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Assessment of Aboveground Biomass Stockpile of Lianas in Three Tropical Dry Evergreen Forest Sites of Southern Coromandel Coast, Peninsular India

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Abstract

It has been recognised that lianas play many roles in forest ecosystem. This study was conducted in three tropical dry evergreen forest sites at southern Coromandel Coast, peninsular India. All lianas ≥1 cm diameter at breast height (dbh) were inventoried. Recorded lianas were identified up to species level with regional floras. This study developed a forest-specific regression equation for liana biomass assessment in TDEFs. A total of 25 species belonged to 24 genera and 19 families were recorded from study area. Stand basal area ranged from 0.47 to 1.55 m^2 ha^{-1}. On an average, each site stored 2145.3 kg of dry biomass in lianas. Species richness, basal area and biomass storage of lianas estimated in present study are comparable with world's tropical forests. Need for liana inventories and assessment of contribution of lianas to biomass storage of forests are emphasized.

Keywords: Lowland forest, Old-growth forest, Palaeo-tropics, Woody climbers.

Introduction

The ecology and role of lianas in most tropical forest ecosystems are still poorly understood[1,2]. Lianas are significant constituents, show diverse and abundant representation in tropical forests; have a high canopy to stem ratio[3], deep roots[4] and high water-use efficiency[5]; grow faster[6] and maintain relatively high rates of photosynthesis in the dry season when compared to co-occurring trees[5]; contribute 10-25% to the total plant diversity in tropical forests of the world[7-9]. They are non-self-supporting woody plants; compete with trees for above and below ground life supporting resources[10-12]. In addition, lianas provide food to forest dwelling animals[9], reduce growth rate of trees[13] and play vital role in forest dynamics both structurally and functionally[14]. They are large, abundant, and frequent, especially at lowland forests[15].

Tropical forest disturbances and biomass enrichments are directly linked with atmospheric carbon dioxide concentration[7,16,17], hence, assessment of stored biomass and continuous monitoring of forest ecosystem with adequate numbers of large permanent plots are essential to determine the changes that can influence the forest structure and function.

Tropical dry evergreen forest (TDEF) is a unique, old-growth and endangered forest ecosystem in India[18-20]. Researchers studied structural and functional aspects of TDEFs (see ref. 19 for more information). Information on liana biomass and allometric equations are limited for most of the Indian forests including TDEF. Details on biomass stockpile and contribution of lianas to stored biomass of forests are important to detect role of lianas in biomass changes in forests. Earlier, De Walt *et al.*[18] emphasised the importance of liana surveys in Asia's forest ecosystems. To our knowledge, no liana biomass data and allometric equation that estimate liana biomass are available for TDEFs. Thus, the primary objective of this study was to develop an allometric equation for liana biomass estimation and quantify the stored aboveground biomass (AGB) of lianas in three TDEF sites.

Study site: This study was conducted in three TDEF sites in southern Coromandel Coast. In Tamil Nadu the Coromandel Coast is extended from Thiruvallur in the north to Ramanathapuram district in south. The site Andurkadu (AK) and Pushpavanam (PV) are located in Nagapattinam district (10°10' and 11°20'N; 79°15' and 79°50'E), whereas the site Jambavanodai (JI) situated in Thiruvarur district (10°20' and 11° 07'N; 79°15' and 79°45'E), both are coastal districts of Tamil Nadu. According to 2001 census the human population is 1.44 million and 1.16 million respectively in Nagapattinam (NP) and Thiruvarur (TV) districts.

The mean maximum and minimum annual temperature and rainfall is 32°C, 24.60° and 1174 mm; 36.9°C, 29.8°C and 1091 mm in NP and TV districts, respectively. The natural forest cover of NP is 3557 hectare and TV is 2542 hectare. Soil is coastal alluvium. Study sites situated ~ 230 to 270 km away from Chennai (the capital city of the state) by road. Inter-distance between site AK and PV is 20 km, while it is 70 km between site AK and JI. The forest type of study area is known as tropical dry evergreen forest. This kind of forest ecosystem is recognised as old-growth and least studied among Indian forests[2,18,19].

