

Investigation of the Allometry of Oil Palm Trees in Nigeria for Mechanization of the Farming Process

Oyedeji Ayodeji Nathanie*, Umar Ali Umar, Kuburi Laminu Shettima
Mechanical Engineering Department,
Ahmadu Bello University, Zaria, Nigeria.

ABSTRACT

Oil Palm importance as edible vegetable oil and biodiesel has caused an increase in its demand across the world, however, the mechanization of its harvest has not increased in such a manner, and this is attributed to the little available information about the oil palm tree. Nigeria is among the world top farmers of the oil palm tree and she is currently ranked as 5th in the world. Nigeria has about 13 states involved in the farming of oil palm tree and Oyo State accounts for 11% (highest) of these farming states. Seven (7) towns in Oyo State are major farmers of the oil palm tree, and with the aid of meter rule and clinometer, the maximum diameter (diameter at breast height), minimum diameter (crown diameter) and height of the trees were obtained for 70 trees which made up the sample space of the population in these towns.

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INTRODUCTION

The oil palm (*Elaeis guineensis*) is a perennial crop that is obtained from the palm tree. The cultivation of oil palm originated in the tropical rain forest of West Africa and spread to South America in the 16th century and to Asia in the 19th century. There is an increase in the cultivation of oil palm across America, Asia and Africa and one of the reasons is the wider use of oil palm biodiesel as an alternative energy source (Chong, *et al.*, 2017). The demand for oil palm is further strengthened as more countries establish mandates on the use of biofuels. Another major factor that contributed to this increase is a more rapid rise in per capita human consumption of vegetable oils in the past 30 years than any other food as vegetable oils are used for food, feed waste and industrial consumption.

Although oil palm is the most productive edible oil crop (10 times the next

most productive), it is one of the least significant food crops that today generally is not mechanically harvested. This is attributed to insufficient knowledge about the geometry of the oil palm tree. Also, knowledge about the geometry of the palm tree will help in understanding the forces guiding macroevolution, roles of adaptive radiation and environmental change in generating diversity (Frederick, 2006).

Nigeria, a top producer and farmer of oil palm in which between 1961 and 1965, 43% of the world oil palm production came from her and though still a developing nation, she is ranked 5th world producer of oil palm producing about 970,000 tons of oil palm in 2018. The major oil palm producing states in Nigeria are Ondo, Edo, Oyo, Cross River, Delta, Ekiti, Rivers, Bayelsa, Abia, Osun, Kogi, Enugu, Imo, and Ogun States (USDA, 2018) as shown in Figure 1 below.

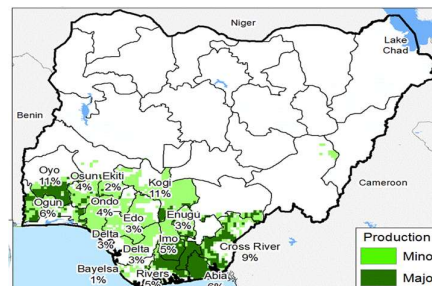


Figure 1: Nigeria Oil Palm producing States.

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Oyo State which accounts for 11% (highest state) of all the oil palm production in Nigeria is located at the southwest geopolitical zone of Nigeria. It consists of 33 local government areas which span across 28,454 square kilometres of landmass with an approximate population of 5.5 million people. Oyo State is bounded to the south by Ogun State, to the north by Kwara State, to the west by Ogun State and Republic of Benin and to the east by Osun State. The climate of the state favours the cultivation of Maize, Palm tree, Yam, Cassava, Cashew, Cocoa Tree, Rice, and Plantain basically because of its relatively long wet season which spans between April to October and an average daily temperature between 25 °C (77.0 °F) and 35 °C (95.0 °F), almost throughout the year (OYSG, 2019).

