Research Article

Correlation Study on Standing Biomass Production and Soil Characteristics of Tropical Thorn Forest, Nilgiri Biosphere Reserve, Tamil Nadu

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Abstract

The investigation was carried out to study the relationship between biomass production and soil characteristics of tropical thorn forest of western Ghats. Totally fifteen sample plots were layout to estimate the above ground and below ground biomass in the study area using simple random sampling method. The total biomass of the tropical thorn forest was estimated as 36.13 t ha,$^{-1}$ in which above and below ground biomass were observed as 29.46 t ha,$^{-1}$ and 6.67 t ha,$^{-1}$ respectively. Fifteen soil samples also collected from the laid sample plots. The soil physical, chemical and biochemical properties were analyzed. Among the soil properties soil bulk density (-0.549) and soil EC (-0.448) showed negative influence on the total biomass of the forest, all other properties like soil pH (0.442), organic carbon (0.495), water soluble carbon (0.185) and microbial biomass carbon (0.483) showed the positives correlation coefficient to the total biomass of the tropical thorn forest.

Keywords: Biomass, density, Basal area, Bulk density, Organic carbon, Soil pH, Water soluble carbon

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Introduction

Forest acts as a source of nutrient through litter depositions and sink of nutrient by increasing the absorption of available nutrients. Higher tree biomass could provide more litter thus increasing the nutrient availability in the soil. Organic matter inputs to soil come primarily from plants. Plants take up a range of soil resources, such as water, nitrogen (N), and phosphorus, and as a result plants strongly influence physical, chemical and biological properties of soil. However, since plants exhibit broad variation in their natural history and physiology, it is likely that differences in plant species traits will create distinctive soil environments and biotic communities. For instance, plant species differ in the quality and quantity of their inputs to soil, root architecture, and nutrient requirements. The biomass productivity of the forest is associated with soil fertility. Tree biomass can be affected by the forest soil. Tropical forest can play a crucial role in maintaining the nutrient cycle in the soil. Understanding the relationships among aboveground biomass production and soil properties of a current generation of trees could help us understand the potential productivity of the next generation of trees. This would also provide some insights on the dynamics of soil properties associated with stand development. The present study helps to identity the factors that affect the biomass productivity of the site. Therefore, there is a need to perform this study since limited data has been reported on biomass and soil properties in the tropical thorn forest of western Ghats.

Materials and Method

Description of the study Area

The Nilgiri Biosphere Reserve was the first biosphere reserve in India established in the year 1986. It is located in the Western Ghats and includes 2 of the 10 bio geographic provinces of India. Wide ranges of ecosystems and species diversity are found in this region. Thus, it was a natural choice for the premier biosphere reserve of the country.

Tropical thorn forest

Tropical thorn forest occurs in the areas where dry season is hot and very long. The vegetation is of open type consisting of small trees and thorny or spiny shrubs of stunted growth. The forests remain leafless for most part of the

year, so they are called as thorn scrub or scrub jungles. The species that dominate in the sites are *Acacia chundra (Roxb. ex Rottl.), Acacia leucophloea (Roxb.), Acacia mearnsii de Wild. Acacia nilotica (Linn.), Atalantia monophylla (L.) Correa, Bauhinia racemosa Lam, Cordia gharaf (Forssk.) Ehren, Dalbergia paniculata Roxb, Euphorbia tirucalli L, Hardwickia binata Roxb., Prosopis juliflora DC* and *Ziziphus jujuba Mill.*

Locating the Sample Plots (Quadrates)

Tropical thorn forest is fairly vast area in the foot hills of Nilgiri Biosphere Reserve. It is impossible to study the entire vegetation. Hence, following [1] and [2] total of 15 quadrates of 20 ×20 m were laid down in the thorn forest using Simple random sampling method. The sampling sites were indentified and located with the help of Google earth software. The geographical co-ordinates for each plot were identified with the help of Global Positioning System (GPS)

