GROWTH AND YIELDS OF *PINUS CARIBAEA* IN NORTHERN NIGERIA

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Abstract

Trial plantings of exotic tree species commenced in some parts of northern Nigeria over 40years ago. Based on data from permanent sample and temporary plots, site index curves and yield tables were constructed for *Pinus caribaea,* var *hondurensis,* one of the promising exotics tried.

The constructed site index curves revealed five (5) site classes at a reference age of 20 years; viz: I (25.8m); II (23.2m); III (20.5m) IV (17.8m) and V (15.2m). The growth figures derived from the yield classes resulting from the five site index classes revealed that the maximum current annual increment (MCAI) was attained between the ages of 9.7 – 11.3 years with a total volume production (TVP) of between 75 – 263 m^3/ha (volume over-bark to 7.5cm diameter top). The maximum mean annual increment (MMAI) was attained at age 18 years for all the classes, but with a TVP of about 489 m^3/ha for class I; 387 m^3/ha for class II; 296 m^3/ha for class III; 216 m^3/ha for class IV and 153 m^3/ha for class V. Among other things discussed was the application of the resulting growth figures in the management of the species.

Introduction

Intensive growth and provenance trials of pines as well another exotic tree species commenced in the savanna region of Nigeria in the late 1950's. Such efforts were directed at meeting the demand for wood and wood products and also to provide shelter for food crops and prevent desertification in the arid north of the country (Kemp, 1969). The encouraging results from the series of selection work that followed the trial plantings (Kemp, 1970; Iyamabo *et al.*, 1972; Anon, 1974) led to the establishment of large scale plantations of some promising species among which are the pines. By 1984,over 300 hectares of plantations of pines had been established in Kaduna State which falls within the Northern Guinea savanna zone while in 1988 the first crop of pines was harvested for the pulp and paper mill at Jebba. Other northern areas where plantations of pines have been raised include Jos Plateau, Nimbia and the Mambilla Plateau. From a preliminary evaluation of the performance of the pines tried, *Pinus caribaea,* var. *hondarensis* is on of the most promising species

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within the low and medium altitude areas (600-1200m) of the Northern parts of Nigeria (Adegbehin *et al.*, 1985). Hence this study was aimed at evaluating the growth and yields of the species in the Northern parts of Nigeria.

Materials and Method

Experimental areas and data collection

The experimental areas were Afaka (Northern Guinea zone) Nimbia and Agwa-Momoh (Derived savanna pocket of land at the foot of the Jos Plateau), Ta-Hoss, and Miango, all on the Jos Plateau (Fig. 1). While detailed descriptions of the original vegetation covers and soil types of the study areas have been documented by Keay (1959), Kemp (1969), and Barrera and Amujo (1971). A summary of site characteristics of these locations is given in Table 1.

The data from permanent sample plots collected from 1967 to 1983 were updated in 1997 based on the re-measurements of the permanent sample plots. The data from the permanent sample plot records were supplemented by data from temporary plots. Plot size varied from 0.020 to 0.110ha and the initial minimum number of trees per plot was not less than 36. The data collected in each plot include tree diameter, height and volume measurements. Data were collected from 43 permanent sample plots, 33 of which were located at Afaka, 2 at Nimbia, 5 at Agwa-Momoh, one (1) at Miango and two (2) at Ta-Hoss (one temporary). Data collection, calculations of top height (mean height of the largest 100 trees/ha), mean height, standing volume, total volume production (TVP) which is made up of the standing volume and thinning volume, standing basal area and total basal area production were in accordance with the sample plot procedure by Horne (1952). Volume figures were calculated overbark and up to 7.5 cm diameter top limit.

Trial fitting of the top-height-age and volume-age data

The Gompertz and the Logistic models are non-linear growth models in which the determination of the constants are usually based on the non-linear least square method using the iterative procedure (Marquardt, 1963). When both models were tried on the top-height- age and volume-age data for the species, it was found that the Gompertz model gave slightly better fits, considering the values for the R^2 and the root mean square error (RMSE). This finding agrees with that of Nokoe (1978) and that of Adegbehin *et al.* (1991) when the two models were used for fitting top-height-age and volume-age curves for the species. Hence the Gompetz model was used in this study.

