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INDEX AGE FOR ESTIMATING SITE INDEX OF *Gmelina arborea* (ROXB.) STANDS IN OLUWA FOREST RESERVE, SOUTH WESTERN NIGERIA

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ABSTRACT
Index age for estimating site index of *Gmelina arborea* (Roxb) stands in Oluwa forest reserve in six year old plantation and ten year old plantation was investigated in this study. A hectare was randomly selected in each of the plantations. Temporary sample plots of 20m x 20m were laid while complete enumeration were carried out in each sampled plot and tree growth variables such as diameter at breast height (Dbh), diameter at the top, diameter at the middle and diameter at the base as well as total height of all trees were measured. Site index equation was constructed using simple linear regression model. The derived site index equation for *Gmelina arborea* plantation in the study area was: SI = exp [Ln(Hd) – 2.85 ((0.05) – A^{-1})]. Based on the site index, a harvesting age of 20 years was found appropriate for the site. Total volume was found to be 2396.94m^3 and 10257.07m^3 for 6 years and 10 years old respectively. The maximum Dbh encountered was 0.55m and that of height was 25.5m. For diameter distribution, highest proportion (54%) of the tree per hectare of 10 years old stand of *G. arborea* belong to diameter class of 30-39cm while the least proportion (1%) belong to Dbh class of 50-59cm. Also for 6 years old stand the highest proportion (51%) and the lowest (2%) belong to Dbh class of 10-19cm and 30-39cm respectively. Initial timber harvesting and further re-establishment of *Gmelina arborea* plantations in Oluwa forest reserve should be concentrated upon.

Keywords: forest, *Gmelina arborea*, index age, site index

INTRODUCTION

The sustainable management of our forest be it natural, monoculture or mixed plantation forest should arouse the interest of individuals. Site quality assessment is the evaluation of innate productive capacity of an area of forest land for one or more tree species (Onyekwelu, 2003). Site quality assessment is very important in forest management because a site could support one species excellently while supporting another species poorly. The oldest, commonest and most widely used technique for evaluating site quality or productivity of even-aged stands is site index. Site index is defined as the average total height of dominant and co-dominant trees (i.e. site trees) at a specified reference or base age, which is commonly selected to lie close to the rotation age (Clutter *et al.* 1983). The principal uses of site index systems are: (1) to estimate height at any given age from site index, (2) to estimate site index from height at any given age, (3) to stratify forest land into productive classes, (4) to provide entry to yield tables, and (5) as predictive variable in growth and yield models (Wang and Payandeh 1995). However, the most common objective of site index is to determine the height development pattern that the stand is expected to follow throughout rotation (Clutter *et al.,* 1983). Site index equations are essential elements of quantitative tools in forest management (Teshome & Petty 2000), which can be evaluated mathematically or graphically. The mathematical approach is preferred because the graphical method involves an element of subjectivity, coupled with the difficulty in performing statistical tests on the goodness of fit of the curve. Most of the mathematical techniques used to fit site index curves could be viewed as special cases of three general equation development methods, namely, the guide curve, difference equation and parameter prediction methods (Clutter *et al.,* 1983). Among the various techniques for developing site index curves, the proportional or guide curve method has become popular in recent times for even-aged single species plantations (Nanang and Nunifum 1999). The predominant use of the guide curve method for even-aged plantations has been attributed to the general lack of permanent plot data for forest plantation, coupled with the fact that most plantation species in the tropics do not show annual or seasonal growth rings (Clutter *et al.*, 1983, Nanang and Nunifum 1999). Currently, there is a change of management objective for *Gmelina* plantations in the study area from pulpwood to timber production. Consequently, the objective of the present study is to investigate the appropriate index age for site index determination in *Gmelina arborea* timber plantations in Oluwa forest reserve in Nigeria.

