Tree species richness in 27 (dominant species *Dimorphocalyx glabellus* Thw.) and 18 (dominant species *Strychnos nux-vomica* L.) in SP and VP respectively. A total density of woody plants are 671 and 1154 individuals in SP and VP respectively. Tree basal area was greater in site VP (45.46 m2 ha-1) compare the site SP (40.70 m2 ha-1). Most abundant families were Loganiaceae, Euphorbiaceae and Rutaceae and their family index values (FIV) were 56.14, 39.12 and 21.40, respectively. The above-ground biomass (AGB) of trees totaled in site SP (405.3 Mg ha^{-1}) and VP (721.3 Mg ha^{-1}). The extent of tree species diversity and estimated carbon stock of the TDEF sites will provide the baseline data on the floristic structure and diversity of these forest sites for better management and conservation.

Keywords: Allometric equation, Anthropogenic pressure, Biomass, TDEFs, Wood specific density

INTRODUCTION

Tropical forest provides numerous goods and ecosystem services such as conservation of species, preventing soil erosion, and preserving habitat for plants and animals (Naidu and Kumar, 2016; Armenteras *et al.*, 2009; Pandian and Ravichandran, 2020). Globally, biodiversity is decreasing unexpectedly due to habitat destruction, overexploitation, pollution (Pragasan and Parthasarathy, 2010) as a result of natural forests is occurring in fragments and in degraded forms inflicting a lot of spatial and temporal variation in species richness, composition and productiveness at local and regional levels. Anthropogenic disturbances regularly lead to altered environmental conditions that lead to species diversity destruction in a forest community (Osuri *et al.*, 2020; Sapkota *et al.*, 2010). Among the diverse forest types, tropical forests are one of the most significant sinks of carbon as they represent as much as 40% of the carbon stored as terrestrial biomass (Raha *et al.*, 2020; Phillips *et al.*, 1998). Tropical forests spread around 7–10% of the worldwide land area. However, it represents 34% of the terrestrial primary productivity (Lewis *et al.*, 2013; Slik *et al.*, 2015). Tropical forests play an important role in the global carbon balance, biodiversity protection, and several other valuable environmental services. Notwithstanding, the carbon stocks of tropical forests are poorly measured in developing countries. The studies remain poorly understood because of the lack of atmospheric monitoring in the tropics (Raha *et al.*, 2020; Kaul *et al.*, 2010; Reichstein *et al.*, 2013).

Forests are important carbon pools that continuously exchange CO_2 with biological system. Indeed, tropical forest ecosystems can hold massive quantities of carbon than the other forest biomes (Vivek and Parthasarathy, 2015; Metz *et al.,* 2001). Tropical forests contain about 40 percent of the total terrestrial carbon stock (Dixon *et al.*, 1994); however, uncertainty prevails in their quantitative contribution to the international carbon cycle (Chave *et al.*, 2005). Above and belowground biomass stocked as carbon in woody plants is impacted directly by anthropogenic disturbances. Deforestation presently represents about 18 % of the international carbon emissions (Vivek and Parthasarathy, 2015). Several major factors, including selective logging, forest fragmentation, and transferring cultivation, play an important role in altering forest biomass (Houghton, 2005). Under the existing scenario of global environmental change and increasing rate of deforestation, it has become important to quantify the carbon stocks in the tropics. However, the direct evaluation of biomass through destructive sampling will probably give a better estimation of forest carbon stocks. It could also be approached using generalized allometric equations (Brown, 1997; Chave et al., 2005) using variables like diameter, height, and wood specific density. Gibson *et al.* (2011) revealed a global meta-analysis that indicates tropical forest disturbance on biodiversity was more extreme in Asia than in Africa, South America and Central America. Globally, forest ecosystems are threatened by various human activities linked with over usage of forest resources and area encroachment for agriculture, settlement and economic development (Iftekhar and Hoque, 2005; Pandian and Ravichandran, 2019). Tropical dry evergreen forests are short-statured, large-ly three-layered, tree-dominated, closed canopy forest type, which is distributed along the Coromandel coast of peninsular India, composed of indigenous species, are mainly sacred groves preserved as a result of the religious belief of the local community (Parthasarathy *et al.*, 2008; Anbarashan and Parthasarathy, 2012; Pandian and Parthasarathy, 2016b). The expanding interest in the land area for human-related activities has increased the stress on these forests over the decade (Pandian, 2015). Tropical dry evergreen forest (TDEF) forests bordering are threatened by the increasing human population, leading to shrinkage in TDEF land areas and increasing forest resource extraction and grazing pressure. Hence, it is of prime importance to estimate the diversity and carbon stocking potential of TDEF ecosystem for conservation with scientific data. The main objective of the present study was to investigate tree population and above-ground biomass (AGB) in two tropical dry evergreen forests of the Coromandel coast of India.