Table 1 Geo referenced Location of sample plots

Plot No	Latitude	Longitude	Altitude (M)	Location of soil sample collection
1	N 11^0 20’ 09.9”	E 076^0 56’ 17.4”	343	+
2	N 11^0 20’ 11.6”	E 076^0 56’ 24.9 ”	340	+
3	N 11^0 20’ 27.4”	E 076^0 56’ 53.4 ”	330	+
4	N 11^0 20’ 44.4”	E 076^0 57’ 02.1 ”	337	+
5	N 11^0 20’ 47.2”	E 076^0 56’ 55.6 ”	346	+
6	N 11^0 20’ 16.4”	E 076^0 56’ 09.3 ”	363	+
7	N 11^0 20’ 16.0”	E 076^0 56’ 01.3 ”	360	+
8	N 11^0 20’ 16.1”	E 076^0 56’ 54.2 ”	358	+
9	N 11^0 20’ 16.4”	E 076^0 55’ 42.2 ”	374	+
10	N 11^0 20’ 17.4”	E 076^0 55’ 34.2 ”	366	+
11	N 11^0 20’ 15.7”	E 076^0 55’ 25.5 ”	360	+
12	N 11^0 20’ 25.4”	E 076^0 55’ 27.3”	380	+
13	N 11^0 20’ 13.18”	E 076^0 55’ 30.4 ”	336	+
14	N 11^0 21’ 14.9”	E 076^0 57’ 30.4 ”	364	+
15	N 11^0 21’ 23.4”	E 076^0 57’ 50.8 ”	344	+

Sampling and Measurements

At each location a square quadrate of 20 m × 20 m was defined with measuring tape. All the tree species present within the quadrate were recorded. Diameter at breast height (DBH, 137 cm) and height of all individuals of tree species which were >137 cm in height were measured. DBH tape was used for measuring diameter and a reference stick of 3 m and altimeter were used to estimate the height of trees.

Estimation of biomass

The above ground and below ground tree biomass will be studied using acceptable tree allometric relationship which construct with the destructive tree sample from a wide range of tropical forest.

Above Ground Biomass

The best predictive allometric equations (models) in estimating AGB developed by [3] on the basis of climate and forest stand types.

$$AGB = 0.112 \times (\rho\, D^2H)^{0.916}$$

Where, ABG = Above ground biomass; ρ = Wood specific gravity; D = Diameter at breast height; H= Height of the tree

For specific gravity of each tree species, the global data base presented by [4] was used.

Below ground Biomass (BGB)

The following regression model can be used to estimate BGB in the forest developed by [5].

$$BGB = Exp [-1.0589 + 0.884 \times \ln (AGB) + 0.284]$$

Estimation of Biomass Carbon stock

$$Total\ biomass = AGB + BGB$$

Total biomass was obtained as the sum of above ground biomass and below ground biomass.

The density of the forest

The density of the forest (No.of stems hectare^{-1}) was calculated using the formula given by [6] as detailed below.

$$Density\ ha^{-1} = \frac{No.of.\ stems\ /\ quadrate}{Quadrate\ area\ (m^2)} \times 10000\ m^2$$

Tree Basal Area

Tree Basal Area is the cross-sectional area (over the bark) at breast height (1.3m above the ground) measured in m^2

$$Tree\ Basal\ Area = (DBH/200)^2 \times 3.142\ m^2$$

Where, DBH is the Diameter at Breast height (cm) and 3.142 is π

Soil Collection

Fifteen soil samples were collected in tropical thorn forest at the depth of 15 cm. The soil samples were air dried in shade for a week and packed in air tight plastic bags.

The physical and chemical properties were analyzed by following standard procedure as listed below.

Table 2 Analytical methods for soil sample analysis

S.No	Parameter	Methodology
1.	pH	pH meter [7]
2.	EC	Electrical Conductivity meter [8]
3.	Bulk density	Core sampler method [9]
4.	Organic carbon	Chromic acid wet digestion method [10]
5.	Water soluble carbon	Chromic acid wet digestion [10]
6.	Microbial biomass carbon	Fumigation- incubation method [11]

Results and Discussion

The biomass production, density and basal area of the tropical thorn forest were illustrated in the **Table 3**.

