ESTIMATING TREE HEIGHT AND VOLUME OF *Gmelina arborea* AND THREE OTHER TREE SPECIES IN PLANTATIONS OF SOUTH-WEST NIGERIA

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Abstract
This study explores the estimation of stand structure of *Gmelina arborea* and three other tree species in two plantations, in Ibadan, South West Nigeria, with the primary objective of estimating plot – level mean tree height, merchantable tree height, and volume of *Gmelina arborea, Terminalia montalis, Tectona grandis, and Triplochiton scleroxylon.* The number of tree species and the volume of wood in the two selected plantations were determined. Random sampling method was adopted in carrying out the assessment of the stand structure. Each plantation was divided into three plots of dimension 32mx32m. Twenty (20) stands were selected randomly in each plot, hence sixty (60) stands in each plantation. Quantitative data were taken on: Diameter at breast height (DBH), Total tree height (TTH), Basal area (BA) and Total volume (of wood) (TVOL). A total of three species were encountered in the two study area; the family *Verbenaceae* has the highest tree species (75%) in the two plantations. During the assessment of the tree species in both plantations, the results revealed that majority of the trees' (68%) diameter were within 10-20cm, and the number of tree species in the upper diameter class (>60cm) (20%) were considerably small. Trees in the *Gmelina* plantation had on average, lower merchantable heights than those in the College Arboretum, despite having higher total tree height, diameter at breast height, basal area, and area volume. Inventory analysis of these plantations will establish a base-line information about the stand, point out possible improvements to the management plan and provide information on the volume of merchantable logs that can be extracted from the stand.

Keywords: Merchantable heights, breast height, tree height, basal area, volume of wood

Introduction
Forest inventory is the systematic collection of data and forest information for assessment or analysis. Forest inventory is the procedure of obtaining information on the quantity and quality of the forest resources and many of the characteristics of the land area on which trees are growing (Kershaw *et al.,* 2016). Surveying and taking inventory of trees originated in Europe in the late eighteenth (18th) century out of a fear that wood (the main source of fuel) would run out (Wikipedia, n.d. In the course of the years, new relationships between diameter, height and volume were discovered and exploited. These new-found relationships allowed for a more accurate assessment of wood type and could accommodate larger forests.

A forest inventory does not only record the tree height, diameter at the breast height and number of tree yield calculation, but also records the condition of the forest. The term forest enumeration simply means taking stock of the forest and describing the forest quantitatively and qualitatively in terms of resources present (Relf, 2001). These resources include; timber, fibre, leaves, wildlife, fruits and watersheds, among others. Stand structure is the distribution of trees by species and size within a stand. The structure is a result of several factors among which are; growth habit of the tree species, especially the degree of shade tolerance, ecological condition, history of disturbance and management. Oliver and Larson (1996) defined forest stand structure as the physical and temporal distribution of trees in a stand within the distribution of species, vertically and horizontally spatial pattern, size of the tree or tree plant, tree age or combination. Sustainable tree and/or sustainable forest management requires information on the growing stock. Such information guides resource management evaluation and location of forest area for exploitation. For timber production, estimates of the growing stock are often expressed in terms of timber value, which can be estimated from easy measurable dimension of the trees (Kershaw *et al*., 2016).

Gmelina arborea belongs to the family *Verbenaceae*, and is a fast growing tree species that is frequently planted to produce wood for light construction, crafts, decorative veneers, pulp production and fuel (Adeyemi

and Ukaegbu, 2016). *Gmelina arborea* grows best in climates with mean annual temperature of 21-28°C, and is a medium-sized deciduous tree that grows up to 40m tall and 140cm in diameter, but can usually be smaller than this. The tree form is fair to good, with a trunk of 6-9m, usually branchless, often crooked and has a large, low-branched crown. *Gmelina arborea* is presently regarded as the most important exotic plantation specie in Nigeria, being the main source of short fiber of desirable quality for the pulpwood industry and major utility timber specie. It has been noted that *Gmelina* has the following characteristics: fast growth rate, ease of establishment, high productivity and a wide range of site tolerance (Ogar *et al.*, 2014).