Methodology

Development of allometric equation: Lianas which slashed for widening the road in site AK were used to develop an allometric equation for the estimation of lianas AGB in TDEFs. The binomial and diameter at breast height (DBH) of lianas were recorded before destruction. All lianas were cut at the ground level, removed carefully from trees and other associated plants. The main stem was cut in to pieces of ~1 m length; diameter of both ends of wood pieces was noted and volume was calculated with the formula: Volume = $\pi r1^2 + \pi r2^2 / 2 \times L$, where r1 = radius at one end of the stem piece, r2 = radius at other end of the stem and L = length of the stem piece. Samples of wood pieces were collected for each destructed individual. Density of collected wood samples was estimated with water replacement method[21], after wood density estimation the samples were kept in hot-air oven at 105°C for 48 h. The mass of wood pieces was quantified with density and volume (Mass = Volume × Density). Other parts such as leaves, small branches and reproductive parts were collected and their fresh mass weighed. A portion of other parts was kept in hot-air oven at 72 °C for 48 h, fresh mass to dry mass ratio was calculated. Finally, the estimated mass of wood pieces was added with mass of other parts to quantify the dry AGB of each destructed liana. With the dbh and total mass of liana, a linear regression formula was constructed for the estimation of dry AGB of lianas in TDEFs.

Forest survey: A one hectare plot (100m × 100m) was marked in each of the three TDEF sites. One hectare plot was sub-divided in to one hundred 10m × 10m workable sub-plots. All lianas with ≥1 cm DBH were inventoried from all the three sites. Point of measurement is 130 cm from the ground. Basal area (BA) was calculated for all lianas, whereas for multi-stemmed lianas (branched before 130 cm from the ground) the stem diameter was measured individually, BA calculated and summed. All inventoried species were identified to species level with regional floras[22, 23] and checklist[19]. The binomial and author citation followed Gamble and Fischer[22].

Results and Discussion

Regression equation: Thirty lianas belonged to each of 11 species and genera, and 10 families were destructed for the construction of regression equation to estimate dry AGB of lianas in TDEFs of Southern Coromandel Coast, India. DBH of destructed individuals ranged from 1.0 to 10.4 cm. Constructed equation can be described as Dry AGB of liana (kg) = 0.9434*(dbh) + 0.5201, where 0.9434 and 0.5201 are constants, and dbh is diameter at breast height in cm. The masses of lianas were tightly linked with stem dbh, and strongly, positively correlated ($r^2 = 0.94$, $p < 0.01$, $n = 30$; $t_{28} = 14.21$, $p < 0.001$). Standard error of the estimate is 0.76.

Liana species richness: A total of 25 species in 24 genera and 19 families were recorded from study area. The site PV had 17 species (16 genera and 15 families), whereas the site AK (18 genera and 14 families) and JI (18 genera and 15 families) had 18 species each. Most speciose families of the study area were Apocynaceae and Menispermaceae (3 species each) followed by Papilionaceae (2), while remaining 16 families represented by just single species' (Table-1).

Liana density and stand basal area: A total of 714 lianas were inventoried from three hectare. Stem density ha^{-1} ranged from 211 to 274. The site PV had more stems (274) than AK (211) and JI (229). Each site dominated by different diameter classes. The forest liana stands' basal area is ranged from 0.47 to 1.55 m^2 ha^{-1}. The site AK dominated by 3.1–6.0 cm dbh class with 83 (39.34%) individuals followed by 6.1–9.0 cm (67, 31.75%), >9.0 cm (43, 20.38%) and 1.0–3.0 cm (18, 8.53%). The site JI had good number of smaller lianas (1.0-3.0 cm dbh, 108 individuals (47.16%)) than 3.1–6.0 cm (53, 23.14%), >9.0 cm (45, 19.65%) and 6.1–9.0 cm (23, 10.04%). Whereas the diameter class >9.0 cm dominated the site PV with 155 (56.57%) individuals followed by 6.1–9.0 cm (66, 24.09%), 3.1–6.0 (37, 13.50%) and 1.0–3.0 (16, 5.84%), (Figure-1). Overall, the study area is common with 9+ cm dbh class (243 individuals, 34.03%) followed by 3.1–6.0 (173, 24.33%), 6.1–9.0 (156, 21.94%) and 1.0–3.0 (142, 19.97%).