MATERIALS AND METHODS

Study area

The present work was carried out in two tropical dry evergreen forest sites (Suryanpet - SP and Velleripet - VP) on the Coromandel coast of peninsular India (Fig.1). Suryanpet (11.73329 N and 79.63897 E) is located 41 km south of Puducherry and the forest area covers around 2.7 ha. The forest is dominated by *Dimorphocalyx glabellus* and soil is red ferralitic. Velleripet (11.7386 N and 79.6944 E) is situated 29 km west of Villupuram, Tamil Nadu, and establishes a two-layered forest with a normal height of 8 m forest area
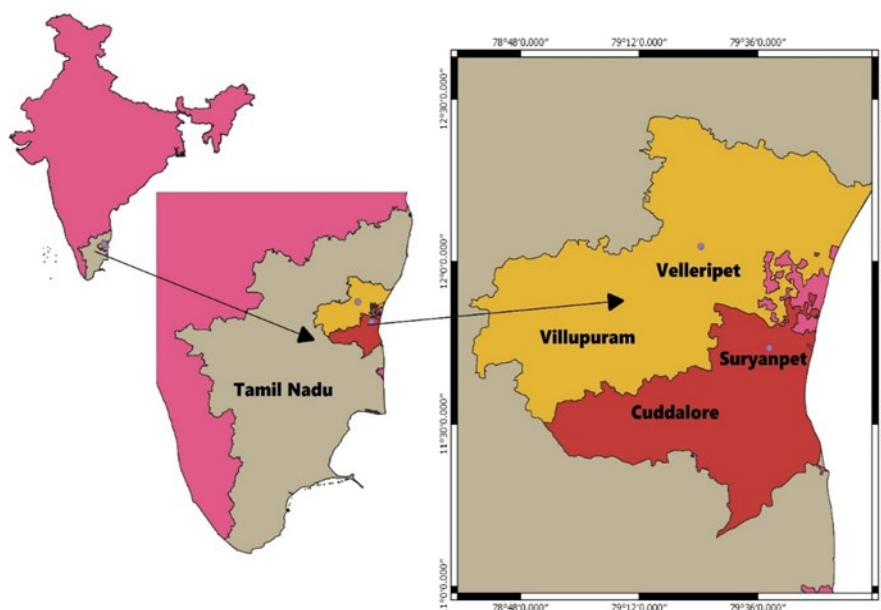
Fig. 1. *Map showing the location of two tropical dry evergreen forest sites (Velleripet - VP and Suryanpet - SP) on the Coromandel coast of India.*

around 2 ha and the predominant tree species is *S Strychnos nux-vomica*. Both the sites under the anthropogenic activities such as forest encroachment for expansion of temple structures, forest resource removal (fodder, firewood, medicinal plants, timber, etc.) and the impact of temple visitors by way of cooking inside the forest during festive occasions and solid waste dumping (polythene, glass bottles). Moreover, both the sites are surrounded by Agricultural fields such as paddy, groundnut, sugarcane, and Cashew plantation. Soils are basically red ferralitic.

Data collection and data analysis

Two 1-ha plots (100 × 100 m) were established and each plot was again divided into one-hundred 10 m × 10 m quadrats for tree assessment. All trees ≥ 10 cm girth at breast height and measured from (at 1.3 m) ground level. For multi-tree stemmed, bole girth was documented separately, basal area was calculated and summed. The extent of the human disturbance was estimated for sites SP and VP. Site disturbance was measured based on human activities such as firewood collection, forest resource removal (fodder, firewood, medicinal plants, timber, etc.), the impact of temple visitors (polythene and glass bottles), grazing by cattle and goats, temple construction and the cultural attachment (local people) by way of cooking inside the forest during festive occasions. The cattle and goat browsing degree was very high in site SP because of nearby human settlements and agricultural fields. In the case

of the site VP there is no evidence of cattle and goat browsing. Forest resource removal in the form of the firewood collection and timber extraction is high in site SP. All the sub-classes in various types of disturbance were ranked into relatively low (1), medium (2), and high (3) levels of disturbance (Table 1). The sum of all scores for each site provides an overall ranking of anthropogenic disturbance in the forest. High ranks signify high levels of anthropogenic activities and low ranks low levels of activities.

Site encroachment like temple construction, birdle path use is medium in both sites. Temple visitor's impact scored in low. Tree diversity was assessed using two common species diversity indices: the Shannon index (which combines species richness and evenness into a single value) and the Simpson index (which gives more weight to the abundance of the most common species) were computed following Magurran (2004). (Shannon, H' = -∑ pi ln pi, where pi is the proportion of ith species; Simpson, D = 1-∑ ni (ni-1)/N (N-1), where ni is the proportion of ith species and N is the total number of individuals). Species-area curve was raised based on species increment by the sequential arrangement of every 0.1 ha area. Paired t-tests in SPSS software was used to test differences of density (≥10 cm), species richness and basal area among vegetation types. After the collection, data assessment was done for the aboveground biomass for using regression equation given by Chave *et al.*, (2005): AGB_{est} = ρ × exp(- 1.499 + 2.148 ln(D) + 0.207 (ln(D))^2 - 0.0281 (ln(D))^3 where, ρ is

Table 1. Present site disturbance score status (1- ranked as rare: 2- occasional: 3- frequent) of two study sites - Velleripet (VP) and Suryanpet (SP).

No.	Attributes	VP	SP
1	Forest encroachment (land use within the forest)		
	i. temple construction	2	1
	ii. forest encroachment	1	1
2	Bridle path use	2	2
3	Temple visitors' impact: area used for		
	i. vehicle parking (area occupied)	2	1
	ii. cooking	1	2
	iii. festive occasion use	3	2
4	Grazing (cattle/goat)	3	2
5	Culture attachment of local people	2	2
6	Resource removal		
	i. fuel wood	2	3
	ii. other: medicinal plants, edible fruits and soil	2	2
7	Approach road to temple (width)	1	1
8	Fodder collection	3	1
9	Solid waste dumping (plastic, polythene, glass, rexin)	2	3
	Total score	26	22

Table 2. Summary of tree diversity inventory (≥10 cm gbh) in two tropical dry evergreen forest sites (Velleripet - VP and Suryanpet - SP) on the Coromandel coast of India.

