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Distribution of woody biomass reserves in tropical dry Sal (*Shorea robusta* roth.) forests of Ranchi

Mihir Ranjan Panda, Prabhat Ranjan Oraon and Pushpa Tirkey

Abstract
The study was conducted during 2018-2019 to estimate the woody biomass and forest floor biomass in two sites at three different layers of dry Sal forest in Ranchi. The variation in biomass for each forest fragment was estimated by non destructive method using allometric equations. The simple random sampling procedure was followed. The forest floor biomass was collected by fixed samples of 1x1 m^2 and oven dried. Total biomass of tree, sapling and seedling was recorded 297.04 - 386.91 t ha^{-1}, 22.3-24.23t ha^{-1} and 7.24-9.23t ha^{-1} respectively. The forest floor biomass was recorded 389.1- 450.78 g m^{-2}, of which were segregated into leaves litter, twigs and dead wood. The study was very much essential to enhance the ecological health and improve the biological stability and ensure proper management of the forest area.

Keywords: Biomass, forest floor, Sal forest

1. Introduction
Forests are the natural storehouses of biomass [1]. The production and patterns of storage of organic matter in forests in relation to the anthropogenic disturbances is critical for management purposes [2, 3, 4].
Quantification of biomass is required for the better knowledge of the structure and function of the ecosystem [5, 6] and for evaluating the status and trends of forest ecosystem along with the wide range of environmental gradients. Biomass provides a primary data necessary for understanding a number of ecological processes like energy flow, water and nutrient cycling in forest ecosystems [7, 8]. Biomass includes all Organic material both above-ground and below-ground and both living and dead, e.g., trees, crops, grasses, tree litter, roots etc. [9]. Biomass leads a major role in assessment of annual increment of the forest and helps to determine proper management of the natural resource in a sustainable manner.
Sal (*Shorearobusta* Roth.) is the dominating tree species in the forests of Jharkhand, corresponding to the Northern Dry Sal-bearing forests $5B/C_1$ type [10]. It is also recognized as the state tree of Jharkhand. This plant put direct impact on livelihood of local residents. It is a major timber species of North India. Besides this, its leaves use for making plates, a natural resin is tapped from this plant i.e. red dammar locally called “Lal Dhuma”. So, anthropogenic influence is clearly visible in this area. Grazing is the most serious threat to the forest. However, the rate of carbon sequestration depends on species composition, the density of large trees in different girth classes, and anthropogenic disturbances in that area. For getting required output there is need for adopt a management practice for improvement of this natural renewable resource.

2. Materials and Methods
The study conducted in 2018–2019 at Ranchi East Division, Jharhand. The entire area is situated on hilly forest tract, which comes under Northern Dry Sal bearing forest. The whole forest area spreads over 651.544 ha (1610 acre). It situates between 23°18'10.072" N to 23°21'18.575" N latitude and 85°26'18.218" E to 85°29'1.539" E longitude. The summer temperatures range from 20°- 38°C, winter temperatures from 5°C to 25°C. Mean annual rainfall is about 1210 mm (47.64 inches). The average humidity is about 63-84%, which is increase and decrease in summer and winter accordingly. The soils of the district are mostly low grade soils having a large admixture of cobbles, pebbles and gravels generally found at the base of the hills. Some area is also covered with alluvial soils aside to small stream. Soil depth depends upon the topographical gradient which decreases with increasing elevation.

The study area was categorized into two sites. The site I had human settlements, slopy and lateritic soil type, while another site was included on hilly track with swallow soil. The biomass study was carried out by randomly placing quadrates of 10x10 $m^2$for trees and saplings; a 2x2 m^2 area was marked for enumeration of seedlings. In each quadrate, GBH (girth at breast height) of individual (≥ 30 cm girth) trees and saplings (individuals >10 cm - ≤ 30 cm girth) and seedlings. (individuals <10 cm girth) was measured. Allometric equations associated with tree circumference to biomass developed earlier by Singh and Misra (1979) [11] was used. Computation protocol as described by Singh and Singh (1991) [12] was followed.

