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Measurement of tree diversity in the Nigerian rainforest

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The diversity of trees 5 cm in diameter and above at breast height was studied at five sites within the Nigerian rainforest. The sites were Gambari, Oban, Omo, Owan and Sapoba forest reserves. Diversity was measured in terms of similarity and heterogeneity and explored at beta and gamma levels. Over 315 species were encountered during the study. In terms of species richness, there are 80, 226, 163, 137 and 159 species in Gambari, Oban, Omo, Owan and Sapoba, respectively. The occurrence of the species showed that, while 26 species are common to all the sites, 62, 17, 15, 8 and 6 species are restricted to Oban, Omo, Sapoba, Gambari and Owan, respectively. Ordination by detrended correspondence analysis indicated gradients along the first two axes. The first axis reflecting rainfall gradient which decreases from Oban through to Sapoba, Owan and Gambari. The second axis showed a separation of Omo, and Owan and Sapoba. This suggests a gradient of soil parent materials, the former site is on the basement complex while the latter is on the cretaceous rock. It is suggested that each forest should be managed based on its particular characteristics, such as species composition and abundance. Thus, forests with high species diversity but fewer numbers of individuals, such as in Oban, should be earmarked for conservation while species-rich forests with relatively more economic species, as in Sapoba and Omo, should be managed for sustained timber production. Floristically poor forest, such as those in Gambari and Owan, should be converted to plantations of fast growing species but with care taken to avoid exposing such sites to soil erosion.

Keywords: Nigerian rainforest; diversity indices; ordination; management and conservation.

Introduction

The moist tropical forest (also called tropical rainforest) has been described as the richest and most heterogenous of the world's ecosystems. There are however variations in the number and abundance of species between the world's three main tropical rainforest blocks – the American, the Asian and the African. This variation is also present in the sub-regional blocks, thus, the West African, the Congo Basin, the East African and the Madagascar sub-regional tropical rainforests are structurally different from one another. This variation persists even within the Nigerian rainforest. It therefore becomes necessary to explore the extent of this variation to enhance characterization of the forest types based on species composition for management and scientific prescriptions. Knowing the number and density of individual species will assist sustainable harvesting of the forest resources.

Previous studies (Redhead, 1971; Hall, 1977; Lowe, personal communication) have qualitatively classified the Nigerian rainforest based on rainfall distribution, soil–rainfall

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interaction and floristic composition. The present study aimed to complement these studies. Also the inclusion of Gambari data in this study from previous work of Ojo (1990) serves to further explore the extent and quantitatively describe the floristic variations within the Nigerian rainforest.

Species diversity is generated by species interaction such as competition and niche diversification (Pianka, 1966; Bada, 1984) which are greatly manifested in the tropics due to high humidity and temperature. The two components of diversity – species richness (the number of species in the community) and eveness/heterogeneity (distribution of individuals among species) have been used to describe species diversity at three levels (Peet, 1974; Wolda, 1983; Gauch, 1986). The three levels are alpha (or within site), beta (or between sites) and gamma (or entire landscape diversities). In this study, diversity in terms of species richness and heterogenity will be applied and explored at the beta and gamma levels.

Materials and methods

THE STUDY AREA

The Nigerian tropical rainforest (otherwise called high forest) is located between latitudes 4° and 9° North and stretches east–west of the country, extending to about 250 km inland from the coast (Fig. 1) and covers a total area of 170 000 km^2 (Sutter, 1979). However, the present extent of the Nigerian high forest is less than this due to deforestation which has been variously estimated at 5% annually between 1976 and 1980 (Lanly, 1982); 5% between 1981 and 1985 (WRI, 1989); 250 km^2 per annum (Umeh, 1989).

The rainforest is dissected by many perennial streams and rivers. The most important being the River Niger. Others are the Ogun, Oshun, Shasha (Omo), Oluwa, Siluko, Ethiope, Anambra, Imo, Uyo, Cross and Kwa Rivers. Five main geological formations can be recognized (Dessauvagie, 1975) within the rainforest area. These are the basement complex found in the northern part; The eocene in the extreme west, the consolidated and unconsolidated cretaceous rock below the basement complex, the holocene formation along the coast and a patch of igneous rock at the eastern edge of the rainforest area (Fig. 2). The mean annual rainfall is generally high and variable. It ranges from about 1000 mm to as high as 3070 mm. Two rainfall gradients are distinguished: increasing from west to east and decreasing from south to north. Daily mean temperature is, however, relatively constant throughout the rainforest area and throughout the year, rarely less than 26°C and hardly above 27°C.

Five sites have been chosen within the rainforest area representing major climatic, geological and edaphic variations. These are the Gambari, Oban, Omo, Owan and Sapoba forest reserves. Oban forest is at the south-eastern end with an annual rainfall of over 3068 mm on haplic nitisols underlain by pre-cambrian and igneous rocks. Owan and Sapoba are at the central position with lower mean annual rainfall (Owan, 1416 mm and Sapoba 2130 mm) on rhodic nitisols. While Owan is underlain by consolidated cretaceous rock, Sapoba has unconsolidated cretaceous rock as parent material (Fig. 2), hence the latter is more sandy than the former. Gambari and Omo forests are towards the western part of the rainforest with Gambari more westerly and northerly than Omo.

