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Aboveground Biomass Stockpile of Trees in Southern Thorn Forest, Tuticorin, Peninsular India

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Abstract

A forest tree inventory study was conducted in Vallanadu Black buck sanctuary, Tuticorin.The current study was conducted to assess tree density, species richness, basal area (BA) and aboveground biomass (AGB) stockpile. The study area has been classified as Southern Thorn Forest (STF). One hundred square plots (total area 1 ha), each 10m × 10m (100 m^2 each) laid randomly across study area. All live trees with ≥5 cm diameter at breast height (DBH) measured at 137 cm above the ground. As the whole, 1335 individual trees ≥5cm DBH recorded. A total number of 18 species recorded from 14 genera and 11 families in study area. The family Mimosaceae has maximum number of species (7 species) followed by Rhamnaceae (2 species), while 9 families had just single species' each. The total basal area recorded was 22.046 m^2 ha^{-1}, while, the mean wood density (WD) of trees estimated as 0.70±0.093 g cm^{-3}.Total amount of 50.065Mg ha^{-1} present in STF. The contribution of different species in terms of total AGB varied significantly. *Commiphora berryi* stocked 45.13% (22.588 Mg ha^{-1}) of AGB followed by *A. planifrons* (23.31%, 11.669 Mg ha^{-1}), *A. mellifera* (7.233%, 3.621Mg ha^{-1}), whereas remaining 15 species collectively stocked 24.327% (12.187Mg ha^{-1}) AGB. The STF had a large number of trees compared to some dry forests within Tamil Nadu. Southern Thorn Forest endowed with a moderate number of trees species. Aboveground biomass stockpile of trees is comparable with the range recorded from Indian dry forests. The study area experiences lesser mean annual rainfall and >6 months dry season. Further, endowed with short-bole and smaller leaved trees, hence stocked a relatively lesser AGB in trees.

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Introduction

About one half of the existing forests are found in world's tropical regions, in which about 42% classed as dry forest.[1] Dry forests are closely linked to human life hence they are relatively highly utilized and are threatened.[2] Research on dry forests have been limited and are less protected compared to moist forests.[3] Perhaps, dry forests are more threatened among all forests, need immediate attention. Baseline information such as density, species richness, basal area and aboveground biomass storage are important to frame conservation measures and protect from further degradation and loss.[4] Soil moisture content acts as one of the determining factors, affecting plant species diversity and dispersion in dry forests.[5, 6] In addition, plants of dry forests are largely subjected to water stress during dry period of the year.[7, 8] Dry forests tends to have moderate to high plant species richness and diversity.[9-11]

Globally, forests hold a significant amount of above (80%) and belowground (40%) terrestrial carbon.[12] Atmospheric CO2 concentration is closely linked with earth's biomass C stockpile. Forest degradation and habitat destruction contributes to global climate change. Besides, global warming influences a range of factors in ecosystem functioning.[13,14] Information on aboveground biomass stockpile of unexplored tropical dry forests are highly important to determine the role they play in the abatement of climate change.[15] In addition, global dry forests have the ability to store a significant amount of carbon in vegetation.[16] Quantitative ecological information such as density and aboveground biomass stockpile of trees has been very limited for dry forests of Tamil Nadu. The currentstudy was planned to assess density, aboveground biomass stockpile and species richness of trees in Vallanadu blackbuck sanctuary located at Tuticorin district, Peninsular India.

Materials and Methods

Study Area

The Vallanadu Blackbuck Sanctuary located in Tuticorin district of Tamil Nadu, one of the southern states of India (Figure 1). The forest type of study region regarded as Southern Thorn Forests (STFs) (6A/DSI), covers an area of 1641 ha.[17] Geographical coordination of study area lies between 80º39'45" and 80 44'00" Northern latitude, and 77º54' 45" to 77º 57'10'' Eastern longitude. Annual rainfall of study area is 75.8 cm. The northeast monsoon is important, the study area receives most part of the annual rainfall during October-December. The study area experiences six to nine months of dry season. Annual mean low and high temperature of study area are 23ºC and 29ºC. Plants of STFs adapted for drought and survive under the dry environment. Additionally, trees are leafless during the dry period. Trees have smaller and thick wax coated leaves to avoid moisture loss through transpiration. Thorny plants such as various species of *Acacia*, *Dichrostachys cinerea*, *Commiphora berryi* and *Ziziphus nummularia*, *Z. mauritiana* and *Z. xylopyrs* are characteristics of STFs. The sanctuary is one of the homes for threatened mammalian species *Antilope cervicarpa* L., commonly known as Black buck. Further, the sanctuary also endowed with considerable number of mammals and birds.[18]

