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Above-and below-ground biomass production and nutrient accumulation in matured age series of *Gmelina arborea* Roxb Stands

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ABSTRACT

The biomass and nutrient content of three stands of Gmelina arborea Roxb, aged 30, 29 and 28 years were estimated in Gmelina arborea Plantation in Shasha Forest Reserve (SFR), Osun State, Nigeria. Five mean trees per stand were destructively sampled and their roots were excavated. Allometric equation relating dry weights of Gmelina arborea tree components (roots, stem wood, branches, leaf, sawn dust and stump root crown) to stem diameter were developed to predict total tree biomass. Total biomass accumulation per hectare increases with stand age; giving 74237kg/ha, 83044kg/ha and948048/ha in stand aged 30, 29 and 28 years respectively. The mean annual biomass production in the three stands stood at 13716.01kg/ha/yr., 12537.60kg/ha/yr., and 11509.73kg/ha/yr. in age 30, 29 and 28 years, respectively. The periodic increment and net primary production showed that the rate of biomass accumulation was highest in 0 – 28 years(12092.33kg/ha/yr.) while the annual net primary production in stands aged 30 and 29 years were 2189.61kg/ha/yr. and 1822.87kg/ha/yr. respectively.

Keywords: Allometric structure, dry matter content, Growing stock volume, Different ages

INTRODUCTION

Studies of biomass provide important basis to analyze ecosystems in terms of organic matter production, cycling of mineral elements, energy and water. Biomass is applicable to both plant and animal lives. It is measurable by weight or volume, though weight is most widely used. Nwoboshi (1985); reported that dry weight is an alternative to volume as a basic unit of measurement in professional and scientific forestry. Also, Ojo (2005) noted that tropical forest nutrient and biomass research is dynamic. However, while data on some tree components are available, data on root biomass especially when the plantation has reached an advanced age are not readily available. This is because of the high cost of sampling and measuring roots. For example, the limited available root biomass data from tropical forests suggest that root shoot ratio varies from 0.03 to 0.49, with below ground biomass ranging from 11 to over13 kg/ton (Anderson and Ingram, 1992). The fact that some root biomass exist below ground is undisputable but the question: how much do we have below the ground that contributed to the total biomass cannot be over emphasize. However, based on the distribution of different nutrient in the tree biomass components of *Gmelina arborea* in Shasha Forest, it can be argued that it is possible to limit nutrient loss in biomass removal to reasonable level at least compatible with site conditions and productivity in the plantation. The organic matter accumulation was proportional to the extent of canopy closure in the stands. This study therefore, provides definite information on the above - and below- ground biomass production and nutrient accumulation in a matured age series of *Gmelina arborea* stands in Shasha Forest Reserve (SFR), Osun State, Nigeria.

MATERIALS AND METHODS

This study was carried out in1976 (40) ha, 1978 (40) ha and 1979 (35) ha *Gmelina arborea* plantations in Shasha Forest Reserve, Osun State, Nigeria. The ages were selected based on the method of plantation establishment and the same silvicultural practices adopted in all the stands. Also for this type of study, only unexploited plantation of *Gmelina arborea* is considered suitable for the research and this was responsible for the age series selected for the study. The plantation was established by direct planting with nursery stock at a spacing of 3 x 3m. The Forest Reserve is located between Latitudes 7^o and 7^o 3^oN and longitudes 4^o and 5^oE. The total land area of the Forest Reserve was 23,064 ha. The total annual rainfall ranged from 887mm to 2180mm. The mean annual temperature was 26.5^o with the annual range between 19.5 to 32.5^oC (Klinge 1977, Kio, 1978, Popoola *et al*.).

Destructive Sampling: In the three stands, sampled plots of 20 x 20 m were measured using meter rule and pegs to establish the plots. In each stand inventory of trees with DBH $\geq$ 3cm were taken for merchantable height (MH) and total height (TH). Tree diameters were grouped into five diameter classes. Within each diameter class, a tree closest to the mean tree were destructively (5 trees/plot) sampled (roots were carefully excavated). Merchantable length of each tree was measured and the trees were divided into: stump, root, crown, stem wood, saw dust, branches, leaves and roots. Allometric structures (relationship between the diameter at the breast height and the total height of the trees) of the stands was expressed as logH = loga + blogD, where H = total height, D = dbh, a, b shows allometric coefficients. The bole was cut into 1m logs to determine wet weight and 3cm discs were cut from each log for dry weight determination. The fresh weight of each part was determined in the field and sub-samples taken to the Laboratory after initial air dried in the field.