Before now, some researchers have studied the estimation methods of the above-ground biomass of oil palm by developing an allometric equation. Notable among these researchers is Aholoukpe, *et al.* (2018) who carried out the development of the allometric equation to determine the palm stem biomass by using non-destructive methods. The study involved the use of twenty mature palms of different ages were subjected to destructive and non-destructive measurements in which parameters such as the dry weight, stem height from the collar to the bottom of the front, and diameter and thickness of cylindrical slices at different height along the stem. From the result of the study, an equation was obtained from the hyperbolic model which can be used in the estimate palm stem biomass with an estimated error of 5%. With these researches, therefore, the determination of oil palm tree geometries would have been easy, however, according to a survey carried out by Feldpausch, *et al.* (2011) on the height-diameter allometry of tropical forest trees concluded that the allometry of trees differs base on region and forest type.

In terms of practicality and economy of a region, an oil palm farm can be grouped into immature fields and mature fields. Generally, the immature oil palm trees are considered as youthful palms of not over 5 years of planting. These palms are planted in a three-sided design with a 9m planting distance as considered optimum for sunlight penetration that produces maximum yield. A planting density of 130–140 palms for every hectare is, for the most part, practised, however, this varies based on the

planting conditions, the economy of the farmers and the type of oil palm breed. The major activities of an ideal oil palm plantation include harvesting, manuring, pruning, and weeding (Chong, *et al.*, 2017). Before there can be an improvement in the mechanization of oil palm activities, it is important to know the allometry of the trees that makes up such plantation or region.

MATERIALS AND METHODS

Determination of Sample Size

There are seven (7) popular oil palm farming towns in Oyo State, South-West Nigeria, namely: Ilora, Odo-Oba, Lagbedu, Irasapa, Ogbomoso, Ipeba and Otamokun (Fatia, Kazeem, Oluwole, & Gbolahan, 2013), and the major palm tree farmers in these towns are small scale farmers, hence it is difficult to obtain the exact number of palm trees in these areas. A sample of these population is obtained by using equation (1) below (Paul & Stanley, 2008):

$$\text{Minimum Sample Size, } n = \frac{Z^2 pq}{d^2} \quad (1)$$

Where: $Z = 1.645$ (from the table of statistics at a 90% confidence level)

Degree of precision in the margin of error, $d = 0.1$,

The portion of the population have in the required characteristics, $p = 0.5$,

The portion of the population not having the required characteristics, $q = 1 - 0.5 = 0.5$.

Hence, the sample size was taken as 70 trees, in which 10 trees each were sampled from the seven (7) oil palm farming towns in Oyo State.

Determination of Tree Diameter

In obtaining the tree geometries, the tape rule was used to determine the maximum circumference from which the maximum diameter (Diameter at Breast Height) (D_{max}) is obtained as given in equation (2) below, while the Minimum Diameter (Crown diameter) is determined from a mathematical model developed by Mahmut (2004) as given in equation (3) below.

$$\text{Maximum Diameter, } D_{max} = P_{max} / \pi \quad (2)$$

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$$\text{Minimum circumference, } D_{min} = 0.49(D_{max})^{0.68} \quad (3)$$

Determination of Tree Height

The heights of the trees were determined using the clinometer, which gives the angle of elevation of the trees from the

observer and a tape rule was used to determine the horizontal distance of the observer from the trees and the height of the observer as shown in Figure 2 below. (FSC, 2016).