Above ground biomass: Cumulatively, 6435.90 kg dry AGB was quantified from study area. The site PV stored a large quantity of AGB (3460.75 kg ha^{-1}) than AK (1563.9 kg ha^{-1}) and JI (1411.25 kg ha^{-1}). Large lianas (>9 cm dbh) contributed a high percentage (63.48%) of biomass (4085. 695 kg) to total stored biomass in study area than other diameter classes, 6.1–9.0 (1193.44 kg, 18.54%), 3.1–6.0 (780.19, 12.12%) and 1.0–3.0 (376.57, 5.85%). In addition, large lianas (>9 cm dbh) accumulated more biomass (40.0%) than smaller ones (Figure-2) in all the sites.

Discussion: Need for the region, forest-specific regression equation: Above ground biomass of destructed lianas is tightly linked with DBH ($r^2 = 0.94$; SEE = 0.76; $p < 0.01$, $n = 30$). To date, no regression equation is available from Indian forests for the estimation of liana biomass. Thus, we constructed a region-specific allometric relationship for the estimation of AGB of lianas in TDEFs of southern India. It has been showed that the regression models developed for AGB estimation of one forest type probably cannot be applicable for other forest type therefore construction of region and forest-specific allometric models are important[23].

Liana species richness: The species richness of this study showed similarities as well as differences when compared to forest types of the Indian sub-continent and the world. Species richness recorded (mean=17.3 species ha^{-1}) in study area is well within the range reported from other TDEF sites from southern Coromandel Coast. Parthasarathy and Karthikeyan[24] reported 16, 13 species from Cuddalore district; Reddy and Parthasarathy[25] estimated a mean of 27 liana species from four TDEFs; Ramanujam and Kadamban[26] inventoried 8, 9 species from two TDEF sites of Coromandel Coast; and Reddy and Parthasarathy[27] reported an average of 24 liana species from four TDEF sites of Pudukottai district. Jamir and Pandey[28] reported 23, 34 species from sacred grove forests of Jaintia hills, NE India.

As to the other forest types of the world, our findings are comparable with the results of Yuan *et al.*[29], who reported 10 to 23 species ha^{-1} from secondary forests of SW China. However, our results are not in-line with the estimation of Lu *et al.*[30] who reported an average of 44 species ha^{-1} from tropical seasonal forest of China; Addo-Fordjour and Kofi-Anning[31] estimated 41 species from Ghana; Putz[32] reported 45 species from 0.2 hectare area for Amazon forests. It has been widely accepted that mean annual temperature and dry season length are deciding factors in liana species richness, diversity and density in forests[18]. TDEF is located in moderately drier environment, experiencing 6-7 months of dry season hence it supports moderate level of liana diversity. Earlier, Parthasarathy *et al.*[19] reported moderate level of liana diversity from TDEFs.

