Original Article *Journal of Sustainability and Environmental Management (JOSEM), Vol. 3, No. 3 (2024), 159 – 164*
p-ISSN 2822-1729, e-ISSN 2822-1737 Available online at https://www.nepjol.info/index.php/josem

Deriving a Template for Sustainable Forest Management in Nigeria's Northern Guinea Savanna: Study of Detarium Microcarpum (Fabaceae)

Justus Eronmosele Omijeh

Department of Forestry and Wildlife Management, Modibbo Adama University, Yola. Nigeria

Corresponding author: jeomijeh@yahoo.com

Abstract: *Detarium microcarpum* (Fabaceae) is a small tree found in the Sudan and Guinea Savanna and used for several nutritional and health purposes. A template was developed to enhance the practice of sustainable forest management. Nineteen sample trees were assessed for different growth parameters, yielding a coefficient of determination (r^2) and Pearson's correlation coefficient (r). The analysis showed the relationship between tree height and crown diameter, crown area, basal area, crown ratio, and volume as 0.22, 0.01, 0.55, 0.10, and 0.70, respectively. To assuage the harsh effects of climate change, deforestation and other anthropogenic activities should be discouraged through vigorous forest extension activities.

Keywords: *Bagale, Climate change, Correlations, Fabaceae, GHG emissions, Volumetric equations*

Conflicts of interest: None
Supporting agencies: None

Received 09.08.2024; Revised 02.11.2024; Accepted 13.11.2024

Cite This Article: Omijeh, J.E. (2024). Deriving a Template for Sustainable Forest Management in Nigeria's Northern Guinea Savanna: Study of Detarium Microcarpum (Fabaceae). *Journal of Sustainability and Environmental Management*, 3(3), 159-164.

1. Introduction

Detarium microcarpum is a small tree that grows up to 10 meters high with a dense and spherical crown found in the Sudan and Guinea Savanna. The plant treats diseases such as diarrhea, rheumatism, and epilepsy and is characterized by a hard dark brown timber. It is also useful in agro-forestry (Mariod et. al., 2011).

Several authors, Brown and Lugo (1992), Chidumayo (2002), Salis et al. (2006), Williams et al. (2008), Lewis et al. (2009) commented on the relative dearth of quantitative estimates of dry forests and Savanna biome relative to most tropical forest biome. Forest inventories are valuable data sources for estimating biomass density (Brown and Lugo, 1992). Very little information on carbon stock is available for the savanna woodland (Lewis et. al., 2009). Knowledge of the volume of wood resources and their growth rate is critical for forest management and planning (Altriell et. al., 20210). Volumetric equations are generally useful and are required for the development and implementation of forest management plans, but must be adjusted for different species, region and physiognomic types (Tonimi and Bookyes; 2015).

There appears not to be any recent study on volume equations in the Northern Guinea Savanna. The importance of volume equations and their relationship to the volume of trees and diameters at breast height and/or height is expressed by Akindele (2005) and Nurudeen et al. (2014).

The role of forest ecosystems in reducing GHG emissions is highlighted by Arora et. al. (2012). Forests play a key role in ecosystem conservation and provide livelihood for many dwellers (FAO, 2006). Climate change affects different sectors (Osbahr, 2007). Forests are responsible for about 17% global GHG emissions. Estimated damage costs of forest loss for the global economy could be about $12 trillion in net present value terms, including climate change damage caused by emissions from other sectors (Elias Chi 2008). The nexus of climate, spatial variation and carbon sequestration on forest productivity is expressed by Toledo et. al., 2011).

Forest management strategies to mitigate climate change include the application of sustainable forest management because the forest sector sustains carbon and absorbs the same from the atmosphere (Lal and Sough, 2000); community forest management can help in the reduction of forest emissions and increase forest carbon stock. Forest management interventions that result in carbon emission reductions or increased carbon sequestration could be rewarded by REDD + (FAO, 2010). Thirdly, a sustainable environment can be achieved by developing and managing agro-forestry systems on lands, farms, and urban and rural tree plantations (FAO, 2010).

