DECEMBER 2014

VOLUME 84 (1)

TANZANIA JOURNAL OF FORESTRY AND NATURE CONSERVATION

ISSN 2408-8129

Published by
Faculty of Forestry and Nature Conservation
Sokoine University of Agriculture
Morogoro, Tanzania

TANZANIA JOURNAL OF FORESTRY AND NATURE CONSERVATION

Background

The Faculty of Forestry and Nature Conservation of the Sokoine University of Agriculture in Morogoro, Tanzania, has inaugurated the *Tanzania Journal of Forestry and Nature Conservation*. This development has been taken in order to elevate the former publication of the then Faculty of Forestry, *Faculty of Forestry Records*, to a status of an International Journal. The last issue of the *Faculty of Forestry Records* was volume 72 and this Journal takes over beginning with volume 73. The list of the 'Records' is given at the last pages of this issue and can be ordered from the office of the Dean, using the address given under the sub-heading 'Subscription' at the bottom of this page.

Scope

The *Tanzania Journal of Forestry and Nature Conservation* accommodates the current diverse and multidisciplinary approaches towards ecosystem conservation, at national and global levels. To be published biannually, the Journal will accept research and review papers covering the technological, physical, biological, social and economic aspects of management and conservation of Tropical flora and fauna.

The Editorial Board

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Notice to authors

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About the Faculty of Forestry and Nature Conservation

The Faculty of forestry and Nature Conservation of the Sokoine University of Agriculture (SUA) attained its present status in July 1998. However, it started in 1973 as a Division of Forestry in the Faculty of Agriculture of the University of Dar es Salaam. Thereafter, it was elevated to a Faculty of Forestry in 1984 when SUA was established. SUA is located 3 km from the centre of Morogoro Municipality, which is 200km west of Dar es Salaam, along the Tanzania-Zambia highway.

There are six departments in the Faculty formed on the basis of specialisation: Departments of Forest Biology, Forest Engineering, Forest Economics, Forest Mensuration and Management, Wood Utilisation and Wildlife Management.
The Faculty maintains three training forests, one which is located at Olmotonyi, on the slopes of Mount Meru near Arusha; devoted to plantation forest management with 848 ha. The second with 320 ha is a fully protected virgin rain forest located at Mazumbai in the west Usambara Mountains devoted to mountain rain forest management. The third is the Kitulanghalo forest reserve with 500 ha located near Morogoro and devoted to the management of Miombo woodlands. These forests offer practical and research venues for both students and staff.

The Faculty offers two three-year undergraduate degrees, i.e., B.Sc. (Forestry), B.Sc. (Wildlife Management) and Bachelor of Tourism Management (BTM). These programmes have attracted students from many African countries. Post-graduate programmes: (MSc) both in Forestry and in Management of Natural Resources for Sustainable Agriculture (MNRSA) and PhD in Forestry, are also offered. These degrees are tailored to produce personnel for higher professional position in forestry, wildlife, natural resource management and administration including teaching and research. Graduate find employment in Forestry, wildlife and other environmental services in government institutions, private or non-government organizations and companies.

Entry Qualifications for all degree programmes are detailed in the SUA prospectus, but specific information related to forestry, wildlife and tourism management may be obtained from:

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FLORISTIC COMPOSITION, TREE CANOPY STRUCTURE AND REGENERATION IN A DEGRADED TROPICAL HUMID RAINFOREST IN SOUTHWEST NIGERIA

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ABSTRACT

Floristic composition, plant species diversity, tree canopy structure and regeneration were assessed in a degraded tropical humid rainforest in Nigeria using a systematic line transect sampling technique for plot demarcation. All plants in a plot were identified and classified into families while the diameters and heights of trees with diameter at breast height (Dbh) >10cm were measured. Tree basal area, total volume, density, dominance, frequency, Importance Value Index (IVI), Shannon-Weiner diversity (H^1) and Equitability Indices (E_H) were then computed. A species-area curve was used to determine the relationship between forest area and number of species encountered while tree height was used to assess canopy structure.

Eighty-three plant species belonging to 78 genera in 39 families were identified. Trees were the predominant plant form with 46 species (172 trees ha^{-1}) while 7 shrubs, 15 lianas, 13 herbs, 1 grass and 1 fern species were recorded. Tree basal area and total volume were 10.29±0.88 m^2 ha^{-1} and 22.43±1.85 m^3 ha^{-1} respectively. The tallest tree height (35m) was recorded for *Terminalia superba* while the shortest (9.3m) was *Ficus mucuso*. The three most abundant families were Fabaceae (15.9%), Sterculiaceae (9.8%) and Moraceae (7.3%) while the most dominant species were *Trema orientalis* (4%), *Terminalia superba* (4%) and *Mansonia altissima* (6.29%) with IVI of 14.92%, 14.79% and 13.73%, respectively. A high level of tree species diversity was observed with H^1 and E_H of 3.65 and 0.97 respectively. There were 29 tree species found to be naturally regenerating (seedlings and saplings) and no species was found in the emergent layer. Despite the high level of anthropogenic interference in the ecological processes, Akure–Ofosu forest reserve remains highly diverse in plant species composition and it has great potential for restoration if properly managed with silvicultural interventions such as seed supplementation and/or enrichment planting which would encourage the rapid return of the complex forest conditions.

Keywords: Natural regeneration, forest restoration, species-area curve, Akure-Ofosu Forest Reserve.

INTRODUCTION

The tropical rainforest ecosystem is known to be among the most diverse and complex species-rich ecosystems on the planet (Parthasarathy 2001; Gillespie *et al*. 2004; Anning *et al.* 2009). 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 and abundance in disturbed and fragmented tropical forests have increasingly become important economically, socially as well as for biodiversity conservation, especially with the alarming rate at which original primary forests are disappearing (Makana and Thomas 2006; Oke and Odebiyi 2007; Houehanou *et al.* 2013).

The ability of such tropical forest ecosystems to recover is limited as high and excessive logging has negative effects on the availability of quality seed germplasm for natural regeneration (Vordzogbe *et al*. 2005; Makana and Thomas 2006). Therefore, information on floristic composition and diversity as well as tree volume are essential for understanding disturbed tropical forest ecosystem dynamics (Addo-Fordjour *et al.* 2009; Houehanou *et al.* 2013). Tree diversity is particularly fundamental to total tropical rainforest biodiversity, as trees provide habitat structure and resources for other flora and fauna species. It is estimated that about 70–90% of living flora and fauna in rainforest ecosystems depend on trees for survival (Cannon *et al.* 1998; Tilman and Lehman 2001).

In Nigeria, selective logging and clear felling are the predominant methods of timber extraction from government owned forest reserves. Forest compartments are allocated to concessionaires who identify mature economic tree species, fell and extract them. These forest reserves were established with the aim of protecting samples of natural ecosystems, conservation of biodiversity, preservation of ecological processes, for scientific research and education, environmental monitoring, and maintenance of genetic resources. The management of such government reserves is governed by policies, rules and regulations enforced by State Departments of Forestry (Adekunle and Olagoke 2010; Awotoye and Adebola 2013). However, a major limitation is the paucity of information on plant species diversity in most Nigerian *in–situ* conservation areas particularly forest reserves. Also, continuous overexploitation results in fluctuation of the status of plant diversity from time to time and this threaten the livelihoods of current users (Parthasarathy 2001; Addo-Fordjour *et al.* 2009; Adekunle *et al.* 2010). The local disturbances alter the successional pattern and subsequent composition, diversity, and canopy structure of these forests (Addo-Fordjour *et al.* 2009; Oke and Odebiyi 2007).