METHODOLOGY

The study area

This study was carried out in Oluwa forest reserve in the rainforest ecological zone of South-western Nigeria, it lies between latitude $6^0 55^l$ and $7^0 20^l$ N and longitude $3^0 45^l$ and $4^0 32^l$ E. The plantation covered an area of about 87,816 ha. It is characterized by a mean annual humidity and temperature of about 80% and 26^OC respectively and mean elevation of 23m above sea level (Onyekwelu, 2001). About 19,000 ha of the land in Oluwa forest reserve has been converted to forest plantation while the remaining area is mostly occupied by degraded natural forest (27,000 ha) and arable farmland (31,000 ha). Over the years, *G. arborea* plantation has emerged the dominant plantation species in Oluwa forest reserve accounting for about 89% of total plantation (Onyekwelu , 2001).

Sample plot location

Two stands of *G. arborea* plantations were investigated. One hectare was selected each at well stocked portion of the stands in the study site. Twenty five (25) temporary sample plots of 20 x 20m per hectare of each age series were laid. A complete enumeration of all the trees were carried out in the selected hectare for each stand making a total of 50 plots in the entire stands of *G. arborea* plantations examined.

Tree growth variables measurement

Measurement was limited to *G. arborea* plantation age of 6 years and 10 years respectively. Diameters at the top, middle, base and total heights of all trees in the stand were measured with Spiegel relaskop.

Basal area calculation

The basal area of each tree was calculated using the formula:

$$BA = \frac{\pi D^2}{4} \quad \text{……………………………………………1}$$

where BA = Basal area (m^2), D = Diameter at breast height (cm) and л = pi (3.142).

The total BA for each plot were obtained by adding all trees BA in the plot

$BA_p = \sum BA_{tree}$

The mean BA for the plot were calculated with the formula

$$BAp = \frac{\Sigma BA}{n} \quad \text{……………………………………2}$$

where BA_p = mean Basal area per plot,

n = number of plots or sampling unit.

Basal area per hectare were obtained by multiplying mean basal area per plot with number of plots in an hectare (25 plots)

$$\boxed{BAha = BAp * 25} \quad \text{……………………………3}$$

Volume estimation

The volume for each tree in each sample plot were estimated using Newton's formula of (Hustch *et al*., 2003).

$$V = \pi H \left[\frac{Db^2 + Dm^2 + Dt^2}{24}\right] \quad \text{……………………………………4}$$

Where V = Volume (m^3), H = height (m), Db = Diameter at the base, Dm = Diameter at the middle, Dt = Diameter at the top and Π=3.142

Site index estimation

$$\text{Ln HD} = b0 + b1\,(A^{-1}) \quad \text{…………………5}$$

where:

Ln= Natural logarithm

H=Tree height

A= Tree age and b_0 and b_1 are regression constants

The index age of 20 years was used to develop equation for the site index estimation for *Gmelina* plantations. Among the various techniques for developing site index equations, the proportional or guide curve method was adopted. This is because the data were from temporary sample plots, thus permitting only the use of this method. Where site index is made the subject of the equation 5, the equation obtained is:

$$\text{Ln (SI)} = b0 + b1\,(A^{-1}) \quad \text{…………………..6}$$

where SI =Site index

A= Index age (years) while b_0 and b_1 are regression constants.

By substituting equation 6 into equation 5 and making SI the subject of the resulting equation, the site index equation is as follows:

$$\text{Ln (Hd)} = \text{Ln(SI)} - b_1 (A_{index}^{-1}) + b_1 A^{-1} \quad \text{……………….7}$$

$$SI = \exp[\text{Ln(Hd)} - b_1 ((A_{index}^{-1}) - A^{-1})] \quad \text{………………. .8}$$

RESULTS

Table 1: Tree growth variables obtained from the study area

Variables	***Gmelina arborea* plantations**		
	6 years	**10 years**	**Combined data**
Basal area (m^2)/ha	23.93	100.34	124.227
Volume (m^3)/ha	2396.94	10257.07	12654.01
Average Dbh (m)	0.16	0.34	0.25±0.10
Average total height (m)	13.34	16.32	14.85±0.10
Confidence limit of Volume estimate /ha(lower limit)	2394.83	10253.24	10154.25
Confidence limit of Volume estimate /ha(upper limit)	2399.42	11342.56	15345.52
No of stems per hectare	1017	1034	2051

Table 2: Descriptive statistics of total height (m) and Dbh (m) of all trees in the study area

