Research Article

Floristic Composition and Diameter Distribution Models for The Management of Omo Biosphere Reserve, Ogun State, Nigeria

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Abstract

Stem diameter distributions is highly needed in most forest management decisions. This study developed some models for describing the diameter distribution of Omo Biosphere Reserve in lowland rainforest ecosystem, Nigeria. Systematic sampling design was used to lay three straight line transects, four temporary plots of 0.25ha (50 m x 50 m) were laid in alternating position along each transect at 100 m interval to make up a total of 12 plots for the study and Diameter at breast height (DBH) was measured for all trees with Dbh ≥ 10cm in every plot. A total of fifty-seven species were encountered and exploratory analysis of the collected data showed that the observation was right skewed consequently resulting in the choice of six probability diameter distributions functions using Maximum likelihood estimator. The selected distribution models are Weibull, Lognormal Distribution (LN), Gamma, Logit-logistic (LL) and Burr distribution. The Kurtosis and Skewness are 6.43 and 1.34 respectively with a mean Dbh of 36.40cm. Burr had the least values of Kolmogorov Smirnov (Dn) (0.046), Anderson Darling (AD) (1.102) and Cramer-von Mises (CvM) (0.178). This is followed by log logistics with 0.05, 2.769 are 0.258 for Dn, AD and CvM respectively. High and positive skewness and kurtosis values reflect abundance of trees in the lower Dbh class. These are sufficient to replace the trees in the upper dbh class through regeneration. Hence, the Burr and Log-logistic distributions were adjudged the most flexible to describe the diameter structure of Omo Biosphere Reserve.

Keyword: Omo Biosphere, Diameter Distribution, Parameter estimation

1. Introduction

The tropical rain forest is the most diverse of all terrestrial ecosystems, containing more plants and animals' species than any other biome (Turner, 2001). Tropical forests are among the richest and most complex terrestrial ecosystems supporting a variety of life forms of not less than half of all the species on earth (Phillips, 1994; Ojo, 2004; Oladoye, 2014). It possesses a tremendous intrinsic ability for self-regeneration if properly maintained. The great number of species that form them is the reason for their fascination to people, their value to the biosphere, and the complexity of their proper management. [1]

In recent times, effort has been focused at conservation of this important ecosystem, because of its richness in biodiversity. Development of growth models for Omo Biosphere reserve will enable sustainable promotion of productive and protective aspects of

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the diverse species present (Gorgoso, et al., 2007). Stem diameter distributions is highly needed in majority of forest management decisions, and this has made diameter distribution modelling procedure to be one of the widely applied practices in forest management techniques (Ajayi, 2005). DeLiocourt (1898) reported the idea of diameter distribution that plotting the number of trees against diameter classes as a frequency histogram results in an inverse J-shaped curve.

Tree size distributions remain the most effective tool to describe the status and structures of any forest estate. Thus, value forests, planning to harvest activities, predicting forest growth, enhancing forest productivity, information on past disturbance events, forest successional status, and aboveground biomass stocks are some of the reasons for tree diameter distributions modelling (Bailey and Dell, 1973; Coomes and Allen, 2007; Burkhart and Tome, 2012; Ezenwenyi, et al, 2018).

Diameter class models allow planning of various uses and provide data about stand structure. These models are used to estimate stand variables and their structure with a density or distribution function, which is fitted to diameter distributions at breast height (DBH) or individual tree volume (Ige et al., 2014). Several authors have established the validity of some probability distributions that provided information about forest stand structure. Some of them are Beta distribution (e.g., Gorgoso–Varela et al., 2008; Ige et al., 2014), gamma distribution (e.g., Mirzaei et al., 2015; Adedoyin et al., 2021), Burr distribution (e.g., Tsogt et al., 2013), Johnson's SB distribution (Tsogt et al., 2013; Mayrinck et al. 2018; Ogana and Ekpa 2020)) and Weibull distribution (Gorgoso et al., 2012; Ezenwenyi et al., 2018; Sun et al. 2019; Egonmwan and Ogana 2020; Ige and Adedapo, 2021), however, No single type of stand model can be sufficiently enough to provide all the needed information for effective decision making (Adesoye, 2002; Ige et al., 2014).

Hence, it is important to test a wide variety of models of varying degree of complexity for the management of Omo Biosphere reserve, Nigeria. Most studies on diameter distribution models in Omo biosphere reserves had been on plantations (Ogana et al., 2017; Ezewenyi, et al., 2018; Ogundipe et al., 2018;) hence, the importance of this study can be well justified from this point of view. Therefore, the main objective of this study was to develop diameter distributions models for Omo biosphere reserve Nigeria.

2. Methodology

2.1 The study area

This study was conducted in Omo Biosphere Reserve, within Omo Forest Reserve, Ogun State, Nigeria. It is an internationally recognized unique habitat. Omo Forest Reserve, Area J4, is located in Ijebu East Local Government Area of Ogun State, Nigeria, on latitude 6° 50' N and longitude 4° 22' E (Figure 1). It became a United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve in 1949 (Were, 2001). IUCN, 1991). The reserve is divided into core (460 ha) and buffer zones (8,165 ha). The reserve falls within the tropical wet- and-dry climates characterized by two rainfall peaks separated by a relatively less humid period usually in the month of August. The mean annual rainfall is about 1750 mm, while mean relative humidity is 80%. The temperature ranged between 25 ˚ C to 31 ˚ C. Generally, sunshine duration during the rainy season varies between 8-10 hours (Ola-Adams, 2014). The soil is a mixture of Ferrallic and Ferruginous soils and the Reserve is a mixed moist semi-evergreen rainforest with undulating terrain and elevation of 150 m above sea level, and with tropical ferruginous soil (Isichei, 1995). The most abundant tree species in the reserve are *Funtumia elastica, Diospyros dendo, Phyllanthus discoideus, Nesogordonia papaverifera and Picralima nitida* (Chenge and Osho, 2018, Chenge, 2021).

