

Research Article

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

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Article Info

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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 \geq 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.

Keywords: 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.

In recent times, effort has been focused at conservation of this im-

portant 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 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; Burkhardt 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; Egomnwan 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; Ezenwenyi, 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 Ferralite 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*, *Neosgardonia papaverifera* and *Picalima nitida* (Chenge and Osho, 2018, Chenge, 2021).

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).

$$\text{Relative Density} = \frac{\text{number of species}}{\text{Total number of species}} \times 100$$

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

$$\text{Relative Dominance} = \frac{\text{Total basal area of all species}}{\text{Total basal area of all species}} \times 100$$

2.4 Model Validation

Model validation is important before they can be used with confidence. Validation involves the process of testing and comparing the

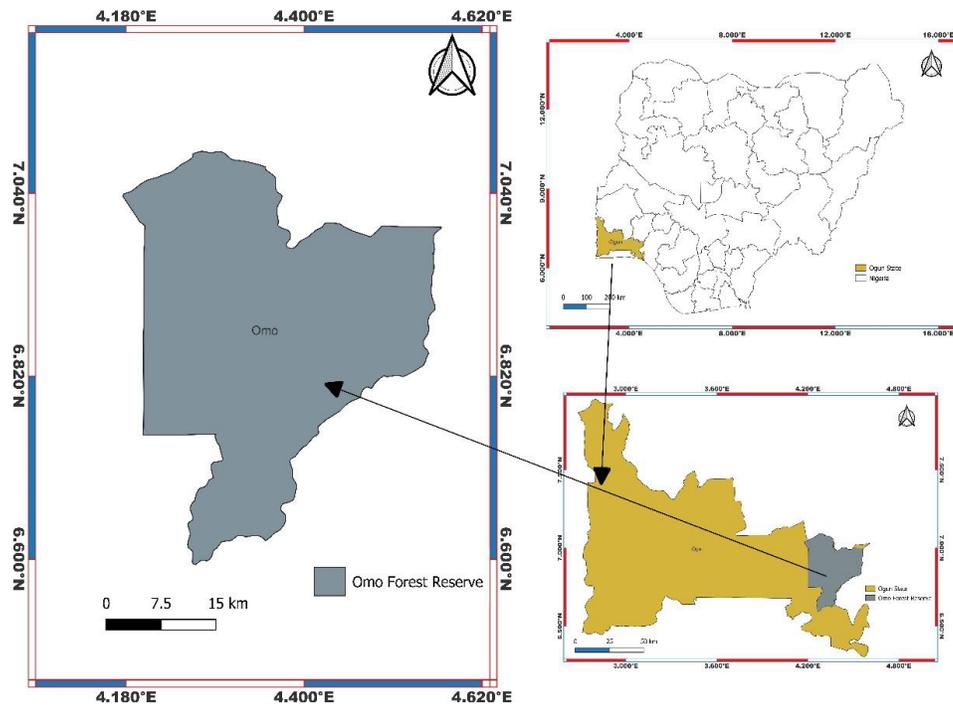


Figure 1: Map of the study area

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., $n=298$) was the calibration set which was used for model construction and the second was the validation set (i.e., $n=99$). (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 ($DBH \geq 10\text{cm}$) 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*, *Desplatsia lutea*, *Diospyros mespiliformis*, *Pycnanthus angolensis*, *Celba pentandra*, *Cleistopholis philippensis*, *Cola gigantea*, *Cordia milleni*, *Diospyros canaliculata*, *Drypetes gilgiana*, *Entadrophragma cylindricum*, *Macaranga bateri*, *Nauclea diderichii*, *Picalima nitida*, and *Pterygota macrocarpa*. Their density ranged from 0.33 to 22.67 trees/ha and the Importance 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).