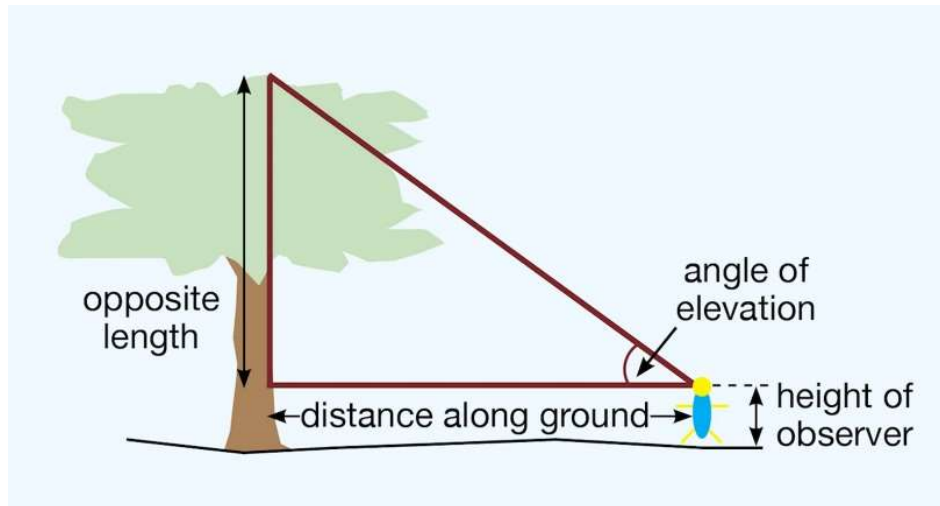


Figure 2: Determination of height of the tree.

The height of the tree was then calculated using equations (4) and (5) below.

Height of the tree from the observer level, $h_1 = R * \tan(\theta)$

$$(4)$$

$$\text{Tree Height, } H = h_1 + h_2 \quad (5)$$

Where R is the horizontal distance of the observer from the tree, θ is the angle of elevation, and h_2 is the height of the observer.

Analysis and Computation of Result

Microsoft Excel software was then used to compute the results of the 70-sample size of the palm tree and the result was then tabulated in the format shown in table 1 below.

Table 1: Tree-Data Format

Sample No.	R (m)	Pmax (m)	Dmax (m)	Dmin (m)	θ (deg)	h1 (m)	h2 (m)	H (m)

RESULTS AND DISCUSSION

With the aid of the tape rule and clinometer, the geometries of the trees (diameter at breast height, crown diameter and height) were obtained. These results were then classified into ranges.

RESULTS

Tables 2-8 below shows the collected and computed allometry data of oil palm trees based on the farming towns in the study area.

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Table 2: Allometry Data of Oil Palm Trees in Ilora Town of Oyo State

Ilora Town							
Sample No.	Pmax (m)	Dmax (m)	R (m)	Θ (deg.)	h1 (m)	h2 (m)	H (m)
1	1.47	0.468	1.5	73.8	5.173	1.65	6.823
2	1.20	0.382	1.5	70.9	4.339	1.65	5.989
3	1.22	0.388	1.5	77.5	6.784	1.65	8.434
4	1.52	0.484	1.5	51.5	1.887	1.65	3.537
5	1.55	0.493	1.5	55	2.144	1.65	3.794
6	1.46	0.465	1.5	56.6	2.277	1.65	3.927
7	1.22	0.388	1.5	68	3.718	1.65	5.368
8	1.60	0.509	1.5	74.4	5.383	1.65	7.033
9	0.95	0.302	1.5	50.5	1.821	1.65	3.471
10	1.27	0.404	1.5	53.7	2.044	1.65	3.694

Table 3: Allometry Data of Oil Palm Trees in Odo-Oba Town of Oyo State

Odo-Oba Town							
Sample No.	Pmax (m)	Dmax (m)	R (m)	Θ (deg.)	h1 (m)	h2 (m)	H (m)
11	1.24	0.395	1.5	60.4	2.643	1.65	4.293
12	1.46	0.465	1.5	79.8	8.364	1.65	10.014
13	1.22	0.388	1.5	69.8	4.083	1.65	5.733
14	1.60	0.509	1.5	78.1	7.137	1.65	8.787
15	0.95	0.302	1.5	51.1	1.860	1.65	3.510
16	1.22	0.388	1.5	57.5	2.357	1.65	4.007
17	1.52	0.484	1.5	56.6	2.277	1.65	3.927
18	1.55	0.493	1.5	68	3.718	1.65	5.368
19	1.46	0.465	1.5	74.4	5.383	1.65	7.033
20	1.45	0.462	1.5	50.5	1.821	1.65	3.471

