DEVELOPING DIAMETER DISTRIBUTION MODELS IN UKPON RAINFOREST RESERVE OF CROSS RIVER STATE, NIGERIA

[1]Bassey S. E. and [2]Adekunle V. A. J.

[1]Department of Forestry and Wildlife Management, Cross River University of Technology (Obubra Campus), PMB102, Obubra, Cross River State, Nigeria.
[2]Federal University of Technology, Forestry & Wood Technology, PMB 704, Akure, Nigeria

***Corresponding Author:** *stanleyeval123456789@gmail.com;* +234 806 807 1551

ABSTRACT

The aim of this study is to provide the most appropriate model for tree distribution into diameter classes in Ukpon tropical rainforest reserve of Cross River State, Nigeria. Systematic line transect was used to lay sample plots. Two transects of 1500m in length with a distance of at least 500m between the two parallel transects were used for this study. Sample plots of 50m x 50m in size were laid in alternate along each transect at 100m interval and thus, summing up to 10 sample plots per 1500m transect and a total of 20 sample plots in the study area. A total of 1100 individual tree species spread across 65 species belonging to 21 different tree families were measured for diameter at breast height, diameters at the base, middle and top and tree total height. The mean diameter at breast height and total height of 28.8cm and 18.6m were obtained. Mean basal area of 50.29 m^2 ha^{-1} was obtained with a mean volume of 271.249 m^3 ha^{-1}. Easy Fit software was used for Diameter Distribution models. Three diameter distribution models were developed and validated for the reserve. However, Dagum four parameters (4P) was the more flexible among the selected diameter models in the reserve. None of the selected model was significant; meaning that each of the three models is accurate and fit for diameter prediction is the reserve. The research has provided easy to use diameter distribution models for prescription of silvicultural treatment per time in the reserve in order to enhance effective and efficient management of the reserve.

Keywords: Diameter distribution, Models, Systematic sampling, Transect and Sustainable management

Correct Citation of this Publication
Bassey S. E. and [2]Adekunle V. A. J. (2022). Developing diameter distribution models in Ukpon Rainforest Reserve of Cross River State, Nigeria. *Journal of Research in Forestry, Wildlife & Environment,* 14(2): 84 – 94.

INTRODUCTION

Sustainable management of forest resources requires a large amount of supporting information especially when managing the forest for production of commercially valuable materials, estimation of present growth of variables which are not possible to measure easily such as timber volume, biomass and estimate of future growth are also essential. The tropical rainforest is one of the major vegetation types of the globe (Richards, 1996; Whitmore, 1998). It occupies a total area of 1818.43 million hectares, representing 47% of the total land area occupied by all forest types of the world (FAO, 2003). According to Turner (2001), the tropical rainforest is the most diverse of all terrestrial ecosystems, containing more plant and animal species than any other biome. In spite of this diversity, most species are locally endemic or rare and patchily distributed (Richards, 1996). Thus, the overall timber value per unit area is generally low, thereby necessitating logging activities over large areas in order to meet the ever-increasing demand. The FAO (1999) estimated that tropical countries are losing 127,300 km^2 of forest annually. In view of the great value of the tropical rainforest and the grave consequences of losing it to unregulated logging activities and over-exploitation, it has become the focus of increasing public attention in recent years. The importance of tropical rainforests for goods, services, wood products, food, and conservation of soil and water resources, recreation and biological diversity has been recognized since long time ago. Now, rainforests are also being recognized as playing important roles in global biogeochemical cycles, particularly the global carbon cycle (Dixon *et al.,* 1994).

Forest managers are interested in being able to estimate the number of trees in different diameter classes in a stand, because the size of the diameter determines the industrial use of the wood and thus, the price of the different products. Diameter distributions also provide information about stand structure, age structure and stand stability. Quantifying yield by size classes is harbinger for prescription of effective silvicultural treatment and harvesting regime for any forest stand. Furthermore, tree diameter is an important factor in harvesting because it determines the type of machines used and how they perform during felling and transportation of the wood. Stand yields have also been predicted based on the assumption that diameter distribution of a stand can be characterized by a probability density function (Poudel & Cao 2013).