Akure–Ofosu Forest Reserve is one of the 16 designated reserves managed by the Ondo State Ministry of Natural Resources in Nigeria. It is a tropical humid rainforest which provides renewable resources to local people, timber to markets and revenue to the government. It is one of the forest reserves that received the tropical shelterwood system of natural forest regeneration, a silvicultural treatment which was abandoned in the early 1970s. Assessing the level of unassisted secondary regeneration in this forest reserve as well as the species distribution resulting from uncontrolled selective logging will provide insights on the level of ecosystem recovery and need for its sustainable management (Adetula 2007; Ogunjemite and Oates 2011). Natural regeneration is a viable tool because it reduces the cost of regeneration after disturbance, seedlings derived *in-situ* are more adapted to adverse environmental conditions, and it enhances biodiversity conservation (Makana and Thomas 2004; Omeja *et al.* 2004; Adekunle and Olagoke 2008b).

This forest reserve is presently undergoing a lot of changes due to anthropogenic activities, especially logging and conversion of forest land to cocoa farms through encroachment. In addition, the current status of the forest reserve with regards to floristic composition, plant species diversity and natural regeneration of trees is not well known. Proper documentation of its plant resources is vital for appropriate management interventions, protection of threatened and economic species as well as biodiversity conservation. Thus, this study determined the floristic composition, plant species diversity, tree canopy structure and regeneration as well as wood volume in this degraded tropical humid rainforest.

MATERIALS AND METHODS

Study area

The Akure-Ofosu Forest Reserve is located between latitude 5° 12´and 5° 30´N, longitude 6 ° 50´and 7° 05´E (Figure 1) 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°C and 32°C while the mean daily humidity is 70% (Folayan and Bifarin 2009).

The forest reserve is dominated by broad-leaved trees that form dense layered stands which usually are above 50 m in height. The trees are mostly green throughout the year because of the retention of leaves resulting from the sufficiently high temperature and precipitation which support continuous growth all year round (Adekunle *et al*. 2013).

An assessment of the forest reserves in Ondo State in 2006 indicated that of the 41,301 ha forest cover gazetted in Akure–Ofosu, 10,275 ha had been encroached on by shifting cultivators and cocoa farmers (Adetula 2007). Thus, the major vegetation types are secondary forest, small holder cultivations and cocoa farms (Ogunjemite and Oates 2011).

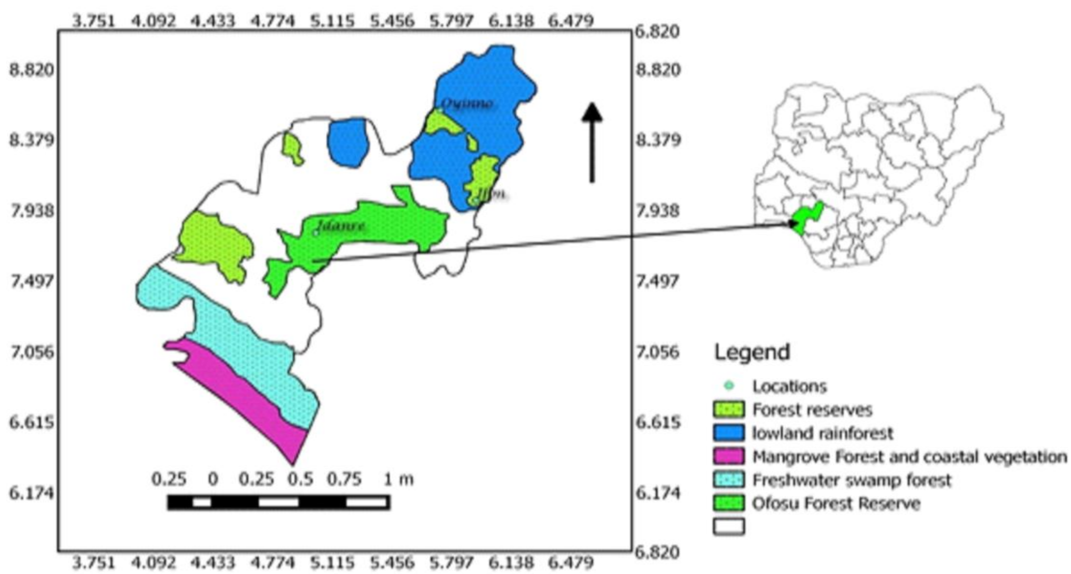

Figure 1: Map of Ondo State indicating Akure-Ofosu Forest Reserve (inset: Map of Nigeria) (Field survey, 2014)

Sample plot demarcation and plant species enumeration

Systematic sampling design (systematic line transect) was used for the laying of square plots in the study site. A point was randomly selected in the forest and then two different transects (2 km each with a distance of 500 m between them) were laid in the secondary forest and then 25 m x 25 m sample plots were laid in alternate succession along each transect at 225m intervals, making a total of 16 plots (modified from Adekunle and Olagoke 2008).

Identification and enumeration of all plant species was done within each of the demarcated sample plots. Leaf, branch and bark samples of the few species which could not be identified on the spot were collected for identification at the Forestry Herbarium Ibadan, Forestry Research Institute of Nigeria, Ibadan, Nigeria. Then, trees were classified using diameter classes as: seedlings (collar diameter < 5 cm), saplings (collar diameter: 5 – 9.9 cm), poles (Dbh ≥ 10 – 19.9cm) and mature trees Dbh ≥ 20 cm). The Dbh, diameter at the base, top, middle as well as the total height of poles and mature trees were determined using a Spiegel relaskop. Then, smaller subplots (5m x 5m) were laid at the centre of each plot to assess the population of shrubs while quadrats (1m x 1m) were used to determine herbs (Omeja *et al*. 2004).

Data Analysis

Tree basal area and volume estimation

The basal area (BA m^2) of all trees in the sample plots were calculated using Equation 1:

$$BA = \frac{\pi D^2}{4} \qquad (1)$$

Where D = Diameter at breast height (m).

The total basal area for each of the sample plots was then obtained by summing the BA of all trees in the plot while mean BA for the plots was determined by dividing the total BA by the number of trees in the sample plot. This was then scaled up to per hectare (ha) basis. In addition, the total volume of individual trees was estimated using Newton's formula (Equation 2):

$$V = \frac{H(\pi D_b^{\ 2} + 4\pi D_m^2 + \pi D_t^2)}{24} \qquad (2)$$

Where V = Volume of tree (m^3)
D_b = Diameter at the base (m),
D_m= Diameter at the middle (m), and
D_t = Diameter at the top (m) of the tree.

Total plot volumes were obtained by adding the volume of individual trees encountered in each plot and then mean plot volume was calculated. This was also scaled up to per ha basis.