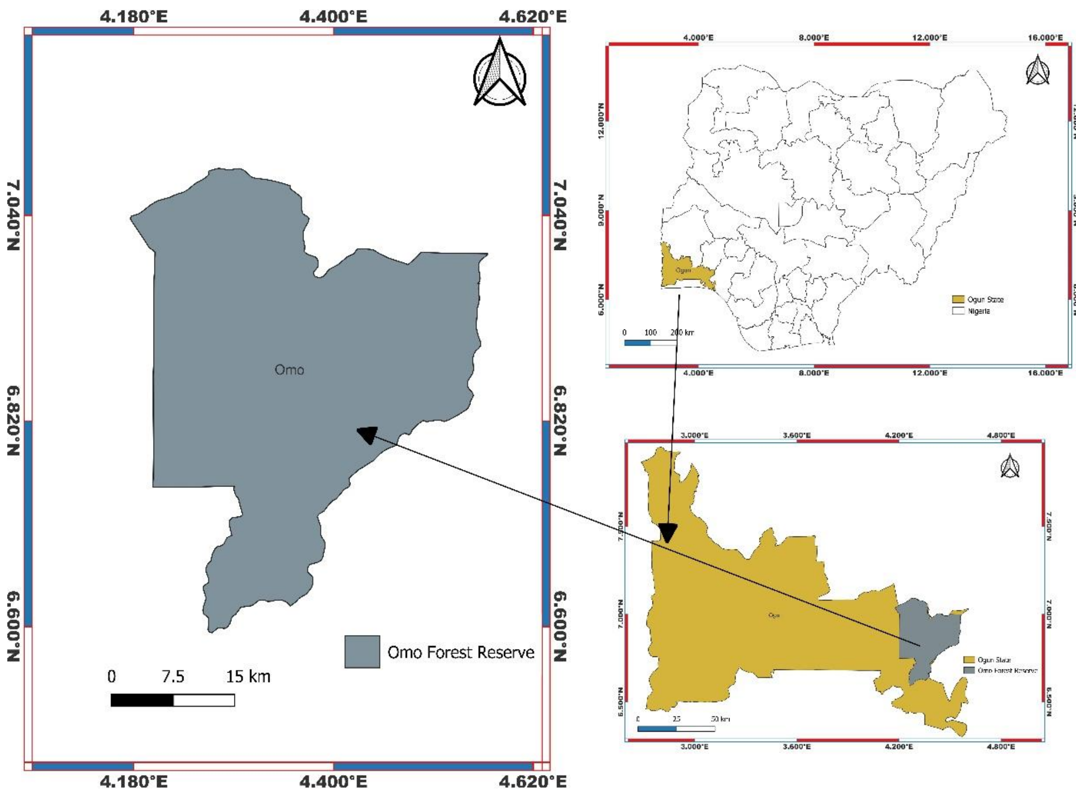

Figure 1: Map of the study area

2.2 Data collection

Data for this study was collected using Systematic sampling (line transect) technique. For plot location**,** 20m from the forest boundary was measured to locate the first transect. The coordinates of the starting point of each transaction were determined with the aid of Geographic Positioning System (GPS) receiver. Three transects were laid out within the study area at 200 m intervals. Four 0.25ha (50 m x 50 m) plots were laid in alternate positions along each transect at 100 m spacing, which makes the total number of plots to be twelve. Diameter at breast height (DBH) of all trees in each plot were measured using diameter tape, while Diameter at the base (Db,), Diameter at the middle (Dm), and Diameter at the top (Dt) and Height were measured using Spiegel Relaskop.

2.3 Data Analysis

The following diameter distribution models were fitted: Burr distribution, logit-logistic (LL), gamma, lognormal distribution (LN), and 3-P Weibull, using R statistical software, version 4.0.35 The distribution models were evaluated with Kolmogorov Smirnov (KS), Anderson Darling (AD) and Cramer-von Mises (CvM) goodness of fit and they were ranked accordingly. Summary statistics of the measured variables is presented on Table 1. The ecological status of the tree species was determined by calculating the Importance Value Index (IVI). The percentage values of the relative frequency, relative density and relative dominance are summed up together and this value is designated as the Importance Value Index or IVI of the species (Curtis, 1959, Oladoye *et al.*, 2014, Oladoye *et al.*, 2018).

Relative Density= $\frac{number\ of\ species}{total\ number\ of\ individual\ species}$ x 100

Relative Frequency (RF) = $\frac{\text{Frequency of a woody plant species}}{\text{Total frequency of woody plant species}}$ × 100.

Relative Dominance = $\frac{Basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species}$ ×100

Table 1: Summary of descriptive statistics of sampled trees in Omo Biosphere Reserve.

