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Biomass and Carbon Storage Pattern in Natural and Plantation Forests of Sub-humid Tropics in Barnawapara Wildlife Sanctuary, Chhatisgarh, India

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ABSTRACT

Biomass constitutes primary data needed for understanding a number of ecological processes like energy flow and water and nutrient cycling in forest ecosystems. Various tree components are economically utilized for fodder, firewood, timber, pulp and paper, plywood, medicines and other uses. Therefore, quantification of total biomass is important. Trees play a vital role in mitigating the adverse effect of environmental degradation and increasing concentration of CO_2 in the atmosphere and also in its consequence on climate change. We studied the biomass and carbon storage pattern in natural and plantation forests of sub-humid tropics in Barnawapara Wildlife Sanctuary. Maximum total biomass (aboveground + belowground) was recorded in closed natural forest i.e. 473.60 Mg ha^{-1} (414.26 + 59.34) followed by open natural forest, 217.59 Mg ha^{-1} (190.55 + 27.04) and teak plantation 134.99 Mg ha^{-1} (112.73 + 22.26). Also total carbon recorded was maximum in closed natural forest, 208.22 Mg ha^{-1} (187.08 +21.14) followed by open natural forest, 95.11 Mg ha^{-1} (85.60 +9.59) and teak plantation, 56.06 Mg ha^{-1} (50.11 +7.95) respectively. The study shows that the natural forest has an edge over plantation forest in terms of biomass accumulation and carbon storage. Also the aboveground accumulation of biomass and carbon storage is higher than belowground in all type of forests.

Key words: Tree biomass, Carbon balance, allometric equation, CHNOS-Auto Analyzer

INTRODUCTION

The tropical forest covers 1376 m ha worldwide which covers 60 per cent of the land area (FAO 2005) and play an important role in biomass accumulation and CO_2 sequestration. Tropical forest in India covers 56.60 m ha, of which 20.84 m ha falls under dry deciduous forest (FSI 2009).

In recent years interest in tropical forest has been simulated, in part, by the alarming rate at which they are being modified or completely destroyed and partly because of their vast store of carbon and the potential effects of their disruption on the world's carbon balance (Murphy and Lugo 1986a). Global models of the C, N, P and S cycles (Bolin et al. 1983) have led to useful insights into global level problems such as increasing atmospheric concentrations of gases of C and N, ozone degradation in the stratosphere and acid precipitation. Biomass constitutes a primary data needed for understanding a number of ecological processes like energy flow, water and nutrient cycling in forest ecosystems (Chaturvedi and Singh 1987, Tiwari 1994). The tree components like bole, branch, leaves and roots are economically utilized for fodder, firewood, timber, pulp and paper, plywood, composite wood, medicinal and other uses. Therefore quantification of total biomass is important as different component play a vital role in structural and functional process of ecosystems.

Trees play a vital role in mitigating the diverse effect of environmental degradation and increasing concentration of CO_2 in the atmosphere and also in its consequence on climate change. It promotes the search for suitable method to sequester the carbon into soil and plant biomass. Tree based land use practice could be one among the viable alternative to store atmospheric CO_2 due to its cost effectiveness, high potential rate of carbon uptake and associated environmental as well as social benefits (Costa 1996).

STUDY AREA

The study area is located between 21° 20' 00″ to 21° 25'47″ North latitudes and 82° 21' 17″ to 82° 26' 27″ East longitudes. It is situated about 17 km away from Patewa on Raipur-Sambalpur NH No. 6 just on the border of Chhattisgarh.

For the present study three sites viz., closed and open natural forests and teak plantation forests of sub-humid tropics in Barnawapara Wildlife Sanctuary were selected. The study was carried during 2009-2010. Soils of study area are Inceptisols. The Inceptisol*s* are immature soils mostly sandy loams having light texture and shallow to moderate depth. They are low in organic matter and available nutrients, which support mainly grasslands and degraded forests. The climate of study area is dry humid tropical consist of three seasons viz. rainy, winter and summer. The rainy season commences from about the middle of June. The winter season, which commences from the beginning of November, lasts till the end of February. The summer commences from the beginning of March. It is quite prolonged and lasts till monsoon sets in. The average annual rainfall in the study area ranges from 1200-1350 mm. The mean monthly maximum temperature ranges from 27.3 °C in January to 41.8 °C in May.

