ISSN (Online): 2349-1183; ISSN (Print): 2349-9265
TROPICAL PLANT RESEARCH
The Journal of the Society for Tropical Plant Research
7(1): 101–109, 2020
DOI: 10.22271/tpr.2020.v7.i1.014

Research article

Growth characteristics of tree species in natural stands of Gambari forest reserve, Southwestern Nigeria

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Abstract: Forestry like any other business venture requires effective management of its resources. Hence, requires quantifiable information on the trees not only for the management decision but also to show the growth, productive capabilities and resistance capability of the trees. This study was carried to examine the growth characteristics of tree species in the natural stand of Gambari forest reserve using a cluster with nested design during the plot sampling. A total of 113 individual tree stem per hectare and 26 tree species per hectare were recorded with *Cedrella odorata* having the highest frequency per hectare (28) while *Antiaris africana*, *Baphia nitida* and *Celtis mildbreadii* having lowest frequency per hectare (1 stem ha^{-1}).The mean DBH and tree height observed were 30.23±2.93cm and 17.07 + 0.95m respectively. The basal area per hectare and tree volume per hectare observed was $0.099 \pm 0.02 m^2 ha^{-1}$and $2.135 \pm 0.54 m^3 ha^{-1}$. Diversity measures obtained included Shannon-weiner index (2.667) and Pielous eveness (0.554). The study revealed that the natural stand of tree species in Gambari forest reserve could not compare favorably with other natural forest ecosystems in terms of species diversity and growth indices, indicating high level of anthropogenic activities. Although, majority of the tree species remaining in the reserve are relatively stable and not readily susceptible to wind damage.
Keywords: Growth characteristics - Natural stand - Gambari Forest Reserve - Species diversity - Nigeria.

[Cite as: Onilude QA, Adewoye R, Akinyemi OA & Osundun SO (2020) Growth characteristics of tree species in natural stands of Gambari forest reserve, Southwestern Nigeria. *Tropical Plant Research* 7(1): 101–109]

INTRODUCTION

Forest ecosystems are very important in the functioning and conserving of biosphere, as they are the origin of many plants and animals (European Union, 2008). One of the major challenges and difficulty encountered in the understanding of the functioning of the forest ecosystems in Nigeria is the dearth of periodic information on stand conditions. However, sustainable management of forest stands can only be ensured if current and reliable information on growth condition of the stand is available which can be used by forest managers/management to provide accurate and timely information on current growing stock.

Globally, the removal or destruction of significant areas of forest cover is moving apace, where every year an integral part of the nation's forest is destroyed through industrialization, indiscriminate logging, urbanization, commercial agriculture amongst others (Okafor *et al*.2013, Bajpai *et al.* 2012, Masens *et al.* 2017, Giday *et al.* 2019, Roychoudhury *et al.* 2019, Bajpai *et al.* 2020). These cumulative anthropogenic activities have resulted in a degraded environment with reduced biodiversity. The effects of these impacts are mostly evident in the developing countries, with highest rate of notoriety in Nigeria, where almost all the ancestral forests are lost in an alarming rate of disappearance (Kabiru 2008, Pelemo *et al.* 2011, FAO2012, Batta *et al.* 2013, Iyagin & Adekunle 2017).

Ihenyen *et al.* (2009) lamented that out of about 565 species of trees existing in Nigeria; over 60 species are faced with extinction and various forms of risk. However, as consequence for the massive loss of valuable and economic plant species and adverse impact on environmental and socio-economic values, policies have been formulated for proper conservation and management of these tree species.

Received: 19 July 2019 Published online: 30 April 2020
https://doi.org/10.22271/tpr.2020.v7.i1.014

Forestry like any other business venture requires effective management of its resources. As a result requires quantifiable information on the trees not only for the management decision but also to show the growth, productive capabilities and resistance capability of the trees (Onilude *et al*. 2017). Good forest management requires accurate and up to date information on the current growing stock and future growth potential. This study was designed to examine the growth indices, species diversity and slenderness coefficient of tree species in Gambari forest reserve in order to categorize them to find out their suitability to resist wind throw, their possible values for more afforestation programmes, forest regeneration and also, their possible uses for establishment of shelter belts to arrest desertification and erosion in the northern part of Nigeria.

MATERIAL AND METHODS

Study areas

The study was carried out in Gambari Forest Reserve (Fig.1). It is situated along Ibadan-Ijebu Ode road in Oluyole Local Government Area of Oyo State on latitude 7° 25′ and 7° 55′ N and longitude 3° 53′ and 3° 9′ E within the low land semi-deciduous forest belt of Nigeria and covers a total land area of 17,984ha. Gambari Forest Reserve is divided into two distinct forests: natural and plantation forests. The natural forest is made up of indigenous species such as *Terminalia* spp., *Irvingia gabonensis* (Aubry-Lecomte ex O'Rorke) Baill., *Treculia africana* Decne, among others while the plantation forest is made up of species such as *Triplochiton scleroxylon* K.schum, *Gmelina arborea* Roxb. and *Tectona grandis* Linn f. The topography of the study area is generally undulating, lying at altitude between 90m and 140m above sea level. In Gambari Forest Reserve, the annual rainfall ranges from 1200mm to 1300mm and spreading over March to November. According to Larinde & Olasupo (2011), the relative humidity is low, the dry season is severe and the average annual temperature is about 26.4ºC.

