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Biomass Stockpile of Trees in Tropical Dry Evergreen Forests, Peninsular India

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Abstract

The uniqueness, importance and restricted geographical distribution of the Tropical Dry Evergreen Forests (TDEFs) flourishing on the coromandel coast of India has drawn the attention of researchers for a decade now and revealed numerous important findings. This work was attempted in few of the hitherto unstudied sites located in Tiruvarur and Nagapattinam districts of Tamil Nadu, India. The present study- assessed species richness (species ha^{-1}), stem density (number of trees ha^{-1}) and stand basal area (m^2 ha^{-1}); quantified above and belowground biomass of trees (Mg ha^{-1}) through allometric equations; and estimated wood density (WD) for selected species of TDEFs which do not have wood density data in published form. The study utilized a pantropical allometric formula. The regression model was applied to trees ≥5 cm dbh from an inventory of ten forest sites each of one hectare area. Ten TDEFs yielded 54 tree species (≥ 5 cm DBH) across 49 taxa under 25 families. Each TDEF yielded an average of 121.33±27.68 (S.D.) Mg ha^{-1} aboveground biomass. The results suggest that, these forests significantly accumulate a greater amount of above and belowground biomass than tropical dry deciduous forests of India. This study indicates that there could be a significant biomass carbon sink in more such remnants of this unique forest type.

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Introduction

Forests cover one-third of Earth's land area, virtually holding its 80 and 40 percent of total above and belowground terrestrial carbon, respectively.[1,2] It is estimated that the forests accumulate as much as 86% carbon pool of vegetation and 73% of the soils.[3,4] Biomass estimation and inventories of unstudied forest types becomes highly important in view of the crucial role they play, in controlling global carbon pools and fluxes.[5] Tropical forests are the largest sink of carbon in the world and it lodges ~212 Gt of carbon (C) in its vegetation.[6,7] Half of all the terrestrial C which account for about 80% of C exchange between terrestrial ecosystem and the atmosphere is present in the forests globally.[1,8]

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The climatic climax vegetation existing on the Coromandel coast region of South India has been classified as TDEF.[9] The total geographical cover of the forest type in India is 2072 km^2, further the forest type was considered as rarest[10] and endangered[11] in India. Notably, most proportion of the original forest cover (~95%) has been converted to other uses.[12,13] Of the remaining forest area, only 1% is being protected as reserve forest.[14] This terrestrial forest type surviving as patches along the Coromandel coast region.[15] Currently, TDEFs are divided and generally preserved as 'sacred groves' (SGs).[16] The characteristic features of TDEFs include lower basal area, uncommon cauliflory, and very rare presence of herbaceous vascular epiphytes and absence of large vertebrate dispersers.[17] Further, the Coromandel coast region is rich in endemic species. The region acts as home for 107 endemic species belonged to 74 genera and 33 species.[18] Besides, information on biomass stockpile of tropical dry evergreen forests (TDEFs) are very limited.[19,20] Therefore, the present study- assessed species richness (species ha^{-1}), stem density (number of trees ha^{-1}) and stand basal area (m^2 ha^{-1}) of trees in ten TDEF patches each with 1-ha study area; estimated wood density (WD) for selected species of TDEFs which do not have wood density data in published form, and quantified above and belowground biomass of trees (Mg ha^{-1}) through suitable allometric equations.

Material and Methods

Study Area

The occurrence of forest patches has been recorded through personal interviews with local people of Nagapattinam and Tiruvarur districts in Tamil Nadu. Personal interviews helped us to recorded 24 patches of TDEF sites, among 24 patches ten sites were selected based on the geographical cover. Ten TDEFs with a vegetation coverage exceeding 1-ha (the area of remaining 14 sites is <1-ha) each were selected for quantitative assessment of trees and estimation of above and below ground biomass. Of these, two were in Tamil Nadu's Thiruvarur (TV) district and eight were in Nagapattinam (NP) district (Fig.1). The selected forests occurring 1-5 km inland from the coast, a part of coastal plains of Coromandel coast region. Nagapattinam (10°10' and 11°20' N; 79°15' and 79°50' E) and Thiruvarur (10° 20' and 11° 07' N; 79° 15' and 79° 45' E) are Coromandel Coast districts of Tamil Nadu. In the NP and TV districts, the average maximum and minimum yearly temperatures and rainfall are 32 °C, 24.6 °C, and 1174 mm; and 36.9 °C, 29.8 °C, and 1091 mm, correspondingly. These forests experiences 5-6 dry months in a year.[21] The soil type of the study area is coastal alluvium, generally considered as moderately or poorly fertile.[22] Notably, the TDEF has been considered as oligotrophic habitat.[22,23] The characteristic species of TDEFs are *Manilkara hexandra, Memecylon umbellatum, Psydrax dicoccos, Pterospermum canescens and Sapindus emarginatus*,[10,24] whereas the dominant species vary across forest patches, for instance, *Memecylon umbellatum, Tricalysia sphaerocarpa* and *Drypetes sepiaria* dominating *Palvathunnan*,[25] Arasadikuppam and Karisakkadu[26] TDEFs, respectively.