The success of any forest management is based on proper data base and record keeping. Forest inventory, which involves taking biometric data, taking stock of individual stand and having a database for any forest stand can be used to elicit information about specific forests in order to facilitate decision making, proper management plan and better felling schedule. Characterizing tree characteristics, will serve as a baseline data for future forest management endeavors, and help compare current forest status with the expected values after specific time frames. The *Gmelina arborea* plantation and the Federal College of Forestry arboretum were established over fifteen years ago, and have been managed without substantive records about the biometric and management activities and plans. This has affected the long term output of these stands. Hence, carrying out an inventory work on these stands will establish base-line information about the stands, improve the management plan and provide information on the volume of merchantable logs and possible volume of logs that can be extracted from the stand. The broad objective of this study is to assess the current state and determine the number of tree species in two selected plantations in Ibadan, South-West Nigeria, and to determine the volume of wood that can be realized from the plantations, and make recommendations on future forest management practices will be made.

Methodology
Study Area
This research was carried out at the Federal College of Forestry, Jericho, Ibadan, located on longitude 3°.36'E, and latitude 7°.28'N. The climatic condition of the area is tropical with an annual temperature of 26°C and daily humidity of about 26%. The two plantations had been established over fifteen years prior to the time of the study.
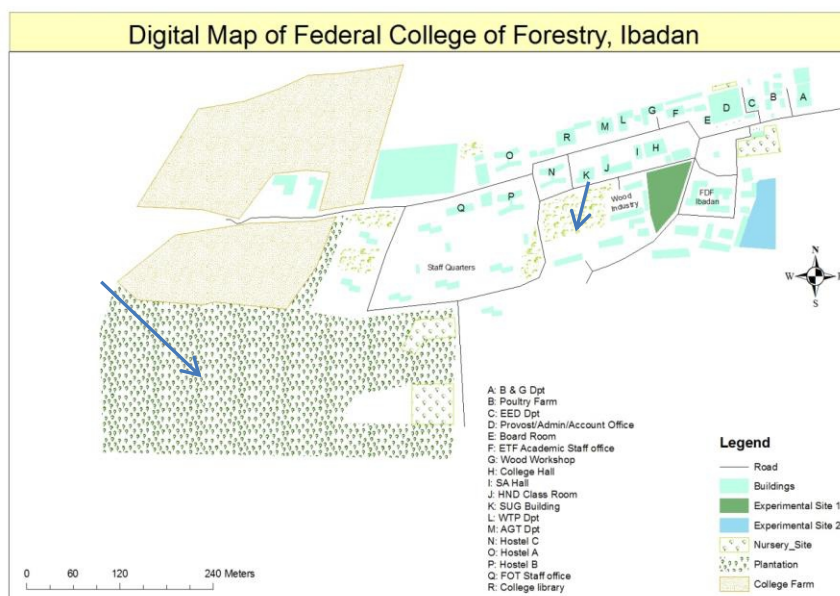

Figure 1: Map of the Federal College of Forestry showing the two plantations used

Plate 1a: College Arboretum

Plate 1b: Gmelina plantation

Sampling method and measurement

Random sampling method was adopted in carrying out the stand structure assessment. Each plantation was divided into three plots for the purpose of organization and ease of sampling. In each stand, a sample plot of 32m x 32m was laid out with the use of diameter tape, ranging pole and linen rope etc. and randomly selected trees were labeled for easy identification. After the laying of the sampling plot, the population of the trees in each of the three plot stands was determined and all the sample trees in each of the three stands were numbered accordingly, e.g. P_1S_1, P_1S_2, P_1S_3 … P_1S_n; P_2S_1, P_2S_2, P_2S_3 … P_2S_n; P_3S_1, P_3S_2, P_3S_3 … P_3S_n. This gives a total of 128 trees in plantation one (*Gmelina*) and 88 trees in plantation two (College arboretum).

