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Original Article

Floristic dynamics and structure of a degraded community forest in Kwara state, Nigeria

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ABSTRACT

The floristic composition and structural diversity of Tumbuyan forest in Nigeria were investigated using two-line transects with 10 plots each of size 25 m × 25 m each laid alternatively to each other. All trees measured (diameter at breast height > 10 cm) were identified to their biological nomenclature. A total of 640 tree species per hectare belonging to 19 families were identified in the community forest. The forest was dominated by *Anogeissus leiocarpus, Dalbergia welwitschii, Parkia biglobosa, and Ficus capensis*, all belonging to the families of *Combretaceae*, *Papilionoideae*, *Fabaceae,* and *Moraceae,* respectively. The Shannon-Weiner index of 2.92 was obtained, an indication of lesser diverse ecosystem. Pielou's evenness and Margalef indices obtained were 0.43 and 8.28, respectively. However, despite high frequency per hectare (640 trees/ha), the mean basal area (0.382 ± 0.056) was very low when compare to other biological hotspots around the globe. The floristic knowledge and structure of the forest will help in identifying important elements of tree diversity, protecting and preserving threatened plant species, and monitoring and providing effective management of the forest. However, the study provides baseline information on Tumbuyan community forest for proper management of the resources therein.

Keywords: Floristic and structural changes, Nigeria, tree species diversity, Tumbuyan forest

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INTRODUCTION

Tropical forests are often referred to as one of the most species diverse terrestrial ecosystems and generate a variety of natural resources to help sustain the livelihood of local communities.[1] Trees form a part of the major structural and functional basis of tropical forest ecosystems and can serve as robust indicators of changes and stresses at the landscape scale. The vegetation communities of the tropical dry forests have been recognized as comprising some of the most endangered ecosystems in the tropics.[2] However, many of these forest communities are facing serious anthropogenic threats and require adequate management interventions to maintain the overall biodiversity, productivity, and sustainability. Furthermore, knowledge and understanding of tree species diversity and their distribution patterns are key important to help managers evaluate the complexity and resources of these forests.[1]

There have been massive deforestation and forest degradation of forest reserves in Nigeria as a result of human activities and inadequate or lack of effective management of the reserves. This endangers the forest reserves and the services (socioeconomic and ecological) they render. In Nigeria, population growth has led to a geometric increase in anthropogenic activities, excessive logging, and overexploitation of these forest resources. As a result, most of these forest reserves only exist on documents and papers. They have either been converted to farmlands of arable and cash crops or other land uses such as large-scale housing units. In addition, the lucrative nature of timber business in Nigeria has attracted both the politicians and other business moguls into the business, causing continuous timber harvesting in both the constituted forest and the free areas. A total of 111,377 timber stems, belonging to 62 different indigenous hardwood species of tropical rainforest ecosystem, distributed among

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16 families, were exploited from Ondo State forest reserve between 2003 and 2005.[3]

Furthermore, the environmental benefits of the forests ecosystems are reduced when trees are being removed indiscriminately. These benefits include windbreaks, microclimate creation, and carbon sequestration. Information on floral composition, yield and growth, and species diversity are very important and critical for understanding forest ecosystem dynamics. Quantification of tree species diversity provides useful information on the genetic resources available in the concerned ecosystem. However, to protect and reclaim our forest reserves from continuous declining, it is very essential to examine the current status of tree species diversity as it will provide guidance and working policy for the management of the reserve areas.

Knowledge of the floristic composition and its dynamics of the reserves are critical to understanding the greater dynamics of forest ecosystems and for identifying important elements of plant diversity, protecting threatened or economic species, and monitoring the state of reserves. The Tumbuyan forest was one of the earlier forests conserved in Nigeria, generally believed to be ecologically rich and biologically abundant with forest tree species but facing serious degradation and depletion from illegal fellers and charcoal producers. Part of the forest has also been converted to plantations and farming.[4] For the glory and conservation status of the reserve to be redeemed, there is a need for proper and current documentation of tree species remain therein. Floristic data and information obtained in this study would be useful for the application of sound management practices in the forest.