Variables	Fitting data (N trees = 296)				Validation data (N trees = 99)			
	Mean	SD	Min	Max	Mean	SD	Min	Max
DBH (cm)	35.52	27.02	10.00	180.00	39.05	24.64	10.00	116.00
MHT (m)	15.55	6.65	4.00	45.00	16.83	7.17	4.00	35.00
THT (m)	22.74	7.61	8.40	40.00	24.37	7.99	7.20	42.00
VOL(m^3)	2.41	6.49	0.03	59.04	3.09	6.20	0.03	29.87
BA (m^2)	0.16	0.31	0.01	2.55	0.17	0.23	0.01	1.06
CL	7.19	3.09	1.00	32.50	75.78	3.35	28.53	180.00
CR	0.33	0.12	0.09	1.00	7.55	0.13	2.00	17.00
SLC	80.25	33.16	17.39	177.42	0.33	31.40	0.05	0.78
Skewness	1.34							
Kurtosis	6.43							

MHT= merchantable Height, THT= Total height, VOL= Volume, BA-Basal area, CL=Crown length, CR=Crown ratio, SLC=Slenderness coefficient.

Table 2: Description of the probability distribution models

	Diameter Distribution Models	**Equations**
1	Burr	$f(x) = \frac{ak\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}}{\beta\left(1+\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right)^{k+1}}$
2	Loglogistics	$f(x) = \frac{\alpha}{\beta}\left(\frac{x-\gamma}{\beta}\right)^{\alpha-1}\left(1+\left(\frac{x-\gamma}{\beta}\right)^{\alpha}\right)^{-2}$
3	Gamma	$f(x) = \frac{(x-\gamma)^{\alpha-1}}{\beta^{\alpha}\Gamma(\alpha)}\exp\left(-\frac{x-y}{\beta}\right)$
4	Lognormal	Form: $f(x) = \frac{1}{\sqrt{2\pi}}\frac{\sigma^{-1}}{x}exp\left[-\frac{\sigma^{-2}}{2}(\log x-\mu)^2\right]$ Parameter: $\mu\ \epsilon(-\infty,+\infty), \sigma > 0$
5	Weibull Distribution	$f(x) = \frac{c}{b}\left(\frac{x-a}{b}\right)^{c-1}\ exp-\left(\frac{x-a}{b}\right)^{c}$

2.4 Model Validation

Model validation is important before they can be used with confidence. Validation involves the process of testing and comparing the models output with what is observed in the real world (Reynolds et al, 1981; Ige et al, 2014). The data were split into two sets randomly; the first set (i.e., n_1=298) was the calibration set which was used for model construction and the second was the validation set (i.e., n_2=99). (Maltamo and Kangas, 2008; Ige *et al.*, 2014).

3. Results

3.1 Diameter Distribution for Omo Forest

The summary of the descriptive statistics for diameter at breast height is presented in Table 1. The Standard Error, kurtosis and skewness are 1.34 trees/ha, 6.43 and 2.28, respectively. The mean DBH is 36.40cm. A total of 395 trees (DBH ≥ 10cm) representing 56 species from 22 families were encountered and identified in the Biosphere Reserve. Among the identified tree species are *Celtis zenkeri*, *Diospyros dendo*, *Diospyros hybridus, Sterculia rhinopatala, strombosia postulate*, *Desplastsia lutea, Diospyros mespiliformis*, *Pycnanthus angolensis*, *Ceiba pentandra, Cleistopholis philippensis, Cola gigantea, Cordia milleni, Diospyros canaliculata, Drypetes gilgiana, Entadrophragma cylindricum, Macaranga bateri, Nauclea diderichii, Picralima nitida, and Pterygota macrocarpa*. Their density ranged from 0.33 to 22.67 trees/ha and the Important Value Index (IVI) ranged from 0.99 to 37.36 (Table 3). The results of the goodness of fit for the various diameter distribution models is presented in Table 4. The results showed that Burr model had the smallest values of Dn, AD and CvM of 0.046, 1.102 and 0.178, respectively followed by Log Logistic with 0.05, 2.769 and 0.258 for Dn, AD and CvM, respectively. The graph of the observed and predicted diameter distribution from 2P Weibull, Burr, lognormal, log logistic and Gamma is presented in Figure 1, the predicted distribution showed no significant difference between the empirical cumulative functions and the theoretical cumulative functions. Figure 2 presents the DBH frequency distribution class for the 395 trees encountered in the study area. The result showed that most of the trees are in the diameter class of 10-50cm (323 trees).

Table 3: List of tree species encountered, families, stem density and Importance Value Index for Omo Biosphere Reserve

Species	Family	Total	Density/ha	IVI
Adenopus breviflorus	Cucurbitaceae	1	0.33	1.40
Albizia ferruginea	Fabaceae	3	1.00	3.01
Alstonia congensis	Apocynaceae	1	0.33	4.61
Brachystegia eurycoma	Fabaceae	1	0.33	2.30
Buchholzia coriacea	Sterculiaceae	1	0.33	1.08
Canthium hispidum	Rubiaceae	3	1.00	2.46
Ceiba pentandra	Malvaceae	4	1.33	9.38
Celtis mildbraedii	Cannabaceae	3	1.00	1.67
Celtis zenkeri	Cannabaceae	55	18.33	37.36
Chrysophyllum albidum	Sapotaceae	1	0.33	1.49
Cleistopholis patens	Annonaceae	2	0.67	1.93
Cleistopholis philippensis	Annonaceae	6	2.00	6.38
Cola gigantea	Sterculiaceae	3	1.00	4.65
Cordia millenii	Boraginaceae	2	0.67	4.34
Desplatsia lutea	Tiliaceae	14	4.67	10.36
Diospyros canaliculata	Ebenaceae	6	2.00	3.21
Diospyros dendo	Ebenaceae	68	22.67	31.81
Diospyros hybridus	Ebenaceae	62	20.67	26.05