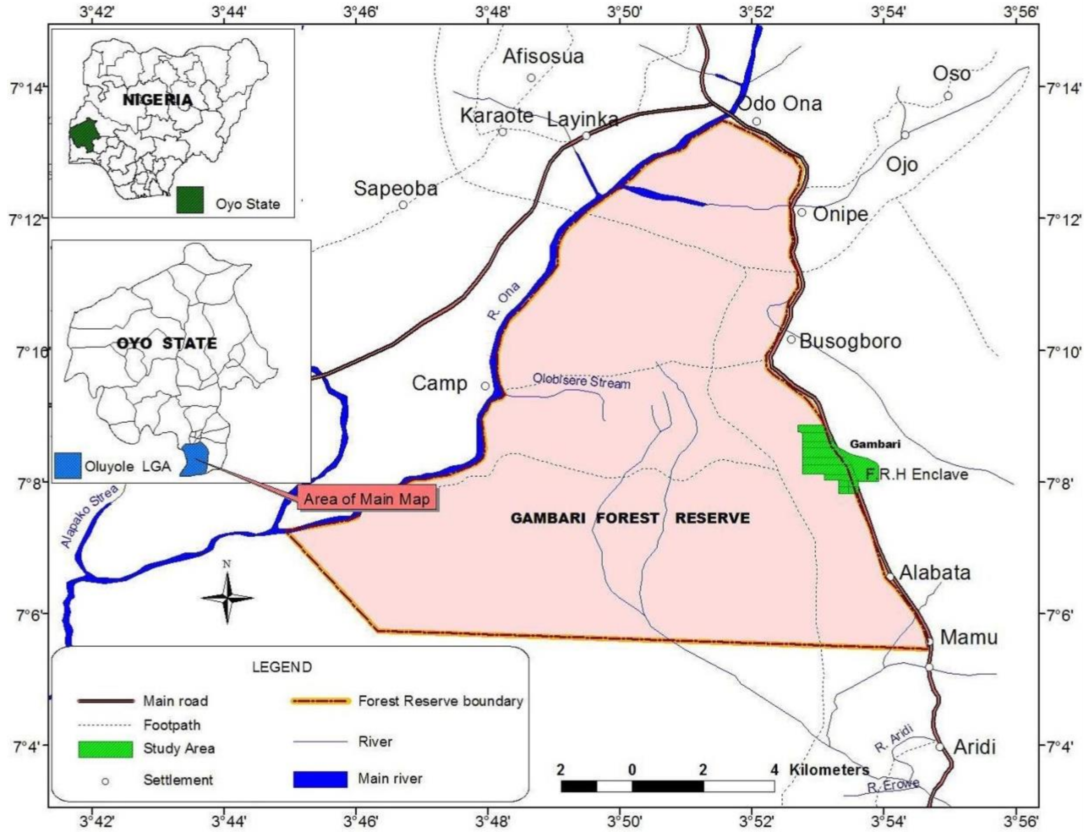

Figure 1. Map of Gambari forest reserve.

Data Collection

A ground base inventory was used to collect information on tree growth characteristics on individual tree species in Gambari forest reserve using cluster with nested design (Fig. 2). The cluster contained 3 plots measured at 35 m × 35 m. Each plot then nested at 25 m × 25 m and 7 m × 7 m. The 3 plots were at:

i. the north point (located at the north-ward and at 100m away from the elbow plot)
ii. the east point (located at the east-ward and at 100m away from the elbow plot)
iii. the elbow plot as shown in figure 2.

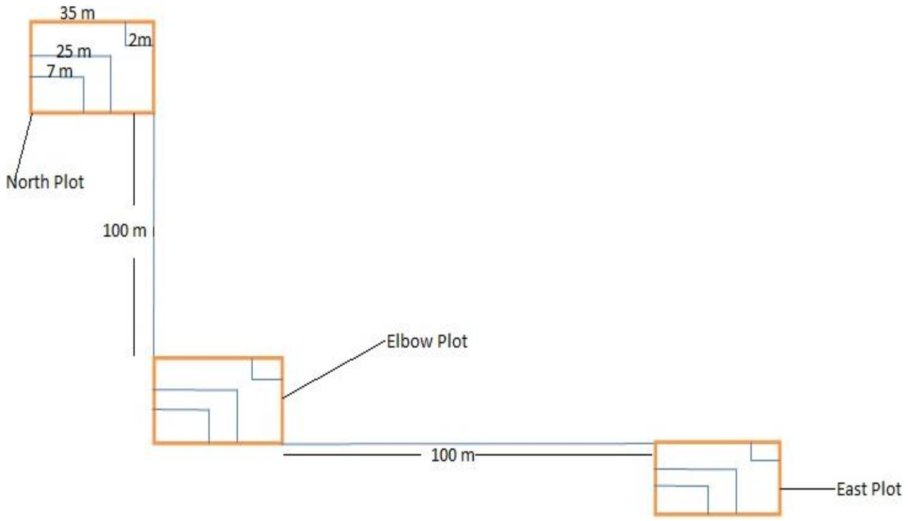

Figure 2. Diagram showing cluster with nested plots design.