The Gompertz model as utilised in this study is expressed as:

$$D = W \exp(-\exp(-c(A-g)))$$ Model (1)

D = Top height (m) or total volume production (m^3/ha)
A = Age of the stand in years
W, c and g are parameters to be determined

Exp = Exponential constant (e) = 2.71828

In forest management, the maximum current annual increment (MCAI), the maximum mean annual increment (MMAI) and the ultimate maximum yield (volume/unit area) that can be obtained, are very important. The age at the MMAI influences the choice of rotation age.

The ultimate maximum yield corresponds with the point at which the first derivative of the function with respect to age is zero while the point of inflection which corresponds with the age at which the second derivative is zero coincides with the age at which the MCAI is maximum (Nokoe, 1978)

By setting the second derivative to zero, it can be shown that A=g and D = W/e at the point of inflection. The coefficient *g* in the Gompertz model thus represents the age at which the current annual increment (CAI) is maximum and the corresponding yield divided by the exponential constant (*e*) gives the ultimate maximum yield.

Fitting of the top height-age (site index) curves The curve for the average site class (the guiding curve) was fitted into the top-height-age data for the species. The upper and lower curves were hand-fitted in such a way that they followed the upper and lower plotted data margins respectively and such that they followed the trend of the guiding curve and also symmetrical with it. At this stage, this resulted in the construction of a set of three (3) curves. Since the width between the guiding curve and the other two curves was large to reasonably accommodate an additional class, two more curves, one on each site of the guiding curve was interpolated, thereby giving a set of five (5) site classes for the species. All the curves (except the guiding curve already modelled by the Gompertz) was then smoothened out using the Gompertz function (see Table for the estimated Gompertz parameters).

Fitting of volume – age curves

The volume-age curves were fitted via the total volume production-top height (TV-Hd) curves based on the constructed site index curves. The (TV-Hd) data were screened using the computer to eliminate odd data. For this reason, only 90 out of the 147 data sets were involved in fitting of the TV-Hd curve using the Gompertz function as shown in (Model (2).

TV = W exp (-exp (-c(Hd-g))) Model (2)

W = 2095.93	e. = 2.71828
c = 0.0592	R^2 = 0.9683
g = 31.0445	RMSE = 29.80
N = 90	

From the Gompertz-fitted TV-Hd curve, the volume- age figures were derived for the set of site index curves for the species. (giving rise to the corresponding yield classes).

The derived volume-age figures were then smoothened out using the Gompertz function. The estimated Gompertz parameters for the total volume production (TVP)- age data for the set of curves (yield classes) can be found in Table 5.

Prediction of total basal production

The total basal area production (TBA) was predicted as a function of top height (Hd) using the Gompertz function. The estimated Gompertz parameters are as shown in Model (3). From the Gompertz fitted TBA-Hd curve. the TBA – age figures were derived for the set of the five (5) yield classes.

TBA = W exp (-exp (-c(Hd-g))) Model (3)

W = 208.2	e. = 2.71828
c = 0.0579	R^2 = 0.9360
g = 26.9022	RMSE = 5.6m2/ha
	N = 90

Results and Discussion

Site index curves

The constructed site index curves revealed the following five (5) site classes at a reference age of 20 years. viz.: I (25.8m); II (23.2m); III (20.5m); IV

(17.8m) and V (15.2m) (see Table 2 & fig 2).

The constructed set of curves has a resemblance with the set of curves constructed for *P. caribaea* at Trinidad and Tabago by Lackhan (1972). Thus the site classes I (25.8m), II (23.2m) and III (20.5m) of the constructed set of curves compare favourably well with site classes I (25.9m); II (22.9m) and III (19.8m) of the set of curves for Trinidad and Tabago (Lackhan. 1972) respectively. This result agrees with the findings of Adegbehin (1985). However. the major difference is that site classes IV (17.8m) and V (15.2m) in this study are not represented at the Lackhan's site index curves.

Out of the 39 plots with trees 20 years old and above, 4 (10.2%) fell in site class I, 6 (15.5%) fell in Class II; 13 (33.3%) fell in site class III; 13 (33.3%) fell in site class IV while the remaining 3 (7.7%) fell in site class V (Table 3). Further it was found that the only plot at Miango fell into site class I while one of the two plots at Ta-Hoss also fell into site class I. All the two plots at Nimbia also fell into site class I. All the five plots at Agwa-Momoh (Nimbia) fell into site class II while most of the plots at Afaka fell within site classes III and IV (Table 3). The oldest plot at Vom (on the Jos Plateau) planted at 1954 with the top height of 23.4m at age 20 (though not included in this study) fell in site class II. From the fore-going discussion, based on the locations where best growth (site class I) has been observed, it can be inferred that the species has the best growth on the Jos Plateau (both Ta-Hoss and Miango) as well as at Nimbia.