MATERIALS AND METHODS

The Study Area

This climate, the tropical savanna climate, exhibits a well-marked rainy season and a dry season with a single peak known as the summer maximum due to its distance from the equator. The average monthly temperature of the site is 26.18°C with highest value recorded in March (28.1°C) and minimum in June and July (24.5°C each) and an annual rainfall of about 1500 mm with single rainfall maxima in September. The number of raining days was highest in September (16 days) while January and December each recorded no raining days. The single dry season experienced in this climate, the tropical savanna climate, is hot and dry with the Harmattan wind, a continental tropical air mass laden with dust from the Sahara desert prevailing throughout this period.[5] In general, the soil is sandy loam and slightly acidic (pH = 6.5) with outcrop of rocks. The soil contains 1.26% of organic carbon, a range of 0.83–3.74% was observed for organic matter content, and the phosphorus constituent ranges between 9.1 mg/kg and 32.3 mg/kg.[5] The study map of the community forest is presented in Figure 1.

Sampling Design and Data Processing

A systematic line transect was adopted for this study. A total of 10 plots of size 25 m × 25 m spaced at 20 m to each other and laid alternatively to each other were obtained from two transect lines of 205 m each at 150 m from each other. An edge effect of 20 m was established before laying the plots [Figure 2]. Measurement and information on all trees above

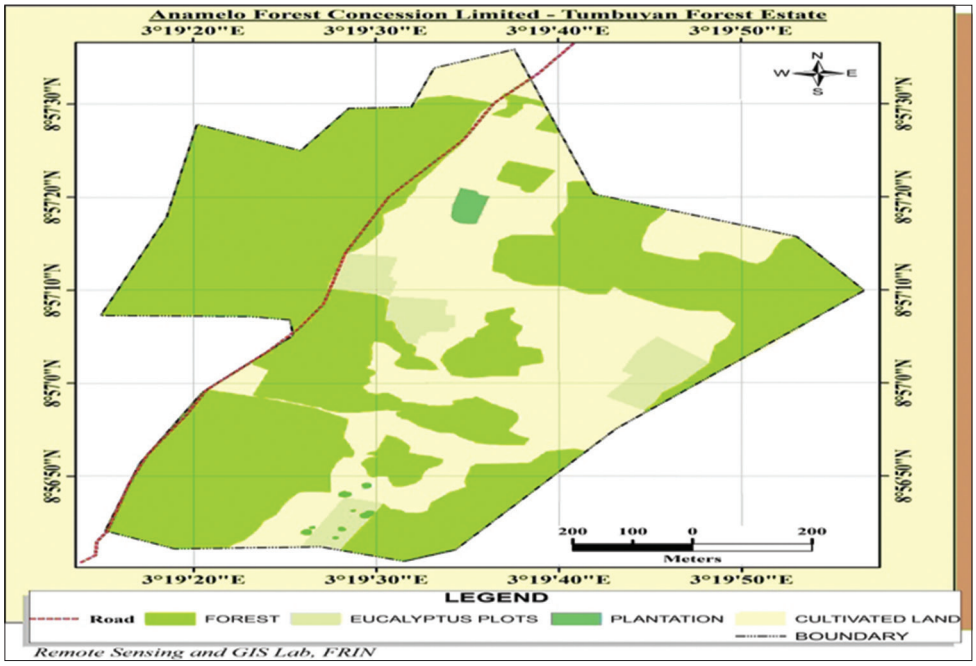

Figure 1: Overview map of Tumbuyan community forest

diameter at breast height (DBh) of >10 cm were collected. With this minimum DBh, most of the classes of woody plants would have been captured. Information collected included Dbh, diameter at the middle, diameter at the base, diameter at the top, and both total and merchantable heights were collected using a Spiegel Relaskop and also, taxonomic identification of the tree species was done.