Data on tree total height and diameter at breast height, diameter at the base, middle and top of the trees were collected using laser hypsometer. All tree species were identified to their nomenclature by a taxonomist. However, trees that couldn't be identified on the field, the specimen of such trees were collected and taken to Forestry Research Institute of Nigeria (FRIN) herbarium for proper identification. Data collected was put to statistical analysis to obtain meaningful information which can be used for managerial policy and decision making in forest management.

Data Analysis

Basal Area: The Basal Area for individual trees within each plot was estimated using;

$$BA = \frac{\pi D^2}{4} \ldots\ldots\ldots\ldots \text{Equation 1}$$

Where, BA = Basal Area (m^2), π = 3.142 (constant), D = diameter at breast height (m).

Stem Volume: The Stem Volume of individual trees within each plot was estimated using the processed Newton's formula:

$$SV = \frac{\pi h}{24}(D_b^2 + 4D_m^2 + D_t^2) \ldots\ldots\ldots\ldots \text{Equation 2}$$

Where, SV= stem volume of individual tree (M^3), π= 3.142 (constant), h= Merchantable height (m), D_b= diameter at the base (m), D_m= diameter at the middle, D_t= diameter at the top (m)

Slenderness Coefficient (SLC): The ratio of total height (H) to diameter outside bark at 1.3m above ground (DBH) when both H and DBH are measured in the same units.

$$SLC = \frac{TOTAL\ HEIGHT}{DIAMETER\ AT\ BREAST\ HEIGHT} \ldots\ldots\ldots\ldots \text{Equation 3}$$

In silvicultural studies, the tree slenderness coefficient often serves as an index of tree stability, or the resistance to windthrow (Onilude & Adesoye 2007). According to Navratil (1996), slenderness coefficient values can be classified into three categories.

SLC values > 99 …………… High slenderness coefficient

70 < SLC values > 99 ………. Moderate slenderness coefficient

SLC values < 70 ……………. Low slenderness coefficient

Tree Species Diversity

The Shannon-Wiener diversity index (H'), species evenness (E) and species dominance index (C) were all calculated to determine the tree species diversity.

Shannon-Wiener Diversity Index (H'): The Shannon-Wiener diversity index is the most widely used index in community ecology. The values of Shannon-Wiener diversity index is usually found to fall between 1.5 and 3.5 and only rarely surpasses 4.5 (Magurran 2004). It is given by,

$$H' = -\sum_{i=1}^{s} PiLnPi \ldots\ldots\ldots\ldots \text{Equation 4}$$

Where, H' is the Shannon-Wiener diversity index; S is the total number of species in the community; pi is the proportion of *S* made up of the i^{th} species; Ln is natural logarithm.

Pielou's Species Evenness Index (E): The ratio of the observed diversity (H) to the maximum diversity (H_{max}) is taken as a measure of evenness (E).

$$E = \frac{\sum_{i=1}^{S} PiLnPi}{Ln(S)} \text{ . . . . Equation 5}$$

Where, S is the total number of species. E is constrained between 0 and 1.0 with 1.0 representing a situation in which all species are equally abundant.

Simpson's Dominance Index (C): Simpson's dominance index is weighted towards the abundance of the commonest species.

$$\text{Simpson Index [C]} = \Sigma P_i^2 \text{ . . . . Equation 6}$$

Where, Pi is the proportional abundance of the ith species

$$P_i = \frac{ni}{N} \text{ . . . . Equation 7}$$

Simpson's index varies from 0 to 1 and gives the probability that two individuals drawn at random from a population belong to the same species. If the probability is high, then the diversity of the community sample is low. The higher the dominance index the lower the Shannon diversity.

Relative Density: Relative density (%) of each species was computed following the equation of Brashears *et al.* (2004).

$$RD = \frac{ni}{N} \times 100 \text{ . . . . Equation 8}$$

Where, RD is the relative density of the species; *ni* is the number of individuals of species *i* and N is the total number of all individual trees.

Relative Dominance: Relative dominance (%) of each species was estimated using the following equation:

$$\text{RDo} = \frac{\sum \textbf{Bai} \times \textbf{100}}{\sum \textbf{Ban}} \text{ . . . . Equation 9}$$

Where, RDo is the relative dominance of the species; Bai is the basal area of all individual trees belonging to a particular species *i*; Ban is the basal area of the stand.