Diospyros mespiliformis	Ebenaceae	9	3.00	7.11
Drypetes floribunda	Euphorbiaceae	10	3.33	6.53
Drypetes gilgiana	Euphorbiaceae	2	0.67	2.25
Drypetes gossweileri	Euphorbiaceae	5	1.67	2.47
Drypetes welwichii	Euphorbiaceae	1	0.33	1.12
Entadrophragma cylindricum	Meliaceae	2	0.67	2.66
Entandrophragma angolensis	Meliaceae	1	0.33	1.54
Fagara indica	Rutaceae	3	1.00	4.14
Funtumia elastica	Apocynaceae	8	2.67	4.99
Hunteria umbellata	Apocynaceae	7	2.33	4.59
Hylodendron gabonensis	Fabaceae	1	0.33	1.12
Irvingia wombulu	Irvingiaceae	1	0.33	1.25
Khaya ivorensis	Meliaceae	3	1.00	5.93
Macaranga barteri	Euphorbiaceae	3	1.00	2.53
Macaranga grandifolia	Euphorbiaceae	1	0.33	1.71
Macaranga spp	Euphorbiaceae	2	0.67	1.29
Malacantha alnifolia	Sapotaceae	1	0.33	1.30
Maranthes glabra	Chrysobalanaceae	11	3.67	6.46
Massularia acuminata	Rubiaceae	1	0.33	1.03
Milicia excelsa	Moraceae	3	1.00	4.04
Mitragyna ciliate	Rubiaceae	1	0.33	1.11
Musanga cecropioides	Urticaceae	1	0.33	1.04
Nauclea diderichii	Rubiaceae	3	1.00	6.53
Nesogordonia papaverifera	Malvaceae	1	0.33	1.00
Nisanga senegalensis	Meliaceae	6	2.00	5.08
Picralima nitida	Apocynaceae	3	1.00	2.56
Pterygota macrocarpa	Malvaceae	2	0.67	3.62
Pycnanthus angolensis	Myristicaceae	7	2.33	6.97
Rauvolfia vomitoria	Apocynaceae	1	0.33	0.99
Ricinodendron heudelotii	Euphorbiaceae	8	2.67	10.75
Sterculia rhinopatala	Sterculiaceae	15	5.00	14.36
Strombosia postulata	Olacaceae	24	8.00	15.21
Terminalia superba	Combretaceae	2	0.67	4.02
Tetraptera tetraplura	Fabaceae	1	0.33	1.11
Treculia odorata	Moraceae	2	0.67	1.36
Trichilia monadelpha	Meliaceae	2	0.67	1.96
Uapaca togoensis	Euphorbiaceae	2	0.67	1.86
Xylopia aethiopica	Annonaceae	3	1.00	2.88
		395	**131.67**	**300**

Table 4: Summary of goodness of fit of distribution functions for Omo Biosphere Reserve.

Distribution	Kolmogorov Smirnov	Anderson Darling	Cramer-von Mises
2p Weibull	0.125	13.582	2.157
Burr	0.046	1.102	0.178
Lognormal	1	inf	132.333
Log Logistic	0.054	2.769	0.258
Gamma	0.104	9.506	1.556