Diameter at breast height is one of the most important and most applied bioassay variables in forest trees, so, its study is important to describe the structure of any given forest (Fallah *et al.,* 2006). Diameter distribution and the related statistical models can play an important role in forest science, for example, in some growth modeling, it is necessary to know the type of diameter distribution function and its parameters to identify the appropriate model for it. Diameter distributions can be used to indicate whether the density of smaller trees in a stand is sufficient to replace the current population of larger trees and to help evaluate potential forest sustainability.

Tree diameter distribution is used to determine the structure of a forest stand (Rouvinen & Kuuluvainen 2005). The ability to predict the distribution of diameters in a stand helps forest managers to make informed decisions such as prescription of silvicultural treatments and determination of distribution (Carretero and Álvarez, 2013). Knowledge of diameter distributions forms the basis for deciding when a stand can be economically harvested for a specific product (Ekpa *et al.* 2014). Diameter structure is an important stand characteristic on which we can evaluate the stability, growth, volume production, structure of assortment, and maturity (Gorgoso-Varela and Rojo-Alboreca 2014). Therefore, the main purpose of the study was to develop diameter distribution model for Ukpon Forest River of Cross River State for effective management of the stand.

MATERIALS AND METHODS

Study Area

The research was conducted in the Ukpon River Forest. Ukpon River Forest Reserve is located within Obubra, Etung and Yakurr Local Government Areas in Cross River State, Nigeria (Latitudes $5^{o}40^{1}30^{11}$ and $5^{o}57^{1}30^{11}$ N and Longitudes $8^{o}12^{1}00^{11}$ and $8^{o}32^{1}00^{11}$ E). The reserve has a total area of thirty-one thousand, three hundred hectares (31,300 Ha.) (NASDRA and FAO, 2014). The elevation of the study areas ranged between 14 m and 87 m above mean sea level. The study area has a moist tropical maritime climate, with high rainfall concentrated during monsoon period from June to September and high temperature. The mean annual rainfall ranges from 2,500mm in January to 4,000mm in August. The rain is fairly distributed through-out the months of April to October. Mean annual temperature range from 27.6^{0} C in August to 33.1^{0} C in February. The Strong winds usually accompany the onset of dry season, which is caused by hot and dry North East wind. The mean relative humidity ranges from 71% in February to 90% in August (Ajayi, 2006).

Sampling Procedure and Data Collection

Systematic line transect was employed in the laying of plots. Two transects of 1500m in length with a distance of at least 500m between the two parallel transects were used in each of the study sites. Sample plots of 50m X 50m in size were laid in alternate along each transect at 100m interval and thus summing up to 10 sample plots per 1500m transect and a total of 20 sample plots in the Forest Reserves (Figure 1).

In each plot, all living trees with dbh ≥10cm were identified and measured for diameters and tree total height. Spiegel relaskop was used for individual tree diameter and tree height measurement. For trees growing on a slope, the dbh was measured from the uphill side. Buttresses were considered to be non-commercial. So, when buttresses extending more than 1.30 m above ground surface were encountered, the equivalent of dbh was measured at a height of 20 cm above the upper limit of the buttresses. When knots or localized deformations occurred at breast-height point, a more representative dbh point either above or below the breast-height point was chosen (Adekunle *et al.*, 2010).