Variable	SP	VP
Species richness	27	18
Number of genera	25	17
Number of families	18	13
Shannon	2.13	1.24
Simpson	4.78	2.15
Fisher's	5.66	3.03
Stand density (stem ha-1)	671	1154
Stand basal area (m2ha-1)	40.7089	45.4621
Above ground biomass (Mg ha-1)	405.363	721.333
Carbon sequestered (Mg ha-1)	202.681	360.667
Number of multi-stemmed trees	118	96
Maximum tree gbh (cm)	365	387

wood specific gravity and D is diameter at breast height.

RESULTS

A total of 35 tree species (≥ 10 cm gbh) belonging to 34 genera and 23 families were recorded in two 1-ha plots of tropical dry evergreen forests. There was significant in species richness (df = 99, P < 0.05), density (df = 99, P < 0.05) and basal area (df = 99, P < 0.05) between the two tropical dry evergreen forest sites. Tree species richness was low (18 species from 13 families) in the moderately disturbed site VP, and site SP harboured 27 tree species from 18 families recorded in site VP (Table 2). The total density of woody plants was 671 and 1154 individuals in SP and VP, respectively. The basal area of trees in the two study sites SP (40.71 m^2 ha^{-1}) and VP (45.46 m^2 ha^{-1}). The above-ground biomass (AGB) of trees totalled in site SP (405.3 Mg ha^{-1}) and VP (721.3 Mg ha^{-1}). The species diversity indices were greater for SP than VP. Shannon index value was 2.13 and 1.24 in sites SP and VP, respectively. Simpson index is 4.78 and 2.15 in sites SP and VP, respectively (Table 2). A positive correlation was revealed in density (R^2 =0.5842) and above-ground biomass (R^2 = 0.8574) with disturbance scores (Fig. 7a and b).

Species and family composition
Total 35 tree species were recorded and 10 species were common in both sites (Table 3). The most abundant tree species are *S. nux-vomica* (768 individuals), *Atalantia monophylla* (129 individuals), *Lepisanthes tetraphylla* (86 individuals) in site VP and *D. glabellus* (263 individuals), *L. tetraphylla* (117 individual), and *Glycosmis pentaphylla* (84 individual) occurred in SP. Seventeen tree species were exclusive to site SP which were totally absent in VP and nine species were exclusive to site VP (Table 3). One individual's tree

species are *Aglaia elaeagnoidea*, *Drypetes sepiaria, Ficus benghalensis*, *Dolichandrone falcata* and *Morinda coreia* in both the sites. The contribution of 23 plant families and stand density varied between the two sites. Loganiaceae contributed only one genus and one species, but the density (768 individuals) of the family was very high than the other families, followed by Euphorbiaceae (473 individuals) and Rutaceae (237 individuals), contributing to high density but low in diversity. The Meliaceae, Rutaceae and Mimosaceae (represe nted by 3 genera and three species each) are taxonomically diverse and constituted the most- speciose family (Table 4). The Moraceae with two genera and three species formed the second most species-rich family in both sites. Two genera and two species each represented Euphorbiaceae, Rubiaceae, Cordiaceae, and Verbenaceae. The other families were represented by one genus and one species each. Fifteen families were common to both the sites. Based on FIV the top families include Loganiaceae (65.14), Euphorbiaceae (43.12), Moraceae (25.42), Meliaceae (22.81) and Rutaceae (21.40) (Table 4).

Tree density and basal area by girth classes
Overall, no distinct difference in stem distribution size class was evident in the two forests. Tree density of girth class distribution consistently decreased with increasing size class of trees from 10 to 210 cm gbh, except for the greatest girth class ≥ 210 cm (Fig 3). Basal area of girth class distribution consistently increased with increasing size class of trees from 10 to 210 cm gbh, except for the girth class ≥ 121 to 150 cm in both sites. The lowest size class of 10 - 30 cm gbh was more abundant and formed 57.4 % of the total basal area, which is 4.29% in SP, while in VP, density is 37.6 % and the basal area is 4.42 % in site VP. In contrast, the tree density and basal area (31 - 60 cm) class were greater in VP than in SP. The density of large trees

Table 3. Species density of trees (≥10 cm gbh) in two tropical dry evergreen forest sites (Velleripet - VP and Suryanpet - SP) on the Coromandel coast of India, arranged in decreasing order of their total abundance and above-ground biomass (AGB).

