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COMPOSITION, STRUCTURE AND SOIL RELATIONS OF *ISOBERLINIA* WOODLANDS IN NIGERIA.

R.M. UBOM and A.O. ISICHEI[1]
Department of Botany
University of Uyo, Uyo
Nigeria

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ABSTRACT

Isoberlinia woodlands in Northwestern Nigeria were studied with a view to elucidating the species composition, and soil-vegetation relationships. Cover, density, height, basal area and frequency were determined for shurbs and trees. Soil properties measured included particle size, exchangeable cations, organic carbon, pH, field moisture and total nitrogen. Principal component ordination of the vegetation data produced five community types. The community structure was defined by the variation in density and dominance of few species such as Isoberlinia sp. *Burkea africana* and *Vitellaria Paradoxa* (syn. *Butyrospermum paradoxum*). The size- structure of trees indicated differences in the community- type stature and pysiognomy. Variation in species composition and ecological status of trees were related to environmental gradients of soil properties.

INTRODUCTION

Quartzite ridges and plinthite extrusions in the Nigerian Guinea savanna are almost exclusively dominated by two species of the woody caesalpinioid genus, *Isoberlinia** (*Isoberlinia doka* and *I. tomentosa*). Kershaw (1968) has noted the poor development of grass cover on savanna ironstone areas, a factor, which minimizes the annual fire damage to the woody species. Kershaw also suggested that such concretionary deposits might contain localized nodules of manganese, which may produce inhibitory, effects on other plants. This factor may account for the domination of a few species in the woodlands.

Cole (1982) observed that many of the present-day African savanna woodlands are associated with old plantation surfaces and are believed to be remnants of a much denser vegetation which existed in the Tertiary geological period (see also Kershaw, 1968). According to Cole, these plantation surfaces lost their soil horizons and the exposed B - horizons became indurated to plinthite. West African *Isoberlinia* woodlands are likened to "miombo" of central and southern Africa characterized by the genera *Brachystegia* and *Julbernadia* which are absent from the West African woodlands (White, 1983). White has also observed that West African woodlands are lower in stature, being rarely 7.2m tall and have a less compact arrangement of trees than the miombo.

Moisture and nutrient availability to plants are the determinants in the variation in savanna vegetation structure (Walker, 1987; Skarpe, 1992). The topographical effects of elevation, aspect and slope play a role in influencing the structure of vegetation through their influence on soil moisture and nutrients concentrations (Morison *et al*, 1948).

We analyse here the components and structure of the *Isoberlinia* woodlands as seen from the vertical and horizontal arrangements of the plants and also the relative abundance of the component species. The roles of various soil factors in the distribution and abundance of the woody species in the woodlands were also examined.

1 Department of Botany, Obafemi Awolowo University, Ile-Ife, Nigeria
*Species nomenclature is according to Hutchinson and Dalziel (1954 – 72) unless otherwise stated

MATERIALS AND METHODS

Study area

This study was carried out in Kainji Lake National Park, Nigeria, located between latitudes 9^0 45' N and 10^0 23'N and longitudes 3^0 40'E and 5^0 47'E. The Park covers an area of about 5340km^2 with two non-contiguous sectors : Borgu and Zugurma (fig.1). Borgu sector is underlain by Basement Complex rocks, which are igneous and metamorphic in origin (Valette and Higgins, 1967). North -South quartzite and schist ridges and bisect the sector, and plinthite occurs close to or at the surface in many areas. Topography is gently undulating with scattered hills and the general elevation of the sector is about 300 - 350m above sea level. The Zugurma sector is almost entirely underlain by Nupe sandstones while rocks of Basement Complex are present in its north-west corner (Klinkenberg, 1965).

Table 1: *Dominance of tree species (basal area in m^2 ha^{-1}) and significance of ANOVA test for variation among five woodland community types. Species with densities less than 5/ha are not included.*