Determination of floristic composition, canopy structure and diversity indices

All plant forms identified were classified into their taxonomic families to determine floristic composition. To assess the forest canopy structure, trees (Dbh≥ 10 cm) were classified into four groups based on their height: understorey (< 20 m), lower canopy (20-30 m), upper canopy (30-40 m) and emergent canopy (> 40 m). The number of tree species in each family was used for tree species diversity classification. Frequency of occurrence was obtained for tree species abundance/richness while the following diversity indices were determined:

(i) The Cottam and Curtis Important Value Index (IVI), which measures the relative importance of species was calculated for all trees as follows (Equation 3):

$$IVI = RD + RD_o + RF \quad \text{.......................................} (3)$$

Where RD = Relative Density,
RD_o = Relative Dominance, and
RF = Relative Frequency which were calculated as follows:

(ii) Species Relative Density (RD) (Equation 4):

$$RD = \left[\frac{n_i}{N}\right] \times 100\% \quad \text{.......................................} (4)$$

Where n_i = number of individuals of species i, and
N = total number of individuals in the entire sampled population.

(iii) Relative Dominance (RD_o) (Equation 5):

$$RD_O = \frac{(BA_i \times 100\%)}{\sum BA_n} \text{.......................................} (5)$$

Where BA_i = Basal Area of all individual trees belonging to a particular species i and
BA_n= Stand Basal Area.

(iv) Relative Frequency (RF) (Equation 6):

$$RF = \frac{F_i}{F_n} \times 100\% \quad \text{.......................................} (6)$$

Where F_i = Frequency of species i encountered, and
F_n = Total frequency of all species.

(v) Species diversity was obtained using Shannon-Wiener diversity index (H^1), which considers both the richness and abundance of each species in the population (Equation 7):

$$H^1 = \sum_{i=1}^{S} p_i Lnp_i \text{.......................................} (7)$$

Where S = the total number of species in the secondary forest,
p_i = the proportion of a species to the total number of plants in the forest, and
Ln = the natural logarithm.

(vi.) Species evenness (E) in the vegetation was determined using Shannon's equitability (E_H) (Equation 8):

$$E = \frac{H^1}{Ln(S)} \quad \text{.......................................} (8)$$

Where S = is the total number of species in the vegetation.

Analysis of variance revealed that there were no significant differences in the pattern of variation of data obtained from plots laid along the two transects, thus the data were pooled for variables such as number of plant species and family richness, number of trees per ha, tree diameter class distribution, basal area and total volume. A species - area curve was fitted to indicate the relationship between forest area and species richness in the forest reserve.

RESULTS

Floristic composition and tree growth parameters

A total of 83 plant species belonging to 78 genera in 39 families were identified during the study (Table 1a and b). Six plant forms (46 trees, 7 shrubs, 15 lianas, 13 herbs, 1 grass and 1 fern) were encountered in the forest reserve with trees being the most dominant and common species. There were 172 trees ha^{-1}, 2800 shrubs ha^{-1}, 90 lianas ha^{-1} and 12 herbs m^{-2} in this secondary forest.

The three highest Relative Frequencies for tree species were observed for *Trema orientalis* (5.22%), *Pterygota macrocarpa* (4.35%) and *Terminalia superba* (4.35%) while the lowest were recorded for *Celtis zenkeri* (3.48%), *Cordia millenii* (3.48%), *Ficus mucuso* (3.48%), *Musanga cecropoides* (3.48%), *Newbouldia laevis* (3.48%), *Pycnanthus angolensis* (3.48%) and *Triplochiton scleroxylon* (3.48%). The individual tree species with the highest number of stems were *Mansonia altissima* (11 trees ha^{-1}), *Pterygota macrocarpa* (7 trees ha^{-1}), *Terminalia superba* (7 trees ha^{-1}) and *Trema orientalis* (7 trees ha^{-1}).

The mean tree BA was 10.29 ± 0.88 m^2 ha^{-1}, mean tree volume was 22.43 ± 1.85 m^3 ha^{-1} while the mean tree height was 22.7 ± 0.7 m. *Terminalia superba* (35 m) was recorded as the tallest tree species while *Ficus mucuso* (9.3m) was the shortest tree species. The population structure revealed that a larger proportion of trees were in the 20 - <30 cm diameter class (45 trees) while 40 - <5 0cm diameter class contributed the highest proportion of basal area (3.63 m^2) (Figure 2).

The herbs were dominated by species such as *Alternanthera pungens*, *Chromolaena odorata*, while lianas were dominated by *Alafia barteri*, *Centrosema pubescens*, *Cissus vogelli*, *Momordica foetida* and *Parquetina nigrescens.* The shrubs that were predominant in the forest were *Alchornea laxiflora*, *Cnetis ferruginea*, and *Icacina trachantha* (Table 1b).

Table 1a Floristic composition of tree species in Akure-Ofosu Forest Reserve, Ondo State, Nigeria

Species	Family	Common Name
Afzelia pachyloba	Caesalpiniaceae	Afzelia
Albizia adianthifolia	Fabaceae	Rough-bark flat crown
Alstonia boonei	Apocynaceae	Cheesewood
Antiaris toxicaria	Moraceae	Antiaris
Blighia sapida	Sapindaceae	Akee apple
Bombax buonopozense	Bombaceae	Wild kapok
Brachestygia eurycoma	Fabaceae	Achi
Bridelia micrantha	Euphorbiaceae	Bridelia
Ceiba pentandra	Bombacaceae	White silk cotton tree
Celtis zenkeri	Celtidaceae	African celtis
Cola gigantea	Sterculiaceae	Witch's bread
Cordia millenii	Boraginaceae	Drum tree
Dialium guineensis	Fabaceae	Velvet tamarind
Dracaena arborea	Asperragaceae	Ope- kanna kanna
Entandrophragma cylindricum	Meliaceae	Tiama Mahogany
Ficus exasperata	Moraceae	Forest sandpaper fig
Ficus mucuso	Moraceae	Fig
Funtumia elastica	Apocynaceae	Rubber tree
Hollarrhena floribunda	Apocynaceae	False rubber tree
Holoptelia grandis	Ulmaceae	Orange-barked terminalia
Khaya ivorensis	Meliaceae	African Mahogany
Lovoa trichiloides	Meliaceae	African Walnut
Mansonia altissima	Sterculiaceae	Mansonia
Massularia acuminata	Rubiaceae	Orin Ijebu
Milicia excelsa	Moraceae	Iroko
Musanga cecropoides	Moraceae	Umbrella tree
Myrianthus arboreus	Moraceae	Giant yellow mulberry
Nesogodonia papaverifera	Sterculiaceae	Danta
Newbouldia laevis	Rubiaceae	Tree of life
Pentaclethera macrocarpa	Fabaceae	Oil of bean tree

Piptadeniastrum africanum	Fabaceae	Dahoma
Pouteria aningeri	Sapotaceae	Aningeria
Pterocarpus osun	Fabaceae	Camwood
Pterygota macrocarpa	Sterculiaceae	African pterygota
Pycnanthus angolensis	Myristicaceae	African nutmeg
Ricinodendron heudolotti	Euphorbiaceae	Corkwood
Spondias mombin	Anacardiaceae	Mombin plum
Sterculia oblonga	Sterculiaceae	White sterculia
Sterculia rhinopetala	Sterculiaceae	Brown sterculia
Sterculia tragacantha	Sterculiaceae	African tragacanth
Terminalia ivorensis	Sterculiaceae	Black afara
Terminalia superba	Combretaceae	White afara
Tetrapleura tetraptera	Fabaceae	Aidan tree
Trema orientalis	Ulmaceae	Pigeonwood
Triplochiton scleroxylon	Malvaceae	Obeche
Zanthoxylum zanthoxyloides	Rutaceae	Toothache bark

Table 1b: Floristic composition of other plant forms in Akure-Ofosu Forest Reserve, Ondo State, Nigeria