Nutrient accumulation: The samples were oven dried to constant weight at $105^{\mathbf{o}}$ C and ground in a willey mill to pass through a 2mm mesh screen. Total P was determined using H_2S0_4 /$HN0_3$ digestion method; total N by the micro – kjeldahl method as described by (Chuyong *et al*, 2000) and K, Ca and Mg by dry ashing and extraction by dilute HCl. Nutrient accumulation for each tree components was calculated by multiplying biomass estimate per hectare by appropriate nutrient concentration. The distribution of dry matter between wood and bark of each sampled tree was estimated with simple linear regression of bark to weight on the bole weight as described by Egunjobi and Bada (1979) was employed. A correction factor of 1.25 – 2.0 was applied to the final data based on the estimated losses due to sampling and processing.

Biomass Estimation

Stand density: The density of *Gmelina arborea* per hectare was calculated using planting espacement of 3 x 3 m Density of 44 trees per 0.04ha was determined.

The basal area (BA) of each trees was calculated in accordance to Tropical Soil Biology and Fertility Programme model developed by Anderson and Ingram, (1992) using:

$BA = 0.7854D^2$ ---------------------------- (1)

Where:

BA = basal area.

D = diameter at breast height (dbh).

Allometric equation of the biomass of each tree components and total tree biomass of the diameter at breast height (cm) and the product of the square of diameter at breast height (cm) and total tree height (m) were derived using the model.

$Ln (X) = a + bL_n (D^2H)$ ------------------ (2)

Where:

L_n = natural logarithmic transformation of the allometric equation

X = biomass (kg)

D = diameter at breast height (cm)

H = total height of tree (m)

The model was used to test the level of accuracy of biomass estimate in *Gmelina arborea* plantation. The Standard Error (SE) and the Coefficient of determination (R^2) were computed as estimates of accuracy for the regression lines.

Model $L_n (X) = a + bL_n (D)$ -------------- (3)

Above model was adopted for the calculation of total tree biomass.

Biomass estimates of tree components were tested with Coefficient of Determination (R^2) and Standard Error (SE).The percentage difference between the biomass prediction by the total tree weights and those of the components biomass.

Estimation of stand basal area and biomass

The values from individual tree basal area in 20m x 20m plot were summed up and basal area per hectare was derived. The total above and below-ground biomass regression equations developed for *Gmelina arborea* plantations were used to predict the biomass of individual trees. Stand biomass was computed for each plot by adding individual tree biomass (kg) and then extrapolating the result in kg per hectare in each stand by multiplying weight of different tree components and plot size.

RESULTS AND DICUSSION

Above and below ground biomass of *Gmelina arborea* tree parts exhibit similar trend of nutrient accumulation in all the stands. Though, there were variations in the dry weights of the parts, the total biomass accumulation increased with the age of the plantation. A major significance of this study is that it quantitatively revealed the contribution of below ground biomass to the total stand biomass which is about is 17.8% (Fig.1); though bole contribution to total tree biomass was the highest which is 30.0% (Fig.1), the leaf component had the lowest contribution which is 0.1%. Table 1showed plots data before destructive sampling while table 2 showed the computed above-and below - ground biomass values per hectare of the *Gmelina arborea* components in each plot. The regression equation to show allometric relationship between bark and bole weight of destructively sampled trees in the plots shows a significant relationship. The bark weight (BW) increased with the bole weight (BLWT).Regression equation for the pooled data;

BW = 1.869 + 0.0002 BLWT------------- (4)

$R^2 = 0.68$, $R^2a = 0.65$, S.E = 0. 208.

The relationship was predicted when semi-log of the dependent variables (bark weight) was taken. The resulting regression equation is express as:

BW = 0. 3229 + 0.0003 BLWT---------- (5)

$R^2 = 0.69$, $R^2a = 0.66$, S.E = 0.027,

BW = Bark weight, and BLWT = Bole weight

The growing stock volume (GSV) variation according to DBH of the stands shows that, as the DBH of trees increases, the growing tree stock volume of the stands also increases. Five different classes of DBH were distinguished with computation based on the frequency distribution (Table 3). The DBH classes provide basic information on the uses to which the wood can be put. Trees with DBH <5cm had very few uses considering the present demand for *Gmelina arborea* wood. The DBH of 5 to 25cm could be used for poles and fire wood. From 25cm DBH, are marketable. In each DBH size, the proportions of (GSV) were 0.02%, 6.32%, 44.47%, 34.12% and 15.08% respectively. The (GSV) variations from the first diameter size, through the second, third, fourth and fifth diameters size were 0.32%, 14.22%, and 130%, 226.40% and 296.60% respectively. In table 3, the smallest and the largest sized trees yield small proportion of the (GSV) (1.89%). The second and the third had the highest number of trees and 56.15% and 31.86% of (GSV) respectively (Table 3). The tree (GSV) was not uniformly distributed because of the ages of the stands.