Yield classes and yield figures

Based on the constructed site index curves, the corresponding yield classes including the yield figures were derived. The derived yield figures extrapolated to some extent were tabulated at 2-year intervals from the age of about 4 years up to the age of 42 years which is within the range of field data. From the yield figures the mean annual increment (M.A.I) and the current annual increment (C.A.I) were calculated.

Yield figures

Five (5) site index classes were delineated for the species and consequently five (5) yield classes were delineated (see Table 4 (a)-(e).)

It was found that the C.A.I. culminates at the ages of about 11.3. 11.3, 11.0. 10.6, and 9.7 years for yield classes I–V respectively with the corresponding TVP of 262.7, 209.0. 158.3. 113.2 and 74.7m^3/ha. (Table 5). The maximum C.A.I attained at the ages stated are 38.2, 29.5, 22.4, 16.1 and 10.5m^3/ha/year for yield classes I-V respectively.

Furthermore, it was found that the M.A.I culminates at the age of about 18 years for the five yield classes, but with the TVP of 488.7m^3/ha for yield class I; 387.4m^3/ha for class II; 296.0m^3/ha for class III; 216.5m^3/ha for class IV and 153.0m^3/ha for site class V. The maximum M.A.I. attained are 27.2, 21.5, 16.4, 12.0 and 8.5m^3/ha/year for yield classes I-V respectively (Table 5).

Age of culmination of C.A.I and M.A.I as related previous findings

There is generally lack of information at which ages the C.A.I. and M.A.I culminate for the species. With regard to *P.caribaea*, Lackhan (1972) pointed out that the age at which the M.A.I reaches its peak varies to some extent. He cited an age range of 25-30 years depending on site quality for *P.caribaea* grown in Trinidad. This range is outside the age of 18 years obtained for *P.caribaea* investigated in this current study.

However, as experienced in the Eastern African countries, for the most commonly planted softwood species, *Pinus patula*, the age at which the maximum C.A.I. and maximum M.A.I. are attained ranges from 8–17 years and 15-25 years respectively (Adegbehin, 1977; Adlard, 1975; Wanene, 1975; Kingston, 1970; Klitgaard and Mikkelsen, 1975). Therefore the results obtained with respect to the ages of culmination of the C.A.I. and M.A.I. in this study could be regarded as normal. However, the peculiarity noted is that the age of culmination of the C.A.I. was attained at some-how earlier ages in poorer sites. For most species, it is normal that the C.A.I. and M.A.I. culminate earlier at better sites than at poorer sites.

Plantation management and rotation age

Most of the stands were not thinned. Using data from some of the thinned stands, the relationships between top height and such stand variables as number of standing trees/ha, standing volume/ha, standing basal area/ha, cumulative thinning volume/ha and the cumulative basal area/ha were derived. Based on these relationships coupled with the information from the yield figures, the growth rate of the species especially the age at which the maximum M.A.I. was attained, as well as possible utilization of the species, an indication of what could be obtained on an average site for the species under a provisional management (thinning) regime is hereby discussed. The species was represented or measured at several experimental sites. This is more widely planted than *P.oocarpa* and is mostly raised by the Kaduna and Plateau State Forestry Services mostly for pulpwood and timber production.

Five (5) yield classes were delineated for the species with the maximum MAI attained at the age of 18 years for all the yield classes. Considering the average site (yield class III), it is possible to have about 1200 trees/ha survival at establishment (1370 plants/ha at the initial spacing of 2.7m by 2.7m). This could be thinned to about 800 trees/ha at the age of 12 years. This again could be thinned to about 500 trees/ha at the age of 20 years and then clear-felled at the age of about 26years when a standing volume of about 280.0m^3/ha and a tree mean diameter of about 30.0cm would have been attained. This recommendation tends to super-cede the earlier recommended rotation age of 33 – 35 years (Adegbehin, 1985) which was based on insufficient growth data. However, this is not to say that the rotation age could not be extended beyond 26 years depending on the price of log among other factors. The thinnings so obtained could be used to feed the Nigerian pulp and Paper industry at Jebba.