The mean annual rainfall is about 1400 mm and 2000 mm in Gambari and Omo,

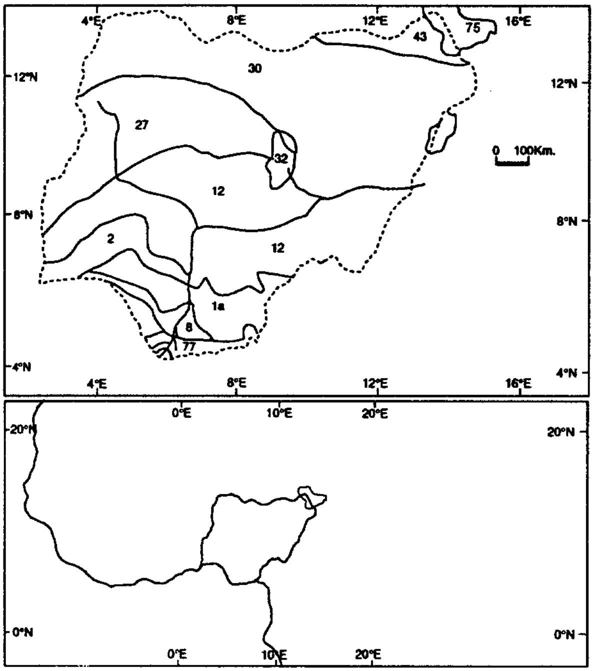

Figure 1. Map of Nigeria showing major vegetation types. (White, 1983). Below is a map of West Africa showing the location of Nigeria. 1a = Lowland rainforest: wetter type (Guineo-Congolian); 2 = lowland rainforest: drier type (Guineo-Congolian); 8 = swamp forest; 12 = mosaic of lowland rainforest: *Isoberlinia*; woodland and secondary grassland; 27 = Sudanian woodland with abundant *Isoberlinia*; 30 = Sudanian undifferentiated woodland with abundant of; *Isoberlinia*; 32 = Jos Plateau mosaic; 43 = Sahel *Acacia* wooded grassland and deciduous bushland; 75 = herbaceous swamp and aquatic vegetation; 77 = mangrove.

respectively. While crystalline rock of undifferentiated basement complex is the parent material in Gambari, Omo is on ferric luvisols underlain by basement complex. These sites also conform with the classification of the Nigerian rainforest by Hall (personal communications in Ojo, 1990) and Redhead (1971) which classified the Nigerian rainforest based on rainfall intensity and floristic composition into four main groups: (1) the south-eastern, (2) the central, (3) the wet western and (4) the dry western. Thus Oban is in the south-eastern group, Owan and Sapoba are in the central group, Omo is in the wet western group and Gambari is in the dry western group.

BASIC DATA

Data for the study except those from Gambari are from the High Forest Monitoring Plots project of the reserved forest in southern Nigeria between 1985 and 1989 produced by the Federal Department of Forestry, Nigeria. These consist of 80 one-hectare permanent sample plots (Oban, 20; Omo, 26; Owan, 13; and Sapoba, 21). Data for Gambari, comprising 16 sample plots, were extracted from the Forestry Research Institute of Nigeria's (FRIN) records of tree measurements in the reserve between 1962 and 1977.

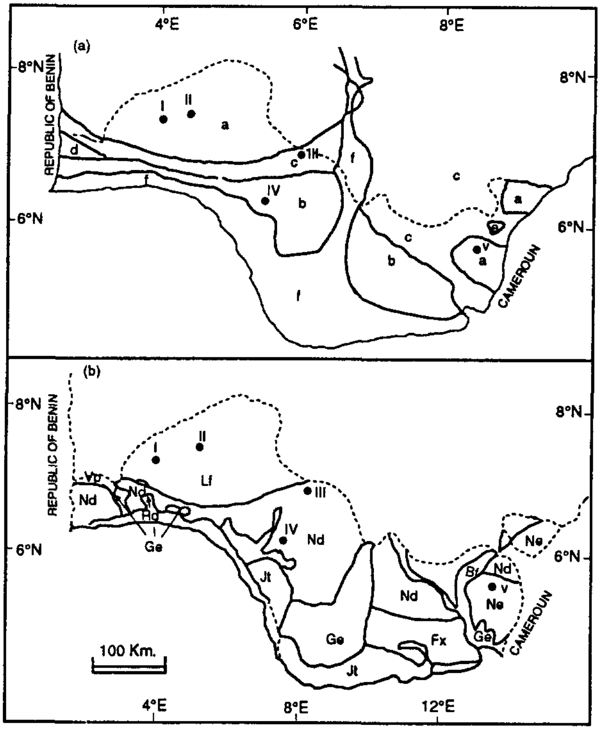

Figure 2. Map of the rainforest area of southern Nigeria showing: (a) Major geological formations (Dessauvagie, 1975), and (b) Major soil types (FAO-UNESCO, 1977, 1984). *Geology*: a = basement complex; b = cretaceous: unconsolidated; c = cretaceous: consolidated (clay, shale); d = eocene; e = igneous; f = holocene: deltaic and lagoonal deposits. *Soil*: bf = ferralic cambisol; fx = xanthic feralsol; ge = gleysol; jt = thionic fluvisol; lf = ferric luvisol; nd = rhodic nitisol; ne = haplic nitisol; rd = regosol; vp = pellic vertisol. *The sites*: I = Gambari; II = Omo; III = Owan; IV = Sapoba; V = Oban.

DATA ANALYSES

The following analyses were carried out to explore the extent of diversity within the rainforest area.

Measurement of species diversity

Diversity indices were calculated for each site at three tree sizes: small trees, 5–20 cm diameter at breast height (dbh); medium trees, 20–40 cm dbh and large trees, of 40 cm dbh and above using Simpson's diversity index. Simpson's diversity index is a measure of heterogeneity of a site taking into consideration the number of species and the density of individual species. It is expressed as:

$$I = \frac{N(N-1)}{\sum_{i=1}^{q} (n_i(n_i-1))}$$

where: I = Simpson diversity index,
N = total number of individuals enumerated,
q = number of different species enumerated,
n = number of individuals of ith species enumerated.

The higher the value of I, the more heterogenous the site is.

Measurement of similarity between sites

Similarity between any two sites was calculated using the Simpson index of similarity (K_{simp}) expressed as:

$$K_{simp} = \frac{a}{\min((a+b)(a+c))}$$

where: a = number of species present in both sites,
b = number of species present in site 1 but absent in site 2,
c = number of species present in site 2 but absent in site 1.

Ordination analysis

This is to ascertain floristic gradient and continuity within the rainforest area thereby arranging the sites and species in such a way that similar sites in terms of species composition and density are arranged close together and dissimilar sites are far apart. For this purpose, a table showing species × stand was drawn up for all trees of 5 cm dbh and above per plot for all the sites. The table was subjected to detrended correspondence analysis (DCA) (Hill, 1979; Ter Braak, 1988) using default options of the CANOCO program (Ter Braak, 1988).

RESULTS

Species composition and diversity

There were 315 species encountered in all three tree sizes from all five sites during the study. In terms of species richness, Oban has the highest number of species (226) decreasing through Omo to Sapoba, Owan and Gambari with 163, 159, 137 and 80 species, respectively (Table 1). There is however variation in this trend for each of the size classes. While Oban has the highest number of species in the small sized trees with 171 species, the highest number of species in the medium and large trees were found in Sapoba and Omo, respectively. The Gambari forest has the least number of species in all the size classes. The diversity indices are highest for Oban in both small and large trees, while Sapoba has the highest value in the medium trees. Gambari has the lowest values of diversity indices in the medium and large trees size classes.