	Woodland community types					
	1	2	3	4	5	r^2
Acacia gourmaensis (**)	0.24	0.03	0.00	0.00	0.02	0.24
Bridelia ferruginea (ns)-	0.04	0.00	0.08	0.10	0.05	0.29
Burkea africana (ns)	2.96	3.07	0.62	6.09	2.36	0.48
Combretum glutinosum (ns)	0.16	0.07	0.00	0.26	0.04	0.32
Combretum molle (ns)	2.20	0.04	0.06	0.02	0.01	0.22
Crossopteryx febrifuga (ns)	0.88	0.39	0.00	2.70	0.06	0.34
Daniellia (ns)	0.28	1.78	1.16	6.39	1.96	0.26
Detarium microcarpum (ns)	0.18	0.28	0.39	0.56	2.86	0.36
Diospyros mespiliformis (ns)	0.34	0.02	0.70	1.16	1.80	0.27
Entada africana (*)	0.14	0.00	0.00	0.14	0.21	0.30
Isoberlinia sp. (**)	50.62	17.92	34.08	76.06	81.22	0.96
Lannea acida (ns)	0.32	0.09	0.96	1.12	1.19	0.31
Lannea schimperi (**)	0.50	1.97	0.75	0.58	0.84	0.40
Monotes kerstingii(ns)	0.67	0.13	2.26	1.88	2.23	0.64
Periscopsis laxiflora (ns)	0.59	0.36	0.89	2.46	0.80	0.44
Pseudocedrella kotschyii (*)	0.00	0.19	0.08	1.00	0.07	0.25
Pterocarpus erinaceus (ns)	0.58	0.00	0.00	0.94	0.27	0.20
Terminalia avicennioides (ns)	0.68	0.05	0.07	0.01	0.58	0.19
Terminalia (**)	0.47	0.28	0.00	0.34	0.06	0.39
Vitellaria paradoxa (ns)	8.36	1.22	1.26	4.66	2.37	0.17
Total basal area (ns)	70.21	27.89	47.36	106.57	101.00	

(ns) = not significant; (*) = significant at $p = 0.05$ (**) = significant at $p = 0.01$

Soils of the Park, are ferruginous tropical on crystalline rocks, are highly weathered, lateritic, poor in humus with low cation exchange capacity. The surface is sandy with the mainly Kaolinitic clay increasing downwards in the profile. The soils are shallow with most profiles less than 150cm deep. Base saturation is low and soils are slightly acidic to neutral (pH 6.1-7.3) (Nnadi and Balasubramanian, 1982).

Table 2: *Density of shrubs (stems ha^{-1}) and significance of ANOVA test for variation among five woodland community types. Species with densities less than 5/ha are not included.*

	Woodland community types					
	1	2	3	4	5	r^2
Acacia hockii (ns)	10	0	15	0	10	0.38
Annona senegalensis (**)	15	0	10	20	15	0.78
Combretum (ns)	10	20	10	25	5	0.37
Gardenia ternifolia (**)	10	0	25	10	40	0.61
Grewia mollis (ns)	5	0	5	0	0	0.24
Maytenus senegalensis (***)	30	0	150	85	160	0.82
Strychnos spinosa (**)	35	0	0	5	5	0.67
Total density (ns)	115	20	215	145	235	

(ns) = not significant; (**) = significant at $p = 0.01$; (***) = significant at $p = 0.001$

Mean annual rainfall varies from 1000mm to 1200mm. The rainy season begins in April and ends in October with an annual potential evapotranspiration ratio ranging from 0.64 to 0.89 (Afolayan, 1982). In the years of this study (1988-1990). mean annual rainfall was 1097mm. Mean annual minimum and maximum temperatures are 20.2°C and 33.1°C respectively. Relative humidity varies according to season being between 60 and 78% at 0900 h in the wet season and between 40 and 60% in the dry season

The Park falls into Keay's (1959) Northern Guinea savanna and "Sudanian woodland with *Isoberlinia*" of White (1983). It lies between the intensely degraded Sudanian savannas to the north and the wetter savanna - forest transaction zones to the south described by Swaine (1992). Kershaw (1968) has observed that the vegetation of Northern Guinea savanna is characterized by the presence of Isoberlinia sp., *Monotes Kerstingii, Lannea* sp., *Bridelia ferruginea, Detarium microcarpum, Swartzia madagascariensis*, *Periscopsis laxiflora* (syn *Afrormosia laxiflora*), *Annona senegalensis, Vitellaria paradoxa* (syn *Butyrospermum paradoxum*) and *Gardenia ternifolia.* Muoghalu and Isichei (1991) gave the descriptions of the vegetation of some parts of the Borgu sector and its environs while the only known description of the Zugurma sector is that of Osemeobo (1978).

Methods

The woodlands were located on a 1:50,000 Nigerian Federal Survey map and subsequently identified on the ground in the Park (Fig.1). A total of 67 woodlands, which ranged in size from about 1 to 100 ha, were identified. Thirty-five woodlands were selected for study taking into consideration their internal homogeneity in terms of topography, gradient and general physiognomy. This allowed comparisons of variable plot sizes.