This paper aims to derive a template for sustainable forest management in Nigeria's Northern Guinea Savanna by studying the growth and yield predictions of Detarium microcarpum.

2. Materials and methods

Bagale Hills Forest Reserve is an old ecosystem located between latitudes 9o 11" and 90 "N and Longitude 120 30" E in the Northern Guinea Savanna Zone. As shown in Figure 1 (Adamawa State Government, 2022), the reserve has an area of 69.4 square miles, or about 18,000 hectares.

A total of 15 sample plots randomized and replicated were laid in the reserve from which 19 individuals of *Detarium microcarpum* trees measuring 10 ≥ cm and above were assessed. This species was identified in the herbarium of the Biological Sciences Department, Ahmadu Bello University Zaria, Nigeria. To eliminate bias, the selected trees were numbered with red paint to avoid double counting. The biggest, smallest, and medium-sized trees were all captured in the sample plots. There was no sign of pruning or pollarding on the trees in the study area. The variables of each tree measured include tree height, crown diameter, diameter at breadth height (dbh), Crown diameter, tree girth, basal area, and volume.

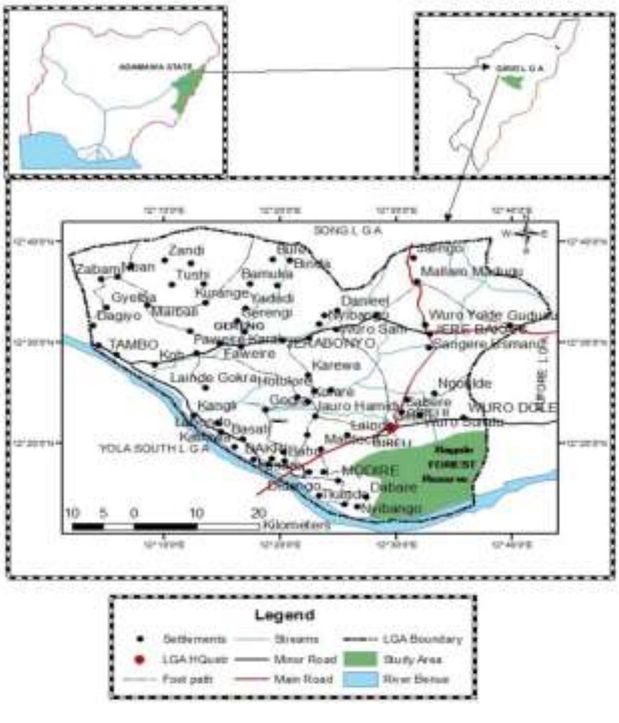

Figure 1: Map of the study area

Tree Height

This is measured as the total height subtracted from the distance from ground level to the base of the crown. The clinometers were used to aim at the peak of the tree, and the distance of the tree angle to the operator was recorded (Gareth, 1991).

$$X = Y \tan A + Z \quad (1)$$

Where X= tree height, Y= distance from the tree to the observer, A= angle of elevation, Z= height of the observer at eye level.

The height of each tree was measured using a clinometer—Haga altimeter—following the procedure of Mugash et al. (2013).

Crown Ratio

This was computed for each of the species in the sample plots using the formula

$$CR = cli/THTi \quad (2)$$

Where Cli = individual tree crown length

THTi = total height of the ith tree (Buba et. al., 2012)

Crown Diameter

This was measured for each tree using the formula

$$CD = \sum \frac{ri}{2} \quad (3)$$

Where CD = Crown diameter

ri = projected crown radii measured on four axes (Arabeyiretal et. al., 2020)

Tree Girth

This is the measurement of the circumference of the tree taken at 1.3 m above the ground level (Eyre et. al., 2000). The stem DBH was calculated as follows:-

$$C = D \times \pi \quad (4)$$

Where C= Circumference,

D= Diameter

π = 22/7 i.e 3.14.

Basal Area

This involves determining the cross-sectional area of a tree trunk at 1.35 meters above the ground measured in square meters. This parameter was determined based on the formula by Wratten & Fry (1980).