Tree Species Identification

All the tree species found in the plots were all identified to their nomenclature. Where a species cannot be identified on the field, botanical specimen of such trees was collected and taken to Forestry Research Institute of Nigeria Herbarium (FHI, Ibadan) for proper identification.

Data Processing

Basal area (BA) estimation

The BA of individual trees sampled was estimated using equation as follows:[6]

$$BA = \frac{\pi d^2}{4} \quad (1)$$

Where,
BA = Basal area (m^2)
D = dbh (cm)
Π = 3.142 (constant)

Volume estimation

The volume of individual trees sampled was estimated using processed Newton equation developed for trees volume estimation.[6]

$$V = \pi H \frac{Db^2 + 4Dm^2 + Dt^2}{24} \quad (2)$$

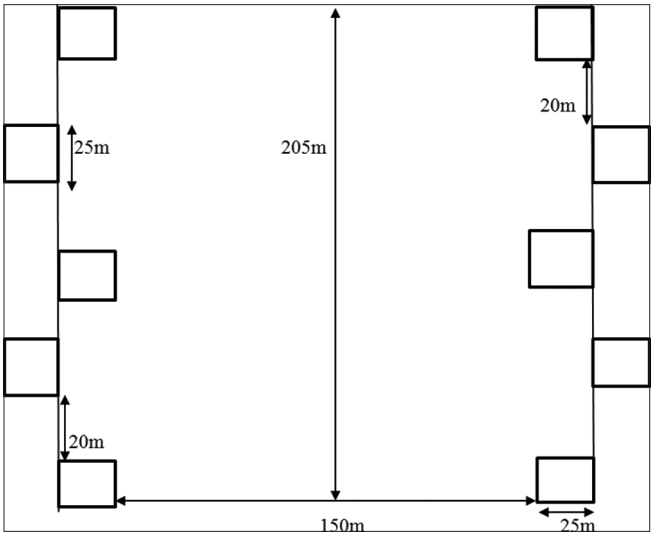

Figure 2: Transect lines used for the plots sampling

Where,
V = Volume (m^3)
H = Merchantable height (in m),
D_b = Diameter at the base, over bark (in m)
D_m =Diameter at the middle position along the stem, over bark (in m)
D_t =Diameter at the top (in m)
π = 3.142.

Tree species diversity

Palaeontological statistics was used extensively for the diversity analysis as suggested by Magurranm.[7] 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 are usually found to fall between 1.5 and 3.5 and only rarely surpass 4.5.[8] It is given by,

$$H = \sum_{i=1}^{s} PiLnPi \quad (3)$$

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; and 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).

$$E = \frac{\sum_{i=1}^{s} PiLnPi}{Ln(s)} \quad (4)$$

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

Margalef's Index (d)

Margalef's index (d) was used to calculate the species richness. The Margalef's index (d) is independent of sample size. It is based on the relationship between total number of species (S) and total number of individuals (N). Margalef's index is given by,

$$d = \frac{s-1}{Ln\,(N)} \quad (5)$$

Where, *S* is the total number of species, *N* is the total number of individuals, and *Ln* is the natural logarithm.

RESULTS AND DISCUSSION

Floristic and Species Composition

The descriptive statistics of the growth and yield variables in the study area is presented in Table 1. The forest can be classified as savannah woodland. The forest ecosystem contains about 43 tree species belonging to 19different families. The forest is dominated by *Anogeissus leiocarpus, Dalbergia welwitschii, Terminalia arjuna, Daniellia oliveri, Entada Africana, Parkia biglobosa, and Prosopis africana* tree species. The three dominating families in this reserve were *Combretaceae*, *Fabaceae,* and *Papilionoideae* with each contributing 38.8%, 13.8%, and 13.8%, respectively. However, families among the least representation in terms of species richness included *Sapindaceae*, *Annonaceae,* and *Euphorbiaceae* with each contributing 1% each in the forest ecosystem. Furthermore, this forest type is usually found in the southern guinea savannah part of Nigeria. As is fairly common in many stands in this area, this forest also contains species more typical of a rainforest: *Khaya* species, *Sterculia* species, and *Albizia* species specifically. Other trees present include *Annona senegalensis, Afzelia africana, Lophira lanceolata, Pseudocedrela kotschyi, Prosopis africana,* and *Canthium glandulosum* among others.