The vegetation in each woodland was sampled in 10m x 10m randomly placed quadrats. The smallest woodlands ranging from 1 to10 ha contained at least 4 quadrats while larger ones greater than 10 ha contained 12 quadrats or more. A total of 280 quadrats were sampled. Vegetation parameters sampled for shrubs and trees include density, height, girth at breast height (GBH), frequency and crown coverage (Mueller - Domvois and Ellenberg, 1974). Cover values for herbaceous species were estimated visually in 5m x 5m subquadrats. The ecological importance value (IV) for each shrub or tree was obtained as the sum of relative density, relative frequency and relative basal area. For each herbaceous species, the ecological importance value was the sum of relative measures of frequency and coverage (Lindsay, 1956).

Table 3 Density of frobs per hectare and significance of ANOVA test for variation among five woodland community types. Species with densities less than 5/ha are not included

	Woodland community types					
	1	2	3	4	5	r^2
Aframomum subbsericeum (*)	31	55	73	120	20	0.52
Andropogon tectorum (ns)	96	47	101	188	204	0.23
Aspilia paludosa (*)	80	15	64	40	62	0.63
Comosa (*)	19	5	103	24	70	0.51
Hyparrhenia filipendula (ns)	75	43	63	134	191	0.31
Imperata cylindrica (ns)	9	6	10	42	35	0.21
Indigofera bracteolata (ns)	39	8	23	52	16	0.26
Pandiaka heudelotii (ns)	19	0	3	27	2	0.18
Rottboellia (*)	69	17	57	66	40	0.50
Sida linifolia (ns)	20	17	43	35	16	0.29
Tephrosia elegans (*)	121	82	62	93	71	0.22
Vigna racemosa (**)	103	6	25	250	32	0.58
Total density (*)	691	386	636	1110	858	

(ns) = not significant; (*) = significant at p = 0.05; (**) = significant at p = 0.01

Two soil samples were randomly taken, to a depth of 20cm in each quadrat. Thus between 8 and 24 samples were taken in each woodland depending on its size. A total of 288 soil samples were collected. The samples were air-dried, passed through 2mm sieve and analysed for particle size (Bouyoucos, 1962); pH, in 0.01M $CaCl_2$ using 1:2 soil: solution ratio (Jackson, 1962); exchangeable cations (Na, k, Ca, Mg, Mn) (Black *et al.*, 1965); exchangeable acidity (Al, H) by titration method; iron, by orthophenanthroline method (Juo, 1979), organic carbon by Walkley-Black method, available phosphorus by Bray No. 1 method and total nitrogen by the Kjeldahl method (Jackson, 1962).

Vegetation data were analysed using principal component Analysis (PCA) with matrix rotation. The importance values of species, considered as an item of the vegetation (Wikum and Wali, 1974), were used to obtain an ordination for the thirty-five woodlands. The purpose was to elucidate relationships among woodlands based on species characteristics. Rank correlation coefficients were obtained for soil variables with PCA ordination axes of the woodlands. Analysis of variance (ANOVA) was used to separate variation in species and soil properties among the wood communities determined by the PCA.

RESULTS

Trees and Shrubs

Forty-two trees and shrubs belonging to 19 families and 34 genera are enumerated in the woodlands. Fabaceae, represented by 15 species, is the most abundant family followed by Combretaceae with 8 species. All other families are represented by one or two species only. Tables1 and 2 show trees and shrubs with density of at least 5 stems/ha. Only *Isoberlinia* sp. is common to all woodlands. It is also the most abundant and dominant in terms of density (Table 1). Other dominant species include *Burkea africana, Combretum molle, Detarium microcarpum Monotes kerstingii, Periscopsis laxiflora, Terminalia schimperiana* (syn *Terminalia glaucescens*,