Sl. No	Species name	Family	SP	VP	Total	AGB (kg)
1	*Strychnos nux-vomica* L.	Loganiaceae	0	768	768	268156.31
2	*Dimorphocalyx glabellus* Thw.	Euphorbiaceae	263	0	263	8792.43
3	*Lepisanthes tetraphylla* (Vahl) Radlk.	Sapindaceae	117	86	203	232406.92
4	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	84	6	90	737.09
5	*Azadirachta indica* A.Juss.	Meliaceae	32	57	89	144851.1
6	*Garcinia spicata* (Wight & Arn.) Hook.f.	Clusiaceae	28	0	28	50847.44
7	*Atalantia monophylla* DC.	Rutaceae	16	129	145	21194.02
8	*Diospyros montana* B.Heyne ex A.DC.	Ebenaceae	15	41	56	7473.85
9	*Pterospermum canescens* Roxb.	Sterculiaceae	15	0	15	8427.1
10	*Tricalysia sphaerocarpa* (Dalzell ex Hook.f.) Gamble	Rubiaceae	15	0	15	1585.64
11	*Syzygium cumini* (L.) Skeels	Myrtaceae	14	0	14	174190.42
12	*Memecylon intermedium* Blume	Melastomataceae	13	0	13	5606.82
13	*Acacia leucophloea* (Roxb.) Willd.	Mimosaceae	0	11	11	2403.14
14	*Cassia fistula* L.	Caesalpiniaceae	10	0	10	728.2319
15	*Premna latifolia* Roxb.	Verbenaceae	0	10	10	2347.46
16	*Albizia amara* (Roxb.) Boivin	Mimosaceae	0	9	9	20003.58
17	*Barringtonia acutangula* (L.) Gaertn.	Baringtoniaceae	6	0	6	22148.23
18	*Walsura trifoliolata* (A.Juss.) Harms	Meliaceae	6	0	6	935.29
19	*Borassus flabellifer* L.	Arecaceae	5	16	21	14509.81
20	*Cordia dichotoma* G.Forst.	Cordiaceae	5	0	5	5898.56
21	*Ficus hispida* L.f.	Moraceae	5	0	5	228.57
22	*Cadaba trifoliata* Wight & Arn.	Capparaceae	4	0	4	742.62
23	*Morinda coreia* Buch.Ham.	Rubiaceae	4	1	5	813.43
24	*Clausena dentata* (Willd.) M.Roem.	Rutaceae	0	4	4	28.23
25	*Pongamia pinnata* (L.) Pierre	Fabaceae	3	0	3	11799.25
26	*Alangium salviifolium* (L.f.) Wangerin	Cornaceae	2	2	4	612.29
27	*Dalbergia paniculata* Roxb.	Fabaceae	2	0	2	850.29
28	*Streblus asper* Lour.	Moraceae	2	0	2	424.73
29	*Vitex negundo* L.	Verbenaceae	2	0	2	29.84
30	*Ehretia pubescens* Royle ex Benth.	Boraginaceae	0	2	2	5323.26
31	*Prosopis chilensis* (Molina) Stuntze	Mimosaceae	0	2	2	526.08
32	*Dolichandrone falcata* (Wall. ex DC.) Seem.	Bignoniaceae	0	1	1	1154.15
33	*Aglaia elaeagnoidea* (A.Juss.) Benth.	Meliaceae	1	0	1	37.15
34	*Drypetes sepiaria* (Wight & Arn.) Pax & K.Hoffm.	Ebenaceae	1	3	4	2351.13
35	*Ficus benghalensis* L.	Moraceae	1	6	7	105309.18
	Total		671	1154	1825	1126695.81
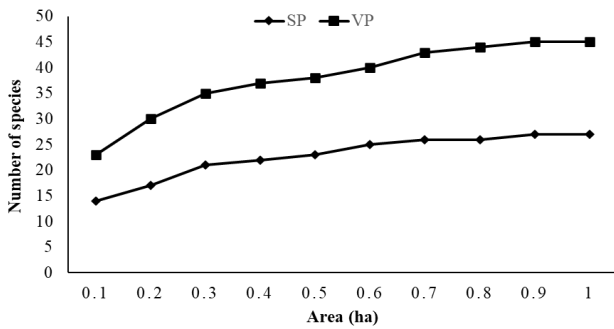
Fig. 2. *Species-area curve for the two tropical dry evergreen forest sites - Velleripet (VP) and Suryanpet (SP).*

(girth ≥ 210 cm) was 23 trees ha⁻¹ in SP and 12 in VP. Tree basal area of the larger tree size class (girth ≥ 210 cm) was 20.1 m² ha¹ in SP and 9.61 m² ha¹ in VP (Fig 3). In both the studied sites, dominant species by girth class varied, *D. glabellus* and *G. pentaphylla* notably abundant in lower girth class (10-30 cm gbh), whereas middle and higher girth class showed no species. *L. tetraphylla* showed more density in the middle girth class while in the lower and higher moderately distributed site SP. (Fig 4). *S. nux-vomica and A. mono phylla most* abundant in lower girth class (10-30 cm gbh) *L. tetraphylla* reveal the density in middle girth class while in lower and higher moderately distributed in site VP. (Fig 5).

Species- area curve

The Species-area curve for the two plots at the 1- ha scale is shown in Fig.2. The observed species accumulation curve for each site captured about 50% of the species at the 0.2 ha scale and about 80% at the 0.8 ha scale. It finally reached an asymptote, indicating tree species saturation and sample sufficiency at 1 ha scale.

Above-ground biomass (AGB)

The total above-ground biomass (AGB) varied among the sites (405.363 Mg/ha in SP) and (721.333 Mg/ha in VP) with the mean value of 563.3 ± 223.4 Mg/ha. The above-ground C stock was 202.68 and 360.6 Mg/ha in sites SP and VP, respectively (Table 2). *S. nux-*

vomica was the top contributor of biomass and C stocks and contributed 23.8% of total biomass and C stocks, respectively, followed by *L. tetraphylla* (20.7%), *Syzygium cumini* (15.4%). This data was pooled for all sites (Table 3). There is a variation in girth class-wise distribution in all the forest types. In SP, AGB increased along with the diameter class, whereas site VP reveal AGB increased in the middle and higher girth class (Fig 6).