Table 4: Allometry Data of Oil Palm Trees in Lagbedu Town of Oyo State

Lagbedu Town							
Sample No.	Pmax (m)	Dmax (m)	R (m)	Θ (deg.)	h1 (m)	h2 (m)	H (m)
21	1.24	0.395	1.5	50.7	1.834	1.65	3.484
22	1.29	0.411	1.5	73.8	5.173	1.65	6.823
23	0.94	0.299	1.5	54.4	2.097	1.65	3.747
24	1.14	0.363	1.5	56.9	2.303	1.65	3.953
25	1.02	0.325	1.5	79.9	8.448	1.65	10.098
26	1.09	0.347	1.5	75.7	5.898	1.65	7.548
27	1.14	0.363	1.5	54	2.066	1.65	3.716
28	1.35	0.430	1.5	64.4	3.134	1.65	4.784
29	1.11	0.353	1.5	76.5	6.263	1.65	7.913
30	1.11	0.353	1.5	57.7	2.375	1.65	4.025

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Table 5: Allometry Data of Oil Palm Trees in Irasapa Town of Oyo State

Irasapa Town							
Sample No.	Pmax (m)	Dmax (m)	R (m)	Θ (deg.)	h1 (m)	h2 (m)	H (m)
31	1.08	0.344	1.5	59.6	2.559	1.65	4.209
32	1.07	0.341	1.5	75.7	5.898	1.65	7.548
33	1.39	0.442	1.5	54	2.066	1.65	3.716
34	1.28	0.407	1.5	64.4	3.134	1.65	4.784
35	1.36	0.433	1.5	76.5	6.263	1.65	7.913
36	1.11	0.353	1.5	70.9	4.339	1.65	5.989
37	1.07	0.341	1.5	77.5	6.784	1.65	8.434
38	1.42	0.452	1.5	51.5	1.887	1.65	3.537
39	1.59	0.506	1.5	55	2.144	1.65	3.794
40	1.37	0.436	1.5	57.5	2.357	1.65	4.007

Table 6: Allometry Data of Oil Palm Trees in Ogbomoso Town of Oyo State

Ogbomoso Town							
Sample No.	Pmax (m)	Dmax (m)	R (m)	Θ (deg.)	h1 (m)	h2 (m)	H (m)
41	1.06	0.337	1.5	66.2	3.405	1.65	5.055
42	1.15	0.366	1.5	79.8	8.364	1.65	10.014
43	1.00	0.318	1.5	71.6	4.517	1.65	6.167
44	1.01	0.321	1.5	64.3	3.120	1.65	4.770
45	1.09	0.347	1.5	70.7	4.290	1.65	5.940
46	1.14	0.363	1.5	67.2	3.573	1.65	5.223
47	1.35	0.430	1.5	56.3	2.251	1.65	3.901
48	1.11	0.353	1.5	71.3	4.439	1.65	6.089
49	1.05	0.334	1.5	52	1.921	1.65	3.571
50	1.53	0.487	1.5	57.3	2.339	1.65	3.989

Table 7: Allometry Data of Oil Palm Trees in Ipeba Town of Oyo State

Ipeba Town							
Sample No.	Pmax (m)	Dmax (m)	R (m)	Θ (deg.)	h1 (m)	h2 (m)	H (m)
51	1.21	0.385	1.5	74.9	5.571	1.65	7.221
52	1.23	0.392	1.5	51.9	1.914	1.65	3.564
53	1.26	0.401	1.5	68.8	3.873	1.65	5.523
54	1.58	0.503	1.5	69.7	4.061	1.65	5.711
55	1.22	0.388	1.5	54	2.066	1.65	3.716
56	1.32	0.420	1.5	64.4	3.134	1.65	4.784
57	1.57	0.500	1.5	76.5	6.263	1.65	7.913
58	1.48	0.471	1.5	70.9	4.339	1.65	5.989
59	1.10	0.350	1.5	70.7	4.290	1.65	5.940
60	1.27	0.404	1.5	67.2	3.573	1.65	5.223