METHODS

Biomass Estimation

For tree species, a total of 10 quadrats were laid down on each site. Species area curve was used to determine minimal sample area which is based on quantitative variation of the vegetation in terms of species number (Mueller-Dombios and Ellenberg 1974). The tree biomass was estimated using allometric equation relating tree circumference to biomass, developed earlier by Singh and Mishra (1979) for the forest species. The tree individuals in each quadrat were categorized into different girth classes. The mean GBH (circumference at beast height) value for each species for a girth class was used in the regression equation to get an estimate of biomass (by component) for that girth class. Then this value was multiplied by the density of trees in that girth class. The girth class values were summed to obtain the biomass estimate for each of the quadrats in each site.

The relationship between girth of a tree and dry weight of a component is given by equation:

$$Log\ Y = a + b \log X$$

where,

Y = dry weight (kg) of component (bole, branch, leaf and root)

X = girth (cm) at 1.37 m height

a and b = allometric constants.

Carbon Estimation

Samples of different tree components (bole, branch, foliage, coarse roots) for all species were separately collected from 20-30 trees of all available girth classes on each site. Composite samples of each component of tree were brought to the laboratory and oven dried at 80ºC. The oven dried samples were mill ground and stored for chemical analysis.

Carbon concentration was analysed using CHNOS-Auto Analyzer "ElementarVario EL. The carbon storage for the vegetation components was computed as the sum of the products obtained by multiplying dry weights of components with their mean carbon concentrations. The values for carbon storage in different components were summed to obtain total carbon storage in the vegetations.

RESULTS

Total biomass in the present study was between 134.99 Mg ha^{-1}and 473.60 Mg ha^{-1}, and it was highest on closed natural forest (473.60 Mg ha^{-1}) followed by open natural forest (217.59 Mg ha^{-1}) and lowest on teak plantation (134.99 Mg ha^{-1}).

Closed Natural Forest

The total biomass estimated for closed natural forest (Table 1) was 473.60 Mg ha^{-1} of which 414.26 Mg ha^{-1} was above ground and 59.34 Mg ha^{-1} below ground. The distribution of biomass in the different components was