The above-ground biomass ranged from 3.63 t ha^{-1} to 83.50 t ha^{-1}, whereas the below ground biomass ranges from 1.09 t ha^{-1} to 17.31 t ha^{-1} in the tropical thorn forest. The lowest total biomass (4.72 t ha^{-1}) was observed in the plot number 1. While the highest biomass of 83.50 t ha^{-1} was recorded in plot number 15. The mean total biomass of the tropical thorn forest was observed as 36.13 t ha,$^{-1}$ this is lower than the total biomass of tropical deciduous forest (56.04 t ha^{-1}) was observed by [12] at Andhra Pradesh. The total biomass of southern thorn forest was estimated as (65.96 t ha^{-1}) in Kolli hills of Tamil Nadu, this was much higher than the present investigation at thorn forest of Western Ghats [13]. In the tropical thorn forest density ranged from 150 to 225 stems ha^{-1} and the basal area ranged from 0.83 m^2 ha^{-1} to 12.42 m^2 ha^{-1}. The mean density and basal area were observed to be 176.63 stems ha^{-1} and 7.75 m^2 ha.$^{-1}$

The physico-chemical and biological properties of the soil samples (15 Nos.) collected from sample plots laid out in tropical thorn forest were analyzed and presented in **Table 4**.

The pH of soil ranged from 6.85 to 7.38 with the mean pH value of 7.12. Electrical conductivity of the soil ranged from 0.54 to 0.85 dSm^{-1} with the mean value of 0.71 dSm.$^{-1}$ The bulk density of the soil ranged 1.12 Mg m^{-3} to 1.33 Mg m^{-3} with the man value of 1.21 Mg m.$^{-3}$ The lowest organic carbon was recorded in plot number 3 with the value of 3.00 g kg,$^{-1}$ while the highest organic carbon was observed as 6.3 g kg^{-1} in the plot number 6. Amount of water soluble carbon ranged from 0.2 g kg^{-1} 1.80g kg^{-1} with the mean value of 1.10 g kg.$^{-1}$ Microbial biomass carbon of tropical thorn forest soil in plot no 5 was observed to be the lowest value of (128.78 µg g^{-1}). The highest microbial biomass carbon of (330.23 µg g-1) was registered in soil sample number 10. The mean value of microbial biomass carbon was 208.49 µg g-1. Amount of dehydrogenase activity of the soil ranged from 6.01 to 26.39 ml H g^{-1} day^{-1} in the tropical thorn forest with the mean value of 13.46 ml H g^{-1} day.$^{-1}$

Table 3 Biomass, density and basal area of tropical thorn forest

Sample Plot No.	AGB (t ha^{-1})	BGB (t ha^{-1})	Total Biomass (t ha^{-1})	Density (Stems ha^{-1})	Basal area (m^2ha^{-1})
1	3.63	1.09	4.72	150	1.04
2	4.07	1.20	5.27	150	0.83
3	11.71	3.05	14.75	150	3.34
4	34.73	7.97	42.70	150	5.49
5	9.54	2.55	12.09	225	1.76
6	49.27	10.86	60.12	200	5.00
7	47.20	10.45	57.65	175	4.12
8	10.81	2.84	13.65	200	2.85
9	83.50	17.31	100.80	175	12.42
10	57.42	12.43	69.85	200	10.28
11	55.00	11.97	66.97	175	6.75
12	9.20	2.47	11.66	175	2.05
13	16.06	4.03	20.09	175	4.25
14	28.99	6.80	35.78	175	6.32
15	20.74	5.06	25.80	175	4.69
Mean	29.46	6.67	36.13	176.67	4.75

Table 4 Physico-chemical, biochemical and biological properties of soils of Tropical thorn forest