Table 1: Summary of Plot Data

Yr. planted	1976			1977			1978		
Age (yr.) in 2006	30			29			28		
Sample plots (ha)	P_1 0.04	P_2 0.04	P_3 0.04	P_1 0.04	P_2 0.04	P_3 0.04	P_1 0.04	P_2 0.04	P_3 0.04
Obs. tree density	40	22	44	47	43	41	24	31	26
Exp. Tree density/ 0.04 ha	44	44	44	44	44	44	44	44	44
No of tree missing / 0.04ha	4	22	0	3	1	3	20	13	18
Range of dbh (cm)	23-43	23-43	23-43	21-37	21-37	21-37	23-41	23-41	23-41
Range of BA at breast height (cm2)	422.78-522.36	422.78-522.36	422.78-522.36	422.78-532.025	422.78-532.025	422.78-532.025	535.09-674.34	535.09-674.34	535.09-674.34
dbh (cm)	22	22	22	19.3	19.3	19.3	21.3	21.3	21.3
BA at breast height (cm2)	472.111 9	472.111 9	472.111 9	491.867	491.867	491.867	578.750	578.750	578.750
Estimated basal area (m2/ha)	11802.7 7	11802.7 7	11802.7 7	122.96.6 7	122.96.6 7	122.96.6 7	14468.6 7	14468.6 7	14468.6 7

Table 2 Computed Total Above and Below Ground Biomass (kg/ha) of *Gmelina arborea* age series.

1	1976	30	12.4	154.8	728.12	24.0	22.8	115.90	1058.02	0.9515
2		"	13.7	159.2	887.13	25.16	21.6	169.60	1276.39	1.0886
3		"	10.6	142.6	762.4	23.90	28.2	132.80	1100.50	0.9613
4		"	11.0	148.2	722.8	24.88	23.2	122.80	1052.88	0.9659
5		"	7.6	127.8	638.2	23.99	19.6	112.4	929.59	0.8243
Mean/S			11.06	146.52	747.73	24.39	23.08	130.70	1083.48	0.95832
Exp.wt. Kg/ha			15484	2051128	1046822	34146	32312	182980	3362872	1341.65
Ob. Wt. Kg/ha			9677.5	21341.25	654263.75	21341.25	20195	114362.5	948048	838.53
S/N	**Years S₂ Planted**	**Age YR**	**LV**	**Branches**	**Stem Wood**	**Dust**	**Stump Root Crown**	**Roots**	**Total weight**	**Volume (M^3)**
6	1977	29	10.8	137.6	672.52	17.17	26.4	149.60	1014.09	0.9006
7		"	6.8	89.7	393.46	19.11	22.8	123.60	655.47	0.6045
8		"	7.2	88.0	441.10	16.97	30.0	149.00	732.27	0.6883
9		"	7.6	112.6	452.65	18.51	27.6	133.90	752.86	0.6688
10		"	8.6	109.8	494.99	18.18	28.6	128.20	788.37	0.8293
Mean/S			8.2	107.54	409.944	17.10	27.08	136.90	706.76	0.7383
Exp.wt. Kg/ha			11480	150556	573921.6	25186	39712	191604	990659.6	1033.62
Ob. Wt. Kg/ha			9653	126359.5	481684.1	21138.25	31819	160857.5	830443	867.50
S/N	**Years S_3 Planted**	**Age YR**	**LV**	**Branches**	**Stem Wood**	**Dust**	**Stump Root Crown**	**Roots**	**Total weight**	**Volume (M^3)**
11	1978	28	10.5	145.2	814.02	23.10	34.4	148.9	1176.12	1.0918
12		"	13.5	151.8	898.48	22.67	23.8	157.8	1268.05	1.1260
13		"	12.0	122.6	692.68	21.9	21.3	128.7	999.18	0.8710
14		"	11.6	141.6	653.27	20.82	32.4	159.6	1019.32	0.8266
15		"	9.4	128.4	695.61	23.4	30.6	147.4	1034.81	0.9844
Mean/S			11.4	137.92	750.81	22.38	28.5	148.8	1099.83	4.8998
Exp.wt. Kg/ha			15960	193988	1051136.8	31332	39900	208320	1539736.8	1371.94
Ob. Wt. Kg/ha			7695	93096	506796.8	15106.5	19237.5	100440	742371.8	3307.37

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Table 3: Volume Variations According to DBH Classes.