Species	Family	Common Name
Fern		
Arthropteris palisotii	Oleandraceae	The Lesser Creeping Fern
Herbs		
Ageratum conyzoides	Asteraceae	Billy Goat Weed
Alternanthera pungens	Amaranthaceae	Joyweed
Argemone mexicana	Papaveraceae	Mexican prickly poppy
Aspilia africana	Asteraceae	Haemorrhage plant
Chromolaena odorata	Asteraceae	Siam weed
Crotalaria retusa	Fabaceae	Rattleweed
Cyperus rotundus	Cyperaceae	Nut grass
Gloriosa superba	Colchiceae	Flame lily
Mucuna pruriens	Fabaceae	Magic Velvet bean
Scoparia dulcis	Scrophulariaceae	Sweet broom weed
Sida acuta	Malvaceae	Spiny head Sida
Sida rhumbifolia	Malvaceae	Arrowleaf Sida
Urena lobate	Icacinaceae	Caesar weed
Lianas		
Alafia barteri	Apocynaceae	Agbari-etu
Calopogium mucunoides	Fabaceae	Wild ground nut
Canthium venosum	Rubiaceae	Raisin-fruit Keetia
Centrosema pubescens	Fabaceae	Centro
Chasmanthera depedens	Menispermaceae	Chasmanthera
Cissus vogelli	Vitaceae	Stemmed vine
Desmodium gangeticum	Fabaceae	Ticktree
Dioclea reflexa	Fabaceae	Bull's eye
Dioscorea mangenotiana	Menispermaceae	Elephant's yam
Ipomea involucrata	Convolvulaceae	Morning glory weed
Momordica foetida	Cucurbitaceae	Bombo leaves
Parquetina nigrescens	Apocynaceae	Ogbo
Piper guineensis	Piperaceae	Bush pepper
Rytygynia nigerica	Rubiaceae	Elegun oko
Strychnos spinosa	Stryhnaceae	Spiny leaf monkey orange
Shrubs		
Alchornea laxiflora	Euphorbiaceae	Three-veined bead string
Cnetis ferruginea	Connaraceae	Ogbakpee
Coffea brevipes	Rubiaceae	Coffee
Icacina trachantha	Icacinaceae	Gbegbe
Napoleona imperialis	Lecythidaceae	Napoleona
Oncoba spinosa	Saliceae	Snuff-box tree
Rinorea elliotii	Volaceae	Iparoko
Grass		
Panicum maximum	Poaceae	Guinea grass

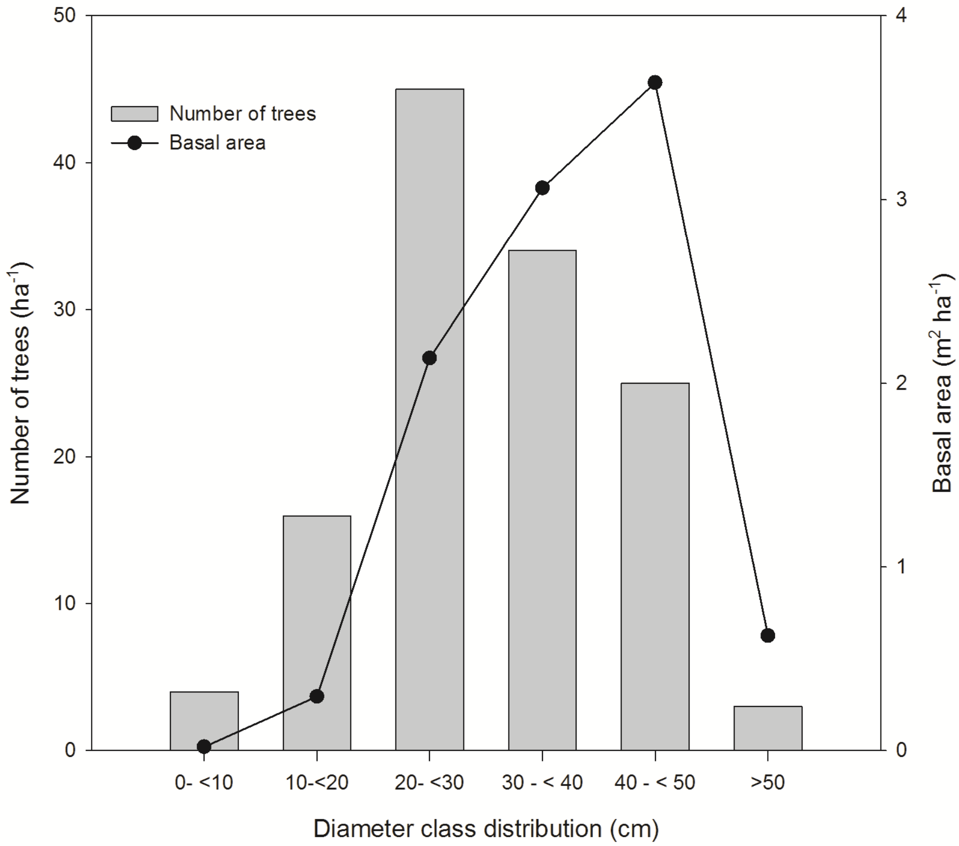

Figure 2: Tree diameter class distribution and basal area classification in Akure-Ofosu Forest Reserve, Ondo State, Nigeria (bars indicate the number of trees; thick circles indicate corresponding basal area)

Forest canopy structure and species spatial distribution

The canopy stratification revealed that 26 tree species were represented in the understorey layer (canopy height < 20 m), 34 species in the lower canopy (canopy height = 20 to 30 m), while only 4 species were found in the upper canopy (Figure 3). The emergent layer was non-existent while the lower canopy dominated the forest canopy structure accounting for more than half of the tree population (63%) in the canopy stratification (Figure 3). *Terminalia ivorensis*, *Milicia excelsa* and *Bombax buonopozense* were found only in the upper canopy layer of the forest, though naturally regenerated seedlings and saplings of these species were present on the forest floor. No tree species was represented in all three canopy layers (Table 3). The influence of continuous sampling (increased area sampled) on number of species encountered revealed additional taxa with increased sampling intensity, but this levelled off to a horizontal asymptote at some point with the maximum number of species at 83, although the slope of the species-area curve did not approach zero (Figure 4). The species-area curve produced a good fit (R^2 = 0.97, P < 0.0001).