3. Results and Discussions

The biomass in different vegetational layers i.e. tree, sapling and seedling layer in both the sites are given below.

3.1 Tree Layer

The total tree biomass recorded in site I was 386.91t ha^{-1} of which 333.31 t ha^{-1} was above-ground biomass and 53.6 t ha^{-1} below-ground. The distribution of biomass in the different components was as follows 142.36 t ha^{-1} in bole, 176.35 t ha^{-1} in branch, 14.59 t ha^{-1} in leaf and 53.6 t ha^{-1} in root. The bole, branch, leaf and root biomass constituted 36.79, 45.58, 3.77and 13.85%, of the total biomass respectively. Among the individual species *Shorea robusta* constituted the highest biomass (276.66 t ha^{-1}) followed by *Diospyros melanoxylon* (33.95t ha^{-1}) and *Adina cordifolia* (13.93t ha^{-1}) which constituted 71.5, 8.78 and 3.60% of the total biomass. However, lowest biomass was recorded in *Limonia acidissima*, *Terminalia catappa* and *Bridelia retusa* (0.43t ha^{-1}).

The total tree biomass recorded in site II was 297.04 t ha^{-1} of which 254.84 t ha^{-1} was aboveground biomass and 42.2 t ha^{-1} below ground. The distribution of biomass in the different components was as follows 109.37t ha^{-1} in bole, 133.84t ha^{-1} in branch, 11.62 t ha^{-1} in leaf and 42.2 t ha^{-1} in root. The bole, branch, leaf and root biomass constituted 36.82, 45.06, 3.91 and 14.21%, of the total biomass respectively. Among the individual species *Shorea robusta* constituted the highest biomass (227.69 t ha^{-1}) followed by *Lagerstroemia parviflora* (23.32 t ha^{-1}) and *Scheichera oliosa* (9.83t ha^{-1}) which constituted 76.65, 7.85 and 3.31% of the total biomass. However, lowest biomass was recorded in *Streblus asper* (0.43 t ha^{-1}) and *Butea monosperma* (1.56 t ha^{-1}).

3.2 Sapling Layer

The total sapling biomass recorded in site I was 22.304 t ha^{-1} of which 18.063 t ha^{-1} was above-ground biomass and 4.241 t ha^{-1} below-ground. The distribution of biomass in the different components was as follows 10.31 t ha^{-1} in bole, 6.36t ha^{-1} in branch, 2.54 t ha^{-1} in leaf and 4.24 t ha^{-1} in root. The bole, branch, leaf and root biomass constituted 46.24, 28.52, 6.23 and 19.02%, of the total biomass respectively. Among the individual species *Shorea robusta* constituted the highest biomass (10.322t ha^{-1}) followed by *Diospyros melanoxylon* (2.186 t ha^{-1}) and *Adina cordifolia* (1.694t ha^{-1}) which constituted 46.28, 9.80 and 7.59% of the total biomass. However, lowest biomass was recorded in *Scheichera oliosa* (0.137t ha^{-1}) and *Madhuca indica* (0.175t ha^{-1}).

The total sapling biomass recorded in site II was 24.226t ha^{-1} of which 19.86 t ha^{-1} was above ground biomass and 4.37 t ha^{-1} belowground. The distribution of biomass in the different components was as follows 11.42 t ha^{-1} in bole, 6.91t ha^{-1} in branch, 1.54t ha^{-1} in leaf and 4.37 t ha^{-1} in root. The bole, branch, leaf and root biomass constituted 47.13, 28.51, 6.34and 18.02%, of the total biomass respectively. Among the individual species *Shorea robusta* constituted the highest biomass (9.984t ha^{-1}) followed by *Diospyros melanoxylon* (3.209t ha^{-1}) and *Terminalia catappa* (2.545t ha^{-1}) which constituted 41.21, 13.25and 10.51% of the total biomass. However, lowest biomass was recorded in *Bauhinia variegate* (0.189t ha^{-1}) followed by *Aegle marmelos* (0.287t ha^{-1}) and *Azadirachta indica* (0.287t ha^{-1}).