Estimation of Tree Density. Species Richness and Basal Area

The total geographical cover of the studied forests varied from 1.5-ha to 5-ha, in order to keep the uniformity and facilitate the comparison, a 1-ha area was selected in each site. Quadrat method was adapted to find tree density (trees ha^{-1}) and species richness (number of species ha^{-1}). A sum of one hundred quadrats, 10m × 10m was laid in each study site (total 100m × 100m, 10,000 m^2, 1-ha). All the living trees with diameter at breast height ≥ 5 cm (DBH) were recorded and stem density (trees ha^{-1}) of these plots were directly calculated by totalling all the individuals in 100 quadrats. All the tree species recorded from 100 quadrats was summed to calculate species richness (number of species ha^{-1}). As recommended by researchers[27] the height of 40 trees, eight trees each in 10-20, 20.1-30, 30.1-40, 40.1-50 and >50 cm DBH classes was measured with the help of hypsometer and recorded in m. The mean height of DBH classes was utilized to estimate biomass storage of trees. Basal area of stem was calculated using the following formula. For multi-stemmed individuals, the BA calculated separately for each stem and summed.

$$\text{Basal area (cm}^2) = \pi \times (\text{DBH}/2)^2$$

Wood Density

By considering endangered status and restricted geographical extension of the TDEFs, the study kept minimum level of bioresource exploitation for the estimation of wood density (WD). WD data for 21

tree species were taken from a published literature.[17] Global Wood Density database provided such information for 16 species.[28] The present study also estimated WD value for 17 species for those species whose WD data is unavailable in published form as follows.[29,30] A sum of six wood cores (two cores each from three individuals) (0.51 cm diameter, 0.255 cm radius) for each species was collected using increment wood borer (make Haglof, Sweden). The length of collected wood cores measured with mm accuracy and recorded. All the collected samples were placed in a well-ventilated hot-air oven at 105 °C for 72 h. Wood cores re-weighed using a pan-top digital balance and dry weight recorded with mg accuracy. The volume of the wood samples was calculated as follows.

Volume of wood sample (cm^3)=$\pi \times r^2 \times L$

where, π is constant; r is radius (cm) and L is length (cm). Finally, the wood density of samples was estimated as follows.

Wood density (g/cm^3)= Dry weight of wood sample (g) /Volume of wood sample (cm^3)