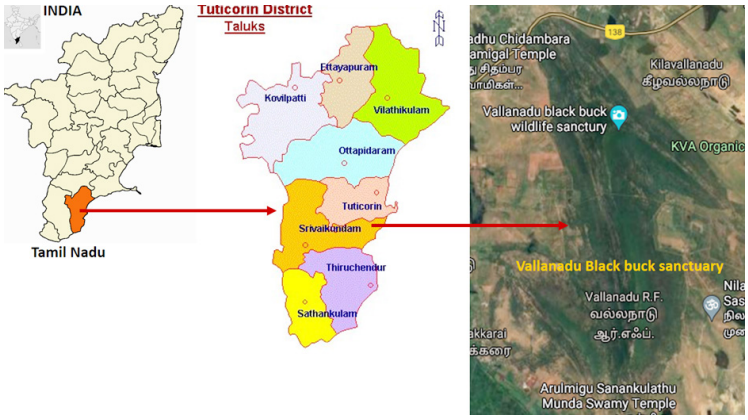

Fig.1: Map of study area wherein quantitative study conducted for estimation of aboveground biomass stockpile of trees

Field Survey

One hundred square plots, each 10m × 10m (100 m^2 each, total 1 ha) laid randomly across Vallanadu Black buck sanctuary. All living trees ≥5 cm DBH measured at 137 cm above the ground. Diameter (cm) of all recorded trees noted. All the species identified with the help of regional floras.[19, 20] The cross sectional area of tree at 137 cm above the ground defined as basal area. The BA of trees estimated through the following formula. $BA=\pi*(DBH/2)^2$. The height of trees ranged from 3 to 6 m, hence it was measured with a graduated pole. Wood density of trees estimated as explained in Chave *et al*.[21] A widely used allometric formula provided by Chave *et al*.[22] was utilized for the estimation of aboveground biomass of trees in study area as follows: $AGB_{Dry} = 0.0559*(\rho D^2H)$; where AGB_{Dry} is dry aboveground biomass of tree (kg); 0.0559 is constant; ρ is tree wood density (g/cm^3); D is DBH (cm); and H is tree height (m). The allometric formula is applicable for trees pantropically, with DBH between 5 to 156 cm, and not applicable for palms.

Table 1: Tree species, family and density (number of individuals) recorded in Southern Thorn Forest, Vallanadu, Tuticorin

Species	Family	Density
Acacia leucophloea (Roxb.) Willd.	Mimosaceae	10
Acacia mellifera (M. Vahl) Benth.	Mimosaceae	165
Acacia planifrons Wight. &Arn.	Mimosaceae	261
Albizia amara (Roxb.) B.Boivin	Mimosaceae	24
Albizia lebbeck (L.) Benth.	Mimosaceae	7
Azadirachta indica L.	Meliaceae	12
Bauhinia racemosa Lam.	Caesalpiniaceae	1
Catunaregam spinosa (Thunb.) Tirveng	Rubiaceae	8
Commiphora berryi (Arn.) Engl.	Burseraceae	334
Dalbergia spinosa Roxb.	Papilionaceae	100
Dichrostachys cinerea (L.) Wight. &Arn.	Mimosaceae	225
Gmelina arborea Roxb.	Verbenaceae	1
Grewia orbiculata Rottler	Tiliaceae	65
Haplophragma adenophyllum (Wall. ex G. Don) Dop	Bignoniaceae	26
Lannea coromandelica (Houtt.) Merr.	Anacardiaceae	1
Prosopis juliflora (Sw.) DC.	Mimosaceae	7
Ziziphus nummularia (Burm.f.) Wight &Arn.	Rhamnaceae	41
Ziziphus xylopyrus (Retz.) Willd.	Rhamnaceae	47
Total	11	1335

Results

Density and Species Richness

A total number of 1335 trees ≥5cm DBH were recorded from one ha area of STF. Density of represented species varied significantly in study area. *Commiphora berryi* dominated the STF with 334 (25.02%) individuals followed by *Acacia planifrons* (261, 19.55%), *Dichrostachys cinerea* (225, 16.85%) and *Acacia mellifera* (165, 12.36%), while *Bauhinia racemosa*, *Gmelina arborea* and *Lannea coromandelica* were represented by just single individual each. Likewise, contribution of families to total stand density also differed considerably. The family Mimosaceae constituted 52.36% (699 trees) of tree community followed by Burseraceae (25.019%, 334) and Papilionaceae (7.49%, 100), while rest of eight families constituted 15.131% in STF (Table 1).