	Values	Parameters
H (m)	Dbh (m)	
Mean	**14.85**	0.25
Standard Error	**0.07**	0
Median	**15.14**	0.26
Mode	**12**	0.38
Standard Deviation	**2.98**	0.11
Sample Variance	**8.9**	0.01
Kurtosis	**1.24**	-1.01
Skewness	**-0.38**	0.07
Range	**22.5**	0.51
Minimum	**3**	0.05
Maximum	**25.5**	0.55
Sum	**30543.16**	523.65
Count	2051	2051

Table 3: Diameter distribution into diameter classes in the study area

Diameter classes	10yrs old *G. arborea* plantation		6yrs old *G. arborea* plantation	
	Freq/ha	% Distribution/ha	Freq/ha	% Distribution/ha
0 - 9	0	0	147	14
10-19	0	0	516	51
20-29	264	26	334	33
30-39	561	54	19	2
40-49	195	19	0	0
50-59	14	1	0	0
>60	0	0	0	0
Total	**1034**	**100**	**1017**	**100**

The site index equation obtained in this study is:

$$SI = \exp[\ln(Hd) - 2.85\ ((0.05) - A^{-1})]$$

($R=0.87$, $R^2=0.75$, $SEE=0.073$)

SI=Site index

Hd=Dominant height

A=Age

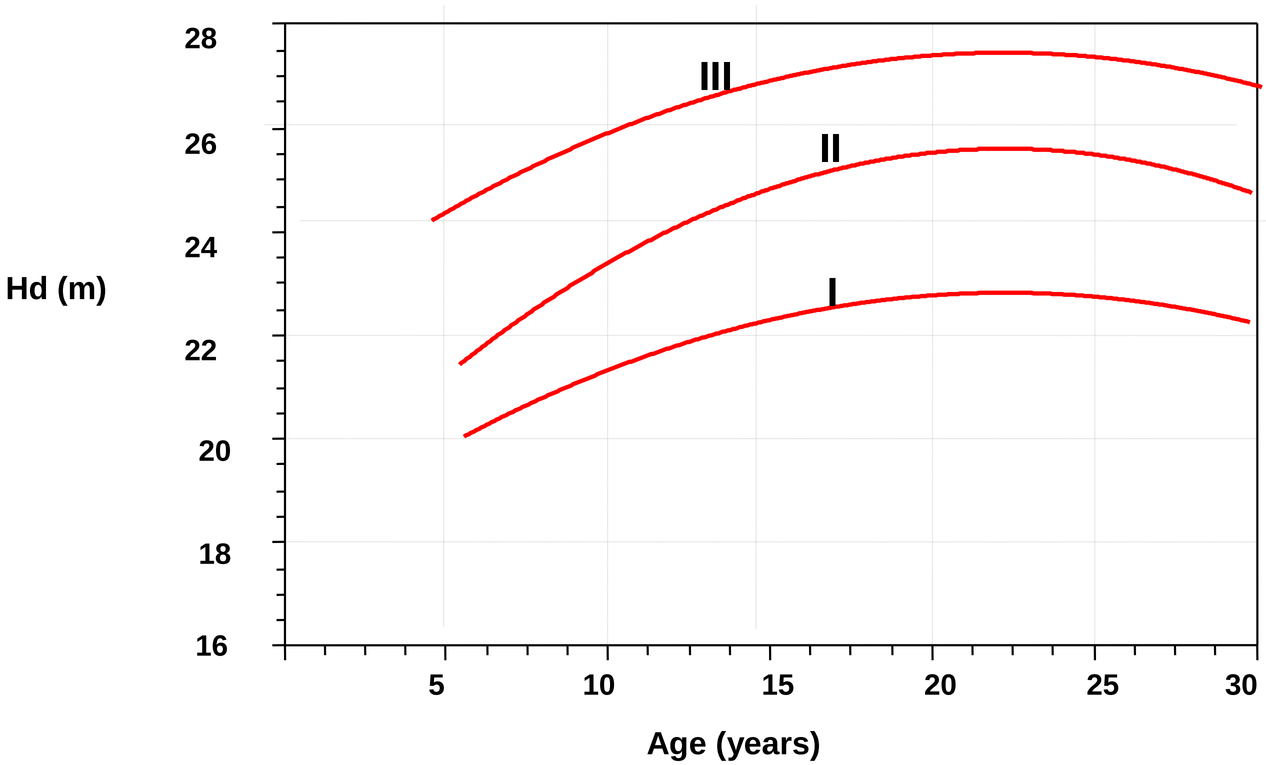

Fig 1*.Site index curves for Gmelina arborea stands*

DISCUSSION

The tree growth variable measured in the study area showed that the mean dbh value was 0.25m for the forest stand (table 1) this shows that most of the trees encountered in this study area are below the minimum merchantable size of 48cm stipulated by logging policy of southwestern Nigeria (Adekunle, 2006).. The basal area per hectare in each of the forest stand was approximately 24m^2 and 100m^2 for six and ten year old stand respectively. The value for basal area encountered in both stands is an indication of a well-stocked forest (Alder and Abayomi, 1994).The skewness and kurtosis (table 2) for the dbh and height were found to be very low for dbh skewness and kurtosis were found to be 1.01 and 0.07 while that of height was 0.38 and 1.24 for skewness and kurtosis respectively. This agreed with the findings of Maltamo (1997) who reported low skewness and kurtosis as an indication of right tailed distribution and also the evidence of a good stock of the stand. The site index values obtained in this study revealed that SI values for the stands were relatively close. One possible reason for this might be due to the closeness of the geographical location of the plantations. This range variation was also observed by Soares and Tome (2001) and Vanclay (1994) stated that meaningful growth and yield forecast requires some evaluation of site differences. Site index equation that was found suitable for site quality evaluation, the model fitted well with the dominant height age data with R^2 of 0.75 and standard error of estimate (SEE) value of 0.30. The suitability of this form of model was also confirmed by Akindele (1990) FORMECU (1991) and Onyekwelu (2003) this equation is useful for predicting current and future value of site index for *G. arborea* in the study area within the age range studied. The high growth rate demonstrated by the dominant trees in an indication of the high growth potentials of *G. arborea* in the study area.