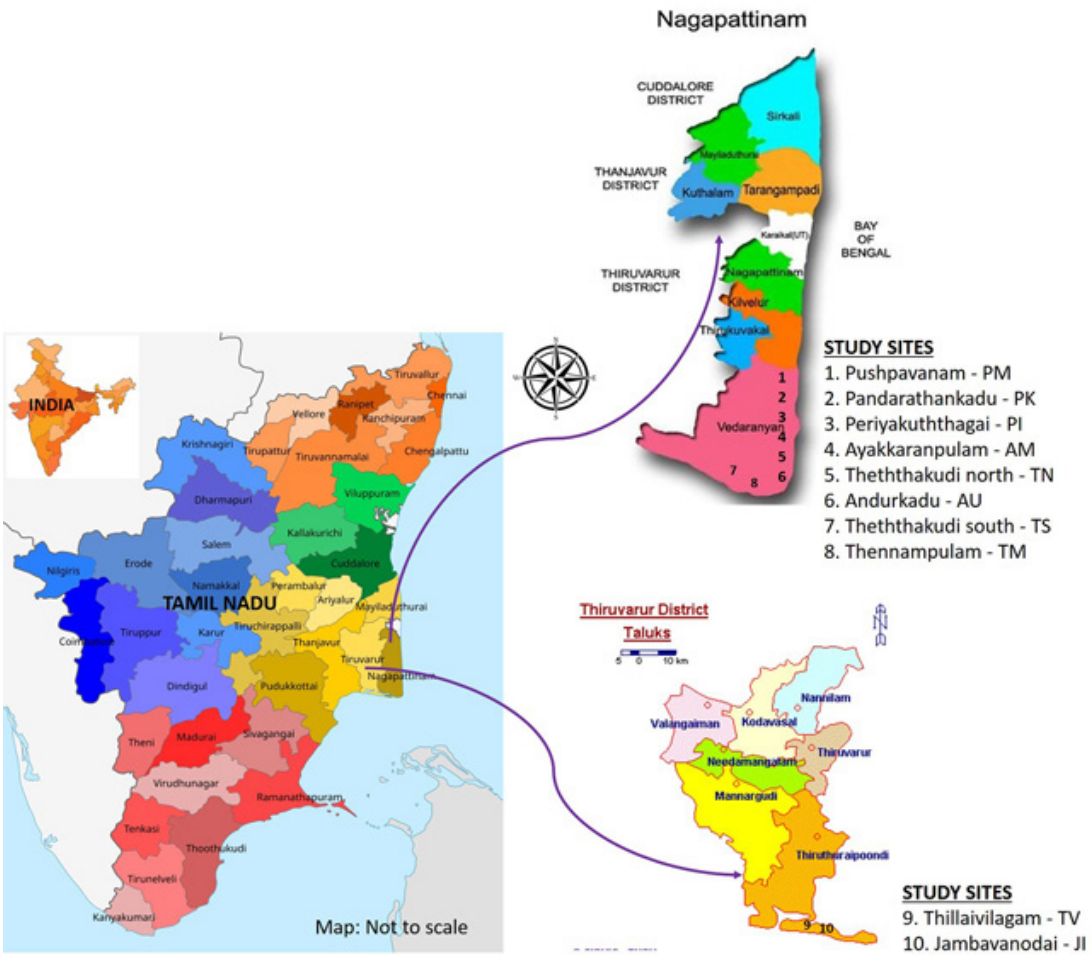

Fig. 1: Map of study area wherein biomass stockpile of trees assessed.

Above and Belowground BiomassEstimation

A regression equation[6] was used to estimate aboveground biomass (AGB): [$(AGB)_{est}$ = 0.0673 × $(pD^2H)^{0.976}$], where 0.0673 is constant, D is the trunk diameter at breast height (cm), H is the height in meters, and p is the oven-dry wood density (g cm^{-3}).

The present study utilized a regression equation[31] developed for the estimation of belowground biomass of trees in global tropical forests. BB = Exp [-1.0587 + 0.8836 × LN (ABD)]; where, -1.0587, 0.8836 are constants; BB is Belowground biomass (dry t ha-1); LN = Natural logarithm; ABD = Above-ground dry biomass (Mg ha^{-1}). Biomass values were multiplied by 0.50 to get carbon storage value of trees.[32] Statistical analyses carried out through a freely accessible online tool (https://www.socscistatistics.com/).

Table 1: Species, genera, family, stem density, basal area, biomass and carbon stockpile of trees in TDEFs, southern Coromandel Coast, peninsular India.