Table 1. Biomass (Mg ha^{-1})of different tree component at Baranawapara Wildlife Sanctuary
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Species	Closed natural forest					Open natural forest					Plantation forest				
	Bole	Branch	Leaf	Root	Total	Bole	Branch	Leaf	Root	Total	Bole	Branch	Leaf	Root	Total
Anogeissuslatifolia Roxb. ex DC.	-	-	-	-	-	4.90	16.14	0.99	3.48	25.51	-	-	-	-	-
Antidesmaacidum Roth.	0.46	0.34	0.04	0.18	1.02	-	-	-	-	-	-	-	-	-	-
Acacia catechu (L.f.) Willd.	-	-	-	-	-	0.86	0.73	0.10	0.32	2.01	-	-	-	-	-
Brideliaretusa Spreng.	7.64	11.12	0.75	2.86	22.37	0.23	0.17	0.02	0.09	0.51	-	-	-	-	-
Buchnanialanzan Spreng.	0.34	0.21	0.05	0.10	0.70	-	-	-	-	-	0.19	0.08	0.03	0.06	0.36
Bauhinia racemosa Lam.	1.45	1.42	0.16	0.54	3.57	-	-	-	-	-	-	-	-	-	-
Bosweliaserrata Roxb. exColebr.	-	-	-	-	-	18.24	34.17	1.62	6.85	60.88	-	-	-	-	-
Bombaxceiba Linn.	1.74	2.44	0.17	0.65	5.00	7.70	13.53	0.70	2.89	24.82	-	-	-	-	-
Cleistanthuscollinus Roxb.	12.95	12.99	1.47	4.85	32.26	2.94	3.27	0.31	1.10	7.62	0.68	0.53	0.08	0.25	1.54
Careyaarborea Roxb.	1.17	1.28	0.12	0.44	3.01	-	-	-	-	-	-	-	-	-	-
Cassia fistula Linn.	-	-	-	-	-	0.23	0.17	0.02	0.09	0.51	-	-	-	-	-
Chloroxylon sweitenia DC.	-	-	-	-	-	5.09	8.44	0.48	1.91	15.92	-	-	-	-	-
Diospyros melanoxylon Roxb.	21.15	34.07	1.28	6.84	63.34	-	-	-	-	-	-	-	-	-	-
Dalbergia paniculata Roxb.	6.90	14.29	0.59	2.59	24.37	-	-	-	-	-	-	-	-	-	-
Emblica officinalis Gaertn.	0.58	0.65	0.06	0.21	1.50	-	-	-	-	-	-	-	-	-	-
Grewia tiliaefolia Vahl.	0.42	0.42	0.05	0.15	1.04	1.76	1.73	0.24	0.67	4.40	-	-	-	-	-
Garuga pinnata Roxb.	1.05	1.05	.11	0.39	2.60	7.89	10.23	0.81	2.96	21.89	-	-	-	-	-
Lagerstroemia parviflora Roxb.	18.58	21.06	2.27	10.73	52.64	0.56	0.47	0.08	0.25	1.36	0.77	0.62	0.11	0.34	1.84
Madhuca indica J.F. Gmel.	30.16	70.14	2.47	11.34	114.11	-	-	-	-	-	-	-	-	-	-
Mitragyna parviflora (Roxb.) Korth	3.45	5.22	0.33	1.30	10.30	-	-	-	-	-	-	-	-	-	-
Ougeinia oojeinensis Roxb.	8.51	15.45	0.76	3.20	27.92	-	-	-	-	-	-	-	-	-	-
Pterocarpus marsupium Roxb	2.48	2.74	0.12	0.44	3.01	-	-	-	-	-	-	-	-	-	-
Semecarpus anacardium Linn. f.	0.23	0.17	0.02	0.09	0.51	-	-	-	-	-	-	-	-	-	-
Tectona grandis Linn. f.	-	-	-	-	-	-	-	-	-	-	66.55	28.65	14.50	21.16	131.25
Terminalia arjuna (Roxb. ex DC.) Wt &Arnott	-	-	-	-	-	2.83	4.54	0.26	1.06	8.69	-	-	-	-	-
Terminalia chebula Retz.	0.64	0.67	0.07	0.24	1.62	-	-	-	-	-	-	-	-	-	-
Terminalia tomentosa Roth.	31.88	53.08	2.98	11.97	99.91	11.87	19.88	1.11	4.45	37.31	-	-	-	-	-
Zizyphus xylocarpa (Retz.) Willd.	-	-	-	-	-	2.45	2.52	0.27	0.92	6.16	-	-	-	-	-
Total	151.8	248.8	13.9	59.3	473.6	67.6	116.0	7.0	27.0	217.6	68.1	29.9	14.7	22.3	135.0

151.78 Mg ha^{-1} in bole, 248.81 Mg ha^{-1} in branch, 13.8 Mg ha^{-1} in leaf and 59.34 Mg ha^{-1} in root. The bole, branch, leaf and root constituted 32.00, 52.53, 2.92 and 12.53 per cent, respectively of the total biomass. Among the individual species *Madhuca indica* constituted the highest biomass (114.11) followed by *Terminalia tomentosa* (99.91) and *Lagerstroemia parviflora* (52.64), which contributed 24.09, 21.09 and 11.11 percent of the total biomass.

Open Natural Forest

The total biomass estimated for open natural forest (Table 1) was 217.59 Mg ha^{-1} of which 190.55 Mg ha^{-1} was above ground and 27.04 Mg ha^{-1} below ground. The distribution of biomass in the different components was 67.55 Mg ha^{-1} in bole, 115.99 Mg ha^{-1} in branch, 7.01 Mg ha^{-1} in leaf and 27.04 Mg ha^{-1} in root. The bole, branch, leaf and root biomass constituted 31.04, 53.30, 3.22 and 12.42 percent, respectively of the total biomass. Among the individual species *Boswelia serrata* constituted the highest biomass (60.88) followed by *Terminalia tomentosa* (37.31) and *Anogeissus latifolia* (25.51) which constituted 27.97, 17.14, and 11.72% of the total biomass.