Importance Value Index (IVI): This index is used to determine the overall importance of each species in the community structure. The sum of the RD and RDo divided by 2 (RD x RDo/2) gave the importance value index for each species (Brashears *et al*. 2004, Yang *et al*. 2008). It is also being used to express the share of each species in the tree community (Rajkumar & Parthasarathy 2008).

RESULTS AND DISCUSSION

Tree Species Composition in natural stand of Gambari forest reserve

In table 1, the descriptive characteristics of the tree species was presented. The mean diameter at breast height (DBH) was 30.23±2.93 cm with minimum and maximum values to be 10.5cm and 98.8cm respectively. The mean tree height was 17.07±0.95 m with minimum and maximum values to be 4 and 30.2 m respectively (Table 1). The mean Basal area per hectare, mean tree volume per hectare and slenderness coefficient was 0.099±0.02, 2.135±0.54 and 64.68±3.27 respectively (Table 1).

Table 1. Descriptive statistics of growth indices of tree species in Gambari Forest Reserve.

Tree variables	Mean ± SE	Min	Max
DBH (cm)	30.23 ± 2.93	10.5	98.8
Tree Height (m)	17.07 ± 0.95	4	30.2
Basal Area (m^2 ha^{-1})	0.099 ± 0.02	0.0087	0.767
Tree Volume (m^3 ha^{-1})	2.135 ± 0.54	0.0585	18.79
SLC	64.68 ± 3.27	23.53	113.76

Note: DBH= Diameter at breast height; SLC= Slenderness coefficient

In the studied natural stand, *Cederella odorata* Ruiz & Pav had the highest number of occurrence (28 trees) (Fig. 3) and a relative density of 0.157. The tree species could be regarded as the most abundant species in the area. It was followed by *Strombosia pustulata* Oliv. with 17 tree stems with relative density of 0.096 (Table 2). However, some of the tree species per one (1) stem recorded in the stand included *Antiaris Africana* Engl., *Baphia nitida* Lodd., *Celtis mildbreadii* Engl., *Chrysophylum perpulchrum* Mildbr. ex Hutch. & Dalziel, *Cola nigerica* Brenan & Keay, *Cordia alliodora* Ruiz & Pav., *Cordia millenii* Chudnoff. Martin., *Daniella ogea* Harms, *Dialium guineense* Willd, *Ficus exasperate* Vahl., *Ficus mucuso* Welw. ex Ficalho, etc. The total Basal area and Volume recorded were 4.17m^2 and 89.656m^3 respectively (Table 2). The highest value of the Importance value index was contributed by *Chrysophylum perpulchrum* (9.191705) while the least Importance value Index was contributed by *Ficus mucuso* (0.106592) as shown in table 2.

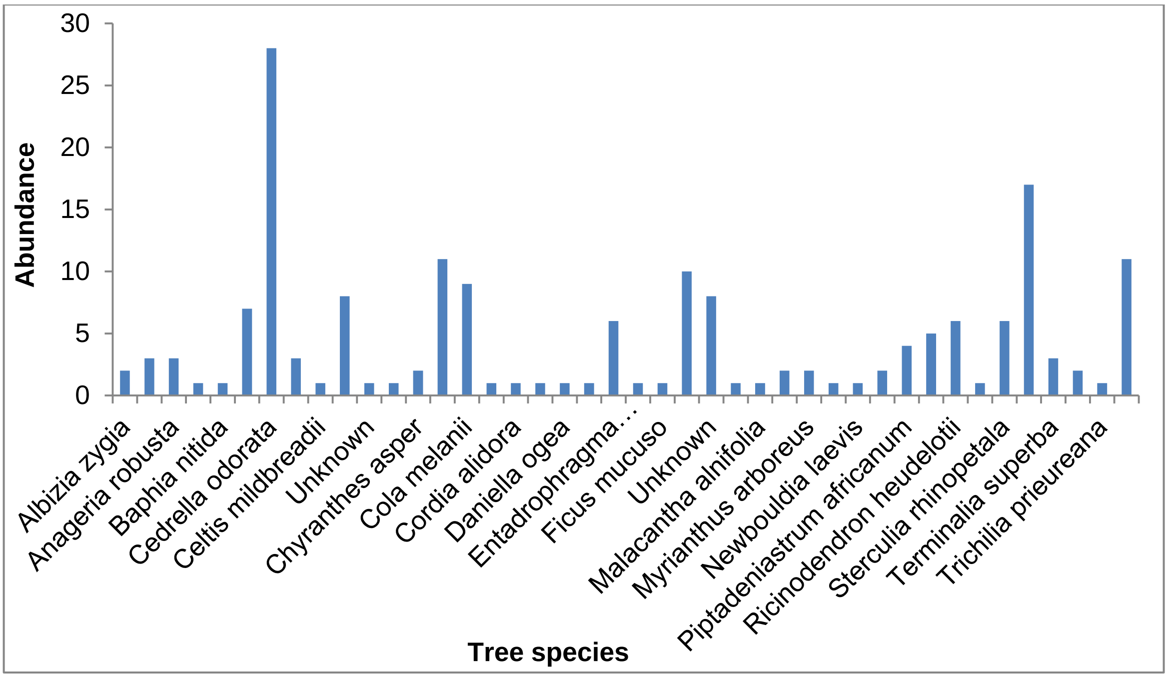

Figure 3. Distribution of tree species based on the number of occurrence (Abundance).