3.3 Seedling Layer

The total seedling biomass recorded in site I was 9.228t ha^{-1} of which 7.143 t ha^{-1} was above-ground biomass and 2.085t ha^{-1} below-ground. The distribution of biomass in the different components was as follows 4.996t ha^{-1} in bole, 1.043t ha^{-1} in branch, 1.105t ha^{-1} in leaf and 2.085t ha^{-1} in root. The bole, branch, leaf and root biomass constituted 54.14, 11.3, 11.98 and 22.59%, of the total biomass respectively. Among the individual species *Shorea robusta* constituted the highest biomass (3.54 t ha^{-1}) followed by *Diospyros melanoxylon* (1.9t ha^{-1}) and *Azadirachta indica* (0.77 t ha^{-1}) which constituted 38.33, 20.56and 8.29% of the total biomass. However, lowest biomass was recorded in *Dillenia indica* (0.05 t ha^{-1}).

The total seedling biomass recorded in site II was 7.243 t ha^{-1} of which 5.62 t ha^{-1} was above ground biomass and 1.63t ha^{-1} below ground. The distribution of biomass in the different components was as follows 4.004t ha^{-1} in bole, 0.701 t ha^{-1} in branch, 0.912t ha^{-1} in leaf and 1.626 t ha^{-1} in root. The bole, branch, leaf and root biomass constituted 55.28, 9.68, 12.59 and 22.45%, of the total biomass respectively. Among the individual species *Shorea robusta* constituted the highest biomass (3.418 t ha^{-1}) followed by *Diospyros melanoxylon* (1.499 t ha^{-1}) and *Limonia acidissima* (0.621 t ha^{-1}) which constituted 47.19, 20.69and 8.58% of the total biomass. However, lowest biomass was recorded in *Millettia pinnata* (0.048 t ha^{-1}) followed by *Streblus asper* (0.072 t ha^{-1}) and *Alstonia scholaris* (0.072 t ha^{-1}).

Total tree biomass was varied between 297.04-386.91 t ha^{-1}, which was similar with tropical dry deciduous forests in Central India [13] and higher than Dry Tropics[14]. The total tree biomass was also compared with the Sal forest of Nepal [15]. In case of trees the higher biomass stored in the branches and bole where as leaves showed the lowest biomass production. Total sapling biomass was varied between 22.30-24.23 t ha^{-1}, which was supported by the studies conducted in Eastern Himalaya, Bhutan [16] along the altitudinal gradint. However the total sapling biomass was much lower than the Tropical deciduous forest [17]. Total seedling biomass was varied between7.24-9.23t ha^{-1}, which was supported by the studies conducted in Tropical deciduous forest [17]. In case of seedling the highest biomass seen in the main stem, however the branch and leaves contributed equal amount of biomass. This may be due to the shading effect of the higher stratum. In seedlings the root biomass is almost equal to the sum of branch and leaves biomass, this indicated abundant root growth at earlier stage.

Particularly Sal contributes 71-76% of the total biomass in case of trees, whereas in case of seedling and sapling the biomass contribution was only limited to 39-47% of the total biomass.

Previous reports on biomass estimation of different forests are

summarized in Table 4. Among the reference data, the highest biomass was estimated in the Tropical Forest, Congo [18] and Tropical rain forest, Brazil [19]. Present study indicates a healthy biomass composition compared to other tropical dry deciduous forest areas.

3.4 Forest Floor Biomass

The forest floor biomass in site I was recorded 389.1g m^{-2}, of which leaves litter 176.46 g m^{-2}, twigs 80.69 g m^{-2} and dead wood 131.95 g m^{-2}, which contributed 45.35, 20.74 and 33.91% of total forest floor biomass respectively. The forest floor biomass in site II was recorded 450.78 g m^{-2}, of which leaves litter 227.06 g m^{-2}, twigs 74.73 g m^{-2} and dead wood 148.99 g m^{-2}, which contributes 50.37, 16.58 and 33.05% of total forest floor biomass respectively. It clearly said that the leaf litter was contributed more to the forest floor than other component; it may be due to the effect of shading season in dry tropics.