Among eight diameter classes, the smallest diameter class 5-8 cm DBH represented by large number of individuals (341 individuals) followed by 11.1-14 (279), 8.1-11 (241), 14.1-17 (215), ≥26 (96), 23.1-26 (89), 17.1-20 (70) and 20.1-23 (4).

The study found 18 species from 14 genera and 11 families in the study area. The family Mimosaceae (= sub family Mimosoideae) had seven species followed by Rhamnaceae (2 species), while 9 families Anacardiaceae, Bignoniaceae, Burseraceae, Ceasalipiniaceae, Meliaceae, Papilionaceae, Rubiaceae, Tiliaceae and Verbenaceae had just single species' each in STF (Table 1).

Table 2: Species, density, basal area and aboveground biomass stock of trees in thorn forest of Vallanadu Blackbuck sanctuary, Tuticorin, Peninsular India

Botanical name	No. of trees/ha	BA m^2/ha	AGB Mg/ha
Commiphora berryi	334	11.748	22.588
Acacia planifrons	261	4.682	11.669
Dichrostachys cinerea	225	1.884	6.572
Acacia mellifera	165	1.412	3.621
Albizia amara	24	0.474	1.124
Haplophragma adenophyllum	26	0.338	0.723
Dalbergia spinosa	100	0.257	0.639
Albizia lebbeck	7	0.267	0.616
Azadirachta indica	12	0.22	0.610
Acacia leucophloea	10	0.177	0.492
Grewia rotundifolia	65	0.211	0.466
Ziziphus nummularia	41	0.15	0.396
Ziziphus xylopyrus	47	0.144	0.348
Prosopis juliflora	7	0.022	0.055
Catunaregam spinosa	8	0.021	0.051
Lannea coromandelica	1	0.018	0.041
Bauhinia racemosa	1	0.011	0.027
Gmelina arborea	1	0.01	0.026
Total	1335	22.046	50.065

Tree Stand Basal Area

The total BA recorded as 22.046 m^2 ha^{-1}. Contribution of BA by species to total stand BA differed significantly. *Commiphora berryi* had maximum BA (11.748 m^2 ha^{-1}) subsequently, *Acacia planifrons* (4.682 m^2 ha^{-1}), *Dichrostachys cinerea* (1.884 m^2 ha^{-1}) and *A. mellifera* (1.412 m^2 ha^{-1}) in STF. Fourteen species had <0.5 m^2 BA ha^{-1} (0.01 to 0.474). As with families, Burseraceae, Mimosaceae and Bignoniaceae had higher BA 11.748, 8.918 and 0.338 m^2 BA ha^{-1}, respectively. All other families jointly had 1.042 m^2 BA ha^{-1} (Table 2).

The diameter class ≥26 cm DBH constituted a larger BA (5.648 m^2 ha^{-1}; 25%) afterwards 23.1-26 cm and 14.1-17 cm hold relatively higher BA 4.323 (19%) and 3.944 (18%) m^2 ha^{-1}, respectively in study area. While, the diameter class 20.1-23 cm DBH hold just 0.144 m2 ha^{-1}BA (Figure 2).

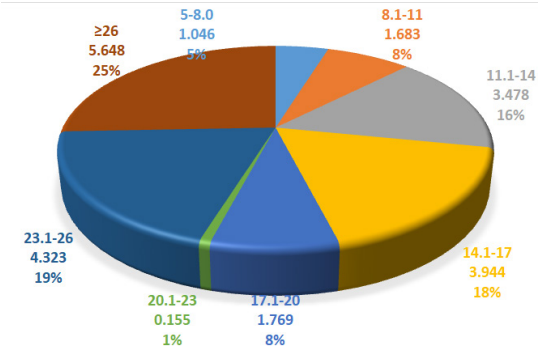

Fig. 2: Contribution of diameter classes to total forests stands' basal area in Vallanadu Black buck sanctuary. Legend order: DBH class (cm), BA (m^2 ha^{-1}) and contribution of DBH classes to total BA (per cent)

Wood Density

The mean wood density (WD) of trees in STF recorded as 0.70±0.093 g cm^{-3}.The wood density varied across species, *Dichrostachys cinerea* found as heavy wooded (0.98±0.04 g cm^{-3}) followed by *Acacia leucophloea* and *Azadirachta indca* (each had 0.78 g cm^{-3}) in STF. The dominant species *Commiphora berryi* had a least WD (0.54±0.04 g cm^{-3}) in our study area (Table 3).