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Table 8: Allometry Data of Oil Palm Trees in Otamokun Town of Oyo State

Otamokun Town							
Sample No.	Pmax (m)	Dmax (m)	R (m)	Θ (deg.)	h1 (m)	h2 (m)	H (m)
61	1.54	0.490	1.5	77.5	6.784	1.65	8.434
62	1.58	0.503	1.5	67.8	3.681	1.65	5.331
63	1.16	0.369	1.5	53.7	2.044	1.65	3.694
64	1.20	0.382	1.5	59	2.499	1.65	4.149
65	1.42	0.452	1.5	64.4	3.134	1.65	4.784
66	1.53	0.487	1.5	76.5	6.263	1.65	7.913
67	1.22	0.388	1.5	70.9	4.339	1.65	5.989
68	1.32	0.420	1.5	70.7	4.290	1.65	5.940
69	1.33	0.423	1.5	52.5	1.956	1.65	3.606
70	1.09	0.347	1.5	55	2.144	1.65	3.794

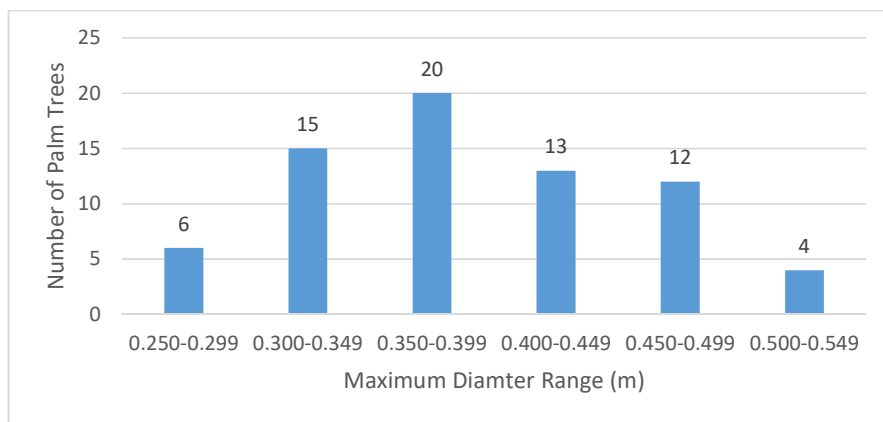


Figure 3: Maximum Diameter at Breast Height Distribution

Result obtained from the computed maximum diameter at breast height (DBH) of the oil palm trees in the study area shows that most of the trees (68.6%) have a maximum diameter at breast height (DBH) within the

range of 0.300m to 0.449m, while 5.7% of the trees in this study area have their maximum diameter at breast height within the range of 0.500m and 0.549m as shown in Figure 3.

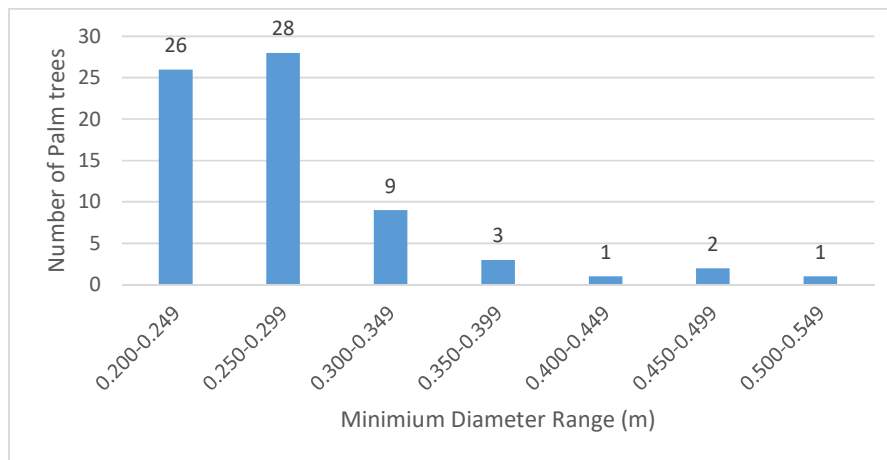


Figure 4: Crown Diameter Distribution

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Using the non-destructive method of determining the crown diameter, which involved the use of the mathematical model as developed by Mahmut (2004), the result showed that majority (77.1%) of the oil palm

trees in the study area has a crown diameter within the range of 0.2m and 0.249m, while only 5.71% of the oil palm trees in the study area have a crown diameter within the range of 0.4m and 0.549m as shown in Figure 4.