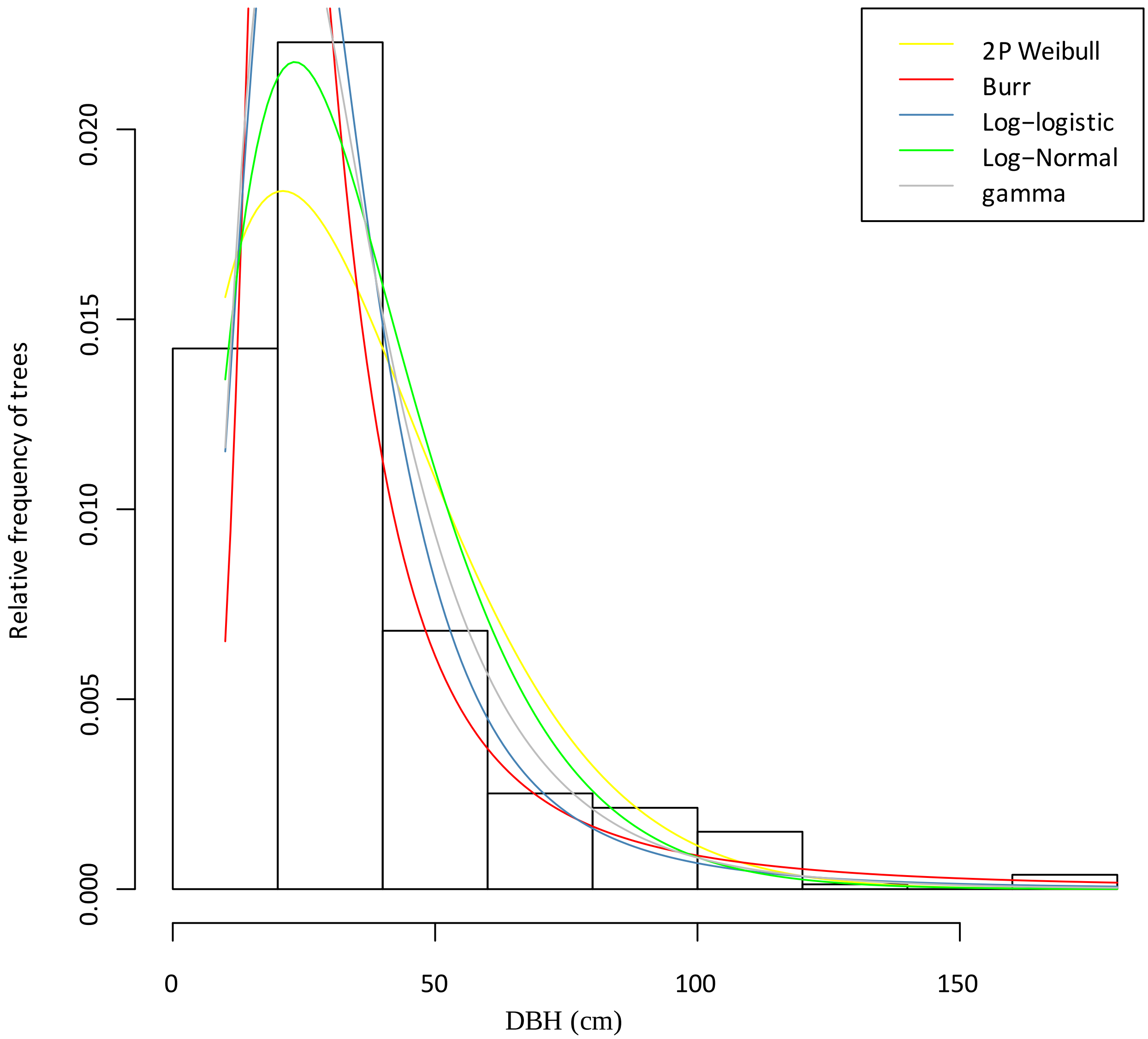

Figure 1: Graphs of observed and estimated probability function of DBH for Omo Biosphere Reserve.

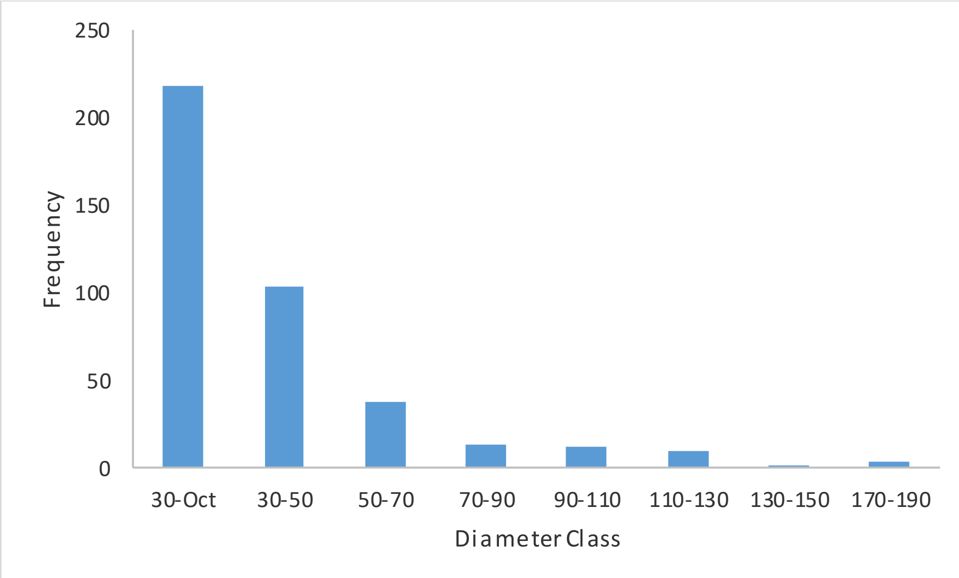

Figure 2: Tree diameter class distribution for Omo Biosphere Reserve.

4. Discussion

A total of 395 trees representing 57 species from 22 families were encountered in this biosphere reserve, indicative of high species richness and abundance of woody species in the lowland rainforest of Nigeria. This is lower than the findings of Tang *et al.*, (2010), who reported 109 species in secondary vegetation community of China, Komolafe *et al.*, (2017) reported 93 species in a Nigerian forest and findings of Seyni *et al.*, (2021) and Oladoye *et al.*, (2014). The floristic richness of Omo Biosphere Reserve could be a function of the favourable climatic condition in addition to contributions from different vegetative typology (Oladoye *et al.*, 2014), and conservation status of the forest reserve.

Importance value index (IVI) describes the overall importance of each species in its community structure (Olajuyigbe *et al.* 2018; Fayiah et al., 2018; Oladoye *et al.*, 2014). Overall, the IVI of the species were generally low ranging from 0.99 to 37.36. Only 15 species have IVI value that is above 5. The relative dominance contributed greatly to the IVI of the species, this could be attributed to the high diameter at breast height and the general low IVI may also be attributed to low frequency and density of the species encountered.

For effective forest management and valid decision-making and forest growth indicator, diameters distribution model is usually needed. The distribution of trees by diameter class allows foresters and ecologists to understand structure and stand dynamics (Ezenwenyi *et al.*, 2018; Ekpa *et al.*, 2020; Ciceu *et al.*, 2021).