Table 3: Wood density of trees recorded from Vallanadu Blackbuck Sanctuary, Tamil Nadu

Species	Wood density (g cm^{-3})
Acacia leucophloea	0.78±0.02
Acacia mellifera	0.72±0.02
Acacia planifrons	0.7±0.04
Albizia amara	0.64±0.01
Albizia lebbeck	0.74±0.03
Azadirachta indica	0.78±0.05
Bauhinia racemosa	0.66±0.04
Catunaregam spinosa	0.68±0.03
Commiphora berryi	0.54±0.02
Dalbergia spinosa	0.7±0.04
Dichrostachys cinerea	0.98±0.04
Gmelina arborea	0.69±0.02
Grewia rotundifolia	0.62±0.03
Haplophragma adenophyllum	0.6±0.04
Lannea coromandelica	0.64±0.05
Prosopis juliflora	0.72±0.02
Ziziphus nummularia	0.74±0.04
Ziziphus xylopyrus	0.68±0.03
Mean±S.D.	0.70±0.093

Aboveground Biomass Stockpile

In total, 50.065 Mg aboveground biomass (AGB) present in one ha area of STF. Contribution of species to total AGB varied significantly. *Commiphora berryi* stocked 45.13% (22.588 Mg ha^{-1}) of AGB followed by *A. planifrons* (23.31%, 11.669 Mg ha^{-1}), and *A. mellifera* (7.233%, 3.621 Mg ha^{-1}), whereas remaining 15 species collectively stocked 24.327% (12.187 Mg ha^{-1}) AGB in STF.With seven species, the family Mimosaceae stocked a highest amount of AGB (48.24%, 24.150 Mg ha^{-1}) followed by Burseraceae (45.12%, 22.588 Mg ha^{-1}) and Bignoniaceae (1.44%, 0.723Mg ha^{-1}), while remaining eight families cumulatively stocked 5.2% (2.603 Mg ha^{-1}) in STF.Of eight diameter classes, the largest diameter class ≥26 cm DBH stocked a highest amount of AGB 10.859 Mg ha^{-1} followed by 14.1-17cm (9.508 Mg ha^{-1}) and 11.1-14 cm (9.098 Mg ha^{-1}), but 20.1-23 cm DBH class stocked just 0.354 Mg ha^{-1} in STF, (Figure 3).

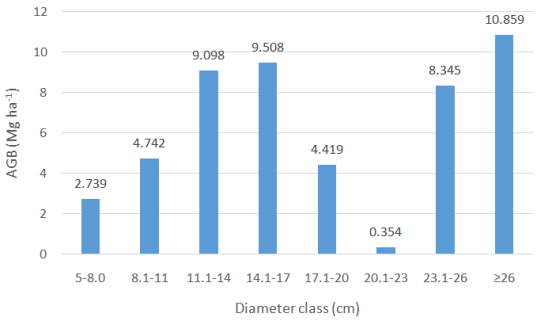

Fig. 3: Aboveground biomass stockpile of diameter classes in study area

Discussion

Density

Density of trees in STF (1335 individuals ha^{-1}) is comparable with dry deciduous forests of Madhya Pradesh (range, 690-2500 individuals ha^{-1}),[23] and tropical dry evergreen forests of Tamil Nadu (range, 432-1341 individuals ha^{-1}).[24] Tree density of STF is higher compared to tropical dry forests of Eastern Ghats (479 individuals ha^{-1}),[25] dry forest of Bannerghatta National Park (994),[26] dry forest of Andhra Pradesh (510-648),[27] dry forests of Southern Western Ghats (350-1120),[28] dry deciduous forests of Andhra Pradesh (395-573),[29] Dharmapuri, Tamil Nadu (292),[30] tropical forests of Garo hills, north-eastern India (570-846),[31] semi-arid forest of Delhi (633-684).[32] The forest is low statured, height of trees varied from 3-7 m. The STF in Vallanadu Black buck sanctuary has been protected legally (Department of Forest, Government of Tamil Nadu) hence cutting of trees for fuel wood and poaching are banned. The bird community of STF depend upon the fleshy fruits of dominant tree species, *Commiphora berryi*. Woody plants of STF produces fruits close to wet season. These are the probable reasons behind the higher density of trees in STF.