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

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							

Table 2: Description of the probability distribution models

Diameter Distribution Models	Equations
1 Burr	$f(x) = \frac{ak\left(\frac{x-y}{\beta}\right)^{a-1}}{\beta\left(1+\left(\frac{x-y}{\beta}\right)^a\right)^{k+1}}$
2 Loglogistics	$f(x) = \frac{\alpha}{\beta} \left(\frac{x-y}{\beta}\right)^{\alpha-1} \left(1 + \left(\frac{x-y}{\beta}\right)^\alpha\right)^{-2}$
3 Gamma	$f(x) = \frac{(x-y)^{\alpha-1}}{\beta^\alpha \Gamma(\alpha)} \exp\left(-\frac{x-y}{\beta}\right)$
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: $\mu \in (-\infty, +\infty), \sigma > 0$
5 Weibull Distribution	$f(x) = \frac{c}{h} \left(\frac{x-a}{h}\right)^{c-1} \exp\left(-\frac{x-a}{h}\right)^c$

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; Ciccu et al., 2021).

The mean DBH of 36.40(±1.34) cm for the biosphere reserve suggests that the majority of the trees 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 Rupert (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 trees 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 Egomwan and Ogana, (2020); Aigbe and Omokhua (2014); Adedoyin and Adeoti, (2021) and Ige et al., (2014).

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

Species	Family	Total	Density (ha ⁻¹)	IVI	Species	Family	Total	Density (ha ⁻¹)	IVI
<i>Adenopus breviflorus</i>	Cucurbitaceae	1	0.33	1.40	<i>Hyiodendron gabonense</i>	Fabaceae	1	0.33	1.12
<i>Albizia ferruginea</i>	Fabaceae	3	1.00	3.01	<i>Irvingia wombolu</i>	Irvingiaceae	1	0.33	1.25
<i>Alstonia congoensis</i>	Apocynaceae	1	0.33	4.61	<i>Khaya grandifoliola</i>	Meliaceae	3	1.00	5.93
<i>Brachystegia eurycoma</i>	Fabaceae	1	0.33	2.30	<i>Macaranga barteri</i>	Euphorbiaceae	1	0.33	2.53
<i>Buckleya disticha</i>	Santalaceae	1	0.33	1.08	<i>Macaranga grandifolia</i>	Euphorbiaceae	1	0.33	1.71
<i>Canthium huilense</i>	Rubiaceae	3	1.00	2.46	<i>Macaranga sp.</i>	Euphorbiaceae	2	0.67	1.29
<i>Ceiba pentandra</i>	Malvaceae	4	1.33	9.38	<i>Malacantha alnifolia</i>	Sapotaceae	1	0.33	1.30
<i>Cola mildbraedii</i>	Sterculiaceae	3	1.00	1.67	<i>Maranthes glabra</i>	Chrysobalanaceae	11	3.67	6.46
<i>Celtis zenkeri</i>	Cannabaceae	55	18.33	37.36	<i>Maesobotrya acuminata</i>	Rubiaceae	1	0.33	1.03
<i>Chrysophyllum albidum</i>	Sapotaceae	1	0.33	1.49	<i>Milicia excelsa</i>	Moraceae	3	1.00	4.04
<i>Cleistopholis patens</i>	Annonaceae	2	0.67	1.93	<i>Mimusops andongensis</i>	Sapotaceae	1	0.33	1.11
<i>Cleistopholis philippensis</i>	Annonaceae	6	2.00	6.38	<i>Musanga cecropioides</i>	Urticaceae	1	0.33	1.04
<i>Cola gigantea</i>	Sterculiaceae	3	1.00	4.65	<i>Nauclea diderrichii</i>	Rubiaceae	3	1.00	6.53
<i>Cordia millenii</i>	Boraginaceae	2	0.67	4.34	<i>Nesogordonia papaverifera</i>	Malvaceae	1	0.33	1.66
<i>Desplazia laurifolia</i>	Icacinaceae	14	4.67	10.36	<i>Nuxia congesta</i>	Loganiaceae	6	2.00	5.08
<i>Diospyros canaliculata</i>	Ebenaceae	6	2.00	3.21	<i>Pterocarpus mildbraedii</i>	Apocynaceae	3	1.00	2.56
<i>Diospyros dendo</i>	Ebenaceae	68	22.67	31.81	<i>Pycnanthus angolensis</i>	Myristicaceae	2	0.67	3.62
<i>Diospyros hybridus</i>	Ebenaceae	62	20.67	26.05	<i>Pyrenacantha angolensis</i>	Icacinaceae	7	2.33	6.97
<i>Diospyros macrophylla</i>	Ebenaceae	9	3.00	7.11	<i>Rauvolfia vomitoria</i>	Apocynaceae	1	0.33	0.99
<i>Drypetes floribunda</i>	Euphorbiaceae	10	3.33	6.53	<i>Ricinodendron heudelotii</i>	Euphorbiaceae	8	2.67	10.75
<i>Drypetes gerrardii</i>	Euphorbiaceae	2	0.67	2.25	<i>Sterculia rhinopetala</i>	Sterculiaceae	15	5.00	14.36
<i>Drypetes gosswileri</i>	Euphorbiaceae	5	1.67	2.47	<i>Strombosia pustulata</i>	Olacaceae	24	8.00	15.21
<i>Drypetes welwitschii</i>	Euphorbiaceae	1	0.33	1.12	<i>Terminalia superba</i>	Combretaceae	2	0.67	4.02
<i>Entandrophragma cylindricum</i>	Meliaceae	2	0.67	2.66	<i>Tetrapleura tetraptera</i>	Fabaceae	1	0.33	1.11
<i>Entandrophragma angolense</i>	Meliaceae	1	0.33	1.54	<i>Trema orientalis</i>	Ulmaceae	2	0.67	1.36
<i>Fagara indica</i>	Rutaceae	3	1.00	4.14	<i>Trichilia monadelph</i>	Meliaceae	2	0.67	1.96
<i>Funtumia elastica</i>	Apocynaceae	8	2.67	4.99	<i>Uapaca togoensis</i>	Euphorbiaceae	3	1.00	2.88
<i>Hunteria umbellata</i>	Apocynaceae	7	2.33	4.59	<i>Xylophia aethiopia</i>	Annonaceae	1	0.33	2.88