Table 2. Frequency, Growth indices, Slenderness coefficient values and Importance Value Index for tree species in natural stand of Gambari Forest Reserve.

Species	FRQ/Ha	BA	VOL	SLC	RD	RDo	IVI
Albizia zygia (DC.) J.F. Macbr	2	0.146593	3.078456	48.61111	0.011236	3.513557	1.762396
Alstonia boonei De Wild	3	0.313748	7.529941	37.97468	0.016854	7.519927	3.76839
Aningeria robusta (A. Chev.) Aubrév. & Pellegr	3	0.128206	2.717971	52.47525	0.016854	3.072856	1.544855
Antiarisa fricana Engl.	1	0.029869	0.403227	69.23077	0.005618	0.715894	0.360756
Baphia nitida Lodd.	1	0.014316	0.143157	74.07407	0.005618	0.343121	0.174369
Bosqueia angolensis Welw.	7	0.068358	1.312476	65.08475	0.039326	1.638413	0.83887
Cedrela odorata Ruiz & Pav.	28	0.072116	1.17549	53.79538	0.157303	1.728481	0.942892
Ceiba pentandra (L.) Gaertn.	3	0.50272	10.00413	24.875	0.016854	12.04923	6.033044
Celtis mildbreadii Engl.	1	0.068358	0.888656	44.0678	0.005618	1.638413	0.822016
Celtis zenkerii Engl.	8	0.038713	0.689084	80.18018	0.044944	0.927866	0.486405
Chrysophylum perpulchrum Mildbr. ex Hutch. & Dalziel	1	0.766761	18.78565	24.79757	0.005618	18.37779	9.191705
Chytranthus macrobotrys (Gilg) Exell & mendonca	2	0.066975	0.823791	42.12329	0.011236	1.605259	0.808248
Cola gigantea A. Chev.	11	0.063802	1.212243	66.66667	0.061798	1.529217	0.795507
Cola millenii K. Schum	9	0.017206	0.161733	63.51351	0.050562	0.412385	0.231473
Cola nigerica Brenan & Keay	1	0.008993	0.058456	60.74766	0.005618	0.215549	0.110584
Cordia alliodora Ruiz & Pav.	1	0.017206	0.206467	81.08108	0.005618	0.412385	0.209002
Cordia millenii Chudnoff. Martin.	1	0.03733	0.925787	113.7615	0.005618	0.894731	0.450174
Daniella ogea Harms	1	0.091339	2.128192	68.32845	0.005618	2.189214	1.097416
Dialium guineense Willd	1	0.02545	0.381753	83.33333	0.005618	0.609992	0.307805
Entadrophragma angolense (Welw.) C.DC	6	0.093494	1.477207	45.7971	0.033708	2.240875	1.137291
Ficus exasperate Vahl.	1	0.01791	0.207758	76.82119	0.005618	0.429273	0.217445
Ficus mucuso Welw. ex Ficalho	1	0.00866	0.090931	100	0.005618	0.207567	0.106592
Funtumia elastic (Preuss) Stapf	10	0.031735	0.701343	109.9502	0.05618	0.760627	0.408403
Macaranga barteri Mull.Arg.	8	0.051881	0.881985	66.14786	0.044944	1.2435	0.644222
Maesobotrya barteri (Baill.) Hutch.	1	0.042279	1.023146	104.3103	0.005618	1.013341	0.509479
Malacantha alnifolia (Baker.) Pierre.	1	0.048702	0.779229	64.25703	0.005618	1.167288	0.586453