Table 1: Tree biomass (t ha^{-1}) of dry Sal baring forest of Ranchi

Sl. No.	Species	Site I					SiteII				
		Bole	Branch	Leaves	Roots	Total	Bole	Branch	Leaves	Roots	Total
1	*Lagerstroemia parviflora* Roxb.	1.565	1.402	0.215	0.766	3.948	9.000	8.565	1.200	4.550	23.315
2	*Shorea robusta* Roth.	96.535	134.198	9.699	36.224	276.655	81.361	107.465	8.339	30.522	227.687
3	*Diospyros melanoxylon* Roxb.	14.981	12.065	1.315	5.591	33.954	3.862	2.951	0.350	1.459	8.623
4	*Adina cordifolia* Roxb.	5.744	5.370	0.666	2.151	13.931	2.697	2.808	0.301	1.011	6.817
5	*Scheichera oliosa* (Lour.) Oken	0.655	0.585	0.077	0.245	1.562	3.933	3.975	0.445	1.473	9.826
6	*Mangifera indica* Linn.	3.649	4.032	0.397	1.368	9.445					
7	*Syzygium cumini* (Linn.) Skeels.	2.217	2.169	0.253	0.830	5.469					
8	*Millettia pinnata* (L.) Panigrahi	1.206	1.129	0.140	0.452	2.926					
9	*Terminalia catappa* L.	0.194	0.145	0.024	0.072	0.435	0.923	0.805	0.110	0.346	2.183
10	*Phyllanthus emblica* L.	1.079	0.967	0.150	0.456	2.653					
11	*Terminalia arjuna* Roxb.	1.281	1.122	0.152	0.479	3.034					
12	*Bombax ceiba* L.	1.030	1.239	0.108	0.386	2.764					
13	*Terminalia tomentosa* Roxb.	6.084	6.243	0.680	2.280	15.286	0.848	0.811	0.097	0.318	2.075
14	*Azadirachta indica* A. Juss	0.551	0.462	0.067	0.206	1.286	2.040	2.125	0.228	0.764	5.157
15	*Dillenia indica* L.	1.042	0.955	0.122	0.390	2.509	1.163	0.977	0.140	0.435	2.715
16	*Gmelina arborea* Linn.	0.655	0.585	0.078	0.245	1.562					
17	*Bridelia retusa* (L.) A. Juss	0.194	0.144	0.024	0.072	0.435					
18	*Madhuca indica* J.F. Gmel.	1.667	1.569	0.193	0.624	4.053	0.907	0.917	0.102	0.340	2.267
19	*Butea monosperma* (Lamk) Taub.	1.845	1.826	0.209	0.691	4.571	0.655	0.585	0.077	0.245	1.562
20	*Limonia acidissima* L.	0.194	0.144	0.024	0.072	0.435	0.924	0.728	0.114	0.346	2.112
21	*Streblus asper* Lour.						0.194	0.144	0.024	0.072	0.435
22	*Bauhinia variegate* (L.) Benth						0.864	0.988	0.093	0.324	2.268
Total		142.36	176.35	14.59	53.60	386.91	109.37	133.844	11.622	42.205	297.041