The mean DBH of 36.40(±1.34) cm for the biosphere reserve suggests that the majority of the tress are in the lower diameter class and a reflection of regeneration potentials of the forest estate. This agrees with the findings of Bobo *et al.*, (2006); Aigbe and Omokhua, (2014) who reported similar trend in Southwestern Cameroon and Oban Forest Reserve in Nigeria, respectively. High positive skewness observed in the current study suggests that considerable number of trees are concentrated within the lower diameter classes and that a good number of these trees are suppressed due to canopy closure of the forest areas. This finding agrees with some previous studies (e.g., Adedoyin *et al.*, 2021; Ekpa *et al.*, 2020; Robson *et al.*, 2016; Adekunle, 2002; Podlaski and Roesch, 2014; Aigbe omokhua, 2014).

High kurtosis coefficients of 6.44 imply that most distribution are platykurtic and correspond to the curves that are flatter than the normal curve with positive excess. This reflects the high concentration of diameter at breast height within the lower-class distribution. The result of this finding agrees with Lima *et al*., (2014; 2017); and Ruppert (2011). Out of five (5) distribution models that were tested, (t test), Burr (0.046) was adjudged the best using Kolmogorov – Smirnov statistics and followed by log-logistics (0.054) as shown in Table 9 suggesting that the data followed a specific distribution. This is similar to findings of the Aigbe and omokehina, (2014), in Orban forest reserve, where the D – value for all the models fitted were lower than the tabulated D-values. The findings of this study also corroborate the studies of Lima *et al.*, (2017), who reported that Burr function showed good flexibility to describe the diameter structure at the stand in Brazilian tropical dry forest.

The pattern of DBH distribution is indicative of positive skewness as evidence in the values and a reflection of abundance of trees in the lower DBH class that are sufficient to replace the trees in the upper DBH class through regeneration. This agrees with the findings of Ekpa *et al.,* (2020) in arboretum of the University of Uyo, Nigeria; Adekunle (2002) in Ala and Omo Forest; Bobo *et al.*, (2006) in Cameroon; Ige *et al.*, (2014) in Onigambari Forest, Nigeria and Boubli *et al.,* (2004) in Congo. This may also suggest that the natural regeneration and recruitment are consistently on going which are vital indications of forest health and vigor (Jimoh *et al.*, 2011; Ekpa *et al.,* 2020). However, the presence of more tress in the lower DBH class may also reflect heavy and continuous disturbance of the forest.

The graphs of observed and predicted DBH class of distribution function showed that there is no significant difference (P>0.05. This finding is in agreement with Egonmwan and Ogana, (2020); Aigbe and Omokhua (2014); Adedoyin and Adeoti, (2021) and Ige *et al*., (2014).

This is further explained as evident in the Figures 1 and 2, that this peculiarity associated to curves with more extended tails of the intermediate diameter classes with a sharper frequency peak to the left in the initial classes implies that the mode of distribution was clearly displayed which is typical of tropical forests as a reflection of forest dynamics.

In addition, some species stood out with their highest density within these lower classes hence the inverted – J shape. (Zheng and Zhou, 2010; Lima et al, 2017; Ekpa, et al., 2020). Omo Biosphere Reserve showed diameter distribution which depicts a single peak to the left with positive skewness and findings from this study have provided information on the ability of other distribution functions such as burr, logit logistic, etc. to describe the diameter structure of a natural forests as well.

5. Conclusion and Recommendations

Tree diameter distribution is an effective method of describing stand properties. Tree volume, value, conversion, cost, and product specification are dependent on stem diameter. The study provided information on tree population and regeneration potential, and strategies with reference to stem diameter classes. Hence the information from the study is important for effective and productive management of Omo Biosphere Reserve and forest reserve with similar ecological conditions. Further studies on comparative assessment based on the number of parameters to best fit the diameter in Omo biosphere reserve and reserves with similar ecosystem is advocated.

References

Adedoyin, E.D, Adeoti, O.O, Awosusi, B.M., Onilude Q and Aina-Oduntan, O. A. (2021). Evaluating diameter distribution model of Parkia biglobosa Plantation (Jacq.) G.Don in Wasangare, Saki West Local Government Area of Oyo State, Nigeria. Journal of Forestry Research and Management, 18(3).198-206.

Adekunle, V. A. J. (2002). Inventory techniques and models for yield and tree species assessment in Ala and Omo Forest Reserve, southwestern Nigeria. South West, Department of Forestry and Wood Technology, Federal University of Technology, Akure, Nigeria, pp170

Adesoye, P. O. (2002). Integrated system of forest stand models for Nauclea diderrichi in Omo forest reserve, Nigeria. Ph.D thesis, Department of Forest Resources Management, University of Ibadan, Nigeria. (2002). 174p.

Aigbe H. I and Omokhua G.E. (2014). Modeling Diameter Distribution of the Tropical Forest in Oban Forest Feserve. Journal of Environment and Ecology 5 (2):130-143.

Ajayi, S. (2005). Growth and Yield Models for Sustainable Production of Gmelina arborea (ROXB) timber from Ukpon River Forest Reserve, Cross River State, Nigeria. PhD Thesis, University of Ibadan, Nigeria. 225pp.

Akinyemi, O.D., Oyelowo, O. J. Oloketuyi, A. J. (2019). Population, diversity, and structure of trees in Omo Biosphere Reserve, Ogun state, Southwestern Nigeria. Australian Journal of Science and Technology, 3 (4):154-160.

Bailey, R.L. and Dell, T.R. (1973). Quantifying diameter distributions with the Weibull function. Forest Science., 19:97– 104.