Teak Plantation

The total biomass estimated for teak plantation (Table 1) was 134.99 Mg ha^{-1} of which 112.73 Mg ha^{-1} was above ground and 22.26 Mg ha^{-1} below ground. The distribution of biomass in the different components was 68.13 Mg ha^{-1} in bole, 29.88 Mg ha^{-1} in branch, 14.72 Mg ha^{-1} in leaf and 22.26 Mg ha^{-1} in root. The bole, branch, leaf and root biomass constituted 50.47, 22.13, 10.90 and 16.49 per cent, respectively of the total biomass. Among the individual species *Tectona grandis* constituted the highest biomass (131.25) followed by *Lagerstroemia parviflora* (1.84) and *Cleistanthus collinus* (1.54) which constituted 97.22, 1.36 and 1.14 percent of the total biomass.

Bomass in Natural and Plantation Forests

Although the young individuals belonging to seedlings and saplings classes dominated all the three site in terms of density, the total biomass accumulation was greater in the >100 cm girth class in natural forest sites while it was maximum in middle girth classes in teak plantation. Data on frequency, density and basal area are presented in Table 4.

Table 4. Species structure of tree layer at Baranawapara Wildlife Sanctuary

Species	Closed natural forest			Open natural forest			Teak plantation forest		
	F	D	BA	F	D	BA	F	D	BA
Anogeissus latifolia Roxb. ex DC.	-	-	-	50	50	1.83	-	-	-
Antidesma acidum Roth.	20	20	0.1881	-	-	-	-	-	-
Acacia catechu (L.f.) Willd.	-	-	-	20	30	0.18	-	-	-
Bridelia retusa(L.) Spreng.	30	50	2.5422	10	10	0.10	-	-	-
Buchnania lanzan Spreng.	10	10	0.1370	-	-	-	10	10	0.0810
Bauhinia racemosa Lam.	10	30	0.4718	-	-	-	-	-	-
Boswelia serrata Roxb. ex Colebr.	-	-	-	40	40	5.54	-	-	-
Bombax ceiba Linn.	10	10	0.5748	20	20	2.43	-	-	-
Cleistanthus collinus (Roxb.) Benth & Hook.	60	330	4.9515	20	40	0.98	30	30	0.2415
Careya arborea Roxb.	30	40	0.3793	-	-	-	-	-	-
Cassia fistula Linn.	-	-	-	10	10	0.07	-	-	-
Chloroxylon swietenia DC.	-	-	-	20	30	1.55	-	-	-
Diospyros melanoxylon Roxb.	50	60	5.5309	-	-	-	-	-	-
Dalbergia paniculata Roxb.	10	10	1.8067	-	-	-	-	-	-
Emblica officinalis Gaertn.	10	10	0.2676	-	-	-	-	-	-
Grewia tiliaefolia Vahl	10	10	0.1640	50	70	0.77	-	-	-
Garuga pinnata Roxb.	20	20	1.3920	60	80	2.31	-	-	-
Lagerstroemia parviflora Roxb.	40	130	7.0502	10	20	0.12	20	30	0.3098
Madhuca indica J.F. Gmel.	30	30	7.8651	-	-	-	-	-	-
Mitragyna parviflora (Roxb.) Korth	20	20	1.1453	-	-	-	-	-	-
Ougeinia oojeinensis (Roxb). Hochr.	20	20	2.4846	-	-	-	-	-	-
Pterocarpus marsupium Roxb.	10	10	0.6851	-	-	-	-	-	-
Semecarpus anacardium Linn. f.	10	10	0.1216	-	-	-	-	-	-
Tectona grandis Linn. f.	-	-	-	-	-	-	100	920	27.30
Terminalia arjuna (Roxb. ex DC.) Wright & Arnott	-	-	-	10	10	0.84	-	-	-
Terminalia chebula Retz.	10	10	0.1410	-	-	-	-	-	-
Terminalia tomentosa (Roxb. ex DC.) Wright & Arnott	70	120	9.4077	30	60	3.84	-	-	-
Zizyphus xylocarpa (Retz.) Willd.	-	-	-	30	50	0.92	-	-	-
Total	480	950	47.30	380	520	21.50	160	990	28.03

