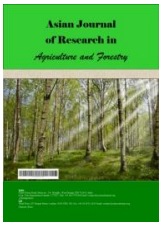

Asian Journal of Research in Agriculture and Forestry

6(3): 41-48, 2020; Article no.AJRAF.59790
ISSN: 2581-7418

Composition and Classification of Tree Species in a Degraded Tropical Humid Rainforest in Southwest Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author STE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MDW managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJRAF/2020/v6i330108
Editor(s):
(1) Dr. Cengiz Yucedag, Mehmet Akif Ersoy University, Turkey.
Reviewers:
(1) V. K. Upadhyay, IPIRTI, India.
(2) Ricardo A. Figueroa R, Chile.
Complete Peer review History: http://www.sdiarticle4.com/review-history/59790

Original Research Article

Received 10 June 2020
Accepted 15 August 2020
Published 09 September 2020

ABSTRACT

Tree species information is essential for forest studies such as forest meteorology, botany and ecology, and across the relevant fields new techniques efficient for classifying tree species are desperately in demand. This study assessed tree species composition and classification in a degraded tropical rainforest in Southwest Nigeria. Data was collected from the Olukayode compartment of the study area of size 2 ha. Eight (8) Temporary sample plots of size 50 m x 50 m was laid using systematic line transect at 100 m intervals in the compartment. Hierarchical clustering in SPSS was used to find clusters of patterns in the measurement space. Tree species such as; *Eucalyptus cameldulensis*, E*ucalyptus tereticornis*, *Khaya ivorensis*, *Khaya senegalensis,Nauclea diderichi*, *Terminalia randii*, and *Terminalia superba* with a total frequency of 60 were identified, belonging to 3 different families. At similarity 5.0 from the dendrogram using ward linkage, samples 48 - 6 formed the first cluster, samples 28 - 9 constituted the second cluster

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while samples 20 - 13 constituted the third cluster. From the dendrogram using centroid linkage, at similarity 5.0, samples 59 - 7 formed the first cluster, samples 32 - 31 constituted the second cluster, and samples 8 - 28 formed the third cluster while the fourth cluster combined samples 17 - 21 which is a combination of trees from the three families. Histogram was used to show the diameter at breast height and total height distribution.

Keywords: Degraded; hierarchical clustering; dendrogram; histogram; Akure-Ofosu forest reserve.

1. INTRODUCTION

Trees are an important part of the terrestrial ecosystem, providing essential habitats including many kinds of the forest for communities of organisms. They stabilize the soil, prevent rapid run-off of rainwater, they help prevent desertification, have a role in climate control and help in the maintenance of biodiversity and ecosystem balance [1]. Tree species information is essential for forest studies such as forest meteorology, botany and ecology, and across the relevant fields new techniques efficient for classifying tree species are desperately demanded. Classification system provides a framework to organize information that differs between vegetation types, such as trees strata, productivity in terms of volume estimation. The classification system also standardized the identification and definition of vegetation groups, enhancing communication among managers and researchers [2]. Cluster analysis is a multivariate method that classifies objects into a different number of groups based on a set of measured variables [3]. A hierarchical cluster analysis can be used to group plant species observed into a series of clusters and build a taxonomy tree of groups and subgroups of similar plants, using the dataset of all the trees in the sample plots. A dendrogram shows the appropriate number of clusters and how the clusters are merged.

The tropical ecosystem is known to be among the most diverse and complex species-rich ecosystems on the planet [4]. However, the expansion of anthropogenic disturbances in primary forest areas is increasingly devastating most tropical rainforests. Activities such as selective logging, shifting cultivation and establishment of palm oil and cocoa plantations have continued to place immense pressure on species diversity in such forests. These activities result in considerable loss of biodiversity, degradation of timber and non-timber resources as well as disruption of the ecological and biological complexities in the forests. Consequently, plant species composition abundance in the disturbed and fragmented tropical forest have increasingly become important economically, socially as well as for biodiversity conservation, especially with the alarming rate at which original forest are disappearing [5]. It is in view of this that this study seeks to assess and provide data on tree species composition and also classify the tree species in the degraded forest reserve to ensure proper planning and management of the reserve.