Three categories of species are identifiable: the 'universal' species present in all the sites, the site specific species and species which occur in two or more sites but not in all the sites. Only the first two categories are of interest in this study. There are 26 universal species which include *Antiaris toxicaria*, *Alstonia boonei*, *Monodora myristica*,

Table 1. Diversity indices and species richness (number of species per site (in parenthesis) in different tree size classes (diameter at breast height) at five locations in the Nigerian rainforest

Sites	Size classes (cm)			
	5–20	20–40	>40	All classes
Gambari	19.82	14.30	10.91	
	(37)	(52)	(50)	(80)
Oban	23.72	28.63	38.67	
	(171)	(75)	(74)	(226)
Omo	16.69	18.72	34.96	
	(121)	(73)	(86)	(163)
Owan	16.97	26.71	28.82	
	(85)	(76)	(72)	(137)
Sapoba	41.89	49.48	24.33	
	(142)	(96)	(87)	(159)

Musanga cecropioides, *Strombosia pustulata* and *Staudtia stipitata* (see Appendix 1) (Nomenclature follows Keay, 1989).

The number of species specific to each site are indicated in the main diagonal of Table 2. Oban has the highest number of such species (62), decreasing through Omo (17), to Sapoba (15), Gambari (8) and Owan (6). These include *Anisophyllea laurina*, *Autranella congolensis*, *Coelocaryon preussii*, *Cola lepidota*, *Cola rostrata*, *Cassipourea gummifera*, *Coula edulis*, *Homalium sarcopetalum*, *Monopetalanthus* sp., *Strombosia glaucescens* and *Trichoscypha arborea* in Oban; *Albizia gummifera*, *Balanites wilsoniana*, *Omphalocarpum procerum* and *Trichilia emetica* in Sapoba; *Chrysophyllum pruniformes*, *Claoxylon hexandrum*, *Mitragyna stipulosa* and *Polysphaeria arbuscula* in Omo; *Aphania senegalensis*, *Conopharyngia ogea*, *Erythrina addisoniae* and *Ouratea* sp. in Gambari and

Table 2. Number of species common between sites and corresponding Simpson's similarity indices (in parenthesis) at five locations in the Nigerian rainforest. Figures in the main diagonal are the number of species restricted to each site

	Gambari	Oban	Omo	Owan	Sapoba
Gambari	**8**	53	58	44	48
		(0.67)	(0.73)	(0.55)	(0.60)
Oban		**62**	110	107	112
			(0.67)	(0.78)	(0.70)
Omo			**17**	96	102
				(0.70)	(0.64)
Owan				**6**	103
					(0.75)
Sapoba					**15**

Angylocalyx zenkeri, *Celtis brownii*, *Cola ficifolia* and *Swartzia fistuloides* in Owan (Appendix 1).

The number of species common between adjacent sites and their corresponding similarity indices are also presented in Table 2. Table 2 also shows that Oban has the highest number of species common between it and other sites followed by Sapoba, Omo, Owan and Gambari. There is a relationship in the trend of similarity indices and the relative location/position and distance of the sites to one another (Oban–Owan–Sapoba–Omo–Gambari) (Fig. 2) in such a way that closer sites have higher similarity indices than more distant sites. Thus, Oban–Owan (0.73), Owan–Sapoba (0.75), Omo–Gambari (0.73), but Owan–Gambari (0.55) and Oban–Gambari (0.67) (Table 2). However, the low value, 0.64, between Omo and Sapoba is an exception to this trend.

Site and species ordinations

The site ordination (Fig. 3) indicates a discontinuous gradient along both the first and second axes. The first (horizontal) axis shows a gradient separating Oban on the negative side of the axis, next Owan and Sapoba are together, Omo is in the central position and Gambari is at the positive end of the axis. This is clearly a rainfall gradient in which rainfall decreases from Oban through Owan/Sapoba and Omo to Gambari. The second (vertical) axis also shows a discontinuous gradient with Omo at the positive and the other sites at the negative ends. The difference between Omo and Owan/Sapoba sites can also be attributed to the difference in the soil and parent materials. While the former is on ferric luvisols of basement complex rock, the latter are on rhodic nitisols of cretaceous rocks. The species ordination diagram (Fig. 4) follows the same pattern as site ordination but with continuous gradients along the two axes. Superimposition of the species ordination diagram on the site ordination diagram gives an insight into the species with optimum abundance in each site, that is, the axis in which the species are located. It can therefore be inferred that *Uapaca* sp., *Calpocalyx dinklagei*, *Memecylon guineense*, *Dictyandra arborescens* have optimum abundance in Oban, *Chrysophyllum pruniformes*, *Christana africana*, *Ficus mucoso*, *Homalium viridiflorum* and *Drypetes chevalieri* are most abundant in Omo, *Coffea* sp., *Albizia gummifera*, *Antrocaryon micraster* and *Trichilia megalantha* are more abundant in Sapoba and *Aningeria robusta*, *Conopparyngia ogea*, *Morus mesozygia*, *Erythrina addisoniae* and *Casearia barteri* have optimum abundance in the Gambari forest reserve.

Discussion and conclusion

Various analyses carried out in this study indicate clear variation in the species composition in different parts of the rainforest area. It is obvious that, while the Oban forest is the richest floristically, the Gambari forest is the most impoverished. The fact that all the analyses indicated that there is a gradient of floristic richness from the western to the eastern parts of the forest zone may be attributed to climatic/geological and management factors. In spite of the low rainfall in the western part of the rainforest area, the soil here is poorer in terms of nutrients and other organic matter (Ojo, 1990). This nutrient deficiency is a major cause of floristic impoverishment. Furthermore, the higher rainfall and temperature which are features of the tropical environment, which have been said to be responsible for diversity of the tropical forests (Richards, 1952; Bruenig, 1986), may be responsible for the floristic gradient with diversity decreasing from high to low rainfall areas. The geological gradient from igneous rock in the east to the ferric luvisols in the west