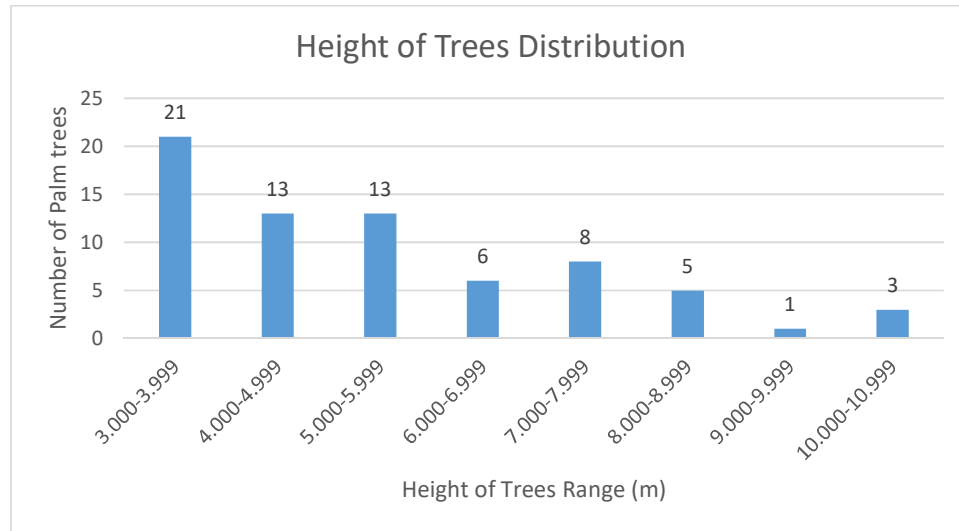


Figure 5: Height of Trees Distribution

With the aid of an inclinometer and meter rule, the height of the oil palm trees in the study area was determined and the result of the study showed that 30% of the oil palm trees in the study area have a height within the range of 3m and 3.999m, 37.1% have a height within the range of 4m and 5.99m, while only about 1.43% have a height within the range of 9m to 9.999m as shown in Figure 5.

The results of the maximum diameter (DBH) and the height of the palm trees in Oyo State are in agreements with the results obtained by Fajardo, Silva, Chagas, and Vieira (2018) who in the bid of examining the genetic and phenotypic association of palm tree got the mean maximum diameter (DBH) of oil palm trees in Brazil as 0.3885m and mean height as 3.20m.

CONCLUSION

From the results and discussion in this study, the following conclusions can be made:

1. The majority (68.6%) of the oil palm trees in Oyo State, Nigeria have a maximum diameter (DBH) within the range of 0.300m to 0.449m.

2. The majority (77.1%) of the oil palm trees in Oyo State, Nigeria have a minimum diameter (Crown Diameter) within the range of 0.2m to 0.299m.
3. The majority (67.2%) of the oil palm trees in Oyo State, Nigeria have a height within the range of 3.000m to 5.999m.
4. The range of geometries of oil palm trees in Oyo State is in close agreement with oil palm trees in Brazil.

From these obtained results on the allometry of oil palm trees in Nigeria, the mechanization of the various activities in the oil palm plantation can be easily done to suit the geometries of the trees. With an increase in the mechanization of the activities in the oil palm plantation, it is believed that there will be a correlative increase in the yield of the oil palm trees and a reduction in the ergonomic risk issues oil palm plantation workers are exposed to.

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