DISCUSSION

Tree diversity, density and girth diameter are vital indicators to assessing the forest above-ground biomass and other ecological processes in tropical forests (Sainge *et al.*, 2020). The tree diversity greatly differs from location to location its mainly due to variation in biogeography, habitat, and disturbance (Neumann and Starlinger, 2001; Padalia *et al.*, 2004; Naidu and Kumar, 2016). Our result revealed tree species diversity represented in site SP (27 species) and VP (18). A number of tree species were recorded in the present study was found to be higher than the number of tree species reported by several researchers in other tropical forests (Fox *et al.*, 1997, 94 species; Kadavul and Parthasarathy, 1999a, 89species; Khera *et al.*, 2001, 92species; Attua and Pabi, 2013, 88 species; Naidu and Kumar, 2016, 129 species; Mohanta *et al.*, 2020, 72 species). Tropical forest showed a wide variation in tree species richness, ranging from 20 species/ ha (low value) in Ngovayang's lowland forests, Cameroon (Gonmadje *et al.*, 2011), to 307 species/ha (high value) in Amazonia Ecuadar (Valencia *et al.*, 1994). Tree species richness, abundance and basal area were higher in the disturbed sites (VP) than the relatively disturbed sites (SP), it coincides with many other studies (Bhuyan *et al.*, 2003; Mishra *et al.*, 2004; Nath *et al.*, 2005; Banda *et al.*, 2006; Muhanguzi *et al.*, 2007; Anitha *et al.*, 2009; Anbarashan and Parthasarathy 2012). Low density and species richness in our SP sites may be due to anthropogenic activities such as collecting fuelwood and fodder and grazing pressure. This scenario leads to thinning the woody layer and changing the forest
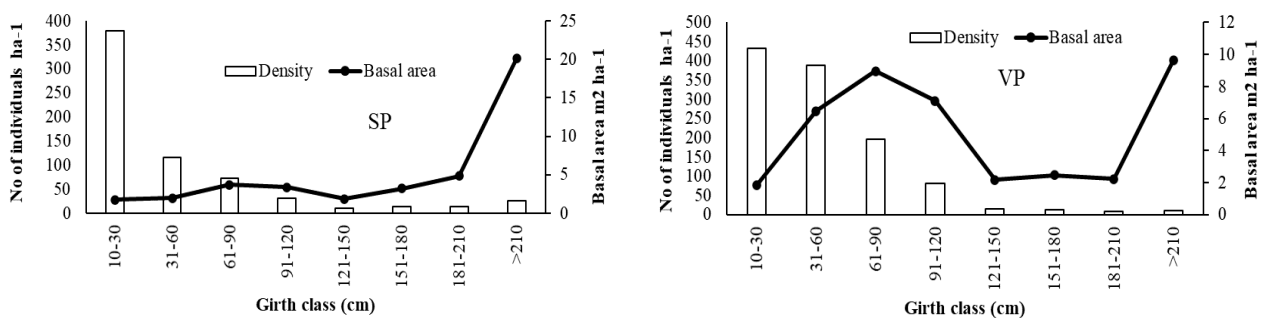

Fig. 3. *Tree density (D) and basal area (B) by girth classes in two tropical dry evergreen forest sites - Velleripet (VP) and Suryanpet (SP).*

microclimate, leading to the impaired regeneration process of tree species resulting in low abundance. Tropical dry evergreen forest sites (DTEFs) are smaller in size, ranging from 0.5 to 20 ha, little-known and understudied forest type, protected on religious beliefs, thus gaining significance from ecological and societal perspectives (Anbarashan and Parthasarathy, 2012). The stand density of TDEF is represented by 671 individuals (SP) and 1154 individuals (VP). Tree density is disturbed by various activities like natural calamities, anthropogenic activities, and soil properties. However, our results are comparable with other tropical forests, Kalarayan hills (640-986 stems/ha, Kadavul and Parthasarathy, 1999b), Eastern Ghats (EG) of northern Andhra Pradesh (639-836 stems /ha, Reddy *et al.*, 2011; 435-767 stems/ha, Naidu and Kumar, 2016), Kalakkad, Western Ghats (575-855 stems/ha, Parthasarathy, 1999), Central Himalayan, India (153 to 457 stems /ha, Kaushal and Baishya, 2021), Anamalais (270-673 stems /ha, Ayyappan and Parthasarathy, 1999), Gandhmaran hills, Eastern Ghats (565-671