* F = Frequency (%); D = Density (stems ha-1); BA = Basal area (m^2 ha)

Carbon Storage of Various Forest Plots

The carbon concentration in bole, branch, leaf and coarse roots were 43.50%, 45.67%, 46.67% and 35.73%, respectively. The total carbon at different sites of Bharnawapara wildlife sanctuary is given the Table 2.

Closed Natural Forest

The total carbon estimated for closed natural forest was 208.22 Mg ha^{-1} of which187.08 Mg C ha^{-1} was above ground and 21.14 Mg C ha^{-1} below ground. The distribution of carbon in the different components was 66.63

Table 2. Carbon (Mg ha^{-1})storage pattern at Baranawapara Wildlife Sanctuary

Species	Closed natural forest					Open natural forest					Plantation forest				
	Bole	Branch	Leaf	Root	Total	Bole	Branch	Leaf	Root	Total	Bole	Branch	Leaf	Root	Total
Anogeissus latifolia Roxb. ex DC.	-	-	-	-	-	2.13	7.37	0.46	1.24	11.2	-	-	-	-	-
Antidesma acidum Roth.	0.2	0.14	0.02	0.06	0.42	-	-	-	-	-	-	-	-	-	-
Acacia catechu (L.f.) Willd.	-	-	-	-	-	0.37	0.33	0.05	0.11	0.86	-	-	-	-	-
Bridelia retusa Spreng.	3.32	5.07	0.35	1.02	9.76	0.1	0.07	0.01	0.03	0.21	-	-	-	-	-
Buchnania lanzan Spreng.	0.15	0.09	0.02	0.03	0.29	-	-	-	-	-	0.08	0.03	0.01	0.02	0.14
Bauhinia racemosa Lam.	0.63	0.65	0.07	0.19	1.54	-	-	-	-	-	-	-	-	-	-
Boswelia serrata Roxb. exColebr.	-	-	-	-	-	7.93	15.6	0.75	2.45	26.73	-	-	-	-	-
Bombax ceiba Linn.	0.75	1.11	0.08	0.23	2.17	3.34	6.17	0.32	1.03	10.86	-	-	-	-	-
Cleistanthus collinus Roxb.	5.89	5.93	0.68	1.73	14.23	1.27	1.49	0.14	0.39	3.29	0.29	0.24	0.04	0.09	0.66
Careya arborea Roxb.	0.51	0.58	0.06	0.16	1.31	-	-	-	-	-	-	-	-	-	-
Cassia fistula Linn.	-	-	-	-	-	0.1	0.07	0.01	0.03	0.21	-	-	-	-	-
Chloroxylon sweitenia DC.	-	-	-	-	-	2.21	3.85	0.22	0.68	6.96	-	-	-	-	-
Diospyros melanoxylon Roxb.	9.2	15.55	0.59	2.44	27.78	-	-	-	-	-	-	-	-	-	-
Dalbergia paniculata Roxb.	3.14	6.52	0.27	0.92	10.85	-	-	-	-	-	-	-	-	-	-
Emblica officinalis Gaertn.	0.25	0.29	0.03	0.07	0.64	-	-	-	-	-	-	-	-	-	-
Grewia tiliaefolia Vahl.	0.19	0.19	0.02	0.05	0.45	0.76	0.79	0.11	0.24	1.9	-	-	-	-	-
Garuga pinnata Roxb.	0.45	0.48	0.52	0.14	1.59	3.43	4.67	0.37	1.05	9.52	-	-	-	-	-
Lagerstroemia parviflora Roxb.	8.08	9.62	1.06	3.83	22.59	0.24	0.21	0.04	0.09	0.58	0.33	0.28	0.05	0.12	0.87
*Madhuca indica*J.F. Gmel.	13.11	32.03	1.15	4.05	50.34	-	-	-	-	-	-	-	-	-	-
Mitragyna parviflora (Roxb.) Korth	1.57	2.38	0.15	0.46	4.56	-	-	-	-	-	-	-	-	-	-
Ougeinia oojeinensis (Roxb). Hochr.	3.87	7.05	0.35	1.14	14.41	-	-	-	-	-	-	-	-	-	-
Pterocarpus marsupium Roxb.	1.07	1.25	0.06	0.24	2.62	-	-	-	-	-	-	-	-	-	-
Semecarpus anacardium Linn. f.	0.1	0.07	0.01	0.03	0.21	-	-	-	-	-	-	-	-	-	-
Tectona grandis Linn. f.	-	-	-	-	-	-	-	-	-	-	28.92	13.08	6.76	7.72	56.48
Terminalia arjuna (Roxb.ex DC.) Wt &Arnott	-	-	-	-	-	1.23	2.07	0.12	0.38	3.8	-	-	-	-	-
Terminalia chebula Retz.	0.29	0.3	0.03	0.08	0.7	-	-	-	-	-	-	-	-	-	-
Terminalia tomentosa Roth.	13.86	24.24	1.39	4.27	43.76	5.16	9.07	0.52	1.58	16.33	-	-	-	-	-
Zizyphus xylocarpa (Retz.) Willd.	-	-	-	-	-	1.06	1.15	0.12	0.33	2.66	-	-	-	-	-
Total	66.63	113.54	6.91	21.14	208.22	29.33	52.91	3.24	9.59	95.11	29.62	13.63	6.86	7.95	58.06