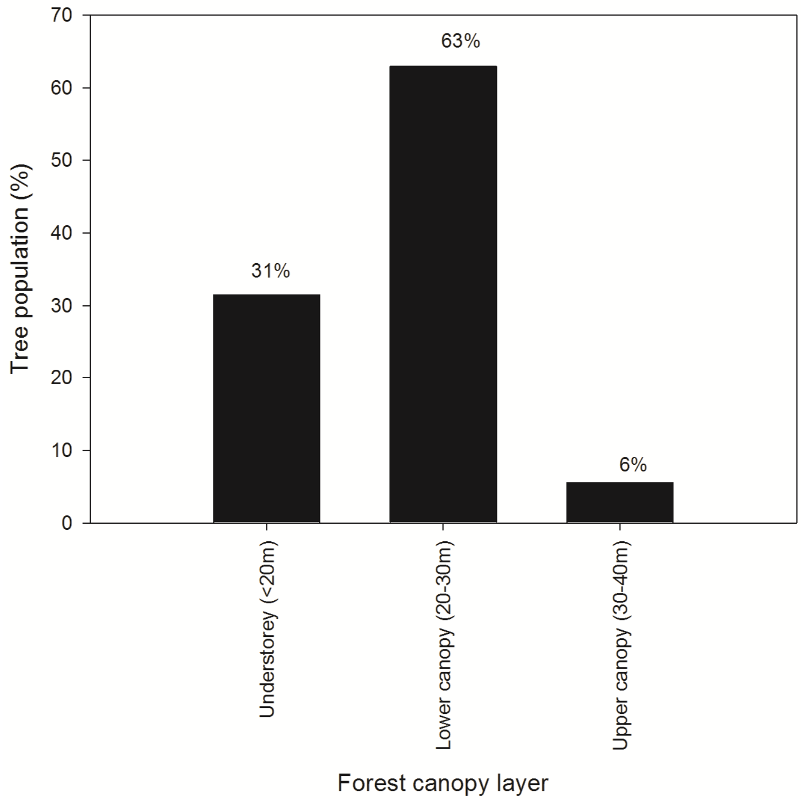

Figure 3: Tree population and canopy structure in Akure-Ofosu Forest Reserve, Ondo State Nigeria

Table 2: Tree species present in the various forest strata of Akure-Ofosu Forest Reserve, Ondo State, Nigeria. (+: indicates species presence, -: indicates species absence)

Tree species	Understorey (<20m)	Lower Canopy (20-30m)	Upper canopy (30-40m)
Afzelia pachyloba	+	-	-
Alstonea boonei	+	+	-
Antiaris africana	+	-	-
Blighia sapida	+	-	-
Bombax buonopozense	-	-	+
Brachystegia eurycoma	+	+	-
Bridelia micrantha	+	-	-
Ceiba petandra	+	+	-
Celtis zenkeri	+	+	-
Cola gigantea	+	+	-
Cordia millenii	+	+	-
Dalium guineensis	+	+	-
Dracaena arboreus	+	+	-
Entandroghrahma cylindricum	+	+	-
Ficus mucuso	+	+	-
Ficus exasperata	+	-	-
Funtumia elastic	-	+	-
Hollarrhena floribunda	-	+	-
Holoptelia grandis	-	+	-
Lovoa trichiloides	-	+	-
Mansonia altissima	+	+	-
Milicia excelsa	-	-	+
Musanga cecropoides	+	+	-

Myrianthus arboreus	-	+	-
Nesogodonia papaverifera	-	+	-
Newbouldia laevis	+	+	-
Pentaclethera macrocarpa	-	+	-
Piptadeniastrum africanum	-	+	-
Pouteria aningeri	-	+	-
Pterocarpus osun	+	+	-
Pterygota macrocarpa	+	+	-
Pyncnanthus angolensis	+	+	-
Ricinodendron heudolotti	+	+	-
Spondias mombin	+	+	-
Sterculia oblonga	-	+	-
Sterculia rhinopetala	+	+	-
Sterculia tragacantha	-	+	-
Terminalia ivorensis	-	-	+
Terminalia superba	-	+	+
Trema orientalis	-	+	-
Tetrapleura tetaptera	+	-	-
Triplochiton scleroxylon	+	+	-
Zanthoxyllum zanthoxyloides	-	+	-

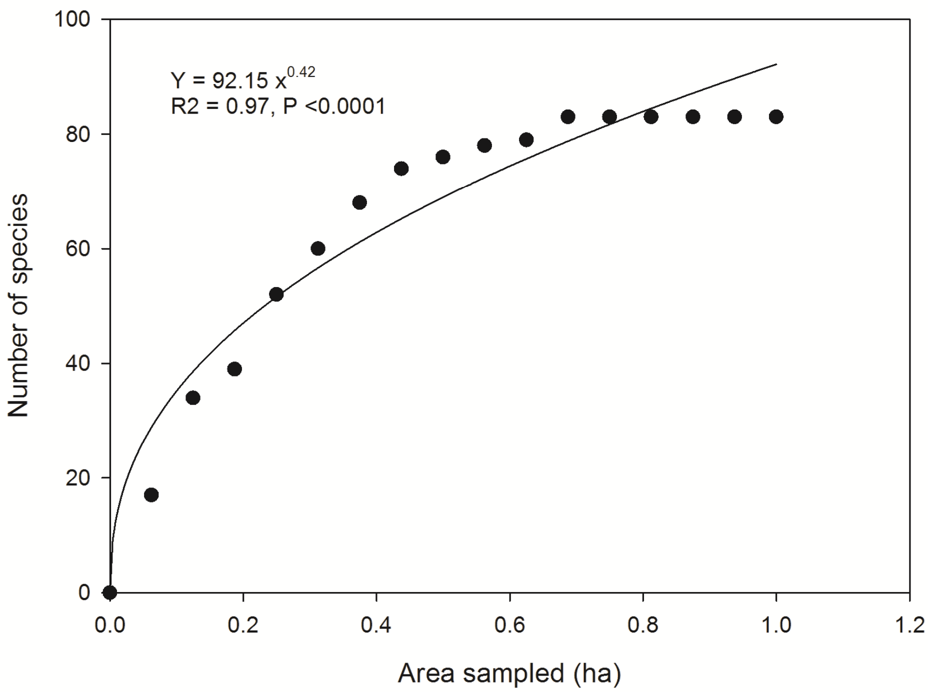

Figure 4: Plant species /area curve indicating increased taxa presence with increased sampling at Akure-Ofosu Forest Reserve, Ondo State, Nigeria

Family dominance, tree species diversity and natural regeneration

Fabaceae, Sterculiaceae and Moraceae were the most diverse and abundant families contributing 15.9%, 9.8% and 7.3%, respectively, to the entire plant species population (Figure 5). The IVI for tree species revealed that *Cola gigantea*, *Mansonia altissima*, *Pterygota macrocarpa*, *Terminalia superba* and *Trema orientalis* were the most dominant species with respective values obtained as: 10.57%, 13.73%, 11.69%, 14.79% and 14.92% (Table 3). On the other hand, the five rarest tree species were *Afzelia pachyloba* (2.0%), *Blighia sapida* (2.25%), *Lovoa trichiloides* (2.54%), *Terminalia ivorensis* (2.83%) and *Tetrapleura tetraptera* (2.39%). The Shannon Weiner diversity Index (H^1) was 3.65 while the species evenness (E_H) was 0.97. There were 29 tree species in the natural regeneration flora (seedlings and saplings) encountered during the study (Table 3). Of these, *Albizia adianthifolia*, *Massularia acuminata* and *Khaya ivorensis* were not present in the adult tree population, while *Mansonia altissima* was the most predominant seedling/sapling encountered during sampling.