Sl.	Forest site	Geographical coordinates	No. of species	No. of genera	No. of families	Stem density (trees ha^{-1})	Basal area (m^2 ha^{-1})	AGB (Mg ha^{-1})	BGB (Mg ha^{-1})	Total biomass (Mg ha^{-1})	Carbon storage (Mg ha^{-1})
1	PM	10°29'29.99" N and 79°50' 19.60" E	26	23	18	638	15.58	110.86	22.23	133.09	66.545
2	PK	10°27'2.88" N and 79°50' 39.84" E	25	24	17	1084	23.84	141.96	27.66	169.62	84.81
3	PI	10°25'06.75" N and 79°49' 47.18" E	26	23	16	955	21.16	138.99	27.15	166.22	83.11
4	AM	10°27'2.88" N and 79°50' 39.84" E	31	31	20	400	15.66	94.36	19.28	113.64	56.82
5	TN	10°24'08.17" N and 79°49' 47.18" E	30	27	19	957	22.54	131.85	25.91	157.76	78.88
6	AU	10°23' 9.6" N and 79°48' 56.16" E	30	26	20	791	10.78	72.09	15.20	87.29	43.645
7	TS	10°26'20.35" N and 79°48'47.18" E	26	26	17	517	16.72	116.02	23.14	139.16	69.58
8	TN	10°26'55.52" N and 79°50' 19.60" E	31	30	18	523	14.3	103.7	20.96	124.66	62.33
9	TV	10°24'24.16" N and 79°32'40.71" E	34	33	18	1337	26.48	169.03	32.27	201.30	100.65
10	JI	10°23' 24.37" N and 79°31' 13.44" E	28	26	19	397	22.87	134.41	26.36	160.77	80.385
		Total	54	49	35	7599	189.9	1213.27	240.17	1453.44	726.755
		Mean (S.D.)	28.7± 2.95	26.9± 3.41	18.2± 1.32	759.9± 317.49	18.99± 5.05	121.33± 27.68	24.02± 4.87	145.35± 32.55	72.67± 16.28

Results

Species Richness, Stand Density and Basal Area

Out of ten TDEFs, 54 tree species (≥ 5 cm DBH) from 49 taxa under 25 families were surveyed (Table 1). The total number of species recorded at each of the ten sites ranged from a low of 24 species at site PM to a high of 35 species at site TV (Table 1). As to the number of genera recorded, site TV with 33 genera was found to be the maximum, and sites PI and PM each had a minimum of 23 genera. The sites, AM and AK had a maximum of 20 angiosperm families, while PI had 16 families. With eight species, the Rubiaceae family was the most speciose, followed by the Euphorbiaceae with six, the Ebenaceae with four, and the Moraceae, Rutaceae, and Sapindaceae with three each (Table 1). Physiognomically, evergreen species (30; 54.55%) dominated the study area followed by deciduous (17; 30.9%) and brevi-deciduous (8; 14.55%) species. The ten 1-ha plots had 7599 tree individuals (≥5 cm DBH). Site JI had a minimum stem density of 397 trees ha^{-1}, while site TV had a maximum of 1337 trees ha^{-1} (Table 1). Individual site basal areas ranged from 10.78 m^2 ha^{-1} for site AU to 26.48 m^2 ha^{-1} for TV (Table 1), whereas the mean BA of study area was 18.99±5.05 m^2 ha^{-1}. Cumulatively, *Memecylon umbellatum* was most abundant with 2331 stems (30.68%), whereas *Commiphora caudata, Premna latifolia, Sapium insigne* and *Terminalia arjuna* were represented by a single individual each in the study area (Table 2).

Table 2: Binomial, family, density (trees ha^{-1}), contribution of trees to total density and biomass recorded from the field study area.

No.	Binomial	Family	No. of trees	Contribution of density%	Contribution of biomass%
1	*Aglaia elaeagnoidea* (A .Juss .) Benth.	Meliaceae	30	0.39	0.42
2	*Albizia lebbeck* (L.) Benth.	Mimosaceae	16	0.21	0.66
3	*Allophylus serratus* (Hiern) Kurz	Sapindaceae	37	0.49	0.82
4	*Anacardium occidentale* L.	Anacardiaceae	12	0.16	0.13
5	*Atalantia monophylla* DC.	Rutaceae	300	3.95	4.78
6	*Azadirachta indica* A. Juss.	Meliaceae	37	0.49	0.71
7	*Benkara malabarica* (Lam.) Tirveng.	Rubiaceae	256	3.37	1.86
8	*Breynia vitis-idaea* (Burm. f.) C.E.C. Fisch.	Euphorbiaceae	55	0.80	0.22
9	*Calophyllum inophyllum* L.	Clusiaceae	5	0.07	0.04
10	*Canthium coromandelicum* Alston	Rubiaceae	51	0.67	0.67
11	*Canthium dicoccum* (Gaertn.) Merr.	Rubiaceae	384	5.05	1.01
12	*Carmona retusa* (Vahl) Masam.	Boraginaceae	9	0.12	0.43
13	Cassia fistula L.	Caesalpiniaceae	138	1.82	1.62
14	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	31	0.41	0.21
15	*Chionanthus zeylanicus* L.	Oleaceae	10	0.13	0.02
16	*Commiphora caudata* Engl.	Burseraceae	1	0.01	0.01
17	*Crateva magna* (Lour.) DC.	Capparidaceae	32	0.42	0.26
18	*Diospyros ebenum* J. König	Ebenaceae	148	1.95	1.64
19	*Diospyros ferrea* (Willd.) Bakh.	Ebenaceae	303	3.98	2.4
20	*Diospyros montana* Roxb.	Ebenaceae	38	0.5	0.42