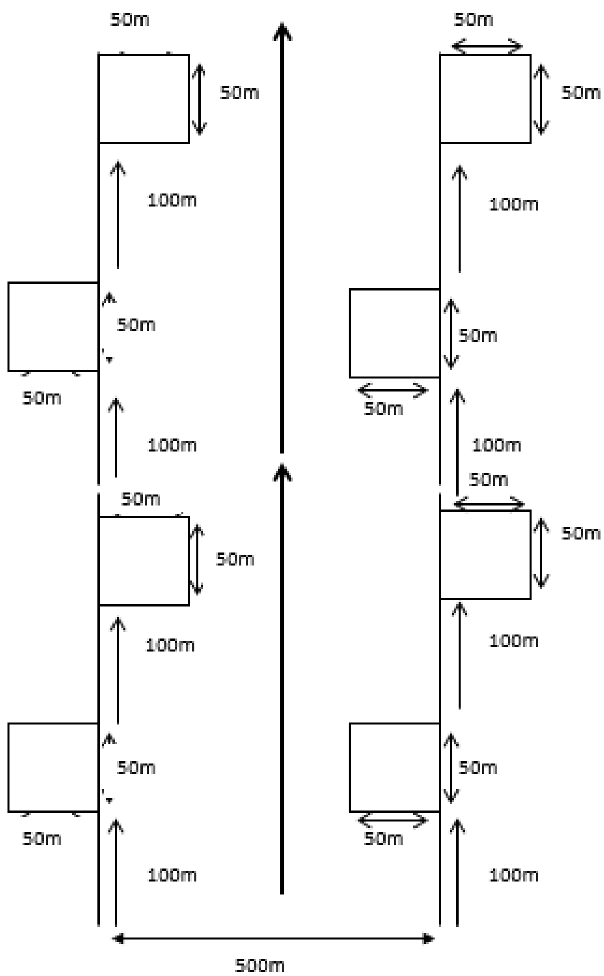

Figure 3: Plot layout with systematic line transects sampling technique.

Data Analysis

Basal Area Estimation

The diameter at breast height was used to calculate the basal area.

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

Where:

D = diameter at breast height (m), $\pi = 3.14$ and BA = Basal Area (m^2).

The total Basal Area (BA) for each plot was obtained by adding all trees basal area in the plot while mean basal area for the plot was calculated with the formula:

$$\overline{BA_p} = \frac{\Sigma BA}{n} \ldots.2$$

Where:

$\overline{\mathrm{BA_p}}$ = Mean basal area per plot ann = Toatal number all possible samplot plot

Stem Volume Estimation

Individual tree volume was calculated using the Newton's formula of Husch *et al.*, (2003):

$$V = \frac{h}{6}[A_b + 4A_m + A_t] \ldots 3$$

Where:

V= Volume (m^3), A_b = Basal area at the base (m^2), A_m = Mid basal area (m^2) and A_t = Basal area at the top (m^2)

The plot volumes were obtained by adding the volume of all the trees in the plot while mean plot volume was obtained by dividing the total plot volume by number of sample plots. The volume of trees per hectare (V_{ha}) was subsequently estimated by multiplying the mean per plot by the number of sampling units in a hectare (Adekunle, 2007).

Diameter Distribution Models

The diameter distribution models were generated using Easy Fit software. Some of the diameter probability functions that were adopted in this study for diameter distribution estimation areas are listed below:

Weibull model: Ratkowsky (1983) and Myers (1986) employed the two-parameter Weibull models in their studies.

The models were:

$$W(t) = \left(\alpha - \beta e^{-kt^{m}}\right) + \varepsilon \;\ldots..4$$

Logistic model: Nelder (1961) and Oliver (1964) employed this model:

$$W(t) = \alpha/\left(1 + \beta e^{-kt}\right) + \varepsilon \;\ldots\ldots5$$

Burr (4P)	$f(x) = \frac{ak\left(\frac{x-y}{\beta}\right)^{a-1}}{\beta\left(1+\left(\frac{x-y}{\beta}\right)^{a}\right)^{k+1}} \ldots 6$
JohnsonS_B Distribution	$f(\mathrm{x}) = \frac{\delta}{\sqrt[\lambda]{2\pi z(1-\mathrm{Z})}} \exp\left[-\frac{1}{2}\left(\gamma + \delta ln\frac{z}{1-Z}\right)^{2}\right] \ldots 7$
Beta Distribution	$F(\mathrm{x}) = \frac{1}{B(\alpha_1,\alpha_2)} \frac{(\mathrm{x-a})^{\alpha_1 - 1}(\mathrm{b-x})^{\alpha_2 - 1}}{(\mathrm{b-a})^{\alpha_1+\alpha_2-1}} \ldots..\ 8$
Weibull Distribution	$f(\mathrm{x}) = \frac{\alpha}{\beta}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1} exp\left(-\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right) \ldots.9$
General Pareto Distribution	$f(x) = \frac{1}{\sigma}\left(1 - \frac{\xi(\chi-\mu)}{\sigma}\right)^{\left(-\frac{1}{\xi}-1\right)} \ldots\ldots10$
Generalized Gamma 4P Distribution	$f(x) = \frac{k(\chi-\gamma)^{k\alpha-1}}{\beta^{k\alpha}\Gamma(\alpha)} \exp\left(-\left(\frac{\chi-\gamma}{\beta}\right)^{k}\right) \ldots..11$
Lognormal Distribution	$f(x) = \frac{1}{x\alpha\sqrt{\pi}} e0.5^{\left(\frac{lnx-\mu}{\sigma}\right)2} \ldots\ldots.12$
Gamma 3P	$f(x) = \frac{x^{\alpha-1}}{\beta\Gamma(\alpha)} \exp\left(\frac{-x}{\beta}\right) \ldots\ldots.\ 13$
Exponential 2P	$f(x) = \lambda e^{-\lambda x} \ldots\ldots\ldots\ldots..14$
Erlang 3P	$f(x) = \frac{\lambda^{k} x^{k-1} e^{-\lambda x}}{(k-1)!} \ldots\ldots\ldots\ 15$
Inverse Gaussian	$f(x) = \left(\frac{\lambda}{2\pi x^{3}}\right)^{1/2} exp \ldots\ldots\ldots\ 16$

