ASSESSMENT OF STAND DENSITY AND GROWTH RATE OF THREE TREE SPECIES IN AN ARBORETUM WITHIN THE UNIVERSITY OF UYO, NIGERIA

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ABSTRACT

Plots of Gmelina arborea, Nauclea diderrichii and Tectona grandis at the arboretum of the Department of Forestry and Wildlife, University of Uyo, were assessed for stand density and diameter growth rates of the tree species. All the trees in the three plots were counted and their diameters at breast height (dbh) measured. Diameter tape was used in measuring dbh. Density of each plot was determined by calculating the number of trees and basal area per hectare of the plot. Gmelina arborea stand had the highest density of 300 treesha^{-1} and a basal area of 36.68m^{2}ha^{-1}, followed by Nauclea diderrichii stand with a density of 168 treesha^{-1} and a basal area of 19.37m^{2}ha^{-1}. Tectona grandis had the lowest stand density of 86 treesha and a basal area of 9.05m^{2}ha^{-1}. The diameter growth rates of the species were determined by calculating their mean annual increments (MAIs) in DBH. Gmelina arborea and Nauclea diderrichii had an average DBH of 38cm each and mean annual increments (MAIs) of 2.21cmyr^{-1} and 2.36cmyr^{-1}, respectively, while Tectona grandis had an average DBH of 36cm and MAI of 2.37cmyr^{-1}. Mean annual increment generally increased with decline in stand density. It was recommended that the stock density in Gmelina arborea plot should be reduced while that of the Tectona grandis should be increased, all to 45% of their initial stockings.

Key Words: Stand density, growth rate, tree Species, arboretum, Nigeria

INTRODUCTION

Due to the innumerable, invaluable and indispensable economic, social and environmental benefits they provide, forest resources are very important to mankind. The diversity of forest resources and their natural ability to renew themselves offer man a very great opportunity to tap these resources for his greatest benefits in perpetuity. This calls for a sound forest management strategy that would ensure the sustainability of the resources and their benefits. According to Higman *et al.*, (2000), the basic requirement of a sound forest management strategy is the availability of reliable database that provides adequate information on the extent, state and potentials of the resources.

Relevant information about forest resources provide forest managers with the necessary guides for rational decision making (Akindele, 2001) and management planning as well as its implementation. For example, the calculation and implementation of sustained yield harvest and long-term planning of forest management operations, such as planting, thinning, pruning and improvement cuttings, cannot be successful without reliable data on the stand density and growth rates of the trees. Stand density determines the amount of growing space available for individual trees growing on a site and the level of competition among them for light, soil moisture and nutrients. It therefore, has great effect on the rate and pattern of tree growth and can be manipulated by the forest manager to maintain a good balance between the site and the trees growing on it for desired economic and silvicultural benefits. According to Nuga and Chima (2010), foresters can influence the growth, quality and health of trees by altering stand density. On its part, growth rates of trees determine the yield of forest stand and the rate of returns on forest investments.

Unfortunately, since their establishment, the *Gmelina aborea*, *Nauclea diderrichii* and *Tectona grandis* stands in the arboretum of the Department of Forestry and Wildlife, University of Uyo, have not been assessed for stand density and growth rates. Thus, there had been no data on the stand densities of these stands and the growth rates of the trees for rational decision making and sustainable management. Therefore, the objective of this study was to assess the stand density and mean annual diameter growth rates of these species in the arboretum, with the view to providing the database necessary for their sustainable management.

MATERIALS AND METHODS

Study Area

The study was carried out in the arboretum of the Department of Forestry and Wildlife, University of Uyo. Uyo lies between Latitudes 4° 58' and 5° 05'N and Longitudes 7° 54' and

8° 00'E. The area is within the tropical rainforest zone of Nigeria. It has a mean annual rainfall of about 2,581mm and an average of 165 rain days per annum. Mean annual temperature varies between 27°C and 28°C, while the humidity in the area varies between 60% and 83%, with the lowest and highest values recorded in January and August, respectively (Ekanem, 2010).

The old area of the arboretum, where the study was carried out, is about 2ha. *Gmelinaarborea* and *Nauclea diderrichii* plots occupy 0.19ha each, while *Tectona grandis* plot has an area of about 0.21ha. The remaining area is used for agroforestry and nursery activities. *Gmelina arborea*, *Nauclea diderrichii* and *Tectona grandis* were planted in 1995, 1996 and 1997 respectively, and so they had grown on the site for 17, 16 and 15 years, respectively, as at the time of this study.

Data Collection

Data were collected through direct enumeration and measurement of trees of *Gmelina arborea*, *Nauclea diderrichii* and *Tectona grandis* in the respective plots. The method used for data collection was total enumeration. All the trees in the three plots were counted in order to obtain the number of trees in each plot. Also, the trees were measured for diameter at breast height by winding the diameter tape round each tree at 1.3m above ground level.