2. MATERIALS AND METHODS

2.1 Study Area

Akure-Ofosu Forest Reserve is located between latitude 5^{o} 12' and 5^{o} 30'N, Longitude 6^{o} 50' and 7^{o} 05'E in the humid, tropical rainforest zone of Ondo State, Nigeria. The state is predominantly agrarian and one of the leading timber producing areas in the country. The forest has two distinct seasons (rainy and dry), with an annual rainfall (March to November) ranging from 1,500 to 2,000 mm and mean annual temperature between 30^{o} C and 32^{o}C while the mean daily humidity is 70 % [6].

2.2 Data Collection

2.2.1 Sampling procedure

Regular line transect was used to lay temporary sample plots (TSPs) in the Olukayode compartment, Akure-ofosu natural forest. Two transects of 500 m in length with a distance of 200 m between the two parallel transects were laid. Sample plots of 50 m x 50 m in size were established in alternate position along each transect at 100 m interval and thus summing up to 4 sample plots per 500 m transect and a total of 8 sample plots in the study area, with a total area of 2 ha. The data set from the trees growth variables were used for classification, i.e., growth variables such as total height, bole height, merchantable height, diameter at the base, diameter at the top, diameter at the middle, diameter at breast height, crown diameter, crown length, and several other growth variables were measured on 60 trees of different families

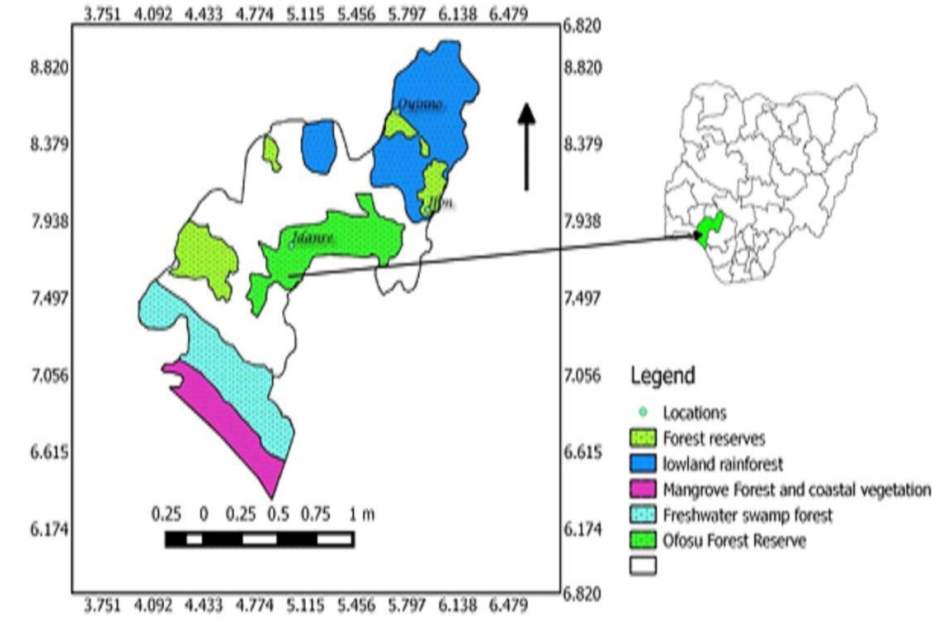

Fig. 1. Map of Ondo state indicating Akura-Ofosu forest reserve
Source: [7]

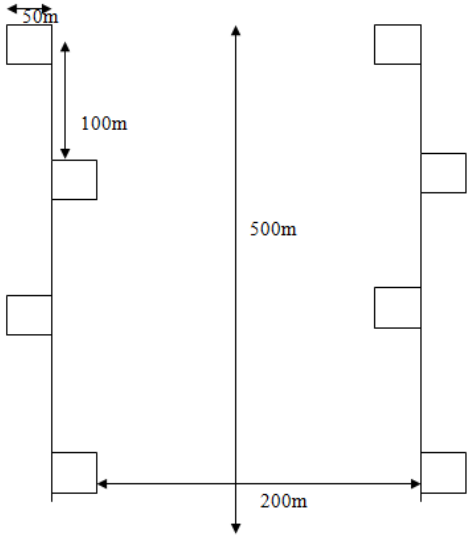

Fig. 2. Study instrumentation

The following instruments were used during the data collection;