Diameter at breast height: The measurement at breast height was obtained by placing the diameter tape at 1.3m above the ground level.

Total tree height and merchantable height: Total tree height is defined as the vertical distance between the ground level to the tip or apex of the leaf i.e., the part for which volume is computed or the section which is to be utilized in commercial operations (Avery and Burkhart, 2003). The Haga-altimeter was used to measure the merchantable height of the tree species by placing it at the base of the tree at the last usable part of the tree.

Data Analysis

Data were randomly collected from 60 tree samples per plantation. Individual tree measurement was done for diameter at breast height and total tree height. Tree basal area was computed thus;

$$BA = \frac{\pi D^2}{4} \dots \dots . (1)$$

Where, BA = Basal area (m^2);　　　 D = Diameter at breast height (1.3m above the ground level).
Tree volume was estimated for both basal area and total height of the tree using Hubers formula according to Hustch *et al*. (2003) thus;

$$V = H \times Ab \dots \dots . (2)$$

Where, V = tree volume (m^3); Ab = basal area respectively (m^2); and H = total height (in m)
Mean Diameter at Breast Height was computed thus;

$$\text{Mean DBH} = \frac{\Sigma DBH}{n} \dots \dots \dots (3)$$

Where, $\sum$ DBH = Summation of diameter at breast height, n = Number of trees sampled.
Mean total tree height was calculated thus;

$$\text{Mean TTH} = \frac{\Sigma TTH}{n} \dots \dots \dots (4)$$

Where $\sum$ TTH = Summation of total tree height, n = Number of tree sampled.
Mean Basal Area was calculated thus;

$$\text{Mean BA} = \frac{\Sigma BA}{n} \dots \dots \dots (5)$$

Where $\sum$ BA = Summation of basal area, n = Number of tree sampled.
Mean Tree volume was computed thus;

$$\text{Mean TVOL} = \frac{\Sigma TVOL}{n} \dots \dots \dots (6)$$

Where, $\sum$ TVOL = Summation of total tree volume, n = Number of tree sampled.
Following the computation of the tree basal area and volume, data were summarized by computing simple descriptive statistics for each of the tree species. Graphs were also plotted to examine the tree height and the Diameter at Breast Height (DBH) between the two plantations.

Results and Discussion

The local names of the tree species and their families found in the *Gmelina arborea* plantation and College arboretum are given in Tables 1 and 2. A total of three species were identified in the two study areas (Tables 1 and 2). The family *Verbenaceae* has the highest tree species (75%) in the two plantations. During the assessment of the tree species in both plantations, the results revealed that most of the trees' (68%) diameter were within 10-20cm and the number of tree species in

the upper diameter class (>60cm) (20%) were considerably small. This is because trees with very large diameters are usually the unfortunate ones which get pulled or uprooted during expansion activities, such as land development for buildings, and roads; while the small number of the tree species in the study area showed that while the area had been disturbed in the recent past due to erection of buildings, frequent replanting activities had been carried out within the time period. Adequate knowledge of the stand volume will enhance future yield prediction of the plantation. Trees in the *Gmelina* plantation had on average, lower merchantable heights than those in the College Arboretum, despite having higher total tree height, diameter a breast height, basal area, and area volume.

Table 1: Tree species found in *Gmelina arborea* plantation with their local names and families

Species	Local name	Family
Tectona grandis	Gedu	*Verbenacae*
Gmelina arborea	Melaina	*Verbenacae*
Triplochiton shcleroxylon	Obeche	*Sterculiaceae*

Table 2: Tree species found in College of Forestry arboretum plantation with their local names and families

Species	Local Name	Family
Tectona grandis	Gedu	*Verbenaceae*
Gmelina arborea	Meliana	*Verbenaceae*
Terminalia montalis	Igiaburada	*Papilionaceae*

Table 3: Summary of data statistics for three tree species found in the Gmelina plantation and College arboretum