Table 2: Sapling biomass (t ha^{-1}) of dry Sal baring forest of Ranchi

Sl. No.	Species	Site I					Site II				
		Bole	Branch	Leaves	Root	Total	Bole	Branch	Leaves	Root	Total
1	*Diospyros melanoxylon* Roxb.	1.131	0.480	0.128	0.447	2.186	1.627	0.719	0.192	0.671	3.209
2	*Lagerstroemia parviflora* Roxb	0.540	0.348	0.087	0.203	1.179	0.703	0.488	0.109	0.281	1.580
3	*Adina cordifolia* Roxb.	0.787	0.508	0.105	0.294	1.694	0.264	0.177	0.035	0.099	0.574
4	*Shorea robusta* Roth.	4.811	3.068	0.644	1.798	10.322	4.664	2.950	0.627	1.743	9.984
5	*Syzygium cumini* (Linn.) Skeels.	0.347	0.225	0.046	0.450	1.070					
6	*Millettia pinnata* (L.) Panigrahi	0.179	0.112	0.024	0.067	0.382					
7	*Phyllanthus emblica* L.	0.390	0.281	0.068	0.186	0.925	0.123	0.074	0.026	0.064	0.288
8	*Terminalia catappa* L.	0.441	0.272	0.060	0.165	0.938	1.200	0.733	0.164	0.448	2.545
9	*Azadirachta indica* A. Juss	0.132	0.088	0.017	0.049	0.287	0.132	0.088	0.017	0.049	0.287
10	*Dillenia indica* L.	0.132	0.088	0.017	0.049	0.287	0.494	0.271	0.070	0.184	1.020
11	*Terminalia tomentosa* Roxb.	0.215	0.137	0.029	0.081	0.462					
12	*Gmelina arborea* Linn.	0.132	0.088	0.017	0.049	0.287					
13	*Bridelia retusa* (L.) A. Juss	0.264	0.177	0.035	0.099	0.574					
14	*Butea monosperma* (Lamk) Taub	0.264	0.177	0.035	0.099	0.574	0.215	0.137	0.029	0.081	0.462
15	*Scheichera oliosa* (Lour.) Oken	0.069	0.032	0.010	0.026	0.137	0.480	0.314	0.064	0.179	1.036
16	*Madhuca indica* J.F. Gmel.	0.083	0.049	0.012	0.031	0.175	0.215	0.137	0.029	0.081	0.462
17	*Limonia acidissima* L.	0.215	0.137	0.029	0.081	0.462	0.526	0.337	0.070	0.197	1.131
18	*Wrightia antidysenterica* (L.) R.Br	0.177	0.096	0.025	0.066	0.364	0.201	0.120	0.028	0.075	0.424
19	*Bauhinia variegate* (L.) Benth						0.094	0.047	0.014	0.035	0.189
20	*Streblus asper* Lour.						0.347	0.225	0.046	0.130	0.749
21	*Aegle marmelos* (L.) Correa						0.132	0.088	0.017	0.049	0.287
Total		10.312	6.361	1.389	4.241	22.304	11.418	6.907	1.536	4.366	24.226

Table 3: Seedling biomass (t ha^{-1}) of dry Sal baring forest of Ranchi

Sl. No.	Species	Bole	Branch	Leaves	Roots	Total	Bole	Branch	Leaves	Roots	Total
1	*Shorea robusta* Roth.	1.997	0.352	0.446	0.742	3.537	1.947	0.296	0.453	0.722	3.418
2	*Diospyros melanoxylon* Roxb.	0.995	0.164	0.216	0.522	1.898	0.780	0.119	0.180	0.419	1.499
3	*Adina cordifolia* Roxb.	0.055	0.008	0.013	0.020	0.096					
4	*Lagerstroemia parviflora* Roxb	0.060	0.017	0.015	0.012	0.104	0.048	0.013	0.012	0.010	0.083
5	*Phyllanthus emblica* L.	0.223	0.072	0.096	0.169	0.559	0.034	0.007	0.021	0.031	0.093
6	*Scheichera oliosa* (Lour.) Oken	0.055	0.008	0.013	0.020	0.096	0.137	0.019	0.033	0.051	0.239
7	*Syzygium cumini* (Linn.) Skeels.	0.055	0.008	0.013	0.020	0.096					
8	*Azadirachta indica* A. Juss	0.420	0.108	0.081	0.156	0.765	0.196	0.052	0.037	0.073	0.358
9	*Mangifera indica* Linn.	0.196	0.052	0.037	0.073	0.358					
10	*Alstonia scholaris* (L.) R. Br	0.055	0.008	0.013	0.020	0.096	0.041	0.006	0.010	0.015	0.072
11	*Dillenia indica* L.	0.027	0.004	0.007	0.010	0.048	0.109	0.015	0.026	0.041	0.191
12	*Bridelia retusa* (L.) A. Juss	0.183	0.050	0.034	0.068	0.335					
13	*Wrightia antidysenterica* (L.) R. Br	0.338	0.097	0.061	0.126	0.621					
14	*Limonia acidissima* L.	0.338	0.097	0.061	0.126	0.621	0.338	0.097	0.061	0.126	0.621
15	*Streblus asper* Lour.						0.041	0.006	0.010	0.015	0.072
16	*Samanea saman* F. Muell						0.183	0.050	0.034	0.068	0.335
17	*Madhuca indica* J.F. Gmel.						0.055	0.008	0.013	0.020	0.096
18	*Millettia pinnata* (L.) Panigrahi						0.027	0.004	0.007	0.010	0.048
19	*Butea monosperma* (Lamk) Taub						0.068	0.010	0.016	0.025	0.120
Total		4.996	1.043	1.105	2.085	9.228	4.004	0.701	0.912	1.626	7.243