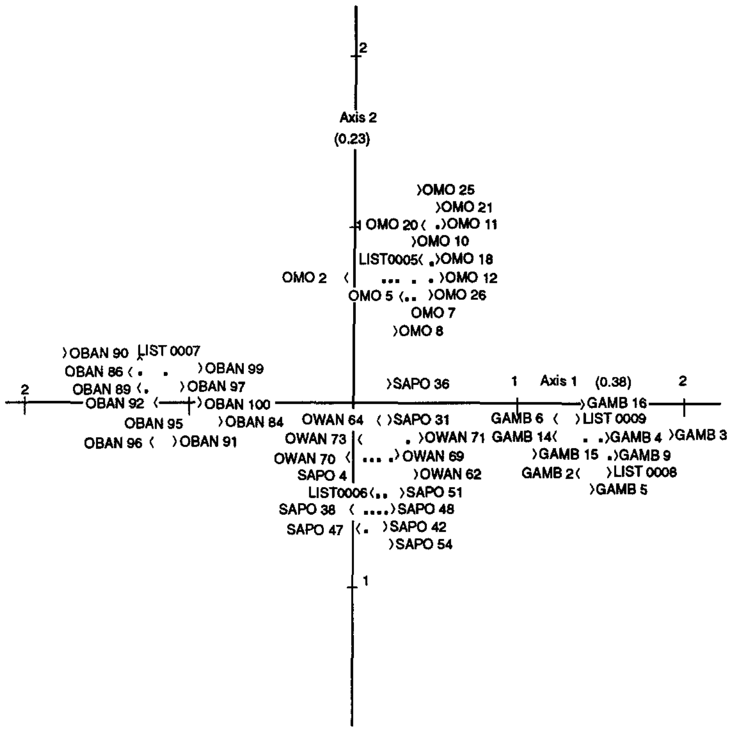

Figure 3. Stand ordination by detrended correspondence analysis (DCA) of tree species > 5 cm diameter at breast height at five sites within the tropical rainforest of southern Nigeria. The sites abbreviated on the diagram are Gambari (Gamb), Oban, Omo, Owan and Sapoba (Sapo) forest reserves. Dots on ordination diagram represent locations of sites too close to be plotted. List numbers refer to positions where two or more stands are located. Figures in brackets are eigen values of the respective axes. Ordination diagram represents 76% (Axis 1, 47%; Axis 2, 29%) of variance accounted for by the first four ordination axes. Stands in respective list number are as follows: list 5 = Omo 15, Omo 16; list 6 = Sapo 46, Sapo 49; list 7 = Oban 81, Oban 88; list 8 = Gamb 1, Gamb 11; list 9 = Gamb 8, Gamb 13.

is another factor responsible for the floristic gradient as the former is richer in nutrient base than the latter and this has been shown clearly by previous study (Hall, 1977; Ojo, 1990).

Data on environmental variables are not available. However, based on previous study in these areas, it has been suggested that differences observed in species diversity are not simply due to phytogeographical effects but that they are related to the underlying edaphic factors (ferrallitic or ferruginous tropical soils; now nitisol and luvisol, respectively; Fig. 2) and rainfall (Hall, 1977; Ola-Adams and Hall, 1987). Hall (1977) sub-divided the ferrallitic soil (nitisol) groups on the basis of geographical location, into western, central and south-eastern sub-groups. Oban belongs to the south-eastern subgroup, and Owan and Sapoba to the central sub-group. These correspond to the rhodic nitisol and haplic nitisol, respectively. The ferruginous soils (ferric luvisol) were grouped into wet and dry sub-groups; Omo belonging to the wet while Gambari belongs to the dry sub-groups.

In the ferralitic soils, there is a very high proportion of coarse sand and a very low clay content. This soil type seldom contains any stone or gravel. Weathering is more advanced

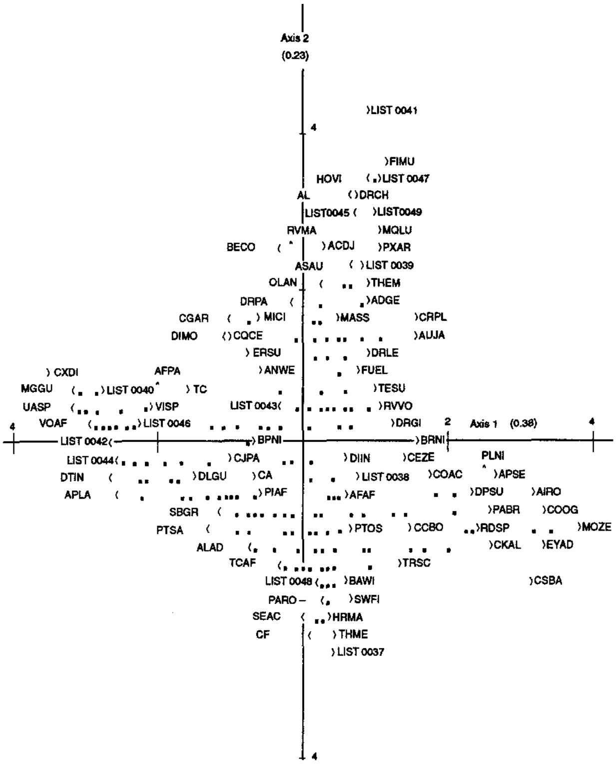

Figure 4. Species ordination by detrended correspondence analysis (DCA) of tree species >5 cm diameter at breast height at five sites within the tropical rainforest of southern Nigeria. The sites are Gambari, Oban, Omo, Owan and Sapoba forest reserves. Full names of species abbreviations are provided in Appendix 2. Dots on ordination diagram represent locations of sites too close to be plotted. List numbers refer to positions where two or more stands are located. Species in respective list numbers are given as annexe to this figure. Figures in brackets are eigen values of the respective axes. Ordination diagram represents 76% (Axis 1, 47%; Axis 2, 29%) of variance accounted for by the first four ordination axes.