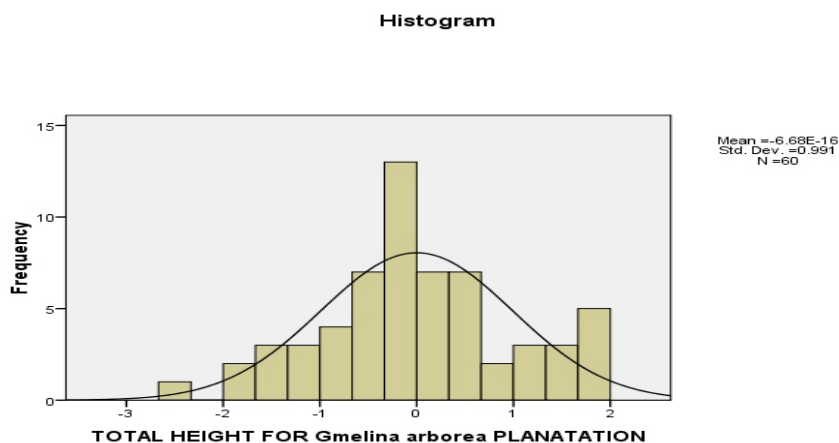| Plantation N = 60 trees		Merchantable Height (m)	Total Tree Height (m)	Diameter at Breast Height (cm)	Basal Area (m²)	Tree Volume (m³)
Gmelina	Total	348.1	1428.3	50.72	44.95	350.41
arborea	Mean	5.801	22.138	0.845	0.749	5.840
College	Total	403.1	1220.3	42.06	37.13	342.59
arboretum	Mean	6.718	20.338	0.701	0.617	5.709

Histogram

Mean =-6.68E-16
Std. Dev. =0.991
N =60

Figure 2: Histogram showing the distribution of total height among the trees for Gmelina arborea plantation

Histogram

Mean =1.87E-16
Std. Dev. =0.991
N =60

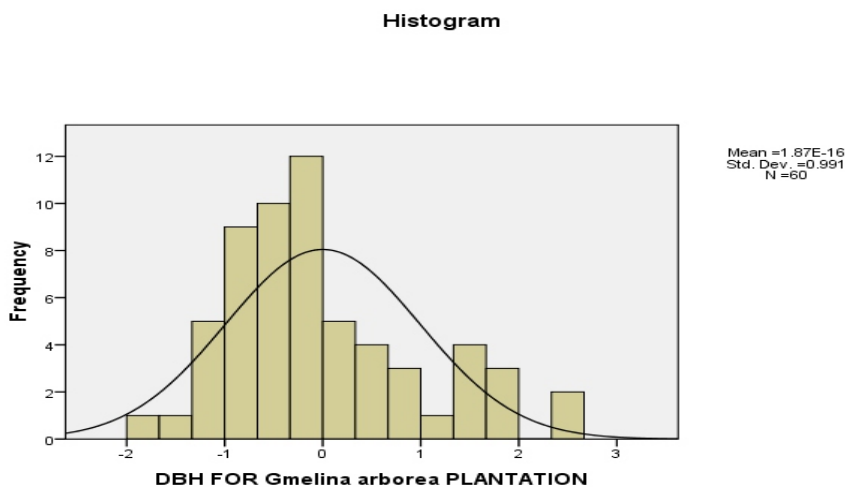*Figure 3: Histogram showing the distribution of Diameter at Breast Height among the trees for Gmelina arborea plantation*