stems /ha, Sahu *et al.*, 2010), Brazil (420-777 stems / ha, Campbell *et al.*, 1992), Sulawesi (408 stems /ha, Whitmore and Sidiyasa, 1986). Shannon-Weiner values are 2.13 and 1.24 in SP and VP, respectively and others also reported between range 0. 81 and 4.1 (Naidu and Kumar, 2016; Visalakshi, 1995; Sahu *et al.*, 2012; Sundarapandian and Swamy, 2000; Kaushal and Baishya, 2021). The extent of dominance (Simpson's index) in sites SP (4.78) and VP (2.15) in other studies also reported nearby values (Knight, 1975; Visalakshi, 1995; Lalfakwma *et al.*, 2009; Naidu and Kumar, 2016; Mohanta *et al.*, 2020). Our results showed tree species richness and abundance of understory drastically declined with increasing forest disturbance in SP and these results are consistent with other tropical forests (Ramirez-Marcial *et al.*, 2001; Anbarashan and Parthasarathy, 2012). The occurrence of anthropogenic as well as natural disturbances creates conditions for recruitment of new individuals or the growth of pre-existing ones in the understory species (Young and Hubbell, 1991; Ramirez-Marcial *et al.*, 2001; Pandian
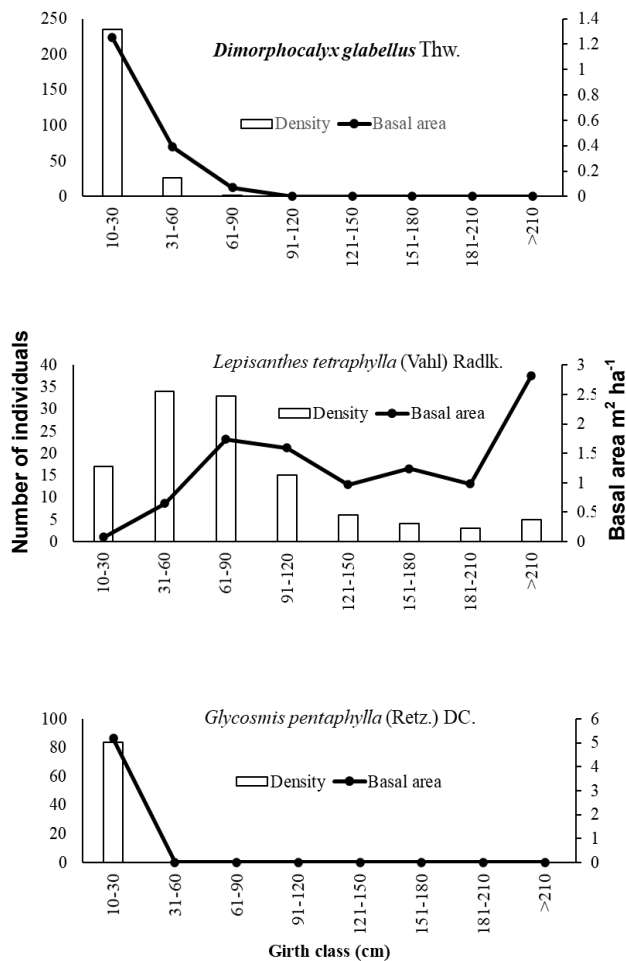
Fig. 4. *Girth class distribution of top three abundant tree species in tropical dry evergreen forest sites (Suryanpet - SP) on the Coromandel coast of India.*
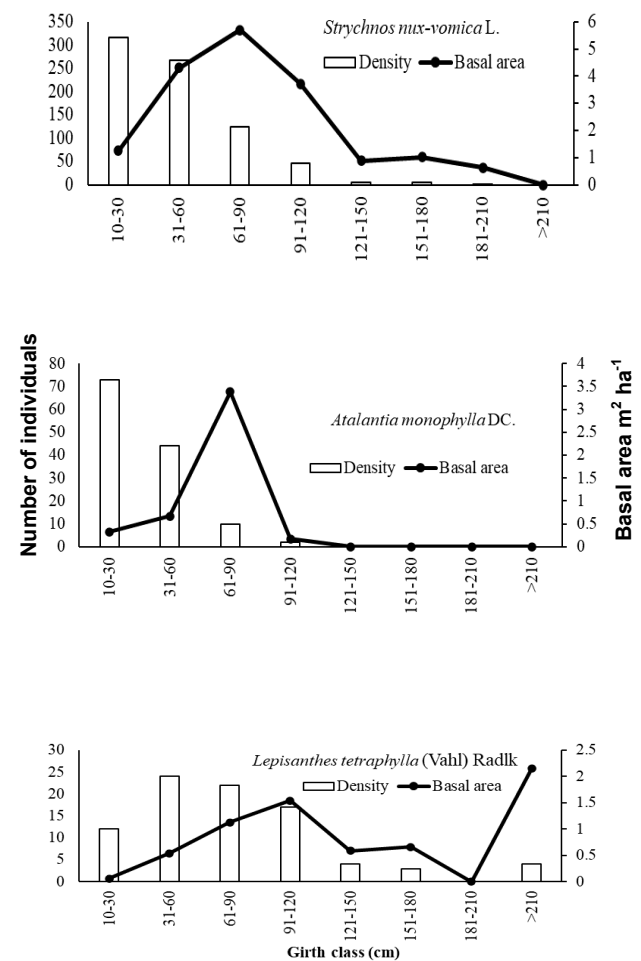
Fig. 5. *Girth class distribution of top three abundant tree species in tropical dry evergreen forest sites (Velleripet - VP) on the Coromandel coast of India.*

Table 4. Family diversity and density (stems ha^{-1}), arranged in decreasing order of FIV in two tropical dry evergreen forest sites (Velleripet - VP and Suryanpet - SP).