Lists of items and corresponding species: List 1 = ADLA, BUCO; List 2 = ADVO, COPA, DUMA, JUSE, PYMI, UVSP; List 3 = AGZE, PTMI; List 4 = ATMA, GUCE, HPGR; List 5 = AUKE, GLBR; List 6 = BE, THLA; List 7 = BLWE, SOGR; List 8 = BNBR, PTOS; List 9 = BQAN, ELGU; List 10 = BREUI, KLGA; List 11 = BTFI, CYGA; List 12 = BTNI, ENAN; List 13 = CAVU, FIER, HIBA, PRCL; List 14 = CCPR, SNTR, CCPR, SNTR; List 15 = CDMA, FUAF; List 16 = CIMI, HNKL, MAAL; List 17 = CK, POOL; List 18 = COHI, LPAL; List 19 = COLE, DHGL, DOZE, EDCA; List 20 = CORO, MLTH; List 21 = CPGU, CUED, KNGA; List 22 = DCED, ENCA; List 23 = DDAF, MP, OUAL, SMTA; List 24 = DGCA, KHIV; List 25 = DIDE, HOLE; List 26 = DRGO, MIST; List 27 = DTSE, PKBI; List 28 = DX, SBPU; List 29 = DYBL, PZAF, SYMA, TSSP; List 30 = EREX, PPST, TCOB; List 31 = EXMA, ISCA, SHAR; List 32 = FAXA, HOMO; List 33 = FIEX, MNMY; List 34 = GCBR, MTAL, PEBU, PUMA, RHCO; List 35 = OXFO, STTR; List 36 = THGI, THHE; List 37 = ALGU, AYMI; List 38 = ANAF, CBPE; List 39 = ASCO, CASU, DRAF; List 40 = AUCO, NSST, PWTU, SBGR; List 41 = CKPR, CSAF; List 42 = CRTA, CZGL, DNTR; List 43 = DIPI, RNOB; List 44 = DIVI, SDPR; List 45 = DRMO, ERIV; List 46 = DTMA, HOSA, PBST, SGGA; List 47 = FIGO, KIAF; List 48 = GOBA, HOAF, ONGO; List 49 = MCPA, RVEM.

in the ferrallitic soils and continued nutrient availability depends on the maintenance of nutrient cycling. The ferruginous tropical soils, particularly those derived from the basement complex rocks, contain weatherable minerals and may be considered to have greater fertility than the ferrallitic soil, except in the case of Oban's soil which has igneous rock as its parent material.

Sub-division of forests based on soil-type further revealed a relationship between forest and rainfall variations. Even though Gambari and Omo are on ferric luvisol derived from basement complex, there is variation in the amount of rainfall. While Gambari receives only about 1223 mm of annual rainfall, Omo receives over 2000 mm per year. Similarly, there is considerable variation in the amount of rainfall received by the nitisol sub-group: Oban (3036 mm), Sapoba (2300 mm) and Owan (1416 mm). The variation observed between Owan and Sapoba could be due to differences in soil texture. Although Owan and Sapoba are both on rhodic nitisol, the soil in Sapoba is sandier than that at Owan and is generally flatter than the undulating ground in Owan. Consequently, Owan's soil is more subject to erosion than that of Sapoba. The variations observed between Oban on one hand and Owan and Sapoba on the other can be related to different soil types and parent materials. While Oban has haplic nitisol of igneous rock parent material, Owan and Sapoba have rhodic nitisol of cretaceous rock parent material, the former being on consolidated rock and the latter on unconsolidated rock (Fig. 2).

Ola-Adams and Hall (1987) observed that typical trees growing on ferrasols of lower nutrient status were replaced by species of ferric luvisols, especially members of sterculiaceae, on soils of superior nutrient status along a drainage line from the western to the eastern ends in natural inviolate plots at Akure Forest Reserve, Nigeria.

The length of the ordinate axis gradient measured in standard deviation (SD) units is a reflection of the extent of variability between the sites along the axis. The first axis gradient length of 4 SD (−2 to +2) indicates a high difference in floristic composition between extreme plots. Species present at one end of the gradient are not likely to be present at the other (Hill, 1979). This is confirmed in this study by the fact that the least number of species common between Oban and any other site is in Gambari (53) against 107, 110 and 112 species in Owan, Omo and Sapoba, respectively (Table 2). The second axis, however, has a slightly shorter length indicating less variation between Omo and Owan but higher variation between Omo and Sapoba.

In the past, most forestry activities early in the century were concentrated in the western part of the country where the Sapoba, Owan, Omo and Gambari forests are located. In fact, the first sets of forest reserves were situated at Mamu, part of Gambari forest reserve (Oseni and Abayomi, 1973). Tree exploitation in these reserves dates back to the 1890s. However, intensive forest exploitation did not start in Oban until the late 1960s. This intensive forest management in the western part of the country could have been responsible for the disappearance of some of the species and hence the reduced floristic richness.

In addition to the above, a plausible reason for the higher floristic richness of the Oban forest has been attributed to it being on igneous rock parent material, an extension of the Korup National park in Cameroun (Hall, 1977) which is one of the most floristically rich forests in Africa.

The forest management implications of the floristic diversity of the Nigerian rainforest is that each forest type needs to be treated with different silvicultual methods and no two forest types may be suitable for the same silvicultural prescription. Each forest type needs to be treated according to its species composition and abundance. For example, in spite of the floristic richness of the Oban forest, there are fewer individuals of these species and fewer merchantable trees than in the Omo and Sapoba forests (Ojo, 1990). Therefore, while Omo and Sapoba forests are suitable for management for timber purposes, extraction of the few exploitable timber species in Oban will cause much damage to the residual smaller trees which are far more numerous. The low density of individual species in Oban predisposes it to species extinction, moreover, the high biological diversity makes it very suitable for conservation. Luckily, part of Oban forest has now been constituted a National Park. The relative species impoverishment of Gambari forest in this study is a result of intensive silvicultural management in the last century which led to the conversion of most of the forest to monoculture plantations of fast growing species such as *Tectona grandis* (teak) and *Triplochiton scleroxylon*. Despite low species diversity and a paucity of 'economic' species in the Owan forest, and as a result of its poor soil nutrients and fragile terrain (Ojo, 1990), it will be ecologically unwise to subject the forest to intensive timber exploitation as this will lead to soil degradation.

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Appendix 1.

Species most peculiar or whose abundance are optimum in the respective forest reserves, moist forest of southern Nigeria.