Table-1
Binomial, family and density of lianas inventoried from three 1 ha plots in Southern Coromandel Coast, India

Binomial	Family	AK	JI	PV	Total for 3 ha
Abrus precatorius	Papilionaceae	10	-	6	16
Acacia caesia	Mimosaceae	-	6	-	6
Asparagus racemosus	Liliaceae	3	2	-	5
Canavalia virosa	Papilionaceae	-	-	7	7
Cansjera rheedii	Opiliaceae	11	7	11	29
Capparis zeylanica	Capparidaceae	3	2	5	10
Carissa spinarum	Apocynaceae	6	1	65	72
Cissus quadrangularis	Vitaceae	1	4	20	25
Cissus vitiginea	Vitaceae	2	-	13	15
Coccinia grandis	Cucurbitaceae	2	1	2	5
Combretum albidum	Combretaceae	29	6	-	35
Grewia rhamnifolia	Tiliaceae	11	16	30	57
Hemidesmus indicus	Apocynaceae	8	-	-	8
Hugonia mystax	Linaceae	48	-	48	96
Ichnocarpus frutescens	Apocynaceae	14	1	10	25
Jasminum angustifolium	Oleaceae	4	16	13	33
Pachygone ovata	Menispermaceae	8	4	-	12
Plecospermum spinosum	Moraceae	-	10	16	26
Pyrenacantha volubilis	Celastraceae	-	120	-	120
Rivea hypocrateriformis	Convolvulaceae	12	9	15	36
Strychnos minor	Loganiaceae	35	-	3	38
Tiliacora acuminate	Menispermaceae	-	2	-	2
Tinospora cordifolia	Menispermaceae	5	1	3	9
Toddalia asiatica	Rutaceae	-	-	3	3
Ziziphus oenoplia	Rhamnaceae	-	1	7	8
Total	-	211	229	274	714