Table 3: Tree species diversity indices for Akure-Ofosu Forest Reserve, Ondo State Nigeria

Name of species	BA (m^2)	RD_o (%)	RF (%)	RD (%)	IVI	H^1
Afzelia pachyloba	0.05	0.56	0.87	0.57	2.00	-0.03
*Alstonea boonei**	0.28	2.82	2.61	2.86	8.29	-0.10
*Antiaris africana**	0.08	0.86	1.74	2.29	4.88	-0.09
*Blighia sapida**	0.02	0.24	0.87	1.14	2.25	-0.05
*Bombax buonopozense**	0.35	3.54	2.61	2.29	8.43	-0.09
*Brachstygia eurycoma**	0.09	0.89	2.61	2.29	5.79	-0.09
*Bridelia micrantha**	0.09	0.95	2.61	2.86	6.41	-0.10
*Ceiba petandra**	0.31	3.15	1.74	2.86	7.75	-0.10
*Celtis zenkeri**	0.27	2.77	3.48	3.43	9.67	-0.12
*Cola gigantea**	0.44	4.53	2.61	3.43	10.57	-0.12
*Cordia millenii**	0.26	2.65	3.48	2.86	8.98	-0.10
*Dialium guineensis**	0.20	2.02	2.61	2.86	7.49	-0.10
*Dracaena arboreus**	0.11	1.12	1.74	1.71	4.58	-0.07
*Entandrophragma cylindricum**	0.06	0.66	1.74	1.71	4.11	-0.07
*Ficus exasperata**	0.21	2.13	2.61	2.29	7.02	-0.09
Ficus mucuso	0.23	2.40	3.48	2.29	8.16	-0.09
Funtumia elastica	0.34	3.44	2.61	1.71	7.76	-0.07
*Hollarrhena floribunda**	0.21	2.14	1.74	1.71	5.59	-0.07
Holoptelia grandis	0.22	2.22	1.74	1.14	5.11	-0.05
*Lovoa trichiloides**	0.05	0.53	0.87	1.14	2.54	-0.05
*Mansonia altissima**	0.56	5.71	1.74	6.29	13.73	-0.17
*Milicia excelsa**	0.12	1.27	0.87	1.14	3.28	-0.05
Musanga cecropoides	0.38	3.90	3.48	2.86	10.23	-0.10
*Myrianthus arboreus**	0.23	2.34	1.74	1.71	5.80	-0.07
Nesogodonia papaverifera	0.31	3.15	2.61	1.71	7.48	-0.07
*Newbouldia laevis**	0.33	3.40	3.48	3.43	10.31	-0.12
Pentaclethra macrocarpa	0.18	1.89	2.61	1.71	6.21	-0.07
Piptadeniastrum africanum	0.22	2.21	0.87	1.14	4.22	-0.05
Pouteria aningeri	0.14	1.42	1.74	3.43	6.59	-0.12
Pterocarpus osun	0.26	2.70	2.61	1.71	7.02	-0.07
*Pterygota macrocarpa**	0.33	3.35	4.35	4.00	11.69	-0.13
*Pycnanthus angolensis**	0.22	2.23	3.48	3.43	9.14	-0.12
Ricinodendron heudolotti	0.33	3.35	2.61	1.71	7.67	-0.07
*Spondias mombin**	0.13	1.35	1.74	2.86	5.95	-0.10
Sterculia oblonga	0.06	0.61	1.74	1.14	3.49	-0.05
Sterculia rhinopetala	0.29	2.94	1.74	1.71	6.39	-0.07
*Sterculia tragacantha**	0.05	0.49	1.74	1.71	3.94	-0.07
*Terminalia ivorensis**	0.08	0.82	0.87	1.14	2.83	-0.05
Terminalia superba	0.63	6.44	4.35	4.00	14.79	-0.13
Tetrapleura tetraptera	0.09	0.95	0.87	0.57	2.39	-0.03
*Trema orientalis**	0.56	5.70	5.22	4.00	14.92	-0.13
*Triplochiton scleroxylon**	0.25	2.59	3.48	3.43	9.49	-0.12
*Zanthoxylum zantholoides**	0.16	1.59	1.74	1.71	5.04	-0.07

(Trees Dbh> 10cm, *: indicate tree species that had naturally regenerating flora (seedlings and/or saplings) on the forest floor)

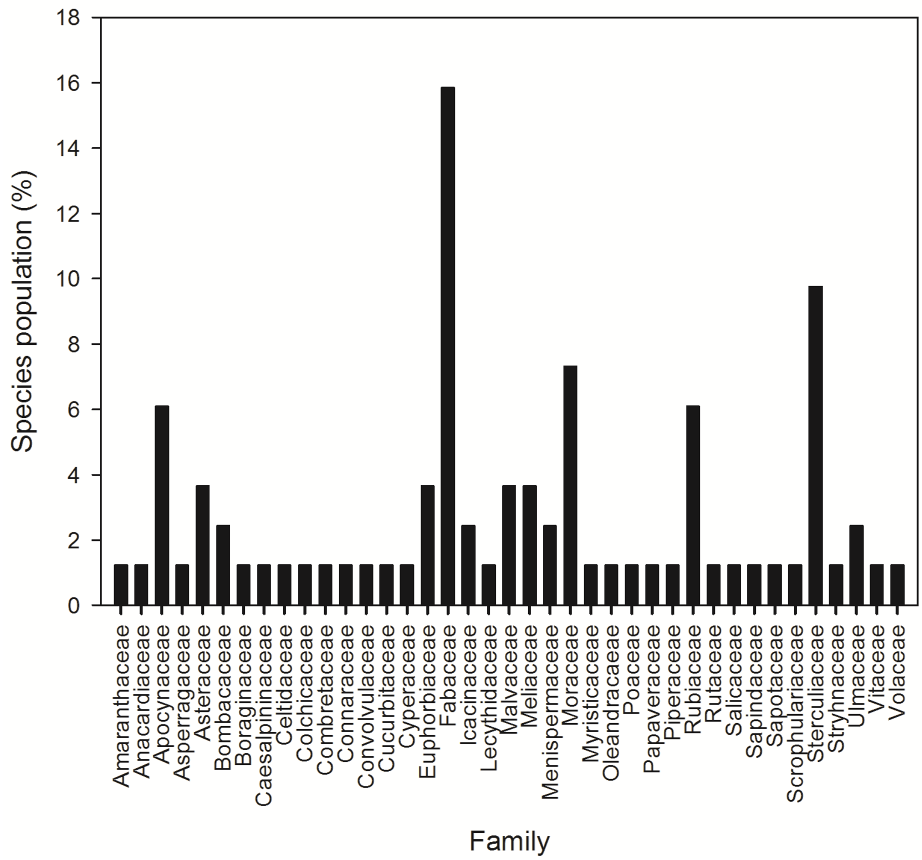

Figure 5: Family dominance of plant species in Akure-Ofosu Forest Reserve, Ondo State, Nigeria

DISCUSSION

Floristic composition

Plant species richness, which is the number of species per unit area, has gained global interest, because, quantifying patterns of species richness in degraded tropical forests provide an insight into the ability of the forest vegetation to recover (Gillespie *et al*. 2004). Hence, regular assessment of the floristic composition and structure of exploited forest ecosystems is instrumental in the management, sustainability and conservation of such areas (Addo-Fordjour *et al*. 2009; Cannon *et al*. 1998). However, only a few studies have monitored species diversity and recovery in degraded tropical rainforest of Nigeria, especially when it is forests that supply the largest amount of timber to the wood industry in the country (Adekunle and Olagoke 2008b; Adekunle and Olagoke 2010; Adekunle *et al*. 2013).