Data Analysis

Stand density was determined for each species using estimated number of trees and basal areas of the species per hectare. The estimated number of trees of each species per hectare was obtained by extrapolating the total number of trees enumerated in the respective plots using the formula:

$$N = \frac{h}{a} \text{ x c.}$$

Where:

h = one hectare

A = area of plot in hectare

c = number of trees counted in the plot.

N = estimated number of trees per hectare.

The basal area of each tree was calculated with the basal area function as stated by Avery and Burkhart (2002). The function is:

$$BA = \frac{\pi D^2}{4(100)^2}$$

Where:

BA = Basal Area (m^2)

π = Constant (3.142)

D = Diameter at breast height (cm).

Total basal area of each species was obtained by adding together the basal areas of the individuals of the species. Basal area of each species per hectare was estimated by extrapolating the total basal area of the species using the formula:

$$BA = \frac{h}{a}\,x\,d.$$

Where:

BA = basal area per hectare

H = one hectare

A = area of plot in hectare

D = basal area in each plot.

Diameter growth rates of the species were obtained by calculating the mean annual increment (MAI) in diameter at breast height (DBH) for each of the species. First, MAI in DBH was determined for each tree by dividing the DBH of each tree by its age. The MAI in DBH of each species was then estimated by adding the MAIs of all the individuals of a species and dividing the total by the number of individuals of the species.

RESULTS AND DISCUSSION

Stand Density

The *Gmelina arborea* plot had 57 standing trees with a total basal area of $6.97m^2$. Estimated number of trees and basal area per hectare stood at 300 $treesha^{-1}$ and $36.68m^2ha^{-1}$, respectively, as shown in Table 1. The *Nauclea diderrichii* plot had 32 standing trees with a total basal area of $3.68m^2$, which were estimated at 168 $treesha^{-1}$ and $19.37m^2ha^{-1}$respective.In the *Tectona grandis* plot, there were 18 standing trees with a total basal area of $1.90m^2$ and the estimated values per hectare were 86 $treesha^{-1}$and $9.05m^2ha^{-1}$, respectively, as shown in Table 1.

Table 1: Density and basal area of tree species at different plots.

Tree species	**Number of trees**		**Basal Area**	
	In the plots	**Per ha**	**In the plots**	**Per ha**
Gmelina arborea	57	300	6.97m^2	36.68m^2
Nauclea diderrichii	32	168	3.68m^2	19.37m^2
Tectona grandis	18	86	1.90m^2	9.05m^2

The trees were planted at the espacement of 5m x 5m, resulting in the initial stocking of 400 trees per hectare. A comparison of the initial stocking with the numbers of trees per hectare obtained in this study revealed the level of reduction in population of trees in each of the plots. Nwoboshi (1982) observed that, as a forest stand develops and individual trees grow larger, the number of trees per unit area decreases. Various factors were responsible for the reduction in number of trees in the plots. In *Gmelina arborea* plot, the diminution was only 25%. Since there was no visible sign of disturbance, this reduction could be attributed to natural selection arising from competition for growth resources among the trees. This agrees with Smith (1962), who opined that the diminution in number usually sets in as a result of some rigorous natural selection which favours the most vigorous trees that survive the intense competition for light, soil moisture and nutrients within the forest stand. In the *Nauclea diderrichii* and *Tectona grandis* plots, the reduction in population were 58% and 78.5%, respectively, which are higher than the effect of natural selection. Other factors such as felling of trees by outsiders and windstorm were implicated as factors responsible for the large scale reduction in population of the trees in these plots. Stumps of trees fell by man and wind were observed in the two plots.

Basal area provides an excellent indicator of the degree of stocking in a stand. Holland *et al*. (1990) recommended a range of 9.18m^{2}ha^{-1} to 22.96m^{2}ha^{-1} as the proper basal area level per hectare. Comparing this with the results, it showed that the *Gmelina arborea* plot, with a basal area of 36.68m^{2}ha^{-1}, was over-stocked, while *Tectona grandis*plot, with a basal area of 9.05m^{2}ha^{-1},was under-stocked. The basal area (19.37m^{2}ha^{-1}) of *Nauclea diderichii* plot fell within the range of proper stocking. Overstocking causes intense competition among the trees for the available space and growth resources, while under-stocking leads to under-utilization of the site resources. Both conditions affect stand yield negatively. Therefore, the stocking densities of both *Gmelina arborea* and *Tectona grandis* plots needed to be adjusted to the range of proper density for optimum yield.

Diameter Growth Rate

In this study, the DBH measurements of *Gmelina arborea* trees range from 20cm to 82cm, with an average of 38cm. *Nauclea diderrichii* trees had DBH measurements ranging from 24cm to 49cm, with an average of 38cm, while *Tectona grandis* trees had DBH measurements ranging from 23cm to 53cm, with an average of 36cm (Table 2). Values of MAI in DBH calculated for *Gmelina arborea* trees range from 1.18cm yr^{-1} to 4.82cm yr^{-1}, with an average of 2.21cm yr^{-1}. *Nauclea diderrichii* trees had values of MAI in DBH ranging from 1.50cm yr^{-1} to 3.06cm yr^{-1}, with an average of 2.36cm yr^{-1}, while those of *Tectona grandis* trees range from 1.53cm yr^{-1} to 3.53cm yr^{-1}, with an average of 2.37cm yr^{-1}, as shown in Table 2.