Milletia thonningii (Schum & Thonn.) Baker.	2	0.022701	0.090804	23.52941	0.011236	0.544098	0.277667
Myrianthus arboreus P.Beauv.	2	0.027175	0.334254	66.12903	0.011236	0.651336	0.331286
Nesogordonia papaverivera A. Chev.	1	0.01003	0.07021	61.9469	0.005618	0.240401	0.12301
Newbouldia laevis P.Beauv.	1	0.013687	0.157395	87.12121	0.005618	0.32804	0.166829
Pentacletra macrophylla Benth.	2	0.072116	1.774053	81.18812	0.011236	1.728481	0.869859
Piptadeniastrum africanum Hook f.	4	0.055579	1.022651	69.17293	0.022472	1.332118	0.677295
Pycnanthus angolensis (Welw.) Warb.	5	0.130117	3.929542	74.20147	0.02809	3.118662	1.573376
Ricinodendron heudelotii (Baill.) Heckel	6	0.152073	3.436845	51.36364	0.033708	3.644893	1.839301
Leucaniodiscus cupanioides Planch. ex Benth.	1	0.287513	8.050354	46.28099	0.005618	6.891126	3.448372
Sterculia rhinopetala K. Schum	6	0.074033	1.502862	66.12378	0.033708	1.774419	0.904064
Strombosia pustulata Oliv.	17	0.039766	0.644208	72	0.095506	0.953113	0.524309
Terminalia superba Engl. & Diels	3	0.03631	0.544646	69.76744	0.016854	0.870275	0.443564
Triclisia subcordata Oliv.	2	0.013275	0.13275	76.92308	0.011236	0.318175	0.164706
Trichilia prieureana A. Juss.	1	0.03142	0.37704	60	0.005618	0.753077	0.379348
Triplochiton scleroxylon K. Schum	11	0.288464	6.605823	37.78878	0.061798	6.913926	3.487862
Unknown	1	0.145239	3.195257	51.16279	0.005618	3.481099	1.743358
Total	**178**	**4.17**	**89.656**				

Note: Frq= Freuency; BA= Basal Area (m^2); Vol= Volume (m^3); RD= Relative Density; RDo= Relative dominance; SLC= Slenderness Coefficient.

The relatively low population of trees observed in the reserve, may be linked to anthropogenic factor and management option. Level of natural disturbance and human impacts have been stated to influence plant populations in tropical ecosystems (Padalia *et al*. 2004, Bajpai *et al.* 2015, Naidu and Kumar 2016, Bajpai *et al.* 2017). Characteristic tree species with large branches are nurtured and are the given choices of the management for construction and utilization purposes. This is in line with the report of Agarwala *et al*. (2016) who asserted that tree species populations is usually impacted by purpose and level of human use in India.

Slenderness coefficient

Slenderness Coefficient is the ratio of total height to DBH of a tree and can be used in measuring stability against wind-throw (Onilude & Adesoye 2007). Low slenderness coefficient value indicates high resistance to wind damage (good stand stability) while high slenderness coefficient show low resistance to wind induced damage (Onilude *et al.* 2012, Adeyemi & Ugo-Mbonu 2017). The categorization of the slenderness coefficient values for the tree species studied show that the majority of the trees (66.67%) sampled fall into low slenderness coefficient category (<70 SLC values) (Fig. 4), indicating good stability during heavy wind velocity. 23.81% has a moderate SLC (Fig. 4), indicating that this class of trees will show resistant to a heavy wind, however, it may be thrown off by excessive wind velocity. While about 9.52% the tree stand has a high SLC indicating that the trees cannot withstand or resist heavy wind throw and thus can have severe impact on the good standing trees during the heavy wind (Fig. 4). However, lower slenderness coefficient can be an indicator of larger crowns, lower centre of gravity and a better developed root system.

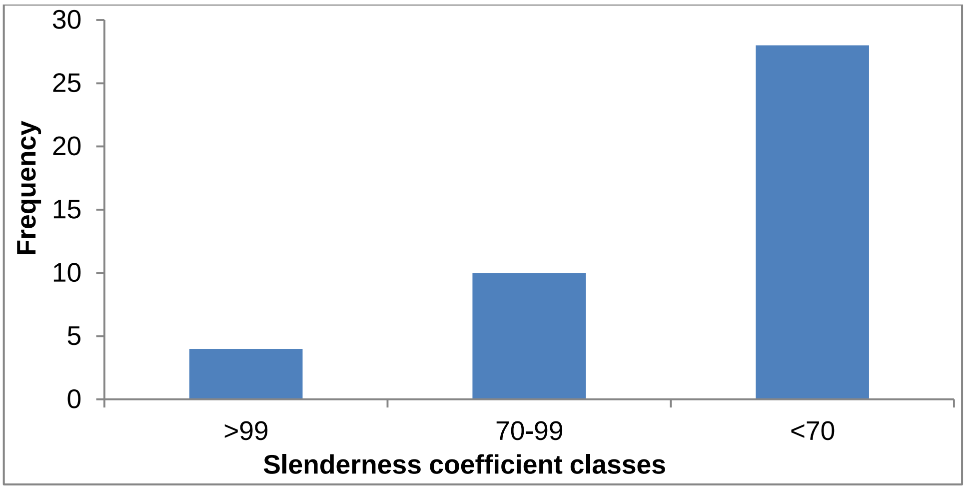

Figure 4. Distribution of slenderness coefficient values for tree species in natural stand of Gambari Forest Reserve.