Soil Sample No	pH	EC (dSm^{-1})	Bulk density (Mg m^{-3})	Organic carbon (g kg^{-1})	Waters soluble carbon (g kg^{-1})	Microbial bio mass carbon (µg g^{-1})	Dehydrogenase activity (ml H g^{-1} day^{-1})
1	7.05	0.72	1.20	2.1	0.12	171.54	11.28
2	6.85	0.85	1.33	0.3	0.02	145.21	6.01
3	7.01	0.83	1.33	0.3	0.04	161.70	6.92
4	6.94	0.75	1.25	1.2	0.10	137.63	12.03
5	7.03	0.79	1.25	0.6	0.05	128.78	7.74
6	7.38	0.54	1.12	6.3	0.22	305.41	26.39
7	7.27	0.59	1.12	3.6	0.12	320.58	17.14
8	7.03	0.61	1.17	3.0	0.12	240.00	16.54
9	7.04	0.71	1.17	2.4	0.04	229.10	15.71
10	7.32	0.57	1.12	5.4	0.18	330.23	23.46
11	7.15	0.79	1.25	0.9	0.09	140.97	7.14
12	7.11	0.83	1.33	0.3	0.16	186.87	10.98
13	7.17	0.72	1.20	2.4	0.12	170.51	12.25
14	7.28	0.58	1.12	3.9	0.15	313.76	19.92
15	7.18	0.79	1.25	0.6	0.06	145.00	8.34
Mean	7.12	0.71	1.21	2.22	0.11	208.49	13.46

The correlation coefficient between Total biomass of thorn forest and soil physio chemical properties are illustrated in the **Table 5**.

The total biomass of tropical thorn forest positively correlated with soil pH (0.442), organic carbon(0.495), water soluble carbon (0.185) and microbial biomass carbon (0.483) and negatively correlated to the soil bulk density (-0.549) and soil EC(-0.448). The correlation coefficient of density showed negative relationship with Soil EC and bulk

density viz., (-0.426), (-0.429). The basal area of tropical thorn forest exhibit positive correlation for soil pH (0.378), organic carbon (0.431), water soluble carbon (0.125) and microbial biomass carbon (0.432). Among the soil properties bulk density has the maximum negative influence on the total biomass (-0.549), density (-0.429) and basal area (-0.498) of the thorn forest. The impact of tree plantations upon soil resources has been very much debated and any complete consolidated view doesn't exist, partly due to the fact that the impact is much dependent on variable site and forest conditions. A number of studies indicated that changes in some soil properties are influenced by tree species [14, 15]. The changes depend on stand age [16], biological factors [17] and intensity of forest management [18]. In present study some of the soil factor (EC and Bulk density) negatively influence the biomass production and most of the factor shows positive relationship to the biomass production of the thon forest.

Table 5 The correlation coefficient between Total biomass and soil properties

Parameters	Total Biomass	Density	Basal area	pH	EC	Bulk density	Organic carbon	Waters soluble carbon	Microbial biomass carbon
Total Biomass	1.000	-	-	-	-	-	-	-	-
Density	0.179	1.000	-	-	-	-	-	-	-
Basal area	0.906	0.154	1.000	-	-	-	-	-	-
pH	0.442	0.447	0.378	1.000	-	-	-	-	-
EC	-0.448	-0.426	-0.390	-0.730	1.000	-			
Bulk density	-0.549	-0.429	-0.498	-0.719	0.953	1.000	-	-	-
Organic carbon	0.495	0.413	0.431	0.767	-0.958	-0.901	1.000	-	-
Waters soluble carbon	0.185	0.331	0.125	0.760	-0.720	-0.594	0.767	1.000	-
Microbial biomass carbon	0.483	0.333	0.432	0.745	-0.905	-0.826	0.889	0.676	1.000

Conclusion

Above ground and below ground biomass of the forest play an important role in carbon sequestration and nutrient dynamics. Delineation of total biomass, density and basal area with respect soil physio chemical and biological properties of tropical thorn forest soil was studied. The results of the study concluded that the total biomass of the thorn forest was positively influenced by the soil properties like pH, organic carbon and water soluble carbon and the total biomass of the thorn forest negatively influenced by soil EC, Bulk density. Future work shall attempt to screen the influences of ecological variations and types of vegetation on biomass allocation.

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