1. Diameter Tape: for measuring diameter at breast height (dbh).
2. Spiegel Relascope: for measuring height and diameter at various points.
3. Measuring tape: for measuring distance.

2.2.2 Tree species identification

Tree species were counted and identified in – situ where possible and by comparison with voucher specimen from the Forest Herbarium, Forestry Research Institute of Nigeria, Ibadan. Tree species enumerated were categorised into families, and the frequency of the species was used to affirm species composition.

2.3 Data Processing

The data processed includes;

2.3.1 Basal area

$$BA = \left(\pi \frac{D^2}{4}\right) \quad (1)$$

Were:

BA = Basal Area (m^2)
D = Diameter at breast height (cm)
Π = 3.142

2.3.2 Volume estimation

The volume of each tree was calculated using Newton's formula of [8]:

$$V = \pi \frac{H}{2}(D_b^2 + 4D_m^2 + D_t^2) \quad (2)$$

Were:

H = Merchantable Height
D_b = Diameter at the base
D_m = Diameter at the Middle
D^t = Diameter at the top
Π = 3.142

2.3.3 Cluster analysis

In SPSS Hierarchical cluster and ward linkage are methods in cluster analysis. The similarity matrix that is formed by first computing the distances between all pairs of points in the dataset is converted into similarity value. It is represented as;

$$S_{ik=1} - \frac{d_{ik}}{d_{max}}$$

Where,

$S_{ik=}$ (varies from 0 to 1) is the similarity between samples I and k.
d_{ik} = is the Euclidean distance between samples I and k
$d_{\max=}$ is the distance between two most dissimilar samples in the dataset.

2.4 Data Analysis

The data collected was arranged in excel. Estimation of basal area, Slenderness Coefficient, Crown Diameter and volume of the collected dataset was performed using Microsoft excel.

SPSS (statistical package for social sciences) was used to conduct cluster analysis for classification of all the trees in the study area.

3. RESULTS

The results of the study shows that the trees species with the highest relative frequency was *Nauclea diderichi* (28.9%), followed by *Eucalyptus tereticornis* (26%) and *Terminalia superba* (20%), while the lowest was recorded for *Khaya senegalensis* (1.7%). Meliaceae were the most diverse and abundant family, followed by Myrtaceae and Combretaceae (Table 1).

Hierarchical clustering in SPSS was used to find clusters of patterns in the measurement space. The result of the tree species classification using ward linkage dendrogram shows that three distinct clusters was formed (Fig. 3), while the result of trees species classification using centroid linkage dendrogram shows that four clusters was formed (Fig. 4). The mean value for each variable of each cluster is calculated and the distance between the centroid is used. Clusters whose centroids are closed together are merged.

Classification of trees in the study area using diameter at breast height (dbh) was made to show the nature of the study area and the various sizes of trees in terms of dbh in the study area (Fig. 5). Diameter at breast height is used in estimating the amount of timber volume in a single tree or stand of trees. It can also be used in the estimation of the age of veteran trees. While, tree species classification by the total height of each tree encountered in the study area was also done to show their various heights in the study area (Fig. 6).

4. DISCUSSION

The number of species per unit area, which refers to plant species richness, has gained global interest because quantifying patterns of species richness in the degraded tropical forest provides an insight into the ability of the forest vegetation to recover [9]. Therefore, constant

assessment and classification of trees to direct succession processes towards composition and structure are essential in order maintaining species of and habitat diversity [10].