Tree species diversity in natural stand of Gambari forest reserve

Tropical forests contain the highest diversity in terms of tree species, genetic materials as well as several ecological processes of all ecosystems. In the Gambari Forest reserve, 26 different tree species occurring were identified. The Shanon-wiener index and Simpson dominance index of 2.667 and 0.8945 were obtained respectively, while Pielous Eveness index was 0.5539. However, the result of species diversity obtained in the study was lower when compare to what had been reported for some natural forest ecosystems in Nigeria (Lowe 1997, Onyekwelu *et al.* 2008, Adekunle 2013). The result of the Pielous eveness showed that the tree species in the stand were not equally distributed as some tree species occurred more that some others (Table 3). This result is in line with the reports by Duran *et al*. (2006) and Rao *et al*. (2011), which reported the same range of Shannon-weiner index value for Mexican tropical deciduous forest and sacred grove in southern Eastern Ghats of India respectively. However, the results of the study revealed that Gambari forest reserve is a repository of diverse indigenous hardwood tree species.

Table 3. Diversity of trees species in natural stand of Gambari Forest reserve.

Species diversity	Values
Species	26
Individuals	113
Simpson Dominance index (C)	0.8945
Shanon-weiner Index (H')	2.6670
Pielou's Species Evenness Index (E')	0.5539

CONCLUSION AND RECOMMENDATION

The study has provided some information on the natural stands in Gambari Forest Reserve, Oyo State. The study revealed that the natural stand of Gambari Forest reserve could not compare favourably with other natural forest ecosystems in terms of species diversity and growth indices. Majority of the tree species in the forest reserve are relatively stable and not readily susceptible to wind damage hence possess the ability to protect the site from soil erosion. Also, the tree species can be used for land reclamation, have possible values and uses for establishment of shelter belts to arrest desertification and erosion in the northern part of Nigeria.

Although, the natural stands still has some economic hardwood tree species but needed to be protected from further encroachments and illegal activities. However, with sound management practices, the stand can be revitalized to be able to compare with other forest ecosystems.Since smaller slenderness coefficient is usually indicating a higher resistance to wind throw, the study suggest that silvicultural treatments, such as producing long crowned trees, and maintaining appropriate stand density through spacing, thinning, or gradually harvesting overstorey trees, can be helpful in reducing the risk of wind throw.

ACKNOWLEDGEMENTS

The authors appreciate the efforts of the Forest Biometric section inventory team for their cooperation during the collection the data and the anonymous reviewers for their timely efforts to go through the manuscript.

REFERENCES

Adekunle VAJ, Olagoke AO & Akindele SO (2013) Tree species diversity and structure of a Nigerian strict nature reserve. *Tropical Ecology* 54: 275–289.

Adeyemi AA & Ugo-Mbonu NA (2017) Tree slenderness coefficients and crown ratio models for *Gmelina arborea* (Roxb) stand in Afi River Forest Reserve, Cross River State, Nigeria. *Nigerian Journal of Agriculture, Food and Environment* 13: 226–233.

Agarwala M, DeFries RS, Qureshi Q & Jhala YV (2016) Factors associated with long-term species composition in dry tropical forests of Central India. *Environmental Research Letters* 11: 105008.

Bajpai O, Dutta V, Singh R, Chaudhary LB & Pandey J (2020) Tree Community Assemblage and Abiotic Variables in Tropical Moist Deciduous Forest of Himalayan Terai Eco-Region. *Proceedings of the National Academy of Sciences, India Section B: Biological Sciences* [https://doi.org/10.1007/s40011-019-01161-2]

Bajpai O, Kumar A, Mishra AK, Sahu N, Pandey J, Behera SK & Chaudhary LB (2012) Recongregation of tree species of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. *Journal of Biodiversity and Environmental Sciences* 2(12): 24–40.

Bajpai O, Kushwaha AK, Srivastava AK, Pandey J & Chaudhary LB (2015) Phytosociological status of a monotypic genus *Indopiptadenia*: A Near Threatened Tree from the Terai-Bhabar Region of Central Himalaya. *Research Journal of Forestry* 9(2): 35–47.

Bajpai O, Suman S & Upadhyay N (2017) Ecological exploration of Kuwana forest A tropical moist deciduous forest of eastern Terai, India. *Annals of Plant Sciences* 6(12): 1811–1816.

Batta H, Ashong CA & Bashir AS (2013) Press coverage of climate change issues in Nigeria and implications for public participation opportunities. *Journal of Sustainable Development* 6: 56–69.

Brashears MB, Fajvan MA & Schuler TM (2004) An assessment of canopy stratification and tree species diversity following clear-cutting in central Appalachian hardwoods. *Forest Science* 50: 54–64.

Deepa MR, Udayan PS & Anilkumar KA (2017) Taxonomical and phytosociological studies on Chithalikavu-A sacred grove, Thrissur district, Kerala. *Tropical Plant Research* 4(1): 20–30.

Duran E, Meave JA, Lott DJ & Segura G (2006) Structure and tree diversity patterns at landscape level in a Mexican tropical deciduous forest. *Boletinde Sociedad Botanica de Mexico* 79: 43–60.

European Union (2010) Available from: http://bioval.jrc.ec.europa.eu/AWRAT/pa/20978/ (assessed: 23 Mar. 2012).