21	*Diospyros peregrina* Gurke	Ebenaceae	5	0.07	0.04
22	*Drypetes sepiaria* (Wight & Arn.) Pax & K. Hoffm.	Euphorbiaceae	259	3.41	14.06
23	*Ehretia pubescens* Benth.	Boraginaceae	46	0.61	0.22
24	*Euphorbia antiquorum* L.	Euphorbiaceae	6	0.08	0.02
25	*Ficus benghalensis* L.	Moraceae	14	0.18	0.78
26	*Ficus hispida* L. f.	Moraceae	27	0.35	0.07
27	*Flacourtia indica* (Burm. f.) Merr.	Flacourtiaceae	34	0.45	0.02
28	*Garcinia spicata* Hook.	Clusiaceae	645	8.49	14.66
29	*Glycosmis mauritiana* Tanaka	Rutaceae	547	7.19	2.31
30	*Gmelina asiatica* L.	Verbenaceae	119	1.57	3.64
31	*Ixora pavetta* Andrews	Rubiaceae	117	1.54	0.74
32	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	82	1.08	0.52
33	*Lepisanthes tetraphylla* (Vahl.) Radlk.	Sapindaceae	126	1.66	6.79
34	*Madhuca longifolia* (J. König ex L.) J.F. Macbr.	Sapotaceae	29	0.38	0.32
35	*Manilkara hexandra* (Roxb.) Dubard	Sapotaceae	153	2.01	2.57
36	*Maytenus emarginata* (Willd.) Ding Hou	Celastraceae	113	1.49	0.65
37	*Memecylon umbellatum* Burm. f.	Melastomataceae	2331	30.68	17.19
38	*Morinda coreia* Buch. -Ham.	Rubiaceae	5	0.07	0.1
39	Ochna serrata L.	Ochnaceae	57	0.75	0.27
40	*Pamburus missionis* (Wight) Swingle	Rutaceae	39	0.51	0.41
41	*Pavetta indica* L.	Rubiaceae	177	2.33	0.09
42	*Phyllanthus reticulatus* Poir.	Euphorbiaceae	14	0.18	0.04
43	*Pongamia pinnata* (L.) Merr.	Papilionaceae	57	0.75	0.21
44	*Premna latifolia* Roxb.	Verbenaceae	1	0.01	0.01
45	*Pterospermum canescens* Roxb.	Sterculiaceae	167	2.19	4.79
46	*Sapindus emarginatus* Vahl	Sapindaceae	16	0.21	0.03
47	*Sapium insigne* (Royle) Benth. & Hook. f.	Euphorbiaceae	1	0.01	0.01
48	*Securenega leucopyrus* (Willd.) Muell.-Arg.	Euphorbiaceae	17	0.22	0.03
49	*Streblus asper* Lour.	Moraceae	53	0.69	0.8
50	*Syzygium cumini* (L.) Skeels	Myrtaceae	160	2.12	9.61
51	*Tamarindus indica* L.	Caesalpiniaceae	13	0.17	0.03
52	*Tarenna asiatica* Kuntze ex K. Schum.	Rubiaceae	270	3.55	0.52
53	*Terminalia arjuna* Wight & Arn.	Caesalpiniaceae	1	0.01	0.01
54	*Thespesia populnea* (L.) Sol. Ex Corrêa	Malvaceae	5	0.07	0.03
	Total	-	7599	100	100

Wood Density

Wood density ranged from a minimum of 0.37±0.03 g cm^{-3} (*Crataeva magna*) to a maximum of 0.98±0.15 g cm^{-3} (*Tamarindus indica*). Among evergreen trees, *Tarenna asiatica* had high WD (0.89±0.06 g cm^{-3}) followed by *Aglaia elaegnoidea* (0.87±0.05g cm^{-3}) and *Atalantia monophylla* (0.84 g cm^{-3}), while *Tamarindus indica* (0.98±0.15 g cm^{-3}) and *Albizia saman* (0.74±0.06 g cm^{-3}) held high WD among deciduous trees. The present study estimated an average of 0.71±0.053 g cm^{-3} WD value for each species (Table 3). The average WD value of evergreen species was 0.723±0.065 g cm^{-3}, while it was 0.662±0.057 g cm^{-3} for deciduous species.