(5)

Volume

The volume of each tree was established using Newton's Formula (Husch et. al., 1982), which is expressed as:

$$V = H (A_b + 4A_m + A_n) \quad (6)$$

Where V= actual tree volume (Overbark in m^3)

H= Tree height (m)

A_b= Cross sectional area at the base of the tree (m^2)

A_m= Cross sectional area in the middle of the tree (m^2)
A_n= Cross sectional area at the top of the tree (m^2).

3. Results and discussion

The minimum and maximum stem diameter obtained were 0.08 and 0.48 cm, respectively (Table 1). This did not agree with the findings of Mugasha et. al. (2013), who obtained figures ranging from 1.1 to 3.5cm minimum and 58.4 to 175cm maximum in different forest types and species groups of trees in a natural tropical forest of Tanzania.

The relationship between tree height, volume, and basal area was negative, while that between tree height and crown diameter was moderately positive. The relationship between tree height and crown area exhibited an extremely weak positive correlation (Table 2).

The coefficient of determination (r2) in the correlation between tree height and crown diameter was 26% (Table 2). This implies that 26% of the variation in the tree height in the 19 samples was accounted for by variation in their diameter.

The r2 between tree height and basal area (54%) and volume 70% respectively (Table 2) were negative. These results do not agree with those obtained in different forest types/species groups by Mugasha et. al. (2020).

The minimum and maximum stem diameters obtained were 0.08 and 0.4cm, respectively, which did not agree with the results obtained by Koirala et al. (2016) and those recorded by Buba (2013), who obtained 0.32 and 0.70 cm, respectively, in the same clime. Koirala et al. (2016) posted dbh and height ranging from 6.1 to 58.9 and 6.1 to 2.8, respectively, in the central lowlands of Nepal.

Positive correlations were observed between tree height and crown diameter, crown area, and crown ratio, while negative correlations were observed between tree height, basal area, and volume using tree height as a predictor variable (Table 2).

The coefficient of determination (r^2) in the relationship between tree height and crown diameter was 26% (Table 2). This implies that 26% of the variations in the tree height in the 19 samples of the study area were accounted for by the variations in their diameter. The r2 between tree height and the crown area was 15%; tree height and basal area 54% and volume 70%, respectively, were negative (Table 2). These results do not agree with those obtained by Mugasha et. al. (2013) in different forest types/species groups. R^2 values for tree height and basal area and volume could not be estimated using tree height as a predictor variable because the correlations and F- values were not significant.

Positive correlations were observed by Troxela et al. (2013), but Ige et al. (2013) found DBH to be a weak estimate of growth dimensions in Gmelina arborea. Figures 2, 3, 4, & 5 show the presence of outliers in the data collected caused by overgrazing, crop destruction, defoliation by animals, and severe soil damage such as soil compaction, which are known to distort an entire forest ecosystem, especially in dry lands, Mousavi et. al., (2022). In addition, deforestation can exacerbate the harsh effects of climate change and affect carbon sequestration negatively, Urban et al. 2010.

EL-Mamoun et. al. (2013) suggested that one algometric model may not adequately represent the growth parameters of different tree species in the same locality; hence, each species should have its own model. Staff Berg et al. (2009) obtained a strong correlation between stem diameter and crown diameter (r2=0.74) but a weaker correlation for tree height and stem diameter ($r \geq 0.63$) and stem diameter and crown height ($r \geq 0.60$) of combretum spp and two species of Searzia.