Assessment of Diameter Distribution Models for Selection

The selection of the best diameter distribution models was based on:

i. Kolmogorov Smirnov
ii. Anderson Darling
iii. Chi-Squared

RESULTS

Summary of Characteristics data for Ukpon Forest Reserve

Results in table 1 below show that a total of 1100 individual tree species spread across 65 species belonging to 21 different tree families were measured for diameter at breast height, diameters at the base, middle and top and tree total height. The mean diameter at breast height and total height of 28.8cm and 18.6m were obtained. Mean basal area of 50.29 $m^2\,ha^{-1}$ was obtained with a mean volume of 271.249 $m^3\,ha^{-1}$.

Summary of Goodness of fit for Assessing the Distribution Functions of Ukpon Reserve of Cross River State, Nigeria

The result in Table 2 shows the summary of the goodness of fit of the diameter distribution functions for Ukpon rainforest reserve of Cross River State. The goodness of fit was tested with Kolmogorov smirnov, Anderson Darling and Chi-Squared as shown in the table. The Kolmogorov smirnov, Anderson Darling and Chi-Squared tests indicate that ten distributions can provide good fits for the diameter data in the selected reserves. calculated D-values (Dagum 4P: 0.02862, Frechet: 0.04615, Gen. Extreme Value: 0.048, Burr: 0.04474, Pearson 5 (3P): 0.03255, Pearson 6 (4P): 0.03161, Frechet (3P): 0.02947, Burr (4P): 0.05089, Gen. Pareto: 0.04732, Log-Pearson 3: 0.0415).

Summary of Parameters for the Diameter Distribution Functions for Ukpon Reserve of Cross River State, Nigeria

The results in Table 3 show the parameters for each of the diameter distribution functions and their estimated values of diameter at breast height associated to each model for the Forest Reserve.

Table 1: Summary of Characteristics data for Ukpon Forest Reserve in Cross River State, Nigeria

S/ No	Parameters	Summary	Min.	Max.	Std. Error	Std. Deviation	Skewness	Kurtosis
1	No. of sample plots measured	20	-	-	-	-	-	-
2	No of trees measured	1100	-	-	-	-	-	-
3	Average DBH (cm)	38.47	3.00	193.80	0.7883	26.03	3.11	12.27
4	Average height	18.6	11.40	46.20	0.55	19.14	2.72	6.84
5	Mean basal area ha^{-1}	50.29	32.05	60.25	0.88	30.21	2.53	13.4
6	Mean volume ha^{-1}	271.25	87.23	234.10	0.53	73.51	2.41	7.12

Table 2: Summary of Goodness of fit for Assessing the Distribution Functions of Ukpon Rainforest Reserves of Cross River State, Nigeria

Forest Reserve	No.	Distribution	Kolmogorov Smirnov		Anderson Darling		Chi-Squared	
			Statistic	Rank	Statistic	Rank	Statistic	Rank
Ukpon	8	Dagum (4P)	0.02862	1	1.345	1	17.01	3
	17	Frechet (3P)	0.02947	2	1.3753	2	17.492	4
	47	Pearson 6 (4P)	0.03161	3	1.7387	4	16.878	2
	45	Pearson 5 (3P)	0.03255	4	1.7307	3	18.573	5
	37	Log-Pearson 3	0.04344	5	7.187	10	N/A	
	2	Burr	0.04474	6	2.3991	6	16.246	1
	16	Frechet	0.04615	7	3.7691	7	29.135	
	23	Gen. Pareto	0.04732	8	143.26	44	N/A	
	20	Gen. Extreme Value	0.048	9	4.461	8	32.075	7
	3	Burr (4P)	0.05089	10	2.2508	5	36.55	8