Table 3: Wood density of trees found in ten TDEFs of southern Coromandel coast, India.

No.	Species	Wood density (g cm^{-3} ± SD)
1.	*Allophylus serratus* (Hiern) Kurz	0.42±0.04
2.	*Anacardium occidentale* L.	0.47±0.06
3.	*Benkara malabarica* (Lam.) Tirveng.	0.63±0.1
4.	*Breynia vitis-idaea* (Burm. f.) C.E.C. Fisch.	0.67±0.05
5.	*Canthium coromandelicum* Alston	0.72±0.03
6.	*Catunaregam spinosa* (Thunb.) Tirveng.	0.67±0.02
7.	*Cordia pubescens* Willd. ex Roem. Schult.	0.67±0.003
8.	*Ficus hispida* L. f.	0.37±0.02
9.	*Flacourtia indica* (Burm. f.) Merr.	0.69±0.05
10.	*Gmelina asiatica* L.	0.49±0.18
11.	*Ixora pavetta* Andrews	0.69±0.12
12.	*Maytenus emarginata* (Willd.) Ding Hou	0.69±0.03
13.	*Ochna squarrosa* L.	0.80±0.04
14.	*Pamburus missionis* (Wight) Swingle	0.78±0.08
15.	*Sapindus emarginatus* Vahl	0.71±0.12
16.	*Streblus asper* Lour.	0.72±0.02
17.	*Tamarindus indica* L.	0.98±0.15
	Sub total (17 species)	11.70±0.065
	Cumulative WD value for 21 species 17	15.63±0.053
	Cumulative WD value of 16 species 28	11.02±0.086
	Total	**38.35/54**
	Mean WD value (54 species)	**0.71**

Aboveground Biomass

An average of 121.33±27.68 (S.D.) Mg ha^{-1} AGB was estimated in each TDEF. AGB ranged from a minimum of 72.09 Mg ha^{-1} in AU to a maximum of 169.03 Mg ha^{-1} in TV. A total of 1213.27 Mg of AGB was present in ten TDEFs (Table 4). At species-level, ten species which include *Memecylon umbellatum* (17.19 %, 208.52 Mg), *Garcinia spicata* (14.66 %, 177.82 Mg) and *Drypetes sepiaria* (14.06 %, 170.53) were contributed 80.49 % (976.55 Mg) to total AGB, whereas rest of 44 species contributed only 19.51 % (236.71 Mg) to total AGB (Fig. 2). Among eight diameter classes (5-10, 10.1-20, 20.1-30, 30.1-40, 40.1-50, 50.1-60, 60.1-70 and >70 cm), the diameter class >70 cm DBH was contributed a maximum of 217.65 Mg (17.72%) to total AGB (ten sites), whereas a minimum was constituted by 5-10 cm DBH (39.39 Mg, 3.25 %) (Table 4).

Belowground Biomass

The mean belowground biomass storage recorded as 5.24±0.14 Mg ha^{-1}. The site TV stored higher below ground tree biomass (BGB) (32.27 Mg ha^{-1}) followed by PK (27.66 Mg ha^{-1}), PI (27.15 Mg ha^{-1})

and JI (26.36 Mg ha-[1]), sites PM, TM and TS showed intermediate value. While, AU and AM had less amount of BGB, 15.2 and 15.44 Mg ha^{-1}, respectively. (Table 1).