Table 1. Species encountered in the study area and their relative frequencies

Species	Family	Frequency of trees	Percentage (%) of trees
Eucalyptus cameldulensis	Myrtaceae	5	8.3
Eucalyptus tereticornis	Myrtaceae	15	26
Khaya ivorensis	Meliaceae	3	1.8
Khaya senegalensis	Meliaceae	1	1.7
Nauclea diderichi	Meliaceae	16	28.9
Terminalia randii	Combretaceae	8	13.3
Terminalia superba	Combretaceae	12	20
Total	3	60	

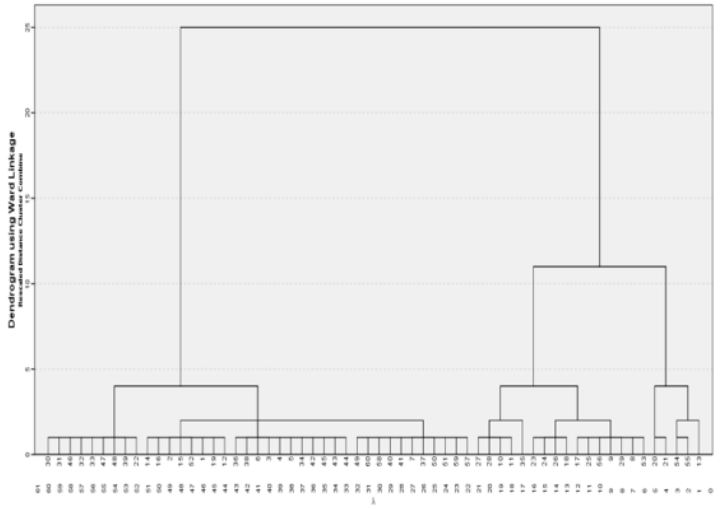

Fig. 3. Ward linkage dendrogram of the trees species dataset

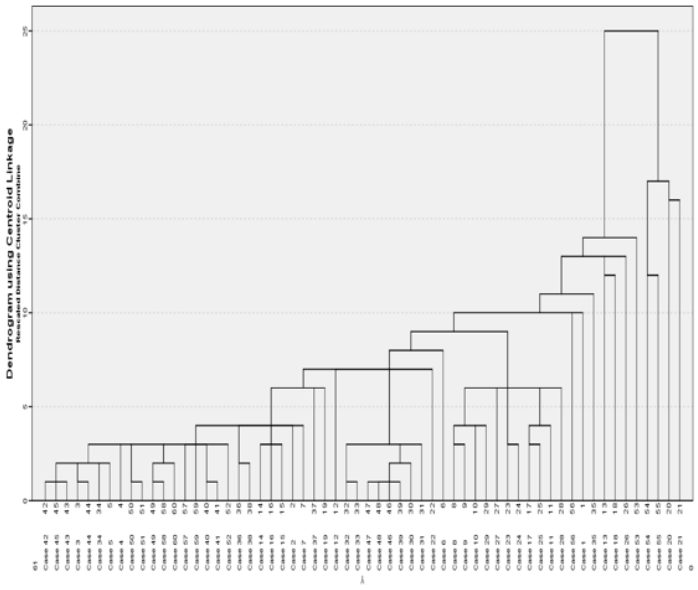

Fig. 4. Centroid linkage dendrogram of the trees species dataset

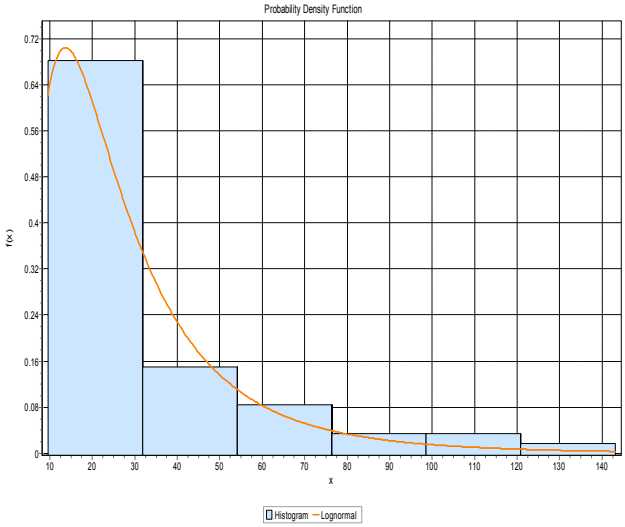

Fig. 5. Tree diameter class distribution

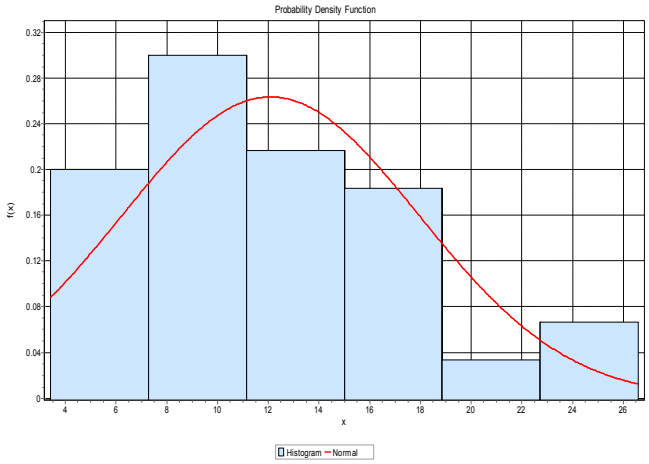

Fig. 6. Trees species classification by total height

Tree species classification is an essential aspect of the forest ecosystem and is also fundamental to tropical forest biodiversity. However, there is little or no baseline information documented on tree species composition and classification in Akure – ofosu forest reserve, Akure, Ondo State, Nigeria. The seven tree species (Table 1) encountered in the secondary forest are of environmental, economic and social values to rural communities and national development. The trees species richness recorded in this study is lower than the richness observed in similar ecosystems in Southern Nigeria. [11] reported 54 timber tree species in Akure Forest Reserve, while [12] reported 46 tropical tree species in Akure-Ofosu Forest Reserve. This very low tree density may be attributed to the large scale disturbances that had occurred in the forest, not withstanding that it is gazetted and protected by the law.

Form Fig. 3, it is evident from the dendrogram using ward linkage that the three distinct clusters revealed the three families of the sampled trees. The resulting dendrogram indicated that it is reasonable to divide the tree species into three categories based on their families. At similarity 5.0, samples 48 - 6 formed the first cluster; samples 28 - 9 formed the second cluster, while samples 20 - 13 formed the third cluster.