Bobo,K.S., Waltert, M., Njokagbor, J., Fermon, H.,& Muhlenbeg,M.(2006). From forest to farmland: Species richness patterns of tree and understorey plants along a gradient of forest conversion in Southwestern Cameroon. Biodiversity and conservation, 15, 4097-4117.

Boubli,J.P., Eriksson,J., Wich,S., Hohmann,G.,& Fruth,B.(2004). Mesoscale transect sampling of trees inthe Lomako-yekokora interfluvium, Democratic Republic of the Congo. Biodiversity and Conservation, 13,2399 -2417.

Burkhart HE & Tomé M (2012) Modelling Forest Trees and Stands, 2nd edition. Springer Dordrecht Heidelberg New York, 271 p.

Chenge, I.B., and Osho, J.S.A., 2018. Mapping tree aboveground biomass and carbon in Omo Forest Reserve Nigeria using Landsat 8 OLI data. Southern Forests 80, 341–350.

Chenge I.B. (2021). Height–diameter relationship of trees in Omo strict nature forest reserve, Nigeria. Trees, Forests and People. (3).

Chima, U.D and Adedire, M.O. (2014). Land Use Change Detection in OMO Biosphere Reserve Using GIS and Remote Sensing. Journal of Environment and Ecology, 5 (2): 159-171.

Ciceu, A.; Pitar, D.; Badea, O. Modeling the Diameter Distribution of Mixed Uneven-Aged Stands in the South Western Carpathians in Romania. Forests 12, 958.

Curtis, J. T. (1959). The vegetation of Wisconsin: An ordination of plant communities. Madison, WI: University of Wisconsin Press.

DeLiocourt F (1898) De lamenagement des Sapiniers. Bul Social ForestFranche-Comptéet Belfort, pp. 396-409.

Egonmwan I. Y and Ogana F. N (2020) Application of diameter distribution model for volume estimation in Tectona grandis L.f. stands in the Oluwa forest reserve, Nigeria. Tropical Plant Research 7(3): 573–580.

Ekpa, N. E., Daniel, K.S., Ukpong, E.E, Etigale, E.B., & Asuquo. O.E. (2020). Modeling Tree Diameter Distributions in Arboretum of Forestry and Wildlife University of Uyo: An Evaluation of 8 Statistical Models. Global Journal of Science Frontier Research, 20 (H2), 13–18. Ezenwenyi, J.U., Oladoye, A.O., Chukwu, O. and Basiru, A.O. (2018). Diameter distribution of Nauclea diderrichii (D Wild) Merr. Plantations in a restricted Tropical Rainforest in Nigeria. Journal of Research in Forestry, Wildlife & Environment, 10 (3):25–32.

Fayiah M, Singh S, Mengesha Z, and Chen B (2018). Regeneration status and species diversity of a mix dry deciduous forest: a case of Barah forest, Jabalpur, Madhya Pradesh, India. Indian J Trop Biodiv 26(1): 17-29

Gorgoso, J.J., Rojo, A., Camara–Obregon, A. and Dieguez–Aranda, U. (2012). A comparison of estimation methods for fitting Weibull, Johnson's SB and beta functions to Pinus pinaster, Pinus radiate and Pinus sylvestris stands in northwest Spain. Forest Systems, 21(3):446– 459.

Gorgoso-V´arela, J.J., A. Rojo-Alboreca, E. Afif-Khouri, and M. Barrio-Anta. 2008. Modelling diameter distributions of birch (Betula alba L.) and pedunculate oak (Quercus robur L.) stands in northwest Spain with the beta distribution. Investigación Agraria: Sistemas y Recursos Forestales. 17(3):271–281.

Ige, P.O, Adesoye P.O and Akinyemi O.D (2014). Modelling diameter distributions of a tropical natural forest in south west Nigeria with the beta distribution function. Elixir Agriculture 74:27160-27166.

Ige, P.O. and Adedapo, S.M. (2021). Modelling diameter distributions of Nauclea diderrichii (De Wild.) Merr. stands with Gamma and Weibull functions in Southwest Nigeria. World Scientific News 160: 247-262.

IUCN, (1991). Caring for the Earth. A Strategy for Sustainable Living. Published in partnership by IUCN/UNEP/WWF.

Gorgoso, J.J Álvarez-González., J.G Rojo A. and Grandas-arias. J.A.(2007) .Modelling diameter distributions of Betula alba L. stands in northwest Spain with the two parameter Weibull function. Invest. Agrar.: Sist. Recur. For. 16(2): 2007. 113-123.

Lima, R. A. F, Batista, J.L.F, and Prado, P.I (2014). Modeling tree diameter distributions in natural forests: an evaluation of 10 statistical models. Forest Science, 61(2): 320-327.

Lima, R. B, Bufalino, L, Alves Junior, F. T, Silva, J.A. D, Ferreira, R. L (2017). Diameter distribution in a Brazilian tropical dry forest domain: predictions for the stand and species. Anais da Academia Brasileira de Ciências; 89(2):1189-1203.

Reynolds, M. R. Burkhart H. E. and Daniels, R. F. (1981). Procedures for Statistical Validation of Stochastic Simulation Models. Forest Science 27 (2). 349-364.

Maltamo, M. and A. Kangas. (2008). Methods based on k-nearest neighbor regression in estimation of basal area diameter distribution. Canadian Journal of Forest Resources. 28:1107-1115.