Table 4: Contribution of diameter classes (cm) to total AGB in TDEFs of southern Coromandel coast, India. (Percentages are in parenthesis)

	Diameter class (cm)								
Site	**5-10**	**10.1-20**	**20.1-30**	**30.1-40**	**40.1-50**	**50.1-60**	**60.1-70**	**>70**	**Site AGB**
AU	3.89 (5.40)	27.64 (38.34)	16.44 (22.80)	10.83 (15.02)	11.11 (15.41)	-	2.18 (3.03)	-	72.09
AM	1.14 (1.21)	15.35 (16.27)	19.62 (20.79)	20.09 (21.28)	23.7 (25.12)	10.47 (11.1)	-	3.99 (4.22)	94.36
JI	1.6 (1.19)	9.53 (7.09)	17.07 (12.70)	17.42 (12.96)	18.66 (13.88)	12.26 (9.12)	11.66 (8.67)	46.21 (34.39)	134.41
PK	6.67 (4.7)	10.63 (7.49)	16.64 (11.72)	20.3 (14.3)	22.94 (16.16)	15.86 (11.17)	14.87 (10.47)	34.05 (23.99)	141.96
PI	6.03 (4.34)	21.07 (15.16)	26.88 (19.34)	22.61 (16.26)	22.62 (16.27)	16.76 (12.07)	13.49 (9.70)	9.53 (6.86)	138.99
PM	2.77 (2.50)	12.26 (11.06)	17.08 (15.40)	17.8 (16.05)	12.43 (11.21)	15.24 (13.75)	11.36 (10.25)	21.92 (19.79)	110.86
TM	3.03 (2.92)	10.52 (10.14)	10.93 (10.55)	17.75 (17.12)	14.14 (13.65)	11.94 (11.50)	9.95 (9.59)	25.44 (24.53)	103.7
TN	4.97 (3.77)	21.82 (16.55)	28.56 (21.65)	20.59 (15.62)	13.51 (10.25)	11.93 (9.05)	9.43 (7.15)	21.04 (15.96)	131.85
TS	1.97 (1.70)	12.38 (10.67)	13.09 (11.28)	13.79 (11.89)	21.77 (18.77)	13.81 (11.90)	18.44 (15.89)	20.77 (17.90)	116.02
TV	7.32 (4.33)	29.44 (17.42)	29.01 (17.16)	23.56 (13.94)	17.73 (10.49)	15.03 (8.89)	12.24 (7.24)	34.7 (20.53)	169.03
Total	39.39 (3.25)	170.64 (14.06)	195.32 (16.10)	184.74 (15.23)	178.61 (14.72)	123.3 (10.16)	103.62 (8.54)	217.65 (17.94)	1213.27 (100)

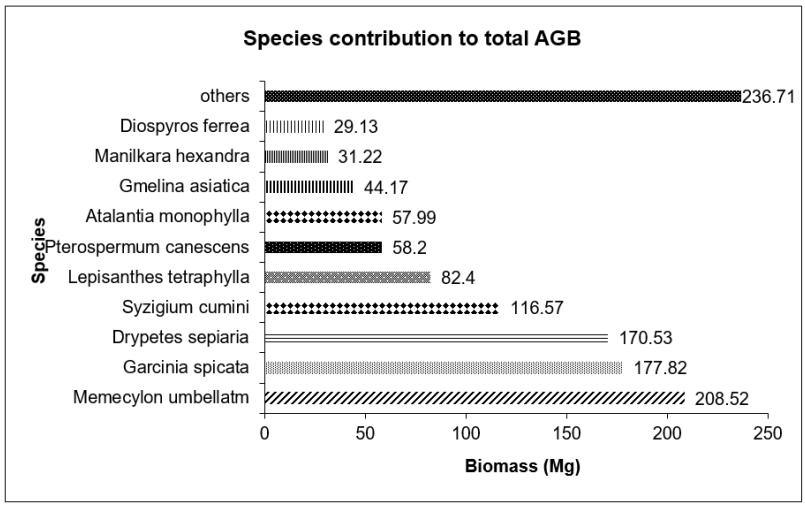

Fig. 2: Contribution of AGB by ten dominant species in TDEFs, Coromandel coast, India

Discussion

Species Richness and Basal Area

Compared to the wet evergreen forests of India's Western Ghats, tropical dry evergreen forests have a comparatively higher tree stand density and are moderate in terms of species diversity and stand basal area.[33] Tree diversity per unit area tends to increase when rainfall increases.[34-36] TDEFs receive less annual rainfall (1100-1200 mm) than Western Ghats (>1400 mm). The total, mean and range of species richness (55 species; range 25-34, mean 28.7±2.95), tree density ha^{-1} (7599 individuals, range 397-1337, mean 759.9±317.49) and forest stand basal area (189.9 m^2; range 10.78-26.48 m^2, mean 18.99±5.05 m^2) found in the present study are comparable with previous studies on TDEFs of Coromandel coast of India.[19,37,38]