Table 4: Comparison of biomass of dry Sal bearing forest of Ranchi with other forests

Location	Layers	Above-ground	Below- ground	Total	Source
Tropical north east forest	Tree	124.6-255	--	--	[1]
Tropical dry deciduous forest	Tree	83.2– 370.1	20.1 - 83.4	103.3- 453.5	[13]
Sal forest in Nepal	Tree	117.2-299.6	5.8-6.3	123- 305.9	[15]
Tropical Dry Forest, East Godavari	Tree	58.04- 368.39	--	--	[20]
Tropical deciduous forests, Nallamalais	Tree	--	--	5.2- 299.3	[21]
Dry Tropics, C. G.	Tree	111.2-199.4	16.5-28.3	127.7-227.7	[14]
Semi Evergreen forest	Tree	197.59±60.06	--	--	[22]
Tropical deciduous forest	Tree Sapling Seedling	211.99 46.46 6.07	29.45 10.13 1.59	241.44 56.59 7.66	[17]
Tropical wet evergreen forest	Tree	101.26-282.61	20.25-56.52	121.51- 339.13	[23]
Tropical dry deciduous forest, Haryana	Tree	37.93 - 63.73	11.12- 17.81	49.05- 81.54	[24]
Tropical forest of Cachar, Assam	Tree	32.47 - 261.64	--	--	[25]
Eastern Himalaya, Bhutan	Tree Sapling	108.24- 407.23 6.65- 28.62	--	--	[16]
Tropical rain forest, Brazil	Open Dense Ecotone	288-346 298-533 298-422	-- -- --	-- -- --	[19]
Tropical Forest, Congo	Tree	291.8- 559.7	68.5- 131	360.3- 690.7	[18]
Savvana	--	12.88	--	--	[26]
Tropical Rain forest, Australia	Tree	307– 909	--	--	[27]
Sundarbans, Bangladesh	Tree	154.8	84.2	239	[28]
Conifer forest Bhutan	Tree	--	--	191.58	[29]
Tropical deciduous forest	Tree Sapling Seedling	254.8-333.3 18.06-19.86 7.14- 5.617	42.2-53.6 4.24-4.37 2.09-1.63	297.04-386.9 22.30-24.23 7.24- 9.23	Present Study