Mg ha^{-1} in bole, 113.54 Mg ha^{-1} in branch, 6.91 Mg ha^{-1} in leaf and 21.14 Mg ha^{-1} in root. The bole, branch, leaf and root constituted 31.94, 54.52, 3.31 and 10.15%, respectively of the total carbon. Among the individual species *Madhuca indica* constituted the highest carbon (50.34) followed by*Terminalia tomentosa* (43.47) and *Lagerstroemia parviflora* (22.54) which constituted 24.17, 21.01 and 10.84 percent of the total carbon.

Open Natural Forest

The total carbon estimated for open natural forest was 95.11 Mg ha^{-1} of which 85.60 Mg C ha^{-1} was above ground and 9.59 Mg C ha^{-1} below ground. The distribution of carbon in the different components was 29.33 Mg ha^{-1} in bole, 52.91 Mg ha^{-1} in branch, 3.24 Mg ha^{-1} in leaf and 9.59 Mg ha^{-1} in root. The bole, branch, leaf and root constituted 30.84, 55.63, 3.04 and 10.08 per cent, respectively of the total carbon. Among the individual species, *Boswelia serrata* had the highest carbon (26.73) followed by *Terminalia tomentosa* (16.33) and *Anogeissus latifolia* (11.20) which constituted 28.10, 17.17 and 11.77% of the total carbon.

Plantation Forest of Teak

The total carbon estimated for plantation forest of teak was 58.06 Mg ha^{-1} of which 50.11 Mg C ha^{-1} was above ground and 7.95 Mg C ha^{-1} below ground. The distribution of carbon in the different components was 29.62 Mg ha^{-1} in bole, 13.63 Mg ha^{-1} in branch, 6.86 Mg ha^{-1} in leaf and 7.95 Mg ha^{-1} in root. The bole, branch, leaf and root constituted 51.01, 23.47, 11.81 and 13.69 percent, respectively of the total carbon. Among the individual species *Tectona grandis* constituted the highest carbon (56.48) followed by *Lagerstroemia parviflora* (0.78) and *Cleistanthus collinus* (0.66) which constituted 97.27, 1.34 and 1.13 percent of the total carbon.

Distribution of Carbon in Natural and Plantation Forests

Distribution pattern of carbon across the girth classes also followed the similar pattern as was the case with biomass distribution. It was negligible in young individuals belonging to seedlings and saplings classes and highest storage was observed in girth class >100 cm in natural forest. In teak plantation carbon storage was maximum in middle girth classes.