Conclusion and Recommendations

The growth and yield figures for the species may be regarded as tentative and it is recommended that further investigations should be carried out to obtain further growth data on the species especially from the older age groups. Tentative yield figures (standing volume) have been derived for the average site based on a provisional management (thinning) regime. Further research work should also be carried out to determine the yield figures for the species under different thinning regimes.

Acknowledgements

As this study is part of the research project on the growth of exotic tree species in the savanna region of Nigeria funded by the African Academy of Sciences, (A.A.S), Nairobi, Kenya, the financial support from this organisation is highly appreciated. The author is also very grateful to the staff of the Forestry Research Institute of Nigeria (Savanna Forestry Research Sub-station, Samaru) for the assistance rendered for the data collection.

Table 1. Site characteristics of study areas

Study Site	Afaka (Kaduna)	Agwa-Momoh	Nimbia	Jos Plateau		
				Miango	Vom	Ta-Hoss
Vegetation Zone	N.G Zone	Derived	Derived			
Location	Lat 10° 37'N Long 7° 11'E	Lat 9° 32'N Long 8° 36'E	Lat 9° 30'N Long 8° 34'E	Lat 9° 51'N Long 8° 52'E	Lat 9° 44'N Long 8° 47'E	Lat 9° 38'N Long 8° 44'N
Attitude (m)	600	600	600	1300	1260	1250
Mean annual Rainfall (mm)	1290	1820	1820	1570	1370	1348
Rainy days/year	180	220	220	180	190	185
Mean Maximum Temperature (Hottest months)	35°C (March, April)	36°C March	36°C March	31°C March	31°C March	31°C March
Mean annual Temperature	25°C	26°C	26°C	22°C	22°C	22°C
Mean Minimum Temperature (coldest months)	14°C Dec, Jan	15°C Dec. Jan	15°C Dec, Jan	13°C Dec,Jan	13°C Dec,Jan	13°C Dec,Jan
Soil type	Ferruginous tropical soils sandy loam on plinthite layer	Eutrophic dark brown soils from basalt, clay loam	Eutrophic dark brown soils from basalt,clay loam	Eutrophic dark brown soil, derived from basalt, mainly clay loam		
PH	5.3-6.2	6.0-6.8	6.0-6.8	5.2-5.6	5.2-5.6	5.2-5.8

N G Zone = Northern Guinea Savanna Zone
Sources: Kowal and Knabe (1972); Iyamabo *et al.*, (1972); Anon (1971)

Table 2. Site classes (m)* for *P. caribaea*

Age (years)	Site I (m)	Site II (m)	Site III (m)**	Site IV	Site V
2	5.7	5.2	4.8	4.4	3.9
4	8.4	7.7	7.0	6.3	5.7
6	11.4	10.4	9.4	8.5	7.5
8	14.3	13.1	11.8	10.6	9.3
10	16.9	15.4	13.9	12.3	10.8
12	19.5	17.6	15.8	14.0	12.1
14	21.5	19.4	17.4	15.3	13.2
16	23.2	20.9	18.6	16.4	14.0
18	24.7	22.2	19.7	17.2	14.8
20	25.8	23.2	20.5	17.8	15.2
22	26.7	24.0	21.2	18.4	15.6
24	27.5	24.5	21.7	18.8	15.9
26	27.8	24.9	22.0	19.0	16.1
28	28.4	25.3	22.3	19.3	16.2
30	28.7	25.7	22.6	19.4	16.3
32	28.9	25.8	22.7	19.6	16.4
34	29.2	26.0	22.9	19.8	16.5
36	29.4	26.1	23.0	19.8	16.5
38	29.4	26.2	23.0	19.8	16.6
40	29.6	26.4	23.1	19.9	16.7
42	29.6	26.4	23.1	19.9	16.7

* Top height figures derived from Table 5

**Represents the average site

Table 3. Sorting of *P.caribaea* plots into site classes at the age of 20 years and above

Site Class	I	II	III	IV	V	Total
	MNNTa	Ag Ag Ag Ag Ag Ta	AAAA AAAA AAAA A	AAAA AAAA AAAA A	AAA	
Total	4	6	13	13	3	39
Percentage	10.2%	15.5%	33.3%	33.3%	7.7%	100.0

A – Afaka; Ag – Agwa-Momoh ; N- Nimbia; M-.Miango; Ta - Ta-Hoss.