Table 3: Summary of Parameters for the Selected Diameter Functions for Ukpon Rainforest Reserve of Cross River State, Nigeria

Forest Reserve	Distribution	A	b	□	□$_1$	□$_2$	□	□	□	K	□	□	□
Ukpon	Dagum (4P)			1.67			2.42	4.78		15.11			
	Frechet (3P)			1.72			12.91	3.94					
	Pearson 6 (4P)				13.00	2.05	0.77	5.67					
	Pearson 5 (3P)			2.04			25.40	5.36					
	Log-Pearson 3			3.59			0.33	1.96					
	Burr			9.46			12.08			0.16			
	Frechet			2.05			17.20						
	Gen. Pareto									0.33		12.47	10.31
	Gen. Extreme Value									0.45		8.37	17.29
	Dagum (4P)			1.67			2.42	4.78		15.11			

Critical values (α=0.05) of Test Statistics for Assessing the Diameter Distribution Models for Ukpon Rainforest Reserve of Cross River State, Nigeria

For the purpose of the goodness of fit and choosing the best diameter distribution functions, three tests of statistics were used to assess the models; Kolmogorov-Smirnov, Anderson-Darling and Chi-Squared across reserve. Results of the tests are presented in Table 4 shows the critical values of the tests across the reserve which was used to determine diameter distribution function. The critical values of test of statistics for assessing criteria in describing the diameter of distribution of the selected observed and estimated probability distribution functions were used to validate the output of the distribution models.

Validation of Diameter Distribution According to Diameter Classes with Distribution Models for Ukpon Rainforest Reserve, Cross River State-Nigeria

The performance of each of the diameter distribution model was assessed to evaluate the distribution function that best predicts the diameter structure of the forest reserve. Results in Table 5 show the analysis for the diameter distribution model validation according to DBH classes. Paired T-test was used to validate the model by comparing the observed and predicted as presented in Table 5. The diameter distribution model selected recorded a non-significant difference (P>0.05) with the computed from the field. It was observed that as the diameter class increases, the number of individual trees for each class reduces. That is, increase in diameter class, the fewer the number of trees in diameter class reduces.

Table 4: Critical values (α=0.05) of Test Statistics for Assessing the Distribution Models of Ukpon Rainforest Reserve of Cross River State, Nigeria

	Distribution		
T- Statistics	Kolmogorov- Smirnov	Anderson- Darling	Chi-squared
T-stat	0.02	1.35	17.01
T-crit	0.04	2.50	18.31

Table 5: Observed and Predicted Diameter Distribution According to Diameter Classes with Dagum (4P)distribution Model for Ukpon Forest Reserve, Cross River State, Nigeria

Dbh Class	Observed	Predicted
6.7 – 24.1	687.30	741.88
24.2 – 42.5	218.20	240.02
42.6 – 59.7	76.37	76.37
59.8 – 77.5	32.73	32.73
77.6 – 95.6	34.91	38.19
95.7 – 112.5	19.64	17.47
112.6 – 130	5.46	7.64
130.1 – 147.5	6.55	7.64
147.6 – 166.1	6.55	6.55
166.2 – 182.5	4.36	4.36
182.6 – 200.5	4.36	4.36

T-Test Analysis for the Most Flexible Model in Ukpon Rainforest Reserve, Cross River State, Nigeria

Result in Table 6 shows the most flexible diameter distribution function for the forest reserve. Dagum four parameters (4P) was the more flexible among the selected diameter models in the reserve. None of the selected model was significant; meaning that each of the model is accurate and fit for diameter prediction is the reserve

Furthermore, Figures 1 show the three best diameter distribution models for the forest reserve that can make appropriate fitting in diameter distribution; Dagum (4P), Frechet (3P) and Pearson 6 (4P).