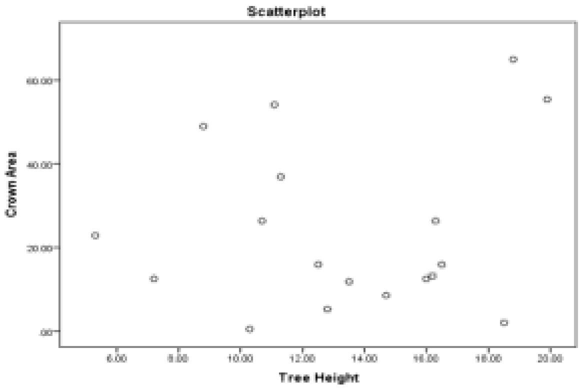

Figure 2: Relationship between CA and TH

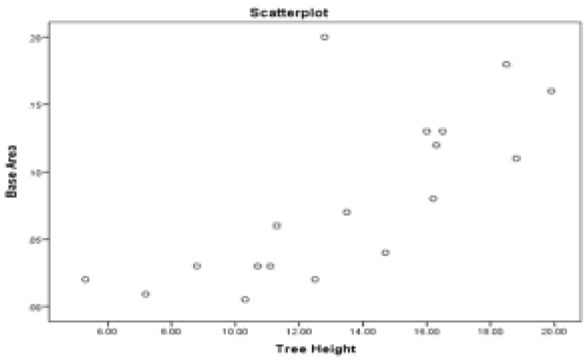

Figure 3: Relationship between BA and TH

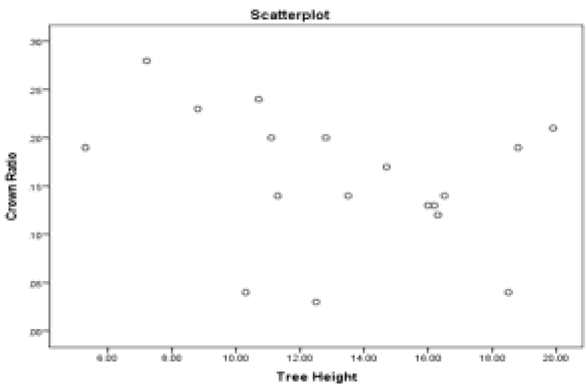

Figure 4: Relationship between CR and TH

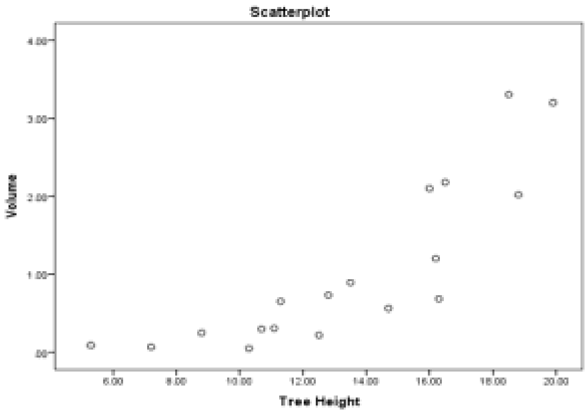

Figure 5: Relationship between V and TH

Table 1: Details of *Detarium microcarpum*

	Diameter at breast height	**Tree height**	**Crown Diameter**	**Crown Area**	**Basal area**	**Crown Ratio**	**Volume**
N	19	19	19	19	19	19	19
Mean	26.5	13.4	2.0	24.1	0.0791	.1567	1.0444
STD error of Mean	.02807	.965	.229	4.7	.01466	.01651	.24927
Median	.2500	13.2	2.0	15.9	.065	.1550	.6650
STD. deviation	.11908	4.09	.97351	19.8	.06219	.07004	1.05756
Range	0.40	14.60	3.80	64.5	0.20	0.25	3.25
Minimum	0.08	5.30	0.40	0.50	0.01	0.03	0.05
Maximum	0.48	19.90	4.20	65.0	0.20	0.28	3.30
Sum	4.77	240.4	36.15	434.61	1.42	2.82	18.80
Percentiles 2	.1800	10.60	1.45	11.07	.0275	.1275	.2425
5	.2500	13.150	2.00	15.90	.0650	.1550	.6650
5	.3800	16.4	2.50	39.92	.1300	.2025	2.04

Table 2: Regression prediction model, pearson correlation coefficient (r) and correlation coefficient determination (r^2) of different tree parameters

	Tree Variable	**F Value**	**Value =Prediction Model**	**r**	r^2	**Sig.**
A.	Tree height V CD	4.419	Y = 0.111x + 0.1530	0.465	0.216	0.026
B.	Tree height V CA	0.240	Y = 0.588x + 16.294	0.122	0.015	0.315
C.	Tree height V BA	19.38	Y = 0.011x – 0.071	0740	0.548	0.000
D.	Tree height V CB	1.85	Y = 0.006x + 0.230	0.322	0.103	0.097
E.	Tree height V Vol.	38.13	Y = 0.217x – 1.852	0.839	0.704	0.000