Table 4a. Yield tables for *P. caribaea:* yield class I

Age (yrs.)	Top Ht (m)*	Total Vol. (m³/ha)**	Total BA (m²/ha)***	M.A.I (m³/ha/yr)	C.A.I (m³/ha/yr)
2	5.7	-	6.9		
4	8.4		11.3		
6	11.4	85.5	17.9	14.2	28.0
8	14.3	141.6	26.2	17.7	33.1
10	16.9	207.8	35.0	20.8	40.7
12	19.5	289.2	44.9	24.1	35.8
14	21.5	360.7	53.1	25.8	33.1
16	23.2	426.9	60.3	26.7	30.9
18	24.7	488.7	66.9	27.2	23.5
20	25.8	535.7	71.7	26.8	19.0
22	26.7	573.7	75.7	26.1	16.0
24	27.5	605.7	79.2	25.2	12.6
26	27.8	630.9	80.2	24.3	9.8
28	28.4	650.6	83.2	23.2	7.6
30	28.7	665.8	84.6	22.1	5.8
32	28.9	677.5	85.4	21.2	4.4
34	29.2	686.4	86.8	20.2	2.3
36	29.4	693.2	87.6	19.3	2.6
38	29.4	698.3	87.6	18.4	2.0
40	29.6	702.3	88.5	17.6	1.4
42	29.6	705.2	89.0	16.8	

* Derived from the Gompertz parameters in Table 5

** Derived from the volume-age model (Table 5) via the top height-volume model (Model 2)

**** Derived from Gompertz parameters in Model (3)

Table 4(b). Yield tables for *P. caribaea:* yield class II

Age (yrs)	Top ht (m)*	Total Vol. (m^3/ha)**	Total BA (m^2/ha)****	M.A.I. (m^3/ha/yr)	C.A.I. (m^3/ha/yr)
2	5.2		6.2		
4	7.7		10.0		
6	10.4	70.4	15.5	11.7	22.8
8	13.1	116.0	22.5	14.5	25.9
10	15.4	167.8	29.7	16.8	30.3
12	17.6	228.4	37.5	19.0	28.7
14	19.4	285.8	44.5	20.4	26.3
16	20.9	338.4	50.6	21.2	24.5
18	22.2	387.4	56.0	21.5	18.0
20	23.2	423.3	60.3	21.2	15.8
22	24.0	454.9	63.8	20.7	12.8
24	24.5	480.4	66.0	20.0	10.1
26	24.9	500.6	67.7	19.2	7.9
28	25.3	516.4	69.5	18.4	6.1
30	25.7	528.6	71.3	17.6	4.8
32	25.8	538.1	71.7	16.8	3.6
34	26.0	545.4	72.6	16.0	2.8
36	26.1	550.9	73.0	15.3	2.1
38	26.2	555.1	73.5	14.6	1.7
40	26.4	558.4	74.0	14.0	1.2
42	26.4	560.8	74.5	13.4	

* See Table 4 (a) for the derivation of the stand parameters in asterisks.

Table 4c. Yield tables for *P.caribaea*, yield class III

Age (yrs)	Top ht (m)*	Stems/ha		Volume (m^3/ha)			Basal Area (m^3/ha)			M.A.I (m^3/ha/yr)	C.A.I (m^3/ha/yr)
		Standing	Thinned	Total	Thinned	Standing	Total	Thinned	Standing		
2	4.8	1200					5.7				
4	7.0						8.8				
6	9.4			57.2			13.3			9.5	17.4
8	11.8			92.1			18.9			11.5	20.2
10	13.9			132.6			24.9			13.3	22.7
12	15.8	800	400	178.0	34.0	144.0	31.1	8.0	23.1	14.8	22.2
14	17.4			222.2			36.8			15.9	19.4
16	18.6			261.1			41.3			16.3	17.0
18	19.7			295.0			45.7			16.4	14.2
20	20.5	500	300	323.5	69.0	220.5	48.9	11.2	29.7	16.2	11.6
22	21.2			346.8			51.8			15.8	9.4
24	21.7			365.6			53.9			15.2	7.4
26	22.0	500		380.5		280.0	55.2		35.3	14.6	5.8
28	22.3			392.2			56.4			14.0	4.5
30	22.6			401.2			57.7			13.4	3.5
32	22.7			408.2			58.2			12.7	2.6
34	22.9			413.5			59.0			12.2	2.1
36	23.0			417.6			59.5			11.6	1.6
38	23.0			420.8			59.9			11.1	1.2
40	23.1			423.1			60.4			10.6	1.0
42	23.1			425.0			61.0			10.1	–