Volume	V_1 (m3)	V_2 (m^3)	V_3 (m^3)	V_4 (m^3)	V_5 (m^3)
With	DBH<5cm	5<DBH25cm	25<=DBH50cm	50<=DBH75cm	75<=1
Total	0.08	31.52	221.81	170.13	75.23
%Tot.Vol.	0.02	6.32	44.47	34.12	15.08
X Vol (m3)	0.01	0.18	2.20	6.54	12.53
No of trees	6	178	101	26	6
% No of trees	1.89	56.15	31.86	8.20	1.89

Regression analysis

The resulting regression equation of DBH and MH to predict wood volume obtainable in each stand are:

Stand one (S_1); CV= -0.257+0.158D – 0.115MHT ------------------------------- (6)

R^2= 0.89; Ra = 0.89; SE= 0.889.

Where CV = cylindrical volume; D = diameter

Stand two (S_2); CV= - 0.230+0.134D – 0.113MHT---------------------------------- (7)

R^2 = 0.90; Ra = 0.89; SE = 0.715.

Stand three (S_3); CV = 0.179 + 0.165D – 0.176MHT------------------------------- (8)

R^2 = 0.88; Ra = 0.88; SE = 0.961.

In S1, age had a significant relationship on increment of the cylindrical volume as DBH increased. Regression equation for the pooled data gave a better prediction.

CV = - 0.403 + 0.145D – 0.104MHT-- (9)

R^2 = 0.88; Ra = 0.88; SE = 0.889.

High value of R^2 (0.88) reveals that better management techniques would improve wood production in the stands. Dry matter increased in the plots (P) in this order 441,480.4 kg/ha > 363,590.2kg/ha > 322,272.4kg/ha-[1] i.e P_1>P_2>P3 respectively. Table 4 showed that mean annual biomass accumulation was highest from 0- 28-years and organic matter accumulation component parts showed similar trends in all the stands.

Table 4: Mean biomass production, net (periodic increment and primary) production (kg/ha/yr.) in the stands

Age (years)	0 – 28	28 – 29	29 - 30
Mean annual production	11509.73	12537.60	13716.01
Mean periodic production	11509.73	1027.87	1178.41
Mean litter fall	582.6	795.0	1011.2
Net primary production	12092.33	1822.87	2189.61

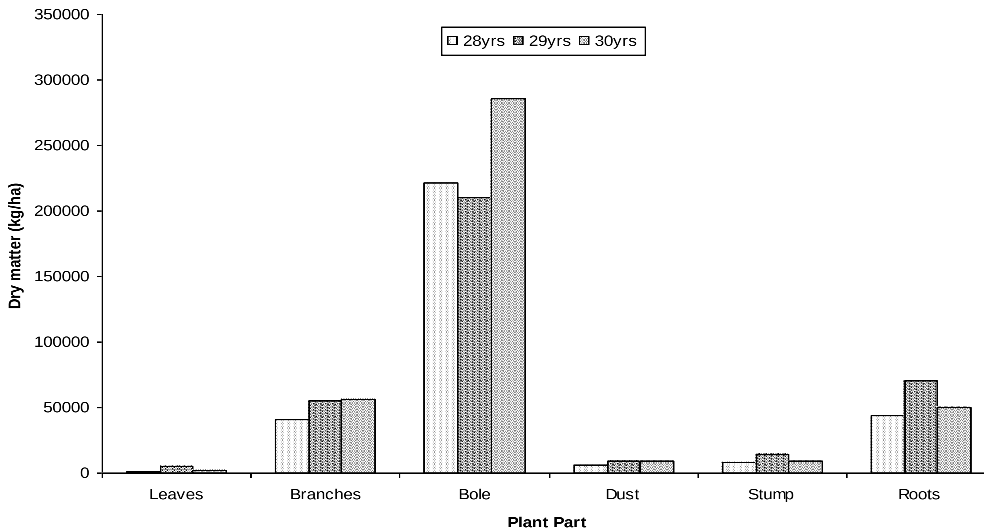

Figure 1: Quantities of dry matter in *Gmelina arborea* stand in different plant parts

CONCLUSION

The tree variables BA, and CV, MH, TH and DBH indicated a fair productivity in terms of wood production. A major significance of this study is that it quantitatively revealed the contribution of below – ground biomass to the total stand biomass (fig.1). The different between this study and the other studies on biomass by Ola-Adams (1987) and Kadeba (1991) can be attributed to the age difference, methods estimating biomass, different climatic zone, site characteristics, skill and the accuracy of the enumerator.

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