4. Conclusion

Growth and yield assessment of trees was carried out in the Northern Guinea Savanna. Out of the 19 sample trees measured, the minimum and maximum stand diameter ~~(CDBH)~~ were 0.08 and 0.48cm, respectively. Using tree height as a predictor variable, weak negative correlations were observed between tree height base area and volume. In contrast, positive correlations were recorded in the relationship between tree height and crown diameter, crown area, and crown ratio. The coefficient of determination (r^2) showed the relationship between trees height on one hand, crown diameter, crown area, basal area, crown ratio and volume on the other, portraying different values. In order to assuage the ravaging effects of climate change, deforestation and other anthropogenic activities in this ecosystem should be discouraged.

Acknowledgements

The author is grateful to Mr. Haruna Dumne and field workers who assisted in data collection. He also thanks the Department of Forestry and Wildlife Management for providing the necessary equipment for the study and appreciates Mr. Inkab Najimriz's help analyzing the data.

References

Aabeyir, R., Adu-Bredu, S., Agyare, W. A., & Weir, M. J. C. (2020). *Allometric models for estimating above-ground biomass in the tropical woodlands of Ghana, West Africa*. Forest Ecosystems.

Adamawa State Nigeria. (2022). *Ministry of Environment*.

Akindele, S. O. (2005, May 11). *Modelling tropical forest data in Nigeria – The challenges*. Seminar presented at the Warnell School of Forestry Resources, University of Georgia, USA.

Akindele, S. O., Dyck, J., Akindunni, F. F., Papka, P. M., & Olaleye, O. A. (2001). *Estimates of Nigeria's timber resources.* In Popoola, L., Abu, I. J. El, & Oni, P. L. (Eds.), Forestry and national development: Proceedings of the 27th annual conference of Forestry Association of Nigeria, Abuja (pp. 1–11).

Altriell, D. A., Branthomme, R., & Tavani. (2010). *Assessing gronta stock and stock changes through multipurpose national forest resources assessment*. FAO Working Paper. Retrieved from www.fao.org.

Arora, P., Iyoti, L., Manju, S., & Chandhry, S. (2012). *Nitisation climate change and role of forest management: A short review*.

Brown, S., & Lugo, A. E. (1992). Above-ground biomass estimates for tropical moist forests of the Brazilian Amazon. *Intersciencia*, 17, 8–18.

Buba, T. (2012). Prediction equation for estimating tree height, crown diameter, crown height and crown ratio of Parkia biglobosa in the Nigerian Guinea Savanna. *Journal of Agricultural Research, 7(*49), 6541–6543.

Buba, T. (2013). Relationship between stem diameter at breast height (DBH), tree height, crown length and crown ratio of Vitellaria paradoxa C.F. Gaertn in the Nigerian Guinea Savanna. *African Journal of Biotechnology, 12(*22), 3441–3446.

Chaidez, J. N. (2009). Allometric equations and expansion factors for tropical dry forest trees in Eastern Sinaloa, Mexico. *Tropical and Subtropical Agroforestry Ecosystem,* 10, 45–50.

Chidumayo, E. N. (2002). Charcoal potential in Southern Africa – Final report for Zambia. INCODEV, Stockholm Environment Institute.

El-Mamoun, H., & El-Zein Osman, A. (2013). Modelling height-diameter relationships of selected economically important natural forest species. Journal of Forest Products and Industries, 2(1), 34–42.

Elias, C. (2008). Climate change: Financing global forests, the Eliasch review. Earthscan.

Eyre, J. J., Berish, C., Brown, B., Price, N., & Raich, J. (1989). Methodology for the establishment and survey of reference site for bio-conditions. Environmental Protection Agency, Biodiversity Science Unit, Brisbane.

Food and Agriculture Organization (FAO). (2006). *Global forest resources assessment: Progress towards sustainable forest management (FAO Forestry Paper No. 147).* Food and Agriculture Organization of the United Nations.