| Sl. no.	Family	Genera	Species	Density	FIV
1	Loganiaceae	1	1	768	65.14
2	Euphorbiaceae	2	2	473	43.12
3	Moraceae	2	3	13	25.42
4	Meliaceae	3	3	95	22.81
5	Rutaceae	3	3	237	21.40
6	Sapindaceae	1	1	103	20.49
7	Mimosaceae	3	3	12	10.89
8	Clusiaceae	1	1	28	10.68
9	Myrtaceae	1	1	14	10.00
10	Ebenaceae	1	1	56	9.48
11	Rubiaceae	2	2	20	7.20
12	Cordiaceae	2	2	7	6.93
13	Verbenaceae	2	2	12	6.49
14	Sterculiaceae	1	1	15	5.68
15	Barrintoniaceae	1	1	6	5.19
16	Arecaceae	1	1	21	5.18
17	Melastomataceae	1	1	14	4.59
18	Fabaceae	1	1	1	3.66
19	Caesalpiniaceae	1	1	9	3.35
20	Capparaceae	1	1	4	3.24
21	Papilionaceae	1	1	2	3.08
22	Alangiaceae	1	1	4	3.08
23	Bignoniaceae	1	1	1	2.88

and Parthasarathy, 2017).

The basal area of trees (40.71 m^2/ha in SP and 45.46 m^2/ha in VP) in tropical dry evergreen forests are much greater than the range (1.31-13.78 m^2/ha, Sagar and Singh, 2006). Whereas, the present results are less comparable with those reported from New Caledonia (47-49.5 m^2/ha, Jaffre and Veillon, 1990), fan-palm dominated forests of east coast peninsular Malaysia (25.3-48.6 m^2/ha, Nizam *et al.*, 2013). Our results corroborative with other reports, 30.23 - 32.77 m^2/ha in the tropical moist deciduous forest (Similipal Biosphere Reserve) of India (Mohanta *et al.*, 2020), 7-23 m^2/ha in tropical dry forest communities in India (Jha and Singh, 1990), 10.79-20.44 m^2/ha in tropical dry evergreen forests of southern India (Parthasarathy and Sethi, 1997), Eastern Ghats (EG) of northern Andhra Pradesh (12.98 - 33.63 m^2/ha; Naidu and Kumar, 2016) and 3.9-16.7 m^2/ha in Miombo woodlands, Tanzania (Backeus *et al.*, 2006). Tree density of girth class distribution consistently decreased with increasing size class of trees from 10 to 210 cm gbh, except for the greatest girth class ≥ 210 cm. Whereas basal area of girth class distribution consistently increased with increasing size class of trees from 10 to 210 cm gbh, except for the girth class ≥ 121 to 150 cm in both sites, this result coincides with Pandian and Parthasarathy, (2016a). Tree different frequency classes distribution is commonly used to check forest disturbance effects (Hett and Loucks,

1976; Denslow, 1995; Anbarashan and Parthasarathy; 2012) and detect tree regeneration trends patterns. The frequency of girth class showed that the population structure of trees exhibited in the study plots is in harmony with other tropical forest stands (Bhadra *et al.*, 2010; Sahu *et al.*, 2010). Tree distribution across the different frequency classes showed how well the growing forest utilises functional and structural resources (Naidu and Kumar, 2016). The girth distribution of trees has been often used to represent the population structure of forests (Rao *et al.*, 1990).

In the present study, the above-ground biomass values were 405.3 Mg/ha in SP and 721.333 Mg/ha in VP, with the mean value of 563.3 ± 223.4 Mg/ha. This may be due to the larger stem density and basal area in the forest and also possibly due to domination of *S. nux-vomica* (VP) and *D. glabellus (SP),* which are the members of larger girth classes in the study sites. The present study of AGB values were comparable to the average AGB values of world tropical forests (Malhi *et al.*, 1999; Návar-Chaidez, 2011; Slik *et al.*, 2010; Becknell *et al.*, 2012; Berenguer *et al.*, 2014; Shahid and Joshi, 2015; Behera *et al.*, 2017). The average AGB in the present study was greater in comparison to Amazon forest (288.6 Mg ha^{-1}; Malhi *et al.*,1999) but the value was closer to the Bornean (458.1 Mg ha^{-1}; Silk *et al.*, 2010), African tropical forest (395.7 Mg ha^{-1}; Lewis *et al.*, 2013), South western Borneo (622 Mg ha^{-1}; Paoli
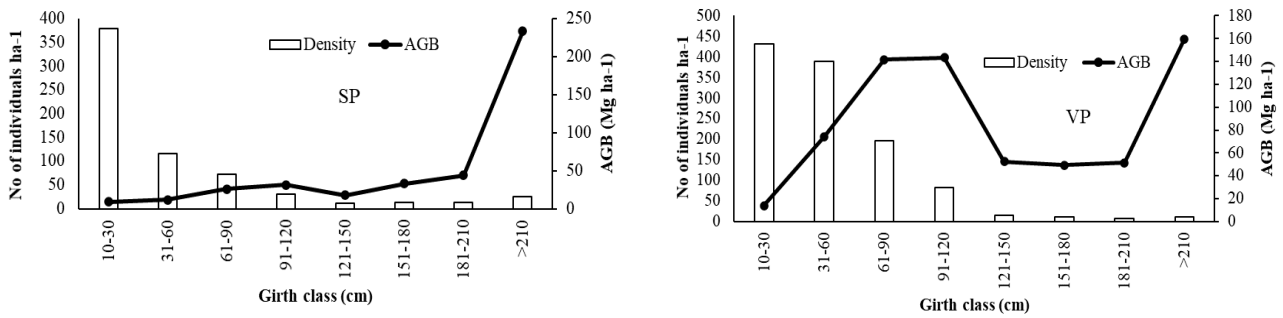
Fig. 6. *Above-ground biomass (AGB) and stem density (D) by girth classes in two tropical dry evergreen forest sites - Velleripet (VP) and Suryanpet (SP).*
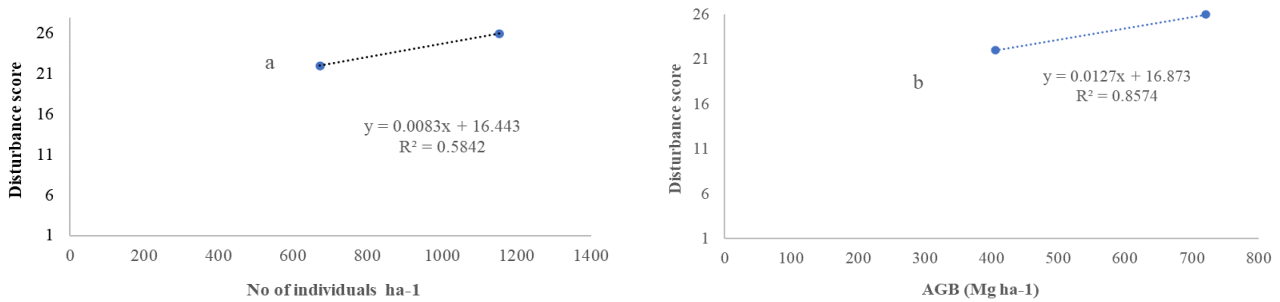
Fig. 7. *Correlation between forest site disturbance score and tree density (a) and above-ground biomass (b) in two tropical dry evergreen forest sites - Velleripet (VP) and Suryanpet (SP).*