FAO (2012) *Global forest resources assessment*. Main report, FAO Forestry paper 163, 340 p. Available from: www.fao.org/docrep/013/i1757e/i1757e.pdf (assessed: 18 Apr. 2012).

Giday K, Debebe F, Raj AJ & Gebremeskel D (2019) Studies on farmland woody species diversity and their socioeconomic importance in Northwestern Ethiopia. *Tropical Plant Research* 6(2): 241–249.

Ihenyen J, Okoegwale E & Menshak J (2009) Timber resources status of Ehor forest reserve, uhunmwode local government area of Edo State, Nigeria, *Natural Sciences* 7: 19–25.

Iyagin FO & Adekunle VAJ (2017) Phytoecological studies of some protected and degraded forest areas of Lowland Humid forest, Ondo state Nigeria: a Comparative approach. *Tropical Plant Research* 4(3): 496–513.

Kabiru Y (2008) *Nigeria's forest to disappear by 2020*. African conservation foundation Network News Report.

Larinde SL & Olasupo OO (2011) Socio-Economic Importance of Fuelwood Production in Gambari Forest Reserve Area, Oyo State, Nigeria. *Journal of Agriculture and Social Research* 11: [https://www.ajol.info /index.php/jasr/article/view/73703/64381]

Lowe RG (1997) Volume increment of natural moist tropical forest in Nigeria. *Commonwealth Forestry Review* 76(2): 109–113.

Magurran EA (2004) *Measuring of Biological Diversity*. Blackwell Publishing, Malden, Oxford and Victoria, pp. 108–256.

Masens da-Musa YB, Ngbolua K-t-N, Masens M, Tambu TM & Gédéon NB (2017) Phytoecological study of Nzundu massif forest of Imbongo city, Kwilu Province, Democratic Republic of the Congo. *Tropical Plant Research* 4(3): 363–375.

Naidu MT & Kumar OA (2016) Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. *Journal of Asia-Pacific Biodiversity* 9: 328–334.

Navratil S (1996) Silvicultural systems for managing deciduous and mixedwood stands with white spruce understory. In: Comeau PG & Thomas KD (eds) *Silvicultural of temperate and boreal broadleaf-conifer mixture*. B. C. Ministry of Forests, Victoria, pp. 35–46.

Okafor E, Lilian C, Ibeawuchi II & Obiefuna JC (2013) Biodiversity conservation for sustainable agriculture in tropical rainforest of Nigeria. *New York Science Journal* 2: 81–88.

Onilude QA & Adesoye PO (2007) Relationships between tree slenderness coefficient and tree growth characteristics for *Triplochiton scleroxylon* (K. Schum) stands in Ibadan Metropolis, Nigeria. *Obeche Journal* 25(2): 16–24.

Onilude QA, Fajemila A, Adeleye IG, Oduola M, Osijo A & Oso AO (2017) Stem Taper and Tree Growth Characteristics for *Triplochiton scleroxylon* (K. Schum) Stands in Ibadan Metropolis, NIGERIA. *International Journal of BioSciences, Agriculture and Technology* 8(4): 28–35.

Onilude QA, Julius AJ, Olaiwola BI, Showunmi IL & Ogunremi OC (2012) Relationship between Canopy Width, Tree Height, Trunk Size and Slenderness Coefficient of Four Tree Species Growing in Ibadan Metropolis, Oyo State, Nigeria. *International Journal of Applied Research and Technology* 1(3): 98–105.

Onyekwelu JC, Mosandl R & Stimm B (2008) Tree species diversity and soil status of primary and degraded tropical rainforest ecosystems in South-Western Nigeria. *Journal of Tropical Forest Science* 20(3) 193–204.

Padalia H, Chauhan N, Porwal MC & Roy PS (2004) Phytosociological observations on tree species diversity of Andaman Islands, India. *Current Science* 87: 799–806.

Pelemo OJ, Akintola BA, Temowo OO, Akande EO & Akoun M (2011) Effects of landscape change on biodiversity in Nigeria: Remote sensing and GIS approach. *Control Journal of Environmental Management*

1: 22–29.

Rajkumar M & Parthasarathy N (2008) Tree diversity and structure of Andaman giant evergreen forests in India. *Taiwania* 53: 356–368.

Rao B, Babu MV, Reddy MS, Reddy AM, Rao VS, Sunitha S & Ganeshaiah KN (2011) Sacred groves in southern eastern ghats, India: Are they better managed than forest reserves? *Tropical Ecology* 52: 79–90.

Roychoudhury N, Sharma R & Mishra RK (2019) Scope and challenges of biodiversity conservation and mangement in Achanakmar-Amarkantak biosphere reserve. *Plants and Environment* 1(1): 46–54.

Yang KC, Lin JK, Hsieh CF, Huang CL, Chang YM, Kuan LM, Su JF & Chiu ST (2008) Vegetation pattern and woody species composition of a broad-leaved forest at the upstream basin of Nantzuhsienhsi in mid-southern Taiwan. *Taiwania*53: 325–337.