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 Cedrela 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±0.02m²ha⁻¹ and 2.135±0.54m³ha⁻¹. Diversity measures obtained included Shannon-weiner index (2.667) and Pielous evenness (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.

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.
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.

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 1. Map of Gambari forest reserve.
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:

\[ BA = \frac{\pi D^2}{4} \]  

Equation 1

Where, \( BA \) = Basal Area (m\(^2\)), \( \pi = 3.142 \) (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:

\[ SV = \frac{\pi h}{24} \left( D_b^2 + 4D_m^2 + D_t^2 \right) \]  

Equation 2

Where, \( SV \) = stem volume of individual tree (M\(^3\)), \( \pi = 3.142 \) (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.

\[ SLC = \frac{\text{TOTAL HEIGHT}}{\text{DIAMETER AT BREAST HEIGHT}} \]  

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,

\[ H' = -\sum_{i=1}^{S} P_i \ln P_i \]  

Equation 4

Where, \( H' \) is the Shannon-Wiener diversity index; \( S \) is the total number of species in the community; \( P_i \) 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).

\[ E = \frac{\sum_{i=1}^{S} Pi \ln Pi}{\ln(S)} \] .......................... 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.

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

Where, Pi is the proportional abundance of the ith species

\[ P_i = \frac{n_i}{N} \] .......................... 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).

\[ RD = \frac{n_i}{N} \times 100 \] .......................... Equation 8

Where, RD is the relative density of the species; n_i 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:

\[ RDo = \frac{\sum Bai \times 100}{\sum Ban} \] .......................... 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 (m² ha⁻¹)    | 0.099 ± 0.02 | 0.0087 | 0.767 |
| Tree Volume (m³ 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., Chrysophyllum 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 4.17m² and 89.656m³ respectively (Table 2). The highest value of the Importance value index was contributed by *Chrysophyllum perpulchrum* (9.191705) while the least Importance value Index was contributed by *Ficus mucuso* (0.106592) as shown in table 2.

**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.)   | 3      | 0.128206 | 2.717971 | 52.47525 | 0.016854 | 3.072856 | 1.544855 |
| Aubr. & Pellegri               |        |      |      |      |     |      |           |
| 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 | 0.83044 |
| 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 | 0.82016 |
| Celtis zenkerii Engl.          | 8      | 0.038713 | 0.689084 | 80.18018 | 0.044944 | 0.927866 | 0.486405 |
| Chrysophyllum perpulchrum      | 1      | 0.766761 | 18.78565 | 24.79757 | 0.005618 | 18.37779 | 9.191705 |
| Mildbr. ex Hutch. & Dalziel   |        |      |      |      |     |      |           |
| Chytranthus macrobotrys (Gilg) | 2      | 0.066975 | 0.823791 | 42.12329 | 0.011236 | 2.189214 | 1.097416 |
| Exell & mendonca              |        |      |      |      |     |      |           |
| 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 | 0.209002 |
| Cola nigeraica Brenan & Keay   | 1      | 0.008993 | 0.58456  | 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  | 0.927578 | 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 |
| Entadophragma angolense (Welw.) | 6      | 0.093494 | 1.477207 | 45.7971  | 0.033708 | 2.240875 | 1.137291 |
| Funnetia elastica (Preuss) Stapf | 10    | 0.031735 | 0.701343 | 109.9502 | 0.05618 | 2.189214 | 1.097416 |
| Macaranga barteri Mull.Arg.    | 8      | 0.051881 | 0.881985 | 66.14786 | 0.044944 | 1.2435  | 0.644222 |
| Maesobotrya barteri (Baill.)   | 1      | 0.042279 | 1.023146 | 104.3103 | 0.005618 | 1.013341 | 0.509479 |
| Hutch.                         |        |      |      |      |     |      |           |
| Malacantha alnifolia (Baker.)  | 1      | 0.048702 | 0.779229 | 64.25703 | 0.005618 | 1.167288 | 0.586453 |
| Pierre.                        |        |      |      |      |     |      |           |

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

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| Species                                   | Frq | BA   | Vol   | RD    | RDo    | SLC    |
|-------------------------------------------|-----|------|-------|-------|--------|--------|
| 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 papaveriervera A. Chev.      | 1   | 0.01003 | 0.07021 | 61.9469 | 0.005618 | 0.240401 |
| Newbouldia laevis P.Beauv.                | 1   | 0.013687 | 0.157395 | 87.12121 | 0.005618 | 0.32804 |
| Pentacletra macrophylla Benth.            | 2   | 0.072116 | 1.774053 | 81.18812 | 0.011236 | 1.728481 |
| Piptadeniastrum africanum Hook f.         | 4   | 0.055579 | 1.022651 | 69.17293 | 0.022472 | 1.332118 |
| Pycnanthus angolensis (Welw.) Warb.       | 5   | 0.130117 | 3.929542 | 74.20147 | 0.02809 | 3.118662 |
| Ricinodendron heudelotii (Baill.) Heckel  | 6   | 0.152073 | 3.436845 | 51.36378 | 0.033708 | 3.644893 |
| Leucamiondiscus cupanioides Planch. ex Benth. | 1   | 0.287513 | 8.050354 | 46.28099 | 0.005618 | 6.891126 |
| Sterculia rhinopetala K. Schum            | 6   | 0.074033 | 1.502862 | 66.12378 | 0.033708 | 1.774419 |
| Stroboisma pastulata Oliv.                | 17  | 0.039766 | 0.644208 | 72     | 0.095506 | 0.953113 |
| Terminalia superba Engl. & Diels         | 3   | 0.03631 | 0.544646 | 69.76744 | 0.016854 | 0.870275 |
| Trilcisia subcordata Oliv.                | 2   | 0.013275 | 0.13275 | 76.92308 | 0.005618 | 0.318175 |
| Trichilia prieureana A. Juss.             | 1   | 0.03142 | 0.37704 | 60     | 0.005618 | 0.753077 |
| Triplochiton scleroxylon K. Schum         | 11  | 0.288464 | 6.605823 | 37.78878 | 0.061798 | 6.913926 |
| Unknown                                   | 1   | 0.145239 | 3.195257 | 51.16279 | 0.005618 | 3.481099 |

Total 178 4.17 89.656

Note: Frq= Frequency; BA= Basal Area (m²); Vol= Volume (m³); 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.](www.tropicalplantresearch.com)
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 Shannon-wiener index and Simpson dominance index of 2.667 and 0.8945 were obtained respectively, while Pielou 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, Onyekwu et al. 2008, Adekunle 2013). The result of the Pielou 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-wiener 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-wiener 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.

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