et al., 2007), natural forests of Colombia (Phillips *et al.*, 2016; 226.9 Mg/ha^{-1}) and Banja forest in Ethiopia (Abere *et al.*, 2017; 720.6 Mg/ha^{-1}). The standing biomass of other Indian tropical moist forests, Western Himalaya (438 Mg ha^{-1}; Shahid and Joshi, 2015), Himalayan foothills (455 Mg ha^{-1}; Behera *et al.*, 2017), tropical moist deciduous forest (408.39 Mg ha^{-1}; Mohanta *et al.*, 2020), dry deciduous forest of Eastern Ghats (85.02 to 723.46 Mg ha^{-1}; Gandhi and Sundarpandian, 2017), Mirzapur forest division (244 to 732 Mg ha^{-1}; Singh and Singh, 1991) and moist deciduous forests of Katerniaghat Wildlife Sanctuary, Uttar Pradesh (290.8–455.9 Mg/ha^{-1}; Behera *et al.*, 2017) in India. In this study, the total tree carbon stock was 202.6 and 360.6 Mg/ha in sites SP and VP, respectively. This is due to the availability of soil nutrients, moisture content, forest type, slope, precipitation, age and stand girth class. Our results are compared with the tropical dry deciduous forest of India (Raha *et al.*, 2020; 32.7 to 135.1 Mg C/ha), Hays Inlet Conservation Park in Australia (Tran and Dargusch, 2016; 58.5–133.9 Mg C/ha), tropical deciduous forests (Becknell *et al.*, 2012; 39–334 Mg C/ha), tropical forests (secondary) of southern Mexico (Aryal *et al.*, 2014; 15–123.3 Mg C/ha), in the tropical dry forest (woody species) of India (Chaturvedi *et al.*, 2011; 15.6–151 Mg C/ha). Our results are greater than the reported (Majumdar *et al.*, 2016; 18.9–42.8 Mg C/ha) in Tripura, India and Silva *et al.*, 2018 reported

(55.91 Mg C/ha) in a seasonal semi-deciduous forest in Minas Gerais, Brazil.

Conclusion

The present study revealed the relationship between tree variables and anthropogenic disturbances using forest disturbance scores, and it found strong support for tree species richness and forest stand structure are influenced by different levels of human disturbance. Tree species richness was 27 (with dominant species *D. glabellus* Thw.), and 18 species (with dominant species *S. nux-vomica* L.) in SP and VP sites respectively. The differences in the edaphic and climatic factors in the study sites might be the reasons for the prevalence of the different dominate species in the study sites. The above-ground biomass values in the present study were 405.3 Mg/ha in SP and 721.333 Mg/ha in VP. This may be due to the larger stem density and basal area in the forest and also possibly due to the domination of *S. nux-vomica* (VP) and *D. glabellus* (SP), which are the members of larger girth classes in the study sites. Multiple factors threaten the tropical dry evergreen forests (TDEFs) and there is the continuous shrinking of TDEFs due to land-use changes such as expanding agriculture, plantations, and village developmental activities with their restricted geographical distribution. The study also revealed that local people have

a poor understanding of the ecological impacts of their resource extraction, leading to forest degradation and biodiversity loss. The conservation activities through the ecological restoration of degraded land portions and sacred groves with native species, the help and cooperation of local people are suggested to save these forests and their biodiversity from further degradation.

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Conflict of interest
The authors declare that they have no conflict of interest.

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