ALL SITES

Antiaris toxicaria
Alstonia boonei
Blighia sapida
Trilepisium madagascariense
Ceiba pentandra
Milicia excelsa
Discoglypremna caloneura
Drypetes gilgiana
Entandrophragma angolense
Enantia chlorantha
Fagara macrophylla
Funtumia elastica
Guarea cedrata
Hannoa klaineana
Homalium molle
Khaya ivorensis
Macaranga barteri
Microdesmis puberula
Monodora myristica
Musanga cecropioides
Piptadeniastrum africanum
Pycnanthus angolensis
Rinorea oblongifolia
Strombosia pustulata
Sterculia tragacantha
Staudtia stipitata

OMO

Albizia (others)
Chrysophyllum pruniformes
Christiana africana
Claoxylon hexandrum
Drypetes chevalieri
Drypetes molunduana
Ficus goliath
Ficus mucuso
Hildegardia barteri
Homalium viridiflorum
Irvingia smithii
Kigelia africana
Macaranga paxii
Mitragyna stipulosa
Morinda lucida
Polysphaeria arbuscula
Rauvolfia emetica

SAPOBA

Albizia gummifera
Aubrevillea kerstingii
Antrocaryon micraster
Balanites wilsoniana
Blighia welwitschii
Coffea
Harungana madagascariensis
Khaya anthotheca
Lonchocarpus sericeus
Maesopsis eminii
Omphalocarpum procerum
Parinari robusta

Stereospermum
Sorindeia grandifolia
Trichilia emetica

OWAN

Angylocalyx zenkeri
Celtis brownii
Cola ficifolia
Mansonia altissima
Pterocarpus mildbraedii
Swartzia fistuloides

GAMBARI

Aphania senegalensis
Aningeria robusta
Conopharyngia ogea
Cuviera acutifloras
Erythrina addisoniae
Morus mesozygia
Ouratea Sp.
Pachystelia brevipes

OBAN

Antidesma vogelianum
Afzelia pachyloba
Anisophyllea laurina
Autranella congolensis
Brenania brieyi
Coelocaryon preussii
Celtis (others)
Cola lepidota
Cola rostrata
Cassipourea gummifera
Crateranthus talbotii
Coula edulis
Calpocalyx dinklagei
Caloncoba glauca
Didelotia africana
Dichostemma glaucescens
Diospyros viridicans
Diogoa zenkeri
Dictyandra involucrata
Detum macrocarpum
Detarium senegalense
Dasylepis blackii
Erismadelphus exsul
Erythroxylum mannii
Glyphaea brevis
Glossocalyx staudtii
Hymenodictyon pachyantha
Homalium sarcopetalum
Isolona campanulata
Julbernardia seretii
Klaineanthus gaboniae
Memecylon guineense
Millettia thonningii
Malacantha alnifolia
Monopetalanthus sp
Nauclea vanderguchtii
Nothospondias staudtii
Oubaguia alata
Oubaguia laxiflora
Oncoba spinosa
Parkia bicolor
Pachypodanthium staudtii
Pycnocoma macrophylla
Pseudospondias microcarpa
Pterocarpus osun
Pausinystalia macroceras
Placodiscus turbinatus
Pycnanthus microcephalus
Plagiostyles africana
Rhaptopetalum coriaceum
Strombosia glaucescens
Spondianthus preussii
Sacoglottis gabonensis
Schrebera arborea
Scaphopetalum talbotii
Scyphocephalium mannii
Treculia obovoidea
Trichoscypha arborea
Trichoscypha sp
Uvariastrum sp
Uvariodendron sp

Appendix 2.

Species codes and their scientific names in the rainforest of Southern Nigeria.

Code	Species Name	Code	Species Name
ABFL	Allanblackia floribunda	ACNI	Acacia nilotica
ACDJ	Anthocleista djalonensis	ACNO	Anthocleista spp.

Code	Species Name	Code	Species Name
ADDI	Adansonia digitata	BNBR	Brenania brieyi
ADGE	Aidia genipiflora	BOAE	Borassus aethiopum
ADLA	Antidesma laciniatum	BOBR	Bombax brevicuspe
ADME	Antidesma membranaceum	BOBU	Bombax buonopozense
ADVO	Antidesma vogelianum	BPNI	Baphia nitida
AELE	Anogeissus leiocarpus	BPPU	Baphia pubescens
AFAF	Afzelia africana	BQAN	Trilepisium madagascariense
AFBE	Afzelia bella	BREU	Brachystegia eurycoma
APSC	Aphania senegalensis	BRKE	Brachystegia kennedyi
AFBI	Afzelia bipindensis	BRNI	Brachystegia nigerica
AFPA	Afzelia pachyloba	BSMA	Beilschmiedia mannii
AGZE	Angylocalyx zenkeri	BTFI	Barteria fistulosa
AIRO	Aningeria robusta	BTNI	Barteria nigritiana
AL	Albizia (others)	BUCO	Buchholzia coriacea
ALAD	Albizia adianthifolia	BYPA	Butyrospermum paradoxum
ALFE	Albizia ferruginea	CA	Canthium (others)
ALGU	Albizia gummifera	CASU	Canthium subcordatum
ALZY	Albizia zygia	CAVU	Canthium vulgare
AMPT	Amphimas pterocarpoides	CBPE	Ceiba pentandra
ANAF	Antiaris africana	CCBO	Coelocaryon botryoides
ANWE	Antiaris welwitschii	CCPR	Coelocaryon preussii
AOMA	Anonidium mannii	CDMA	Combretodendron macrocarpum
APKL	Anopyxis klaineana	CE	Celtis (others)
APLA	Anisophyllea laurina	CEBR	Celtis brownii
ARSO	Araliopsis soyauxii	CEMI	Celtis mildbraedii
ASAU	Anthostema aubryanum	CEZE	Celtis zenkeri
ASBO	Alstonia boonei	CF	Coffea
ASCO	Alstonia congensis	CGAR	Cyrtogonone argentea
ATFR	Anthonotha fragrans	CHEX	Milicia excelsa
ATMA	Anthonotha macrophylla	CIMI	Copaifera mildbraedii
ATOB	Anthonotha obanensis	CJPA	Corynanthe pachyceras
AUCO	Autranella congolensis	CK	Chrysophyllum (others)
AUJA	Aulacocalyx jasminifolia	CKAL	Chrysophyllum albidum
AUKE	Aubrevillea kerstingii	CKPR	Chrysophyllum pruniforme
AUPL	Aubrevillea platycarpa	CLPA	Cleistopholis patens
AYKL	Antrocaryon klaineanum	CMHA	Cynometra sp
AYMI	Antrocaryon micraster	CR	Croton sp
AZIN	Azadirachta indica	CMME	Cynometra megalophylla
BATO	Baillonella toxisperma	CNSC	Canarium schweinfurthii
BAWI	Balanites wilsoniana	COAC	Cola acuminata
BDGR	Bridelia grandis	COOG	Conopharyngia ogea
BDMI	Bridelia micrantha	COFI	Cola ficifolia
BE	Berlinia spp.	COGI	Cola gigantea
BEAU	Berlinia auriculata	COHI	Cola hispida
BECO	Berlinia confusa	COLA	Cola laurifolia
BKAF	Burkea africana	COLE	Cola lepidota
BLSA	Blighia sapida	COME	Cola megalophylla
BLUN	Blighia unijugata	COMI	Cola millenii
BLWE	Blighia welwitschii	CONI	Cola nitida