Table 6: T-Test Analysis for the Most Flexible Model in Ukpon Tropical Rainforest Reserve, Cross River State

Forest Reserves	Distribution	T-stat	T- crit	P-value	Remark
Ukpon	Dagum (4P)	0.08	2.09	0.94	Ns

* *Ns = Not significant*

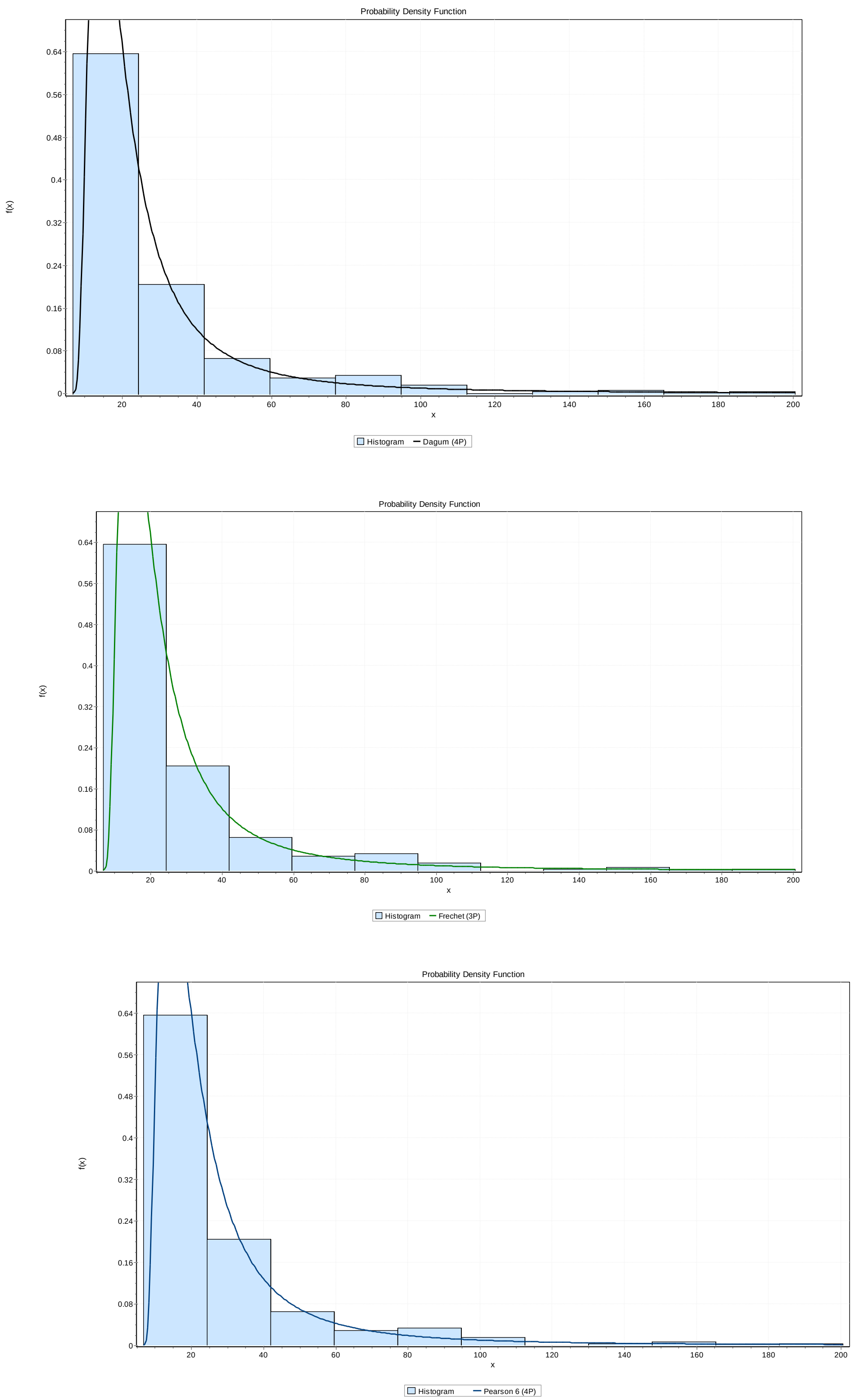

Figure 1: Three Best Diameter Distribution Models for Ukpon Forest Reserve

DISCUSSION

In this study, it was observed that there was a reduction in the number of stems per hectare as dbh class increases across reserve. The reductions in the number of stems per hectare as the dbh size class increased reflected the characteristics of a natural forest. This confirms the report of Avery and Burkhart (1983) that trees in an uneven-aged forest grow continuously and have different reproductive periods. This continuous reproduction of new trees has been noted to bring about variation in ages especially in an undisturbed stand. Furthermore, diameter distribution in an uneven-aged stand is irregular. Baker *et al.*, (1999) stressed that as the area of the stand increases, the irregularities tend to even out and the inverse J-shaped diameter distribution becomes apparent. There was high positive skewness and peakedness forest reserve. This high positive skewness and peakedness means that considerable numbers of trees are concentrated in the lower diameter classes in each of the reserve (Gadow, 1983).

The high positive skewness could also be attributable to the size of sample plot (50 m x50 m) and number of trees per plot(≥ 60). This finding agrees with the report made by Shiver (1988) who found that 50 trees per sampling plots would be acceptable for most of the investigation works that try to capture the diameter distribution in Slash pine plantations. Nord-Larsen and Cao (2006) affirm that the diameter distributions are affected by the spatial structure and the size of the plots. Nord-Larsen and Cao (2006) further emphasized that a better fit can be obtained with larger plots, but the number of plots should also be considered.

The high positive skewness could also mean good stand stock; by extension, it means even though there is continuous logging across reserves, logging is still very low and management approach should be intensified in the management of the reserve in order to sustain it especially because it is among few of the remaining rainforest reserves in Nigeria. This finding further agreed with the findings of Nurudeen, (2011) who reported high skewness and kurtosis as an indication of right tailed distribution and also the evidence of a good stock of a stand. The diameter distribution models developed for Ukpon Forest Reserve showed that Dagum (4P) diameter distribution model is the most flexible model and therefore judged to be the best for diameter distribution for the reserve. . To further test the validity, accuracy and consistency of the models, validation tests carried out revealed that there were no significant differences between the observed and the predicted values of all the model's parameter fitted. Validating a model consists by comparing its predictions with observations independent of those used for its fitting (Rykiel, 1996). Hence, the model can be used for future management of the forest and can also be used for management practices in the study area.