DISCUSSION

The above values are comparable with the estimates made by many workers (Murphy and Lugo 1986, Singh and Singh 1991, Haripriya 2000, Swamy et al. 2010). The biomass reported in important tropical forests of the world is presented in Table 3. Singh and Mishra (1979) reported 77 Mg ha^{-1} and Singh and Singh (1991) reported 42-78 Mg ha^{-1} biomass in dry tropical forests of U.P., India. Hall and Uhlig (1991) estimated the biomass density of forests in South and South East Asia using the volume estimates and biomass expansion factors derived from Brown et al. (1989). Their biomass estimates for India ranged from 116 Mg ha^{-1} for forest undisturbed for 60-80 years and 35, 66 and 84 Mg ha^{-1} for logged, unproductive and managed forests, respectively. How-

Table 3. Comparision of stand biomass (Mg ha^{-1}) of certain tropical forests of the world

Forests	Location	Stand biomass			Source
		Aboveground	Belowground	Total	
Tropical lower montane Rain	New Guinea	310	39	349	Edward and Grabb (1977)
Tropical wet	Cambodia	322	60	382	Hozum et al. (1969)
Tropical wet	Global pattern	213-1173	11-135	269-1186	Murphy and Lugo (1986b)
Tropical Rain	Sarawak			210-650	Proctor et al. (1983b)
	India	420-649	14-20	434-669	Rai and Proctor (1986a)
	Thailand	295-371	31-33	326-404	Ogawa et al. (1965)
	Ghana	233	54	287	Greenland and Kowal (1960)
Tropical montane wet	Venezuela	347	73	420	Brun (1976)
Tropical Moist	San Carlos	340	56	396	Bruning et al. (1979)
		326	55	381	Folster et al. (1976)
	Global	316	11	327	Golley et al. (1975)
	Brazil Amazonia	377	104	481	Klinge and Herrera (1978
	Ivory Coast	243	48	291	Muller and Nielson (1965)
Tropical Plantations	Puerto Rica	-	-	0.4-506	Lugo et al. (1988)
Tropical premontane Moist	Papua-New Guinea	286	46	332	Enright (1979)
	Zaire	320	51	371	Freson et al. (1974)
	Ivory Coast	431	24	455	Huttel and Bernhard-Reversat (1975)
Subtropical lower montane wet	Jamaica	279	65	344	Tanner (1980)
Subtropical wet	Puerto Rico	237	116	353	Crow (1980)
	Global pattern	228	89	317	Jordan (1971a)
		198	73	271	Odum (1970)
Subtropical Moist	Thailand	253	10	263	Drew et al. (1978)
Subtropical Dry	Senegal	82	58	140	Jung (1969)
	Thailand	69	10	79	Ogawa et al. (1965)
	India	28	12	40	Vyas et al. (1977)
	Puerto Rico	53	45	98	Murphy and Lugo (1986a)
Tropical Dry	Global pattern	428	10-45	78-320	Murphy and Lugo (1986b)
	India	77	20	97	Singh and Mishra (1979)
	India	42-78	42993	53-94	Singh and Singh (1991)
	India	112.7-414.3	22.36-59.3	135.0-473.6	Present study

ever, the present estimates were comparable to Murphy and Lugo (1986), where they reported 30 to 276 Mg ha-1 above ground biomass for variety of dry tropical forests of the world. Tiwari (1994) reported average total above ground biomass in different forest types of Rajaji National Park, Dehradun, India ranged between 52.36 Mg ha^{-1} (Plantations) and 371.08 Mg ha^{-1} (Sal forest).

CONCLUSION

The present study reveals that the disturbance created in the forest had significantly influenced diversity, biomass and carbon storage status of sub-humid tropics. It reflects that tropical deciduous forest of Chhattisgarh is ecologically rich. The increasing biotic interferences are degrading these forest. The study recommends adopting intensive conservation measures especially in degraded areas of the wildlife sanctuary, which helps in reducing the biotic pressure and also restoring and conserving the fragile tropical deciduous forests of Chhattisgarh.

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