Code	Species Name	Code	Species Name
COPA	Cola pachycarpa	DRGI	Drypetes gilgiana
CORO	Cola rostrata	DRGO	Drypetes gossweileri
COVE	Cola verticillata	DRLE	Drypetes leonensis
CPGU	Cassipourea gummifera	DRMO	Drypetes molunduana
CPPR	Carapa procera	DRPA	Drypetes paxii
CQCE	Craterispermum cerinanthum	DR	Drypetes spp
CRPL	Cordia platythyrsa	DSBE	Distemonanthus benthamianus
CRTA	Crateranthus talbotii	DTAR	Dictyandra arborescens
CSAF	Christiana africana	DTIN	Dictyandra involucrata
CSBA	Casearia barteri	DTMA	Detarium macrocarpum
CSMA	Camptostylus mannii	DTSE	Detarium senegalense
CSSI	Cassia sieberiana	DUMA	Duboscia macrocarpa
CTAL	Cathormion altissimum	DX	Dracaena
CTEN	Ctenolophon englerianus	DYBL	Dasylepis blackii
CUED	Coula edulis	ECMA	Eriocoelum macrocarpum
CVAD	Crateva adansonii	EDCA	Endodesmia calophylloides
CUAC	Cuviera acutifloras	EKSE	Ekebergia senegalensis
CXDI	Calpocalyx dinklagei	ELGU	Elaeis guineensis
CXHE	Claoxylon hexandrum	ENAN	Entandrophragma angolense
CYGA	Cylicodiscus gabonensis	ENCA	Entandrophragma candollei
CZGL	Caloncoba glauca	ENCY	Entandrophragma cylindricum
DAOG	Daniellia ogea	ENUT	Entandrophragma utile
DAOL	Daniellia oliveri	EREX	Erismadelphus exsul
DBGL	Desbordesia glaucescens	ERIV	Erythrophleum ivorense
DCED	Dacryodes edulis	ERSU	Erythrophleum suaveolens
DDAF	Didelotia africana	ETCH	Enantia chlorantha
DGCA	Discoglypremna caloneura	EUUN	Eurypetalum unijugum
DHGL	Dichostemma glaucescens	EXMA	Erythroxylum mannii
DIAL	Diospyros alboflavescens	EY	Erythrina (others)
DICR	Diospyros crassiflora	EYAD	Erythrina addisoniae
DIDE	Diospyros dendo	EYMI	Erythrina mildbraedii
DIIN	Diospyros insculpta	ELDA	Elaeophorbia druefera
DIMA	Diospyros mannii	FAMA	Fagara macrophylla
DIME	Diospyros mespiliformis	FAZA	Fagara zanthoxyloides
DIMO	Diospyros monbuttensis	FIER	Ficus eriobotryoides
DINI	Diospyros nigerica	FIEX	Ficus exasperata
DIPI	Diospyros piscatoria	FIGO	Ficus goliath
DISU	Diospyros suaveolens	FIMU	Ficus mucuso
DIUN	Diospyros undabunda	FIPL	Ficus platyphylla
DIVI	Diospyros viridicans	FITH	Ficus thonningii
DLDI	Dialium dinklagei	FIVA	Ficus variifolia
DLGU	Dialium guineense	FIVO	Ficus vogelii
DMBA	Dichapetalum barteri	FLDI	Fillaeopsis discophora
DNTR	Dennettia tripetala	FUAF	Funtumia africana
DOZE	Diogoa zenkeri	FUEL	Funtumia elastica
DPSU	Desplatsia subericarpa	GAIM	Gardenia imperialis
DRAF	Drypetes aframensis	GBEH	Guibourtia ehie
DRCH	Drypetes chevalieri	GBPE	Guibourtia pellegriniana