Histogram

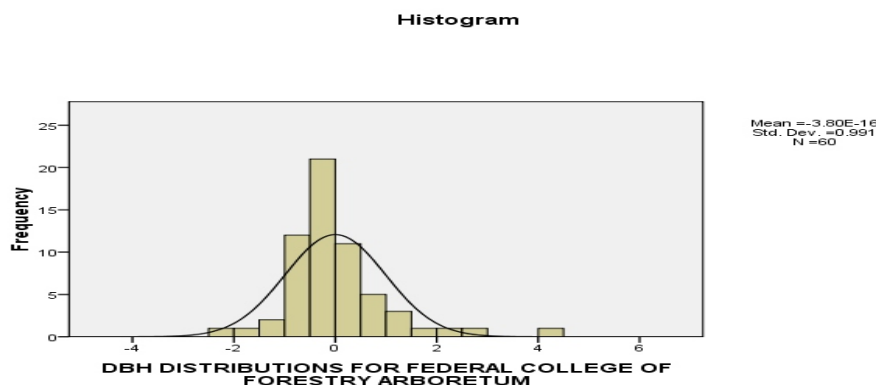Mean =-3.80E-16
Std. Dev. =0.991
N =60

Figure 4: Histogram showing Diameter at Breast Height distribution for Federal College of Forestry Arboretum

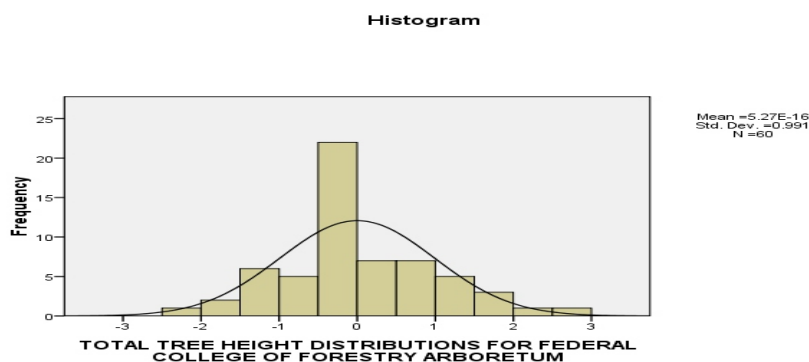**Histogram**

Mean =5.27E-16
Std. Dev. =0.991
N =60

Figure 5: Histogram showing Total tree height for Federal College of Forestry Arboretum

Conclusion

This study showed the low quality of the stands in the two plantations in terms of the volume and basal area of the trees; most stands are distributed in the middle class (20-40cm) and the percentage in the upper diameter class (>60cm) were considerably small. Therefore, proper assessment needs to be done continually on the plantation for better growth yield.

References

Adeyemi, A.A. and Ukaegbu, O.C. (2016). Tree height-diameter and yield functions for *Gmelina arborea* (roxb.) stand in Edondon *Gmelina* plantation, Cross River state, Nigeria. *Journal of Research in Forestry, Wildlife & Environment,* 8(2):14 – 28.

Avery, T.E. and Burkhart, H.E. (2003). Forest Measurement. 5th eds. McGraw-Hill, Higher Education, New York, USA, 456pp.

Husch, B., Beers, T. W., & Kershaw, J. A. (2003). Forest

Mensuration. Hoboken, NJ: Wiley & Sons.

Kershaw, J. A., Ducey, M. J., Beers, T. W., and Husch, B. (2016). Forest Mensuration. 5th eds. Wiley. 10.1002/9781118902028.

Mohapatra, A., Nayak, H. and Das, O. (2020). Factors influencing establishment of teak (Tectona grandis Linn. f) plantation: A review. *E-planet*, 18 (1): 85-94.

Ogar, D.A., Out, D. and Mgbang, E. (2014). Assessment of second generation *Gmelina arborea* stock in Awi, Nigeria. *European Journal of Agriculture and Forestry Research*, 2 (4): 32- 40.

Oliver C. D. and Larson, B. A. (1999). Forest stand dynamics, Update edition. (1996). Yale School of the Environment, Other Publications. Available at: .https://elischolar.library.yale.edu/fes_pubs/1

Relf, D. (2001). Reducing erosion and runoff. Virginia Cooperative Extension, Publication No. 426-722, Virginia Polytechnic Institute and State University, Blacksburg, VA, USA.

Wikipedia. (n.d.). Forest Inventory. https://en.wikipedia.org/wiki/Forest_inventory