Table 2: Range and Averages values of DBH and MAI for different species

Averages and Ranges of tree parameters	**Tree species**		
	Gmelina arborea	***Nauclea diderrichii***	***Tectona grandis***
Average DBH	38cm	38cm	36cm
Average MAI	2.21cmyr.$^{-1}$	2.36cmyr.$^{-1}$	2.37cmyr.$^{-1}$
DBH range	20cm-82cm	24cm-49cm	23cm-53cm
MAI range	1.18cmyr^{-1}– 4.82cmyr^{-1}	1.50cmyr.$^{-1}$ – 3.06cmyr.$^{-1}$	1.53cmyr^{-1} – 3.53cmyr. $^{-1}$

Comparing the population densities with the average growth rates recorded for the three species in the respective plots, it was observed that the two parameters varied in the opposite directions. *Gmelina arborea* had the highest population density ofabout 300 $treesha^{-1}$ (Table 1), but recorded the least average growth rate of about $2.21cmyr.^{-1}$ (Table 2). *Nauclea diderrichii* came second in both population density (168 $treesha^{-1}$) and average growth rate (2.36cm yr^{-1}), while *Tectona grandis* had the least population density (86 $treesha^{-1}$), but recorded the highest growth rate (2.37cm yr^{-1}).

Gmelina arborea had individuals which recorded the lowest and highest DBH measurements of 20cm and 82cm, respectively (Table 2). In the *Gmelina arborea* plot, it was observed that the trees with the lowest DBH measurements were all surrounded by bigger neighbours, whose DBH measurements were above the average DBH recorded in the plot and whose crowns occupied the upper positions in the crown canopy. It was also observed that only small openings existed in the canopy. Based on the highest population density of this species, its basal area per hectare, which was above the proper range of $9.18m^2ha^{-1}$ – $22.96m^2ha^{-1}$ (Hollland *et al*., 1990), its wide range of DBH distribution and the canopy configuration observed in the plot, it was deduced that the major factor responsible for the least average growth rate recorded by *Gmelina arborea,* as compared to the other two species in the arboretum, was intense competition between the trees. When competition between trees in a planted stand for such resources as soil moisture, light and nutrients becomes so intense, height growth is emphasized rather than diameter growth (Nwoboshi, 1982; Holland *et al*., 1990). Such competitions also put the weaker competitors in a disadvantage position, whereby they gradually become stagnated in growth and may eventually be eliminated from the population. According to Holland *et al*. (1990), a stand needs thinning when its rate of growth begins to slow down as a result of competition.

Disturbances due to felling of some trees by man and windstorm in the *Nauclea diderrichii* and *Tectona grandis* plots created many gaps in these two plots, which agree with the observation by Singh (2004). The existence of these gaps had reduced the competition between the residual trees, thus, providing them access to more growth resources, which according to Smith (1962), induces faster diameter growth rate. Also, diameter growth in trees is a lateral growth, which is usually affected by the amount of growing space available to trees in a stand. According to Nwoboshi (1982), reduction in stand stocking and the resultant increase in the amount of growing space available to the residual trees usually stimulate both crown expansion of the trees and mean diameter increment of the stand. Thus, the felling of some trees in these two plots actually increased the amount of growing space available to the residual trees in the plots, which stimulated the mean diameter increment of the two stands. The *Tectona grandis* plot, which recorded the highest average growth rate had many more and much larger gaps than the *Nauclea diderrichii* plot. Although creation of gaps usually favours diameter growth rate of individual trees, it can cause a reduction in stand growth and yield (measured in basal area or volume per hectare) if it leads to inadequate stocking as it was the case of the *Tectona grandis* stand, which recorded a very low basal area per hectare compared to the other two stands (Table 1).

CONCLUSION AND RECOMMENDATIONS

The sharp variation in stand densities among the tree species indicates the level of human encroachmentin the arboretum and their preference for quality wood from *Nauclea diderrichii* and *Tectona grandis* valued for construction and furniture. Generally, tree growth increased with more gaps in a stand. Trees with DBHs of 45cm and above in the *Gmelina arborea* stand should be selectively harvested for timber to reduce its population density to 45% of its initial stocking. This will help to reduce the level of competition among the residual trees. The gaps in *Tectona grandis* stand should be planted up to 45% of the initial stocking in order to increase the density of trees for optimum utilization of the growth resources in this plot. The Department should ensure adequate security of the arboretum. Permanent sample plots should be established in the arboretum for continuous inventory to provide data for research and sustainable management of the resources.

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