Code	Species Name	Code	Species Name
GCBR	Garcinia brevipedicillata	LKDE	Lindackeria dentata
GCGN	Garcinia gnetoides	LOTR	Lovoa trichilioides
GCKO	Garcinia kola	LPAL	Lophira alata
GCMA	Garcinia mannii	LSTA	Loesenera talbotii
GCMA	Garcinia polyantha	LUCU	Lecaniodiscus cupanioides
GC	Garcinia spp	MAAL	Mansonia altissima
GIDE	Gilbertiodendron dewevrei	MASS	Mansularia acuminata
GIMA	Gilbertiodendron mayombense	MBBI	Microberlinia bisulcata
GLBR	Glyphaea brevis	MBLA	Maba lancea
GLST	Glossocalyx staudtii	MCBA	Macaranga barteri
GOBA	Gossweilerodendron balsamiferum	MCPA	Macaranga paxii
GRCO	Grewia coriacea	MDPU	Microdesmis puberula
GUCE	Guarea cedrata	MEEM	Maesopsis eminii
GUTH	Guarea thompsonii	MGGU	Memecylon guineense
HDPA	Hymenodictyon pachyantha	MHTO	Markhamia tomentosa
HECR	Hexalobus crispiflorus	MICI	Mitragyna ciliata
HIBA	Hildegardia barteri	MIST	Mitragyna stipulosa
HMAF	Hymenostegia afzelii	MKOB	Manilkara obovata
HNKL	Hannoa klaineana	MLTH	Millettia thonningii
HOAF	Homalium africanum	MMAF	Mammea africana
HOAY	Homalium aylmeri	MNMY	Monodora myristica
HOLE	Homalium letestui	MNTE	Monodora tenuifolia
HOMO	Homalium molle	MOZE	Morus mesozygia
HOSA	Homalium sarcopetalum	MP	Monopetalanthus spp.
HOVI	Homalium viridiflorum	MQLU	Morinda lucida
HO	Homalium spp	MSSP	Mimusops sp
HPGR	Holoptelea grandis	MTAL	Malacantha alnifolia
HPMA	Haplormosia monophylla	MTDU	Maesobotrya dusenii
HRMA	Harungana madagascariensis	MUCE	Musanga cecropioides
HSZE	Hypodaphnis zenkeri	MYAR	Myrianthus arboreus
HUUM	Hunteria umbellata	NADI	Nauclea diderrichii
HYGA	Hylodendron gabunense	NAPO	Nauclea pobeguinii
IRGA	Irvingia gabonensis	NAVA	Nauclea vanderguchtii
IRGR	Irvingia grandifolia	NBLA	Newbouldia laevis
IRSM	Irvingia smithii	NEPA	Nesogordonia papaverifera
ISCA	Isolona campanulata	NPVO	Napoleona vogelii
JUSE	Julbernardia seretii	NSST	Nothospondias staudtii
KEBR	Keayodendron bridelioides	NW	Newtonia spp.
KHAN	Khaya anthotheca	OCAF	Ochthocosmus africanus
KHGR	Khaya grandifoliola	OKAU	Okoubaka aubrevillei
KHIV	Khaya ivorensis	OLAN	Octolobus angustatus
KHSE	Khaya senegalensis	OMEL	Omphalocarpum elatum
KIAF	Kigelia africana	OMPR	Omphalocarpum procerum
KLGA	Klainedoxa gabonensis	ONGO	Ongokea gore
KNGA	Klaineanthus gaboniae	OPZE	Ophiobotrys zenkeri
LAWE	Lannea welwitschii	OR	Ouratea
LCSE	Lonchocarpus sericeus	OTWI	Octoknema winkleri
LDPS	Laccodiscus pseudostipularis	OUAL	Oubaguia alata

Code	Species Name	Code	Species Name
ONSP	Oncoba spinosa	RNOB	Rinorea oblongifolia
OXFO	Oxyanthus formasus	ROHI	Rothmannia hispida
PACH	Parinari chrysophylla	ROLU	Rothmannia lujae
PACO	Parinari congensis	ROWE	Rothmannia welwitchii
PAEX	Parinari excelsa	ROJE	Rothmannia others
PAGL	Parinari glabra	RVEM	Rauvolfia emetica
PARO	Parinari robusta	RVMA	Rauvolfia macrophylla
PBST	Protomegabaria stapfiana	RVVO	Rauvolfia vomitoria
PCMA	Pentaclethra macrophylla	RX	Raphia spp.
PCSU	Poga suaveolens	SAEL	Sapium ellipticum
PDAF	Pierreodendron africanum	SBGL	Strombosia glaucescens
PEBU	Pentadesma butyracea	SBGR	Strombosia grandifolia
PEEL	Pericopsis elata	SBPU	Strombosia pustulata
PELA	Pericopsis laxiflora	SBTE	Strombosiopsis tetrandra
PGBE	Pterygota bequaertii	SCCO	Scottellia coriacea
PGMA	Pterygota macrocarpa	SDMO	Spondias mombin
PHDI	Phyllanthus discoideus	SDPR	Spondianthus preussii
PABR	Pachystelia brevipes	SEAC	Stereospermum
PIAF	Piptadeniastrum africanum	SGGA	Sacoglottis gabonensis
PKBI	Parkia bicolor	SHAR	Schrebera arborea
PKCL	Parkia clappertoniana	SMMI	Stemonocoleus micranthus
PLNI	Picralima nitida	SMTA	Scaphopetalum talbotii
PLTE	Pachyelasma tessmannii	SNMA	Schumanniophyton magnificum
PMSU	Polyalthia suaveolens	SNTR	Santiria trimera
PNOL	Panda oleosa	SOGR	Sorindeia grandifolia
POOL	Poga oleosa	SONI	Sorindeia nitidula
PPHY	Pteleopsis hylodendron	SSST	Synsepalum stipulatum
PPST	Pachypodanthium staudtii	STOB	Sterculia oblonga
PQMA	Pycnocoma macrophylla	STRH	Sterculia rhinopetala
PRCL	Porterandia cladantha	STTR	Sterculia tragacantha
PSBR	Pachystela brevipes	ST	Sterculia spp
PSMI	Pseudospondias microcarpa	SUST	Staudtia stipitata
PTER	Pterocarpus erinaceus	SWFI	Swartzia fistuloides
PTMI	Pterocarpus mildbraedii	SYGL	Symphonia globulifera
PTOS	Pterocarpus osun	SYMA	Scyphocephalium mannii
PTSA	Pterocarpus santalinoides	TAIN	Tamarindus indica
PTSO	Pterocarpus soyauxii	TAPA	Tabernaemontana pachysiphon
PUJO	Pausinystalia johimbe	TC	Teclea
PUMA	Pausinystalia macroceras	TCAF	Treculia africana
PUTA	Pausinystalia talbotii	TCOB	Treculia obovoidea
PWTU	Placodiscus turbinatus	TEGL	Terminalia glaucescens
PXAR	Polysphaeria arbuscula	TEIV	Terminalia ivorensis
PYAN	Pycnanthus angolensis	TESU	Terminalia superba
PYMI	Pycnanthus microcephalus	THEM	Trichilia emetica
PZAF	Plagiostyles africana	THGI	Trichilia gilgiana
RHCO	Rhaptopetalum coriaceum	THHE	Trichilia heudelotii
RIHE	Ricinodendron heudelotii	THLA	Trichilia lanata
RD	Randia sp	THME	Trichilia megalantha

Code	Species Name	Code	Species Name
THPR	Trichilia prieuriana	TUAF	Turreanthus africanus
TIHE	Tieghemella heckelii	UAAC	Uapaca sp
TMGU	Trema guineense	UVCO	Uvariodendron sp
TPTE	Tetrapleura tetraptera	UVSP	Uvariastrum sp
TRSC	Triplochiton schleroxylon	VESP	Vernonia sp
TSAC	Trichoscypha acuminata	VISP	Vitex sp
TSAR	Trichoscypha arborea	VOAF	Voacanga africana
TSPR	Trichoscypha sp	XY	Xylopia sp
TTDI	Tetrorchidium didymostemon		