The site index curves generated for *Gmelina arborea* plantation (Fig 1), reveals the height development patterns of dominant trees in *Gmelina* stands in the study area are expected to follow the height development patterns exhibited by class III since area of good site quality are also areas where height growth are high (Adekunle, 2006). The best site quality class for *Gmelina* stands in the study area is site III, while the average and poor site quality classes are II and I respectively (Fig 1). Thus, a 20 year-old *Gmelina* stand attained average dominant height of 27.5m, 25.5m and 23m on site classes III, II and I, respectively. The implication of this is that a stand with height development similar to curve III is growing on a better site and has higher volume production than a stand with height development pattern similar to curve l. This stand (site class III) will attain merchantability before stands on poor site classes. This is in consonance with the view of Onyekwelu (2003) who reported a similar curve with that of class III as a suitable curve indicating a good yield of merchantability in the study area.

Consequently, site index equation and index curve generated in this study will be a useful tool on yield studies in *Gmelina arborea* plantations in Oluwa forest reserve. The reason for this good performance can be attributed to the good soils. (Onyekwelu 2003) noted that ferruginous tropical soils which are found in the study area are among the most fertile soils in southwestern Nigeria. The high growth rate can also be attributed to the fact that the extremes of temperature of 18^0C and 35^0C and annual rainfall of 1778 and 2286mm required by the species for optimum growth is adequately met in the study area (Onyekwelu 2003).

CONCLUSION

The result of this study reveals that the suitable index age of 20 years were found to be more accurate for the study site. Based on this age, the appropriate site index equation generated for site quality is therefore recommended for use but should, however, be applied within the age range of 20 years in the study area. Initial timber harvesting and further re-establishment of *Gmelina arborea* plantations in Oluwa forest reserve should be concentrated upon. The models developed are useful aid for making sound silvicultural management decision. This study should help promote the development of tree volume predictions for multispecies stand. It is believed that this study will provide a basis for further data collection management of Oluwa forest reserve.

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