Species Richness

Tree species richness (18 species ha^{-1}) of STF is higher than in dry forests of Chhattishgarh (5-9 species ha^{-1})[33] Madhya Pradesh (2-14)[23] and Mandla (12-14).[34] Tree species richness of STF is comparable with dry forests of Tamil Nadu. Tiwari and

Ravikumar[35] found 17 species in Carnatic Umbrella Thorn forest,[20] in dry bamboo brake,[17] in *Hardwickia* forest,13 in riverine and 14 in Southern dry scrub forest occurring within Hosur district forest division, Tamil Nadu. Conversely, species richness of STF is lower compared to dry forests of Nagapattinam (21-25 species ha^{-1}),[36] Tiruvarur (26-34),[36] Cuddalore (28-31),[37-39] Pudukottai (28-35)[40] and Mudumalai (64)[41] in Tamil Nadu state and parts of India such as Biligiriranganhills (69-72),[42] Uttar Pradesh (70),[43] Karnataka (46)[44] and Andhra Pradesh (31-55).[45]

Basal Area

Tree stands' basal area i.e. 22.046 m^2 ha^{-1} in STF is higher than in what have been found in dry forests of Tiruvarur (10.78-14.3 m^2 ha^{-1}),[36] Villupuram (4.31),[46] Cuddalore (21.54),[37-39] Vindhyan hills (1.3-13.78),[26] and Andhra Pradesh (7.79).[45] The current study area experiences a less disturbance and protected through stringent rules and regulations by department of forests, Tamil Nadu. In addition, the present study area have large number of trees, thus associated with a relatively higher BA compared to other dry forests. Earlier, it has been found that tree density positively linked with dry tropical forest in northern India.[47] On the other hand, basal area of STF is lower compared to dry forests of Villupuram (36.5 m^2 ha^{-1}),[46]Mandla (27-55.3),[34] Mudumalai (24.7),[41] and Madhya Pradesh (93.53-155.48).[23]

Aboveground Biomass

Aboveground biomass (AGB) stockpile of trees in STF (50.065 Mg ha^{-1}) is comparable with tropical forests of Pachaimalai, Tamil Nadu (50.6 Mg AGB ha^{-1});[48] dry forests of Andhra Pradesh, India (range, 13.96 to 514.5 Mg ha^{-1});[25] tropical dry evergreen forests of Tamil Nadu (39.69-170.02 Mg ha^{-1}).[49]

However, AGB stock of STF is lower than in dry forests of Sivagangai, Tamil Nadu (58.43-102.76 Mg ha^{-1});[50] dry deciduous forests of Tamil Nadu (64.81 to 624.96 Mg ha^{-1});[51] dry forest of Javadi hills, Tamil Nadu (99-216 Mg ha^{-1});[52] dry forests of East Godavari, Andhra Pradesh (58.04-368.39 Mg ha^{-1}).[27] The mean annual rainfall is positively associated with tree density, AGB and species richness in semi-arid forest ecosystems in Gujarat, India.[53]The study area have lesser mean annual rainfall, >6 months dry season, short-bole trees and smaller leaves. These are some of the important factors could be behind a relatively lesser AGB stockpile of trees in study area. Tree species such as, *Acacia leucophloea, Albizia amara, Albizia lebbeck, Azadirachta indica, Dichrostachys cinerea, Lannea coromandelica* and *Prosopis juliflora* constituted a considerable amount of AGB in dry forests in Sivagangai, Tamil Nadu.[50] In general, Southern Thorn Forests are short-statured and endowed with a large number of short bole trees, hence had a larger BA and lesser AGB. For instance, with lesser BA (6.55 to 12.32 m^2 ha^{-1}) dry forests of Sivagangai stocked a higher amount of AGB (58.43-102.76 Mg ha^{-1}).[50] Besides, dry forests of Eastern Ghats had 98.87 Mg AGB ha^{-1} and 15.2 m^2BA ha^{-1} (mean).[48]

An array of factors affect AGB stockpile of forests. Density, species composition, diversity, height, wood density, age, growth condition, length of growth period, mean annual precipitation and temperature, soil moisture contents and nutrient availability are some of the influencing factors widely determine AGB stockpile of trees in forests. In one meter square of tree basal area moist forest can stores about 100 Mg AGB while dry forests stores less. Aboveground biomass stockpile of a secondary dry forests in northwestern Costa Rica, Brazilvaried from 1.7 to 409 Mg ha^{-1}. Age of the forest determined AGB stockpile in dry forests of Brazil.[54]

Conclusion

The present study area had a large number trees compared to some dry forests within Tamil Nadu and other Indian states. Southern Thorn Forest supports a moderate number of trees species. Aboveground biomass stockpile of trees is within the range recorded in Indian tropical dry forests. The study area experiences lesser mean annual rainfall and >6 months dry season. Further, endowed with short-bole and smaller leaved trees, hence stocked a relatively lesser AGB in trees. This study concentrated on AGB only, further studies to be conducted to estimate total biomass stockpile viz. biomasses of all life forms both above and below ground.

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Conflict of Interest

The author(s) declares no conflict of interest.

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