CONCLUSION AND RECOMMENDATIONS

Modeling stand structure is important in predicting forest growth and yield determination of product specification through distribution of trees into diameter classes and also prescribing silvicultural treatments such as thinning, pruning and selective harvesting. It is advantageous in forest management to use appropriate statistical distribution in predicting the condition of a forest stand so that silvicultural treatments and harvesting regimes could be prescribed. The changes in stand structure can be assessed by present measurements and the past knowledge of a stand. These are of great importance in detecting the changes that have taken place over a period of time and possible causes of those changes. This is the attempt made in this study.

Since the wise use of forest resources is paramount to the forest managers and planners, diameter distribution information is germane for making decisions on product specification and overall management of the forest reserves. However, the diameter distribution models developed in this can serve as a common tool for creating reference distributions of uneven-aged stands in similar forests and conditions to ours across Cross River State and beyond.

Based on the findings of this study, the following recommendations were made:

1. Permanent sample plots should be established in the study area to enhance

and promote accurate data collection, and the development of models for informed management decisions.

2. Further and comprehensive studies involving parameter prediction and parameter recovery methods taking information provided in this study as a foundational resource should be carried out across the study areas.
3. The fitted models should be used by the Cross-River State Forestry Commission for effective monitoring and better management practices in the reserves.

REFERENCES

Adekunle V.A.J., Akindele S.O. and Fuwape J.A. (2004): Structure and yield models of tropical lowland rainforest ecosystem of southwest Nigeria, Food, Agriculture and Environment 2 (2) 395-399.

Adekunle V.A.J. (2007): Non-linear regression model for Timber Volume Estimation in Natural Forest Ecosystem, Southwest Nigeria. *Research journal of forestry* 1 (2) 40-54.

Adekunle VAJ, Olagoke AO, Ogundare LF. (2010). Rate of timber production in a Tropical Rainforest Ecosystem of Southwest Nigeria and its implications on Sustainable Forest Management. Journal of Forestry Research. 21: 225–230.