Food and Agriculture Organization (FAO). (2010). *Managing forests for climate change* (1960E/1/11, 101 960E).

Ige, P. O., Akinyemi, G. O., & Smith, A. S. (2013). Non-linear growth functions for modelling tree–height diameter relationships for Gmelina arborea (Roxb) in South-Western Nigeria. *Forest Science & Technology, 9(*1), 20–24.

Koirala, A., Kizha, A. L., & Baral, S. (2017). Modelling height–diameter relationships and volume of Tectona grandis (L. f.) in central lowlands of Nepal. *Journal of Tropical Forestry and Environment, 7(*1), 28–42.

Lal, M., & Sough, H. R. (2000). Carbon sequestration potential of Indian forests. Environmental Monitoring and Assessment, 60, 315–327.

Lewis, S. L. (2009). Tropical forests and the changing earth system. *Nature*, 457, 1003–1006. https://doi.org/10.1038/nature

Mariod, A. A., Tahair, H. E., & Komia, M. G. (2011). *Detarium microcarpum: Chemical composition, bioactivities, and uses*. In Wild fruits: Composition, nutritional values, and products. Springer.

Mogasha, W. A., Tron, E., & Boanndsus, O. M. (2013). Relationship between diameter and height of trees in natural tropical forests in Tanzania. Southern Forests: *Journal of Forest Science, 75(*4), 221–237.

Mousavi, S. A., Ghatifarokhi, M. S., & Konpaeiss. (2020). Negative impacts of nomadic livestock grazing on common rangelands' function in soil and water conservation. *Ecological Indicators*, 110, 105946.

Nurudeen, T. A., Abiola, J. K., Salami, K. D., Erinle, O. A., & Olaniyi, N. A. (2014). Regression models for tree volume prediction in stands of Tectona grandis (Linn) at Federal College of Forestry, Jericho, Ibadan, Oyo State, Nigeria. *Science Journal of Agricultural Research and Management*, 2014, Article ID sjarm-233. https://doi.org/10.7237/sjarm233

Osbahr, H. (2007). Building resilience, adaptation mechanisms, and mainstreaming for the poor.

Background paper for UNDP Human Development Report.

Pullan, R. A. (1974). Farmed parkland in West Africa. *Savanna, 3(*2), 119–151.

Salis, S. M., Assis, M. A., Mattos, P. P., & Piao, A. C. S. (2006). Estimating above-ground biomass and wood volume of a savanna woodland in Brazil's Pantanal wetlands based on allometric correlations. *Forest Ecology and Management,* 228, 61–68.

Stoffberg, G. H., Rooney, M. W., Linde, M. J., & Groeneveld, H. T. (2009). Modelling dimensional growth of three street tree species in the urban forest of Tshwane, South Africa. *Journal of Forest Science, 71(*4).

Toledo, M., Poorter, L., Peña-Claros, M., Alarcón, A., Balcázar, J., Leaño, C., Licona, J. C., Lanque, O., Vroomans, V., Zuidema, P., & Bongers, F. (2011). Climate is a stronger driver of tree and forest growth rates than soil and disturbance. *Journal of Ecology*, 99, 254–264.

Tonini, H., & Borges, R. A. (2015). Equação de volume para espécies comerciais em floresta ombrófila densa no sul de Roraima. *Pesquisa Florestal Brasileira, 35(*82), 32–37.

Troxel, B., Max, P. B., Mark, S. A. S., & Colien, M. D. (2013). Relationships between bole and crown size for young urban trees in the North-Eastern USA. *Urban Greening*, *12(*2), 144–153.

Urban, J. K., Rebrosora, L., & Dobrovolay, J. (2010). Allometry of four European beech stands growing at contrasting localities in a small-scale area. *Folia Oecologica*, *37(*1), 103–112.

Williams, M., Ryan, E. M., Rees, R. M., Sambane, E., Fernando, J., & Grace, J. (2008). Carbon sequestration and biodiversity of regrowing Miombo woodlands in Mozambique. *Forest Ecology and Management,* 254, 145–155.

Witten, S. D., & Fry, G. (1980). *Laboratory techniques in ecology*. London.