Wood Density

Trees with dense wood have reduced leaf water potential, smaller leaves, and lower mortality.[29] The current study's mean WD (0.71±0.053 g cm^{-3}) falls well within the range of WD found in Indian forests (0.232-1.280 g cm^{-3}).[29] The mean WD of the current study is relatively higher than that reported for the nation-wide mean WD recorded for Africa (0.648 g cm^{-3}) and North America (0.540 g cm^{-3}) and lesser than in Australia (0.725 g cm^{-3}).[29] Physiognomically, Indian TDEFs are dominated by evergreen species.[16,21] This study recorded 30 (54.55 %) evergreen tree species; their mean WD value was 0.723±0.065 g cm^{-3}. This result complies with that of an earlier findings,[39] they found dense wood in species with slow returns on investment (evergreens). Amount of soil carbon, phosphorous and nitrogen appears to be less in TDEFs.[37,40] A negative correlation (wood density increases when soil fertility decreases) was obtained by many.[41-43] High mean WD of present study could have contributed by less soil fertility and good proportion of evergreen species.

Above and Belowground Biomass Storage

The stored AGB in the study area (1213.27 Mg) is relatively higher than that reported earlier,[17] the previous study estimated a total of 1022.4 Mg AGB from ten TDEFs of Coromandel coast. The total AGB of this study was estimated from the basal areas of 189.9 m^2 (ten sites) compared to 218.3 m^2 basal areas quantified by them. It could be reasoned for arriving a higher AGB in our study that the present study considered WD and height (H), whereas, they used only basal area to estimate AGB in a similar forest type. Further, the mean total biomass storage of present study area is higher than in average total biomass storage of tropical dry deciduous forests of India (93.8 Mg ha^{-1}).[44]

A total of 240.17 Mg of BGB estimated from ten TDEFs, and shoot to root ratio and percentage of BGB were 5.024 (range 4.74 to 5.24), and 19.91 (range 19.09 to 21.08 %), respectively. It is complying with the original findings[31] (range 18–30 %) who suggested a generalized regression equation to estimate BGB in forest ecosystems. Results on BGB showed that percentage of (19-21%) accumulation of BGB in TDEFs is higher than that of other forest types of India. A group of researchers from India[45] reported 5, 6.4, 9.3, 10.7 and 12.1 % BGB, respectively, from southern thorn forests, Euphorbia scrub, evergreen scrub, deciduous and secondary deciduous forests, respectively.

Carbon Storage of Trees

The mean carbon storage value (72.67±16.28 Mg C ha^{-1}) of present study area is greater than what has been reported for tropical (44.3 Mg C ha^{-1}), sub-tropical (40.5 Mg C ha^{-1}) and alpine (45.3 Mg C ha^{-1});[46] mangrove (28.24 Mg C ha^{-1}), Dipterocarp (28.00 Mg C ha^{-1}) and Sal (24.07 Mg C ha^{-1}) forests of India.[47] The average C storage of our study area is comparable with area weighted average C storage of world's forest (70 Mg C ha-^{1}).[48]

Conclusion

TDEFs accumulate higher AGB and BGB in its vegetation when compared to other dry forests of India. Considering its moderate biodiversity and restricted geographical extension, conservation and protection measures are needed to protect/preserve these valuable forest sites. Data obtained from this study could be useful as a tool for foresters, forest managers and ecologists to select indigenous species for afforestation and re-forestation programmes. The present study contributes substantial amount of essential information on biomass and C storage of TDEFs. However, long-term studies are needed to evaluate annual biomass and C sequestration potential of TDEFs in southern Coromandel Coast, India.

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Conflict of Interest
The author(s) do not have any conflict of interest.

Data Availability Statement
The manuscript incorporates all datasets produced or examined throughout this research study.

Ethics Statement
This research did not involve human participants, animal subjects, or any material that requires ethical approval.

Informed Consent Statement
This study did not involve human participants, and therefore, informed consent was not required.

Author Contributions
MU designed and conceptualized the study. MU and JE conducted field surveys, collection and estimation of biomass from study area. JE prepared the first draft of the manuscript, MU corrected and revised it.

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