* See Table 4(a) for the derivation of the stand parameters

Table 4d. Yield tables for *P. caribaea:* yield class IV

Age (yrs)	Top ht (m)*	Total Vol. (m³/ha)**	Total BA (m²/ha)****	M.A.I. (m³/ha/yr)	C.A.I. (m³/ha/yr)
2	4.4		5.4		
4	6.3		7.7		
6	8.5	47.0	11.5	7.8	13.5
8	10.6	74.0	16.0	9.2	15.2
10	12.3	104.5	20.3	10.4	15.6
12	14.0	135.8	25.2	11.3	14.8
14	15.3	165.5	29.4	11.8	13.4
16	16.4	192.4	33.2	12.0	11.6
18	17.2	215.6	36.1	12.0	9.7
20	17.8	235.0	38.3	11.8	8.0
22	18.4	250.9	40.6	11.4	6.4
24	18.8	263.7	42.1	11.0	5.1
26	19.0	273.8	42.9	10.5	4.0
28	19.3	281.7	44.1	10.1	3.1
30	19.4	287.9	44.5	9.6	2.4
32	19.6	292.6	45.3	9.1	1.8
34	19.8	296.3	46.1	8.8	1.4
36	19.8	299.1	46.4	8.3	1.1
38	19.8	301.2	46.9	7.9	0.8
40	19.9	302.8	47.2	7.6	0.6
42	19.9	304.1	47.4	7.2	—

* See Table 4 (a) for the derivation of the stand parameters in asterisks

Table 4e. Yield tables for *P. caribaea:* yield class V

Age (yrs)	Top ht (m)*	Total Vol. (m^3/ha)**	Total BA (m^2/ha)****	M.A.I. (m^3/ha/yr)	C.A.I. (m^3/ha/yr)
2	3.9		4.7		
4	5.7		6.9		
6	7.5	36.3	9.6	6.0	9.4
8	9.3	56.0	13.1	7.0	10.0
10	10.8	77.5	16.4	7.8	10.6
12	12.1	98.8	19.7	8.2	10.4
14	13.2	118.5	22.8	8.5	8.3
16	14.0	135.7	25.2	8.5	9.2
18	14.8	150.3	27.8	8.4	4.8
20	15.2	162.1	29.1	8.1	5.1
22	15.6	171.6	30.4	7.8	3.8
24	15.9	179.1	31.4	7.5	2.6
26	16.1	184.9	32.1	7.1	1.4
28	16.2	189.3	32.5	6.8	1.4
30	16.3	192.8	32.8	6.4	1.4
32	16.4	195.3	33.2	6.1	1.4
34	16.5	197.3	33.3	5.8	0.0
36	16.5	198.8	33.6	5.5	1.4
38	16.6	199.9	33.9	5.2	1.4
40	16.7	200.7	34.3	5.1	0.0
42	16.7	201.4	34.5	4.8	–

* See Table 4 (a) for the derivation of the stand parameters in asterisks

Table 5. Estimated parameters of the Gompertz model for *P. caribaea* for the dependent variables for top height-age and total volume production (TVP) – age Dependent Variable (D) = W exp. (-exp. (-c(A-g)))

		Parameter Estimates				Vmmai		Vmmai		Mmai	Mcai
	Dependent Variable	W	c	g	RMSE	(m^3/ha)	R^2	Vol. (m^3/ha)	Yrs	(m^3/ha/yr)	
Site Class I	Top ht. (m)	32.0234	0.1120	6.1281	0.8129		0.9993				
		714.28	0.1421	11.3177	3.6529	262.67	0.9996	488.70	18.0	27.2	38.2
Site Class I		28.4634	0.1134	5.8748	0.7007	–	0.9993	–	–	–	–
		568.44	0.1401	11.2803	3.0366	208.98	0.9998	387.4	18.0	21.5	29.5
Site Class I		24.9178	0.1150	5.5501	2.6600		0.9770				
		430.62	0.1397	11.0430	2.2855	158.31	0.9998	296.0	18.0	16.4	22.4
Site Class I		21.3811	0.1173	5.1375	0.4710	–	0.9996	–	–	–	–
		307.99	0.1386	10.5611	2.0854	113.23	0.9999	216.5	18.0	12.0	16.1
		17.8384	0.1215	4.5952	0.3643		0.9998	–	–	–	–
		203.23	0.1451	9.7463	1.8257	74.72	0.9999	153.0	18.0	8.5	10.5