However, from Fig. 4, the dendrogram using centroid linkage is in four distinct clusters that did not reveal the accurate representation of the three families of the sampled trees. The first three clusters formed the three families encountered in the study area while the fourth cluster combined trees from the three families. The resulting dendrogram indicated that it is relatively reasonable to divide the tree species into three categories based on the family they belong. At similarity 5.0, samples 59 - 7 formed the first cluster; samples 32 - 31 formed the second cluster and samples 8 - 28 formed the third cluster, while the fourth cluster combined samples 17 - 21.

In Fig. 4, trees with dbh less than 30 cm occurred more frequently in the study area than trees with dbh above 30 cm. The diameter distribution irrespective of species class shows a negative exponential or an inverse J pattern, which is typical of an uneven-aged forest stand. Also, from Fig. 5, trees that fall between 8 and 10 m height occurred more frequently than trees with a height below 8 m and above 10 m, while trees that fall between 20 m and 22 m had the least total height.

5. CONCLUSION AND RECOMMENDATIONS

Human disturbances have so greatly affected trees species composition of the Akure-Ofosu Forest Reserve, with low tree density and volume attributed to the removal of large and tall trees. Management interventions (such as enrichment planting, regulated selective logging and protection of naturally regenerated germplasm) can further assist in the restoration of this ecosystem. This will ensure sustainability and the ability of the forest to continue to provide benefits for local communities while biodiversity conservation is achieved. Also, cluster analysis can be used for classifying trees species in a natural forest for proper management.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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