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

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.

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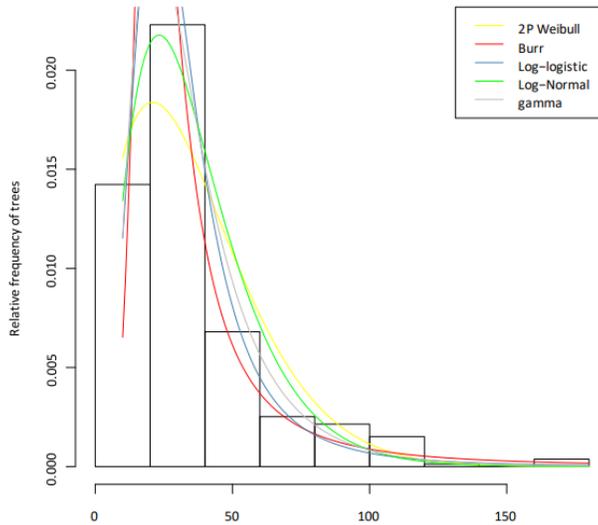


Figure 2: Graphs of observed and estimated probability function of DBH for Omo Biosphere Reserve.

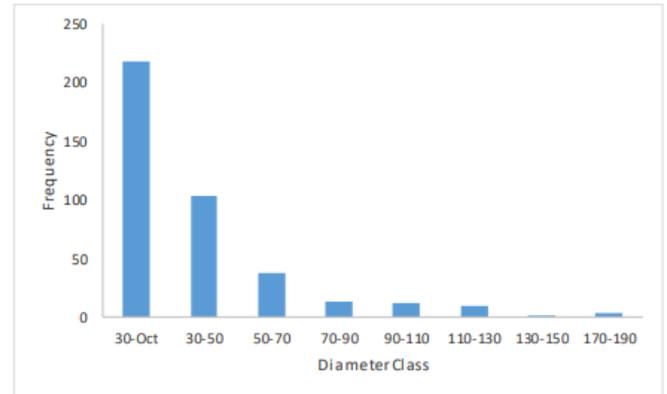


Figure 3: Tree diameter class distribution for Omo Biosphere Reserve.

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