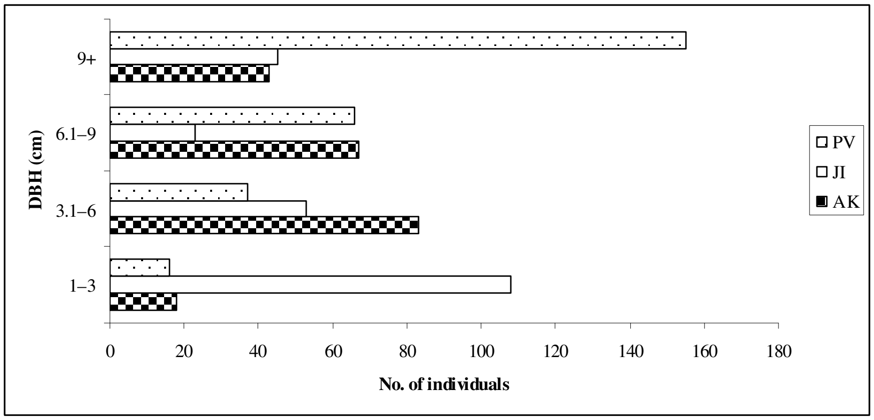

Figure-1
Distribution of diameter classes of lianas in three TDEFs

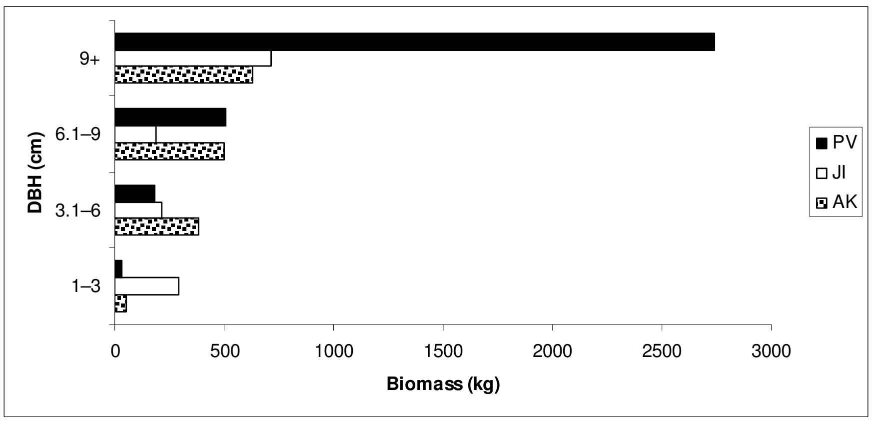

Figure-2
AGB storage in various diameter classes of liana in study area

Liana density: Lianas can contribute 10-25% to the total plant diversity in world's tropical forests[7-9]. The liana density recorded from study area (mean = 238 lianas ha^{-1}) is high as well as low than what has been reported for other tropical forests in the world. From the same forest type Reddy and Parthasarathy[25] reported 827 individuals ha^{-1} (mean) for four sites in Cuddalore district, and Reddy and Parthasarathy[27] inventoried 670 individuals ha^{-1} (mean) from four sites of Pudukottai districts. However, the present study area harbours high liana density than two TDEF sites of Cuddalore districts in Coromandel Coast of Tamil Nadu[24] (117, 131 individuals ha^{-1}).

Findings of this study are consistent with Allen *et al.*[33] and Jirka *et al.*[34] they quantified 213 and 232 liana stems ha^{-1} from tropical rain forest of northwestern Mato Grosso, Brazil. Conversely, stem density ha^{-1} recorded from study area is lesser to world's tropical forests. Bornean lowland tropical forests support 673 individuals ha^{-1} [35]; lowland forests of Bolivia contain 1652 lianas ha^{-1} [35]; on an average the world's lowland forests harbor 376 lianas ha^{-1} [18]; secondary forests of the Costa Rica have 3951 lianas ha^{-1} [36]; forests of NE Ecuador possess 1402 lianas ha^{-1} [37]; and lowland Neo-tropical forests contain 929 lianas ha^{-1} [38]. Existing and past anthropogenic disturbances, rainfall, temperature and soil nutrition of habitats play crucial role in liana species richness, density, diversity and stand basal area of world's forests[3,18]. TDEFs receive a moderate amount of rainfall[19] and possess poor nutrient soils[39,40] hence supports moderate level of liana as well as tree species richness, stands' basal area and density[19]. On an average, each study site contributes 29.23% to total forest woody plant density (AK, 21.065; JI, 36.58%; PV, 30.04%). Our result is well compromised with that of Schnitzer[6], he reported that liana can comprise between 10% and 45% of woody stems in forests.

Basal area: Stand basal area of lianas (mean = 0.84 m^2 ha^{-1}) is well within the range reported for other TDEF sites in Coromandel Coast. Reddy and Parthasarathy[25,27] reported a range of 0.44 to 1.85 m^2 basal area ha^{-1} for eight TDEF sites. The stem basal area estimated in present study area is greater than in tropical seasonal forests of Xishuangbanna[30] (mean=0.34 m^2 ha^{-1}) and many others, also lesser than in many tropical forests, such as lowland Neotropical forests[38] (0.9 m^2 ha^{-1}) and many others (Table-2).

Table-2
Basal area (m^2 ha^{-1}) and above ground biomass of lianas (ha^{-1}) reported from tropical forests around the world

Forest type (place)	Basal area (m^2 ha^{-1})	Above ground biomass (Mg ha^{-1})	Reference
Low land tropical (Borneo)	0.18-0.8	1.3-7.6 (mean=3.9)	35
Secondary (Costa Rica)	0.21	3.38	36
Sub-tropical wet (Puerto Rico)	0.29	-	50
Tropical dry (SE Brazil)	0.36-0.56	-	51
Tropical dry evergreen (India)	0.44-1.85	-	25, 27
Lowland (World)	0.71	-	18
Lowland tropical (Amazon)	0.73	14.3	52
Evergreen lowland, premontane and lower montane (NE Ecuador)	0.75	-	37
Tropical dry evergreen (India)	0.836	1.41-3.46 (mean=2.15)	Present study
Lowland Neotropical (Neotropics)	0.9	13	38
Tropical wet (Costa Rica)	0.9	-	1
Piedmont (New Jersey, USA)	1.07	-	53
Lowland (Neotropics)	1.1	-	54
Forests of Barro Colorado (Panama)	1.4	-	14
Lacandan tropical rain forest (SW Mexico)	1.95	-	55
Rain forest (Central Amazonia)	-	8.3	41
Moist tropical (Panama)	-	7.7	46
Evergreen tropical rain (Venezuela)	-	15.7	32
Lowland tropical moist (Peru)	-	3.97-6.59 (mean=5.28)	54
Rain forests (Eastern south America)	-	7.6	55
Rain forests (China)	-	3.9	41
Tierra Collectiva (Panama)	-	8.8	43
High Dipterocarp (Malaysia)	-	9.0	56
Tropical rain (Ghana)	-	14.0	57
Tierra Firme (Venezuela)	-	15.0	58
Seasonal evergreen (Thailand)	-	20.0	59
Dry tropical forests (Mexico)	-	20.89-32.88 (mean=28.24)	60