Table 1: Descriptive statistics of the growth and yield variables in the study area

Growth variables	Values
Mean DBH (cm)	18.9±0.721
Mean BA (m^2/ha)	0.382±0.056
Mean height (m)	9.17±0.222
Mean volume (m^3/ha)	3.66±0.612
Number of stems per hectare	640

Dbh: Diameter at breast height, Ba: Basal area

Table 2: Correlation matrix of growth variables of tree species in Tumbuyan community forest

Variables	Dbh	Ba	Vol	LnBa	LnVol
Dbh	1				
Ba	0.99	1			
Vol	0.91	0.80	1		
LnBa	0.98	0.95	0.84	1	
LnVol	0.72	0.69	0.85	0.76	1

Dbh: Diameter at breast height (cm), Ba: Basal area (m^2), Vol: Volume (m^3), Ln: Natural logarithm

Stand Density and Structure

The forest has fair stand density and tree distribution. It comprises 640 trees/ha. This could be as a result of the fact that the site is a secondary savannah forest. It currently has a mean BA per hectare of 0.382 ± 0.056 m^2/ha. BA, a measure of stand density, is the sum of the cross-sectional area of all trees measured at breast height, (1.3 m from the base of the tree) expressed as a per hectare amount. When BA is too low, the stand is underutilized and may result in trees that are excessively branchy or prone to windthrow damage. If BA is too high, the growth of individual trees is stunted due to competition for resources, and trees may become more prone to pest damage. The mean height (m) and volume per hectare obtained were 9.17 ± 0.222 m and 3.66 ± 0.612 m^3/ha, respectively. This forest has an abundance of 400 trees/ha of small-diameter trees in diameter class 10–20 cm [Figure 3] and a slight deficit of trees of 12 trees/ha in larger size diameter classes of >60 cm [Figure 3]. In terms of size, majority of the tree species were in diameter class 10–20 cm, diameter class of 20.1–30 had 160 trees/ha, followed by diameter class of 30.1–40 with 32 trees per hectare while diameter classes with the least number of trees species per hectare are 50.1–60 and >60 cm classes with 12 trees/hectare each [Figure 3]. The result of diversity analysis includes Shannon-Weiner index to be 2.92, species evenness was 0.432 while the Margalef index was 8.28.

DISCUSSION

Studies on forest structure and knowledge of floristic composition of a forest are very instrumental in their

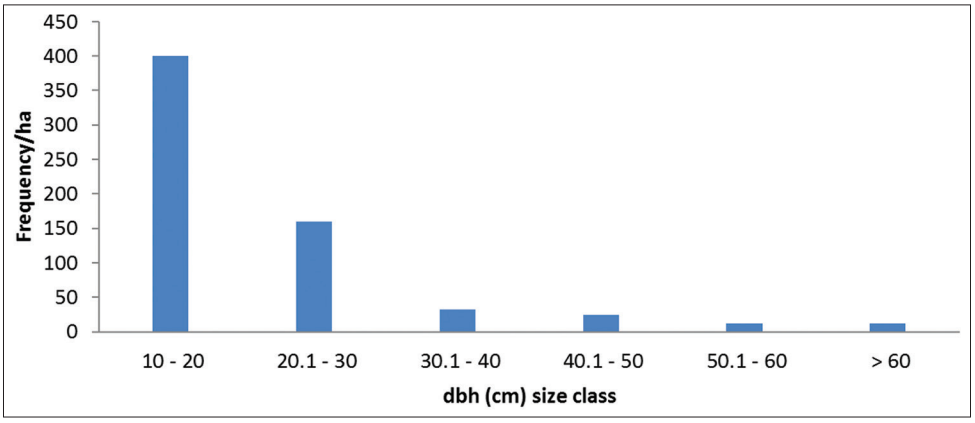

Figure 3: Distribution of tree species into different diameter classes

management and sustainability since they play a major role in the conservation of plant species and the management of forest ecosystems as a whole.[8,9,10,11] Despite being affected by anthropogenic activities such as felling of mature trees for timber, collection of fuelwood, and other non-timber forest products, the forest reserve still compare favorably with another forest reserve in other parts of the country and outside the shore of the country. Furthermore, the species values obtained in this study were greater compare to the range of values reported[12] that 62–247 species per hectare as an evidence of mature tropical forest in Southeast Asia.