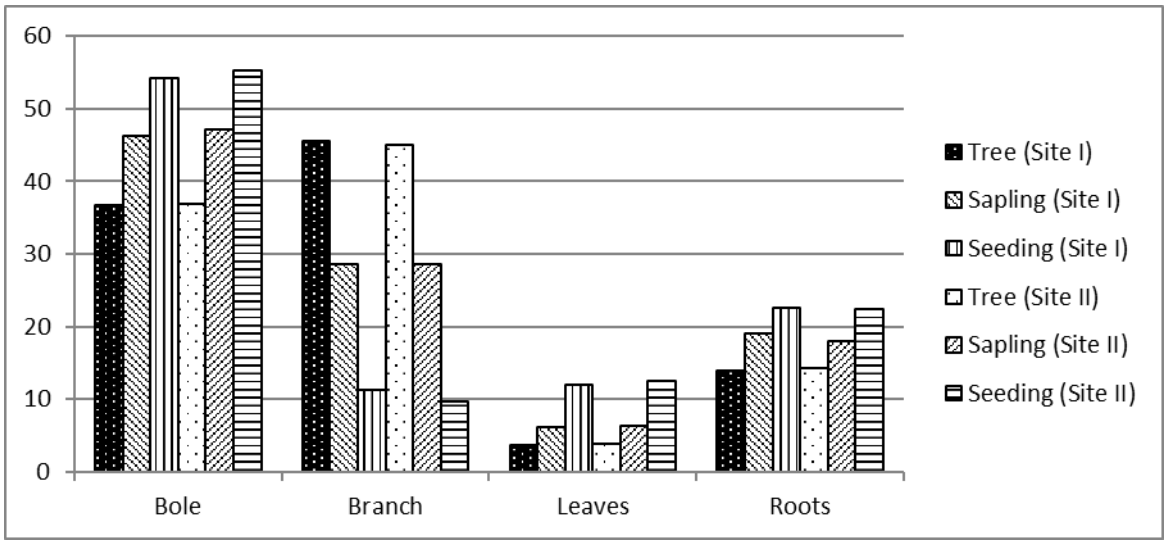

Fig 1: Biomass of different parts of the vegetation

5. Conclusion

In tropical dry Sal bearing forest Sal keep a dominating role with higher amount of biomass production. However the co-dominant and associate species also have equal contribution to the total biomass of that area. Besides the anthropological interference particularly the seedlings contribute good amount of biomass which reflects a healthy future growth. According to the location of the forest area with proper management and controlling the grazing and fire, this forest can create a scope for eco-corridor for wild fauna. Besides this, the forest contributes abundant amount of biomass to the local residence.

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7. References

1. Thokchom A, Yadava PS. Biomass and carbon stock along an altitudinal gradient in the forest of Manipur, Northeast India. Tropical Ecology. 2017; 58(2):389–396.
2. Keller M, Palace M, Hurtt M. Biomass estimation in the Tapajos national forest, Brazil examination of sampling and allometric uncertainties. Forest Ecology and Management. 2001; 154:371-382.
3. Ketterings QM, Coe R, Noordwijk M, Ambagau Y, Palm CA. Reducing uncertainty in the use of allometric biomass equations for predicting above ground tree biomass in mixed secondary forests. Forest Ecology and Management. 2001; 146:199-209.
4. Cairns MA, Olmsted I, Granados J, Argaez J Composition and aboveground tree biomass of a dry semi-evergreen forest on Mexico's Yucatan peninsula. Forest Ecology and Management. 2003; 186:125-132.
5. Ovington JD. (Quantitative ecology and the woodland ecosystem concept. Adv Ecol Res. 1962; 1:103-192.
6. Brown SL, Schroeder P, Kern JS. Spatial distribution of biomass in forests of the eastern USA. Forest Ecology and Management. 1999; 123:81-90.
7. Chaturvedi OP, Singh JS. The structure and function of pine forest in central Himalaya. Dry matter dynamics. Annals of botany. 1987; 60:23S7-252.
8. Tiwari AK. Mapping forest biomass through digital processing of IRS-1A data. International Journal of Remote Sensing. 1994; 15(9):1849-1866.
9. Intergovernmental Panel on Climate Change Good practice guidance for land use, land-use change and forestry. Task Force on National Greenhouse Gas Inventories, Kanagawa, Japan, 2003.
10. Champion HG, Seth SK. A Revised Survey of the Forest Types of India. Government of India Publication, New Delhi, India. 1968.
11. Singh KP, Misra R. Structure and functioning of natural, modified and silvicultural ecosystems of Eastern Uttar Pradesh: technical report October 1975-October 1978. Banaras Hindu University, Varanasi. 1979, 161.
12. Singh L, Singh JS. Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. Annals of Botany. 1991; 68:263-273.
13. Joshi RK, Dhyani S Biomass, carbon density and diversity of tree species in tropical dry deciduous forests in Central India, Acta Ecologica Sinica, 2018.
14. Pawar GV, Singh L, Jhariya MK, Sahu KP. Effect of anthropogenic disturbances on biomass and carbon storage potential of a dry tropical forest in India. Journal of Applied and Natural Science. 2014; 6 (2):383-392.
15. Neupane B, Sharma RP. An assessment of the effect of vegetation size and type, and altitude on above ground plant biomass and carbon. Journal of Agricultural and Crop Research. 2014; 2(3):44-50.
16. Tashi S, Keitel C, Singh B, Adams M. Allometric equations for biomass and carbon stocks of forests along an altitudinal gradient in the eastern Himalayas; Forestry. 2017; 90:445–454.
17. Jhariya MK, Yadav DK. Biomass and Carbon Storage Pattern in Natural and Plantation Forest Ecosystem of Chhattisgarh, India, Journal of Forest and Environmental Science. 2018; 34(1):1-11.
18. Ekoungoulou R, Nzala D, Liu X, Niu S. Tree Biomass Estimation in Central African Forests Using Allometric Models; Open Journal of Ecology. 2018; 8:209-237.
19. Cummings DL, Kauffman JB, Perry DA, Hughes RF. Above ground biomass and structure of Rain Forests in the southwestern Brazilian Amazon; Forest ecology and management. 2002; 163:293-307.
20. Srinivas K, Sundarapandian S. Biomass and carbon stocks of trees in tropical dry forest of East Godavari