Mayrinck RC, Filho ACF, Ribeiro A, de Oliveira XM & de Lima RR (2018) A comparison of diameter distribution models for Khaya ivorensis A.Chev. Plantations in Brazil. Southern Forests: Journal of Forest Science 80 (4): 373–380.

Mirzaei, M., Aziz, J., Mahdavi, A. and Mohammad, A. (2015). Modeling frequency distributions of tree height, diameter and crown area by six probability functions for open forests of Quercus persico in Iran. Journal of Forestry. Resources., DOI 10.1007/s11676–015–0194–x.

of Forestry and Wood Technology, Federal University of Technology, Akure. 170p.

Ogana FN & Ekpa NE (2020) Modeling the non-spatial structure of Gmelina arborea Roxb Stands in the Oluwa Forest Reserve, Nigeria. Forestist 70 (2): 133–140.

Ogana F.N, Itam E.S, Osho J.S.A. 2017. Modeling diameter distributions of Gmelina arborea plantation in Omo Forest Reserve, Nigeria with Johnson's SB. Journal of Sustainable Forestry 36: 121-133.

Ogundipe, O. C., Osho, J. S. A., and Olukunle, O. D. (2018). Modeling Diameter Distributions of Nauclea diderrichii Stands in Omo Forest Reserve, Nigeria with Johnsons SB. Agricultural Research and Technology, 18(3) 149-154.

Ojo L.O. (2004). The fate of a tropical rainforest in Nigeria: Abeku Sector of Omo Forest Reserve. Global Nest: The International Journal 6.2: 116-130.

Oladoye A.O, Aduradola A.M, Adedire M.O and Agboola D.A. (2014). Composition and Stand Structure of a Regenerating Tropical Rainforest Ecosystem in South-western Nigeria. International Journal of Biodiversity and Conservation, 6(11) 765-776.

Oladoye, A. O., Fapojuwomi A. O. Ogungbenro R. O. and Osaguona.P.O (2018): Open

Grown Tree Species Composition and Diversity in Research Institutes in Ibadan Metropolis. Nigerian Journal of Botany 31(2):34-40. Published by the Botanical Society of Nigeria.

Olajuyigbe S.O., Omole, K.O. and Bankole, P.O. (2018). Floristic Composition and Diversity in a Restored Community-Based Forest, Otun Ekiti, Ekiti State, Nigeria. Applied Tropical Agriculture, 23 (1) 97-104,

Olatidoye, O.R.1, Orimoogunje, O.O.I., Oyelowo, O.J., Olubode, O.S. and Oloketuyi, A.J. (2021). Mapping riparian vegetation change in the Omo Biosphere reserve, Ogun State, Nigeria. Makerere University Journal of Agricultural and Environmental Sciences 10 (1): 47 – 59.

Onyekwelu, J.C, Mosandi R.,and Stimm B. (2007). Tree species Diversity and Soil status of Primar y and Deg raded Tropical Rainforest Ecosystems in South western Nigeria. Journal of Tropical Forest Science, 20(3): 198- 204.

Orimaye JO, Ogunjemite BG, Agbelusi EA. Density and abundance of the red-capped mangabey (cercocebus torquatus) in omo biosphere reserve and idanre forest reserve, south western Nigeria. MOJ Proteomics Bioinform. 2017;5 (2):63-67.

Phillip, M.S. (1994). Measuring trees and forests. (For African Students) Aberdeen University Press, Aberdeen, Scotland. 338pp.

Podlaski R, and Roesch FA (2014) Modelling diameter distributions of two-cohort forest stands with various proportions of dominant species: a two-component mixture model approach. Math Biosci 249:60–74.

Robson,B.L, lima .B, Franciso.T, Jose .A, Rinaldo.L(2016). Diameter distribution in a Brazilian tropical dry forest domain: predictions for the stand and species. Anais da Academia Brasileira de Ciências 89(2):1189-1203

Salami, K. D. and Akinyele, A. O (2018). Floristic Composition, Structure and Diversity Distribution in Omo Biosphere Reserve, Ogun State, Nigeria. Ife Journal of Science. 20 (3): 639-648.

Seyni, B. M., Awodoyin, R. O., Olubode, O. S., Adeniji, S. A. and Ibrahima, D. B. (2021). Floristic composition, diversity and community structure in a secondary rainforest in Ibadan, Nigeria. International Journal of Biodiversity and Conservation, 13(4):183-199.

Sun S, Cao QV & Cao T (2019) Characterizing diameter distributions for uneven-aged pine-oak mixed forests in the Qinling Mountains of China. Forests 10 (7):596.

Tang CQ, Li Y, Zhang Z (2010). Species diversity patterns in natural secondary plant communities and man-made forests in a Subtropical Mountainous Karst Area, Yunnan, SW China. International Mountain Society 30(3):244-251.

Tsogt, K., Zandraabal, T. and Lin, C. (2013). Diameter and height distributions of natural even–aged Pine forests (Pinus sylvestris) in Western Khentey, Mongolia. Taiwan Journal of Forest Scince 28(1):29– 41.

Turner, I. M. (2001). The ecology of trees in the tropical rain forest. Cambridge University Press, Cambridge, UK. 298pp.

Were, J. L.R (2001). Nigerian lowland forests (ATO 123). http://www.wild life .org /wild word/profiles/terrestrial/at 0123- full. Html.

Zheng, L.& Zhou, X. (2010). Diameter distribution of trees in natural stands managed on polycyclic cutting system. Forest Studies in China 12:21-25.

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