Above ground biomass: A good proportion of the available literatures showed that the AGB of lianas varied from a minimum of 1.3 to a maximum of 32.88 Mg ha^{-1} in world's tropical forests (Table-2). The AGB estimated from present study area is equal, higher as well as lower than in many tropical forests. Our study area stored higher AGB than Amazon forests of southern Brazil[34] (0.9-1.9 Mg AGB ha^{-1}) and lowland tropical forests of Borneo[35] (1.3-2.8 Mg AGB ha^{-1}), lesser AGB than in Central Amazonian rain forests[41] (8.3 Mg AGB ha^{-1}); tropical forests, China[42] (3.9 Mg AGB ha^{-1}); and, tierra Collective of Panama[43] (8.8 Mg AGB ha^{-1}) etc. (Table-2). Even though the basal area of present study is greater than in many tropical forests, TDEF holds less AGB because mean height of the TDEF is 5-8m [44], which is smaller, compared to other forests. Stature of the forests could have contributed to the larger AGB storage of lianas in other tropical forests.

Contribution of lianas to forest biomass: Lianas contribute substantially to total stored biomass in the tropical forests[16, 38]. Lianas contribution to total forest AGB (mean = 2.06%; AK, 2.11%; JI, 1.04%; PV, 3.03%, tree AGB obtained from Udayakumar[40]) estimated for present study area is well within the range reported from wet, moist and dry tropical forests. Chave *et al.*[45], DeWalt and Chave[38] and Putz[32] reported that lianas store less than 10% of the AGB in mature tropical forests, however they can constitute up to 30% of the total AGB in liana rich areas[16]. TDEFs have been recognised as mature, old-growth forest[18]. For instance, in tropical seasonal rain forests of China, lianas constituted 0.86-1.4% of total biomass[30,46]; in rain forests of Amazon they contribute 2.1% [41]; in tropical forests of Barro Colorado Islands, Panama they constituted 2.74% [45]; in tropical rain forests of Venezuela they contributed 4.5% [32]. Increase in liana biomass may significantly affect tree diversity, recruitment, growth, fecundity and survival[14,47,48] at the community level. At ecosystem level, liana biomass increase may substantially influence tree growth and mortality; reduce carbon sequestration and storage potential of trees and the whole forest[17, 49] hence information of stored biomass of lianas and continuous assessments of liana biomass changes are important to determine their deleterious effects on TDEFs. This study recommends forest researchers to estimate the AGB of lianas and their contribution to total biomass to find out the impacts of liana on the Indian forest ecosystems.

Conclusion

In conclusion, species richness, density, biomass storage of lianas of the present study is greater as well as lesser than in many. This study is first of its kind concentrated on AGB of woody climbers in TDEFs of Coromandel Coast, India. By making these forest sites as permanent plots we could study the changes of liana density, their biomass and its effect on TDEFs. Estimation of AGB of lianas and continuous assessments of forests are the foremost important parameters to know about how much of carbon is accumulated in lianas, their carbon sequestration potential and population changes, and structural and functional dynamics of forests. By now, worldwide researchers have laid permanent plots in forests and started to reveal impacts of liana on forest ecosystem. The data on lianas AGB is limited for the Indian sub-continent hence studies on lianas are needed and essential.

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