D = Top height (m) or total volume production (m^3/ha)
A = Age of stand (yrs.)
W, c and g = Coefficients determined;
g = Age at which C.A.I is maximum.
Vmcai = Vol. At maximum C.A.I Exp. = Exponential constant (2.71828)
VMMAI = W/exp.
Vmmai = Vol. At maximum M.A.I
R^2 = Proportion of variation in the dependent variable explained by the model
Mmai = Maximum M.A.IRMSE = Root mean square error.
Mcai = Maximum C.A.I

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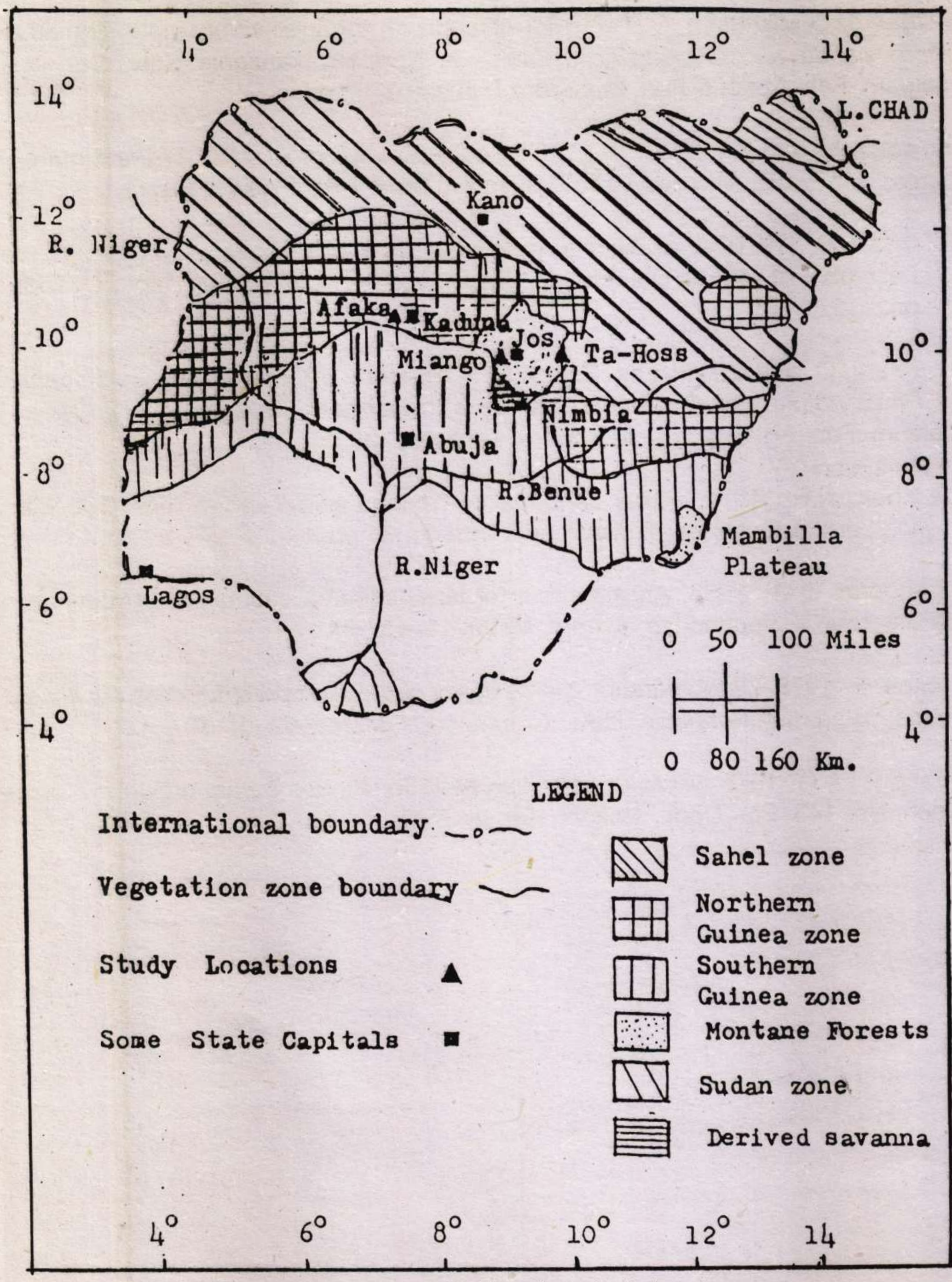