In Akure-Ofosu Forest Reserve, a major environmental change had been created by indiscriminate logging, which resulted in fragmentation, gap formation as well as negative impacts on animal and plant species composition and richness (Adetula 2007; Folayan and Bifarin 2009; Ogunjemite and Oates 2011). This excessive opening of canopy gaps usually stimulates growth of dense, herbaceous and woody lianas which in turn suppress tree regeneration (Omeja *et al*. 2004). The 83 plant species (Table 1a and b) encountered in the secondary forest have environmental, economic and social values to rural communities and national development. Of great significance is the fact that 46 tropical tree species were identified in this forest reserve revealing the biodiverse nature of the ecosystem even though the tree species richness recorded in this study was lower than the richness observed in similar ecosystems in southern Nigeria. For example, Adekunle *et al*. (2013) reported 54 timber species in Akure Forest Reserve, southwest Nigeria. Nevertheless, the floristic composition compared favourably with many other tropical forests in Africa. For instance, Vordzogbe *et al.* (2005) and Anning *et al.* (2008) reported 80 species ha^{-1} and 37 species ha^{-1}respectively in a moist semi-deciduous forest in Ghana while Addo-Fourdjour *et al.* (2009) observed a lower value (48 species ha^{-1}) in the Tinte Bepo Forest Reserve, also in Ghana. As a matter of fact species richness could be as high as 125 species ha^{-1} in less disturbed tropical forest as reported by Parthasarathy (2001) in Sengaltheri forest, Western Ghats of India.

Trees constituted the predominant (55%) life form in the forest reserve while grass and fern were the least. *Cola gigantea* which had a frequency of 8% had been earlier reported to have a high abundance in similar forest types (Adekunle *et al*. 2008; 2013) while threatened species such as *Afzelia pachyloba* and *Khaya ivorensis* had low (0.53% each)frequencies as observed by previous studies (Awotoye and Adebola 2013). Nonetheless, the abundance of trees in the secondary forest suggest that despite anthropogenic disturbances, tree species continue to dominate plant structures in tropical rainforest (Gillespie *et al*. 2004; Makana and Thomas 2006; Adekunle *et al*. 2013). Moreover, the tree density (172 trees ha^{-1}) was low indicating sparse and dwindling forest cover. For instance, Adekunle and Olagoke (2008) reported tree density of 609 trees ha^{-1} and 541 trees ha^{-1} in Legge (Oluwa Forest Reserve) and Atijere (Eba Forest Reserve) around bitumen producing areas in the same region. This low tree density could be attributed to the large scale disturbances that had occurred in the forest despite the fact that it is gazetted and protected by law.

There were 13 different herb species and 15 liana species some of which are invasive e.g. *Chromolaena odorata.* These identified herbs and lianas are common plant species occupying the forest floor of tropical rain forests in southwest Nigeria, especially where there is good light penetration (Adekunle and Olagoke 2010). However, the proliferation of these herbs and lianas could limit natural tree regeneration and development. These conditions may further result into serious land degradation and loss of tree population if harvesting is not controlled.

Tree growth parameters
Majority of the trees were in the lower diameter classes (10-30 cm) (Figure 2) with the number of individual trees decreasing with increasing diameter class. Also, the BA (10.29 ± 0.88 m^2 ha^{-1}) was low when compared with other tropical rainforest. For example, Addo-Fordjour *et al.* (2009) recorded BA as high as 54.2 ± 4.9 m^2 ha^{-1} in a secondary rainforest. The felling of mature trees for timber, clearing of land for farming, collection of fuelwood and other non-timber forest products, as well as farmers encroachment most likely have affected species quantity and quality in the forest reserve (Akinyemi *et al.* 2002). Therefore, BA did not favourably compare with recommended mean tree BA (25 m^2 ha^{-1}) for fully stocked forests (Alder and Abayomi 1994). Past studies in disturbed tropical rainforest have documented higher BA values. For example, Parthasarathy (2001) reported 25.5 m^2ha^{-1} for tropical humid forest in Rio Xingu, Brazil; Akinyemi *et al.* (2002) obtained BA of 25.5 m^2 ha^{-1} at OniGambari forest Reserve in Nigeria while Adekunle and Olagoke (2008) obtained 26.69 m^2 ha^{-1} for forests around bitumen producing areas of southwest

Nigeria. However, the estimated BA is similar to that reported for highly disturbed and degraded forests in Nigeria. For example, Omotoso free area forest had BA of 12.13 m^2 ha^{-1}; Ode-Aye forest: 16.73m^2 ha^{-1} and Omo Forest Reserve: 16.84 m^2 ha^{-1}; all degraded rainforest in southwest Nigeria (Adekunle *et al.* 2002; Adekunle and Olagoke 2008a). Similarly, the tree volume (22.43±1.85 m^3 ha^{-1}) was relatively low in consonance with the diameter distribution, and implies that most of the trees are not of harvestable size.

The high frequency of trees in the 10-30cm diameter classes coupled with the absence of trees in >50 cm diameter category, is further evidence of the high level of disturbance and degradation that had occurred in the past (Addo-Fordjour *et al*. 2009). The absence of large trees explains the low BA and volume recorded in this forest. However, the somewhat inverted J-curve, where the abundance decreases with increasing diameter (Fig. 2), is an indication of good regeneration of the constituent species and probably suggests the potential capacity of this forest community to recover over a space of time (Nath *et al*. 2005; Adekunle and Olagoke 2008a).

Usually the combination of selective logging and agricultural clearing (especially cocoa farming encroachment) would result in the degradation and impoverishment of natural forests. Secondary forests are generally seen as having much lower conservation value than mature forests. They generally have fewer tree species, are dominated by widespread pioneer trees, and have a simpler structure (Figure 3 and Table 3) (Makana and Thomas 2006). In Akure-Ofosu secondary forest, BA was highly influenced by the large presence of fast growing pioneer species. It is suggested that early pioneer tree species which do not persist beyond the senescence of the initial cohort portend great potential for early recovery (Aide *et al*. 2000). Hence, the presence of early successional and short-lived tree species (such as *Musanga cecropoides* and *Trema orientalis*) as well as keystone species (*Ficus* spp.) may be a positive indication of the health and future recovery of the forest. Also, volume recovery would be enhanced and supported by long-lived early colonizers such as *Albizia pachyloba* and *Alstonia boonei* (Lambert and Marshall 1991; Makana and Thomas 2006; Addo-Fordjour *et al.* 2009).

Forest canopy structure and species spatial distribution

Tree height distribution did not follow the expected pattern for the vertical structure of a rainforest, with the lower canopy containing 63% of the total tree population and no trees in the emergent layer (Fig. 3). This reveals the high impact of logging (disturbance and degradation) and probably the state of recovery of the tree population. The number of trees in the lower layers (understorey and lower canopies) were higher than those in the upper strata (upper canopy and emergent layers) suggesting the young age of the secondary forest (Addo-Fordjour *et al.* 2009; Anning *et al*. 2009).

Understanding how and why species richness varies over space and time is a major endeavour in ecology; with some authors suggesting that species richness is greater in tropical forest than other forest communities, regardless of plot size (Parthasarathy 2001; Gillespie *et al.* 2004; Adekunle *et al.* 2013). The species-area relationship helps in the design of nature reserves or to predict extinctions during biotic collapse: i.e. the loss of species due to reduction in habitat area. The species-area relationship asymptotically approach or level off at the maximum value of richness (Lomolino 2000; Hambler and Canney 2013). Thus, the shape of the species-area accumulation curve has been used to infer biological processes such as disturbance, competition, and division of niches. The species-area curve holds much promise as a tool in conservation biology, because by fitting a function to the species-area curve, one could potentially extrapolate to an area much larger than the area sampled (Palmer and White 1994). Thus, the species accumulation curve remains an important guide for plot and stand size studies that aim to portray representative species composition (Mueller-Dombois and Ellenberg 1974). In this study, though the sampled area was small compared to the entire forest area, it was homogeneous and the plant species were well represented. The study showed that a minimum area of 0.69 ha was relatively sufficient to obtain a maximum representation of the species diversity and floristic similarity among sample plots (Fig. 4; R^2= 0.97). This further implies that the quantitative sampling of the vegetation was representative.