region, Andhra Pradesh, India; Geology, Ecology and Landscapes, 2018.
21. Rao VS, Rao BRP. Carbon sequestration potential of tropical deciduous forests of Nallamalais, India; Asian Journal of Plant Science and Research. 2015; 5(3):24-33.
22. Giri K, Das DJ, Pradhan B, Mishra G, Buragohain P, Hazarika S. Tree diversity, Above Ground Biomass and Carbon Stock in Eastern Alluvial Secondary Semi Evergreen Forest of Assam; Archive of Life Science and Environment. 2018; 2(2):105-111.
23. Gogoi A, Sahoo UK, Singh SL. Assessment of Biomass and Total Carbon Stock in a Tropical Wet Evergreen Rainforest of Eastern Himalaya along a Disturbance Gradient; Journal of Plant Biology and Soil Health. 2017; 4:1.
24. Singh V, Gupta SR, Singh N. Carbon Sequestration Potential of Tropical Dry Deciduous Forests in Southern Haryana, India; International Journal of Ecology and Environmental Sciences. 2016; 42:51-64.
25. Borah N, Nath AJ, Das AK. Aboveground Biomass and Carbon Stocks of Tree Species in Tropical Forests of Cachar District, Assam, Northeast India; International Journal of Ecology and Environmental Sciences. 2013; 39(2):97-106.
26. Oliveira C, Francelino M, Daher M, Araújo E, Sanches L, Andrade K *et al*. Estimation of the aboveground biomass and carbon stocks in open Brazilian Savannah developed on sandy soils; Carbon Balance and Management. 2019; 14:5.
27. Bradford M, Murphy HT. The importance of large-diameter trees in the wet tropical rainforests of Australia; PLoS ONE. 2019, 14(5).
28. Kamruzzaman Md, Ahmed S and Osawa A Biomass and net primary productivity of mangrove communities along the Oligohaline zone of Sundarbans, Bangladesh; Forest Ecosystems. 2017; 4:16.
29. Tshering S. Importance Value Index and Assessment of Carbon Stocks in Western Bhutan Himalaya (Thimphu); Current Journal of Applied Science and Technology. 2019; 32(2):1-8.