Ajayi, S., Osho, J. S.A. and Ijomah, J.U (2006). The use of DBH and Stem Height to Determine Tree Volume Equation for *Gmelina arborea* (ROXB) Plantations in Okpon River Forest Reserve, Cross River State, Nigeria. *Global Journal of Agricultural Sciences*. 5(2): 141 – 146. (http//www.inasp.info/ajol).

Avery E.T and Burkhart H.E (2002): Forest measurements.*Mc Graw Hill New York U.S.A* 5th Edition 456pp.

Baker, S. F.; Theodore, W. D. and John, A. H. (1999). Principles of Silviculture. McGrawHill Book Company, New York. 7th Edition. 500pp.

Carretero A. C. and Álvarez ET (2013) Modelling diameter distributions of *Quercus suber* L. stands in "Los Alcornocales" Natural Park (Cádiz-Málaga, Spain) by using the two parameter Weibull functions. *Forest Systems* 22(1): 15–24.

Dixon, R., Brown, S., Houghton, R. A., Solomon, A. M., Trexler, M. C. and Wisniewski. J. (1994): Carbon pools and flux of global forest ecosystems. *Science* 263: 185-190.

Ekpa NE, Akindele S. O. and Udofia SI (2014) Gmelina arborea Roxb. graded stands with the Weibull distribution function in Oluwa Forest Reserve, Nigeria. *International Journal of Agroforestry and Silviculture* 1(9): 110–113.

Fallah, A.; M Zobeiry; Marvie Mohadjer, M.R., Iranian Journal natural resources, 2006, 58, No.4: 813-821. (in Persian)

FAO (2003). *State of the World's Forests, 2003*. Food and Agriculture Organization of theUnited Nations, Rome. 151pp.

FAO. (1996). *Forest Resources Assessment 1990. Survey of Tropical Forest Cover and Study of Clunge Processes Based on Multi-Date High-Resolution Satellite Data Forestry* Paper 130-Rome: FAO, Pp. 152.

Gadow, K. V. (1983). Fitting distributions in P*inus patula* stands. *South African Forestry Journal*, 20-29.

Gorgoso-Varela JJ & Rojo-Alboreca A (2014) Short communication: A comparison of estimation methods for fitting Weibull and Johnson's SB functions to pedunculate oak (*Quercus robur*) and birch (*Betula pubescens*) stands in northwest Spain. *Forest Systems* 23(3): 500–505.

Husch, B., T.W. Beers and J.A. Kershaw Jr., (2003): *Forest Mensuration.* 4th Edn., John Wiley and Sons, Inc., New Jersey, USA., pp: 949.

Myers, N., 1984. The Primary Source. W.W. Norton, New York, London. 17: 461-463.

NASDRA and FAO (2014). Deforestation and Forest Degradation Data gathering. YouTube: *NTA News* April 28, 2014 (2.41 mins).

http://www.youtube.com/watch?v=TMV4HhFM118.

Nord-Larsen, Thomas; Cao, Quang V. 2006. A diameter distribution model for even-aged beech in Denmark. Forest Ecology and Management. 231: 218-225.

Nurudeen T.A (2011): Nonlinear regression models for volume estimstion in *Gmelina arborea* (Roxb) stands at Oluwa forest reserve South western Nigeria. *M.sc Thesis submitted to the Department of Forest Resource Management, University of Ibadan, Nigeria* 78pp

Poudel KP & Cao QV (2013) Evaluation of methods to predict Weibull parameters for characterising diameter distributions. *Forest Science* 59(2): 243–252.

Richards, P.W., 1996. The Tropical Rain Forest, 2nd ed. *Cambridge University Press, Cambridge*, p. 599.

Rouvinen S & Kuuluvainen T (2005) Tree diameter distributions in natural and managed old *Pinus sylvestris*-dominated forests. *Forest Ecology and Management* 208: 45–61.

Rykiel, E.J.J. 1996. Testing ecological models: the meaning of validation. Ecol. Model., 90: 229–244. 171

Whitmore, T. C. (1998). *An introduction to tropical rain forests*. Second Edition. Oxford University Press, Oxford. 296p.