Family dominance, tree species diversity and natural regeneration

Previous studies (Akinyemi *et al.* 2002; Onyekwelu *et al.* 2006; Adekunle *et al.* 2013) have reported the dominance of members of the Euphorbiaceae, Meliaceae, Moraceae, Sterculiaceae and Ulmaceae families in the Nigerian tropical forests. This study concurs with this assertion as the dominant families were Fabaceae (15.9%) Moraceae (7.3%) and Sterculiaceae (9.8%). The Important Value Index (IVI) which combines the attributes of relative density, relative frequency and relative dominance (Table 3); measures the relative importance of a species in a forest (Anning *et al.* 2009). In this study, IVI for tree species revealed that *Cola gigantea, Mansonia altissima, Pterygota macrocarpa, Terminalia superba* and *Trema orientalis were* the five most dominant species with respective value indices as 10.57%, 13.73%, 11.69%, 14.79% and 14.92%. On the other hand, the five rarest tree species were *Afzelia pachyloba* (2.0%), *Blighia sapida* (2.25%), *Lovoa trichiloides* (2.54%), *Terminalia ivorensis* (2.83%) and *Tetrapleura tetraptera* (2.39%). *Trema orientalis* (which had the highest IVI), is a pioneer species found in clearings and abandoned farmlands. The species is considered to have immediate potential for the rehabilitation of poor exposed soils. It has a short lifespan indicating that it would eventually be outcompeted in the succession stages as ecosystem recovery progresses in the forest. On the other hand *Terminalia superba* and *Mansonia altissima* are light demanding, hardwood timber species which are in high demand in the market. The high economic values attached to them make them future targets for selective logging with attendant implications for the expected recovery.

The Shannon diversity index (H^1) has been used for characterizing community diversity in tropical forest ecosystems (Parthasarathy 2001; Guo *et al.* 2003; Onyekwelu *et al.* 2005; Adekunle and Olagoke 2013). The value of H^1 obtained for the forest reserve (3.65) was slightly higher than the general limit of 1.5–3.5 (Kent and Coker 1992), but similar to 3.89 and 4.02 reported by Parthasarathy (2001) and Adekunle and Olagoke (2008), respectively. Also, the Shannon's equitability index (E_H = 0.97) was higher than 0.66 reported by Onyekwelu *et al.* (2005) for an inviolate biosphere reserve (Queen's Forest) and 0.86 reported by Adekunle and Olagoke (2008), for natural forest around bitumen producing sites in Nigeria. The closeness of the diversity indices obtained in this study to other studies in similar ecosystems, reveal the similarities in tree species distribution patterns.

The ability of secondary forests to return to the complex, species-rich primary forest conditions is generally slow, partly due to the limited availability of seeds of tree species (Makana and Thomas 2006).

Therefore, the reforestation of any site through natural regeneration requires planning and follow-through. In some cases, specific management and harvest practices can be selected to promote natural regeneration and minimize the impacts on the ecosystem. This study revealed that three important economic tree species (*Albizia adianthifolia*, *Massularia acuminata* and *Khaya ivorensis*) were not present in the adult tree population. Future surveys of the advance regeneration will be needed to ensure that such plants are undamaged and healthy enough to compete with shrubs, herbs and grasses and become part of the forest succession. This is necessary because the timber industry in Nigeria has grown beyond the forests' regeneration capacity, with associated poor conventional harvesting practices and the destruction of forest ecosystems during logging operations (Adekunle and Olagoke 2010).

Implications for conservation and future management

The high level of plant species diversity in degraded forest suggests that there is a need to place an economic value on the forest vegetation and other biological diversity. Failure to institute that could result in complete degradation and the truncation of forest restoration, especially with the continuous pressure from resource utilization and drivers of deforestation (Adekunle and Olagoke 2008). In this study, threatened and endangered species identified included; *Afzelia africana*, *Alstonia boonei*, *Antiaris africana*, *Brachystegia eurycoma*, *Cordia millenii*, *Dialium guineensis*, *Khaya ivorensis*, *Mansonia altissima*, *Milicia excelsa*, *Nesogordonia papaverifera*, *Pterygota macrocarpa*, *Sterculia rhinopetala*, *Terminalia superba* and *Triplochiton scleroxylon* (Onyekwelu *et al.* 2006; Akinyemi *et al.* 2002; Adekunle *et al.* 2013). Thus, there is an urgent need for the implementation of conservation strategies that would encourage the protection and restoration of such species.

The secondary forests, growing after selective logging and initial clearing of primary forests for shifting cultivation, contain a large number of small diameter trees. The tendency for rapid forest recovery is probably due to low land-use intensity, seed fall from remnant trees and the ability of this remnant trees to attract seed dispersers. Therefore, the structural characteristics of degraded forest such as Akure-Ofosu Forest Reserve indicate the capacity for it to reach levels found in mature forest, early, during succession, if the disturbance is minimized (Aide *et al.* 2000; Makana and Thomas 2006).

However, a disturbing finding is that only 29 out of the 46 tree species were found in the natural regeneration flora on the forest floor (Table 2). This pattern of reduced abundance for tree regeneration in degraded forests is a common phenomenon in the tropical forests of Africa and Latin America. It has been attributed to low availability of seeds in the soil bank resulting from the removal of most large reproductive trees; creation of small forest gaps due to single-tree removal; high levels of seed and seedling predation; as well as rapid invasion of gaps by herbaceous and liana vegetation (Hall *et al.* 2003; Makana and Thomas 2004; Hall 2008).

Forest recovery is possible only if secondary forests are protected from repeated clearing because the return of the species composition of secondary vegetation to assemblages similar to that of old-growth forests may require over 100 years due to limited seed availability and dispersal, and slow growth of mature forest tree species (Makana and Thomas 2004; 2006). Human intervention in the recovery process may therefore, be desirable in Akure-Ofosu Forest Reserve, with silvicultural interventions such as seed supplementation and/or enrichment planting encouraging the rapid return of the complex and species-rich mature forest conditions.

CONCLUSIONS AND RECOMMENDATIONS

Human disturbances have influenced the canopy and structural complexity of the Akure-Ofosu Forest Reserve, with the removal of large and tall trees resulting in low tree density and volume, the absence of an emergent layer as well as gap creation. However, despite the degradation, high floristic composition and tree species diversity were observed in the forest. Furthermore, the presence of pioneer species (such as *Trema orientalis*) and other naturally regenerated seedlings and saplings, indicate that the process of ecosystem recovery had commenced in the forest. The observed potential for natural recovery opens an avenue for reconciling conservation, environmental, social and economic demands on this degraded forest. Management interventions (such as enrichment planting, regulated selective logging and protection of naturally regenerating 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.

ACKNOWLEDGEMENTS

The authors wish to thank staff and management of the Ondo State Ministry of Natural Resources, Nigeria for providing technical support and relevant information that made the research work successful. We also wish to thank the reviewers and editors for their constructive inputs and contributions, which helped to improve the manuscript.

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