Fig.1. Map of Nigeria showing study locations

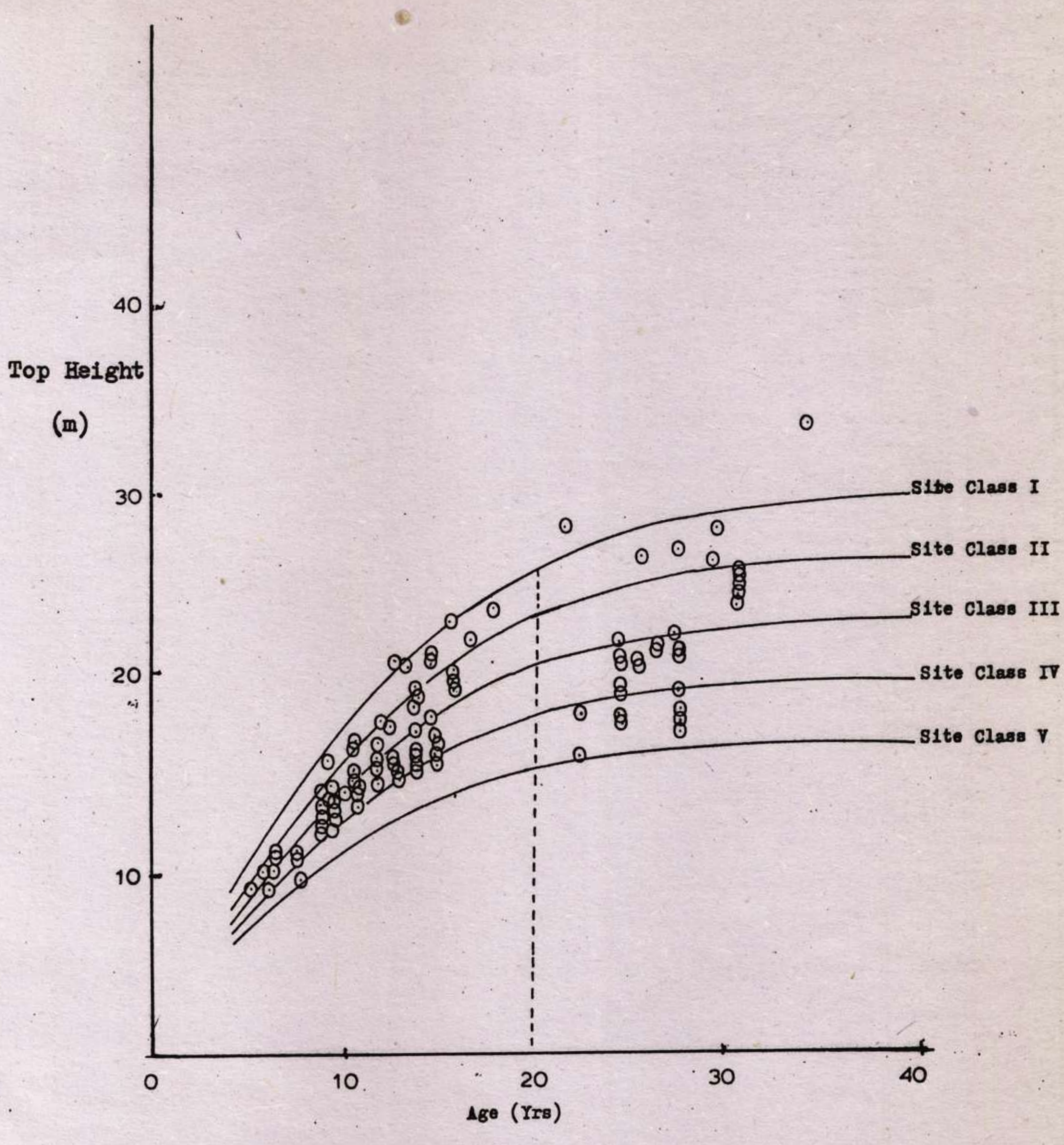

Fig.2. Site index curves for *Pinus caribaea*