The result of this study showed that floristic composition of Tumbuyan forest reserve was higher than the report presented by Addo-Fordjour *et al*.,[13] as he recorded a much lower species richness (48species/ha) in a moist semi-deciduous forest in Ghana. Furthermore, another researcher, Mohandass and Davidar[9] recorded 86 species in a tropical montane evergreen forest in India. An average stand density of 422 stems/ha was reported for Borneo rainforest[14] and as high as 544 for a primary forest in Indonesia.[15] In addition, the floristic distribution of this forest was found to be higher when compare with distribution of other protected reserves in Nigeria. For instance, Aigbe *et al*.[16] reported 323 trees/hectare in Afi river forest reserve in Nigeria. Furthermore, Adekunle *et al*.[17] reported 387 stems per hectare in strict nature reserve, Akure, Nigeria.

Diameter size class distribution is a very important indicator of changes occurring in population structure and species composition of a forest.[8,18] The distribution of the tree into diameter size class has shown that the forest was characterized by small and young tree species whose diameter was mostly between 10–20 cm, 21–40 cm, and 41–60 cm with fewer number of trees found in higher diameter classes. This might be as a result of selective felling and illegal logging of higher diameter size class trees. This shows that the forest reserve is disturbed and they are in their early successional stages. However, the tree distribution in the forest followed reverse J-shaped distribution with greater number of individuals in small size classes. Such a trend was also reported in the forests of Great Andaman groups.[3,17,19,20] The mean basal area of the tree species (0.382 + 0.056) revealed that the forest was characterized by small diameter stems and actually recovering from disturbance. The general small BA of most species is an evidence of disturbance and degradation in Tumbuyan forest. The result of the correlation matrix obtained for this study showed a high and positive correlation between the growth variables assessed [Table 2].

Biodiversity indices of a forest reserve are examined to generated and understand the diversity. The very high values of the diversity indices revealed a forest with very high tree species diversity and abundance. The Shannon-Weiner index obtained for this study compare favorably within the range of 2.94–3.96 reported by[21] for sacred grooves in South Eastern Ghats, India. Furthermore, the Margalef index which is an indication of species richness for this study is in very close or in tandem with results reported by Aigbe *et al*.[16] for Afi river forest reserve in Cross River, Nigeria (Margalef = 10.44) and higher than the result reported by Eilu *et al*.[22] with Margalef index range of 7.54–8.20 of forest located in Albertine Rift, Western Uganda.

CONCLUSIONS AND RECOMMENDATION

Floristic composition and species diversity of a degraded Tumbuyan forest, Kwara state, Nigeria, were investigated. A total of 640 tree species per hectare were recorded belonging to 19 different families. The diversity indices showed a high number of tree species per hectare but with low BAs when compared with other biological hotspots as majority of the tree species were found in small diameter classes. The diameter distribution of the forest showed a forest with a growing structure/stem as majority of the tree species in the forest followed reverse J-shaped distribution with the larger number of individual stems in small diameter size classes.

The study revealed that Tumbuyan forest reserve has a reasonably standing good tree species composition and richness despite facing serious anthropogenic activities from illegal fellers and charcoal producers. This has greatly affected the structural balance of the forest reserve through the removal of large and tall trees. Therefore, there is a need to control human activities in the forest reserve so as to protect the remaining tree species for effective management, utilization, and sustainability.

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DECLARATION OF INTEREST STATEMENT

The authors declare that they have no competing interest.

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