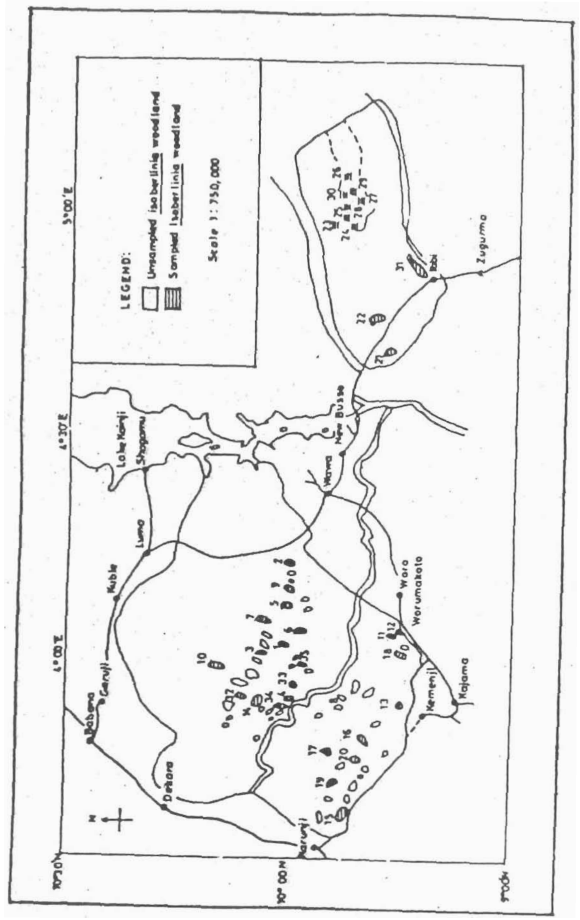

Fig 1: *Isoberlinia* woodlands in Kainji Lake National Park of northwestern Nigeria.

and *Vitellaria paradoxa*.

There are differences in size - structure of the tree species in the woodlands. For instance, the largest girth size *Isoberlinia* is 210 cm and the smallest, 14 cm. The girth - class frequencies of the five most abundant tree species in the woodlands show differences (Fig.2). *Isoberlinia* sp. is mostly found in 80 - 120 cm girth - class (fig.2A) which forms a significant proportion (65%) of the vegetation. *Burkea africana* belongs to the modal girth - class of 40 - 80 cm (fig.2B) while *Detarium microcarpum* and *M. kerstingii* are found more in the smaller girth - class frequency of 0 - 40 cm (fig. 2C, D). *Vitellaria paradoxa* has bimodal frequency in girth - class of 0 - 40 cm and 80-120 cm (fig.2E).

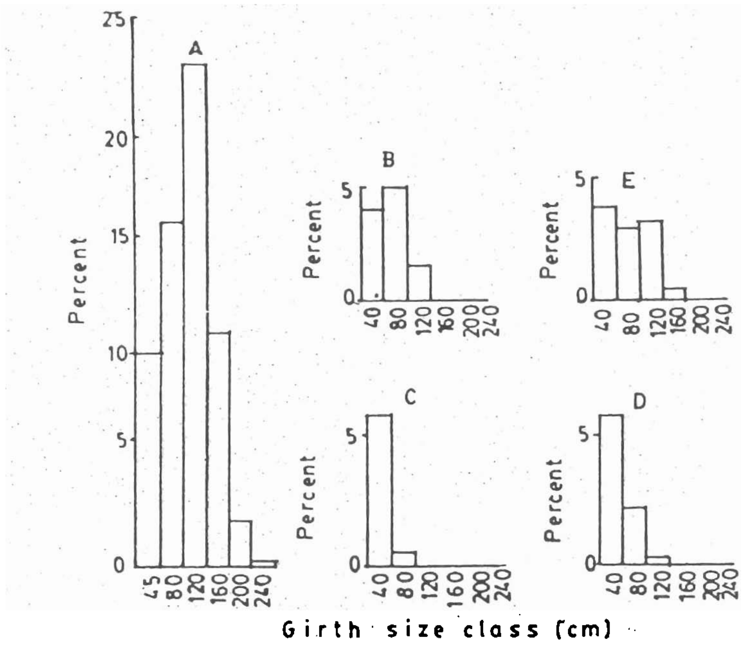

Fig 2: Girth size distribution of (A) *Isoberlinia* sp., (B) *Burkea africana*, (C.) *Detarium microcarpum*, (D) *Monotes kerstingii* and (E) *Vitellaria paradoxa* in *Isoberlinia* woodlands of northwestern Nigeria.

Table 4. Distribution of woodlands in community types in the two sectors of Kainji Lake National Park.

	Actual woodlands in each sector	
Community type	Borgu	Zugurma
1	1, 4, 12, 13, 14, 9	30
2	15, 32, 34	
3	7, 17.	21, 24, 26, 28
4	2, 8, 9, 10, 11, 20, 33.	22, 23, 31
5	3, 5, 6, 16, 18, 35.	25, 27, 29

Herbaceous species

There are 32 herbaceous species (12 grass; 20 forb species) from all the quadrats. Of the grass species, *Andropogon tectorum* and *Hyparrhenia filipendula* are common to all woodlands and the most abundant. In addition *Rottboellia cochinchimensis* (syn *Rottboellia exaltata*) is more frequently found while *Imperata cylindrica* is least frequent (Table 3).

Table 5. Mean structural properties (± SE) and significance of ANOVA test for variation among five woodland community types. (ns): not significant; (*): p = 0.05; (**): p = 0.01.

Woodland community types	Basal area ($m^2 ha^{-1}$)	Canopy cover	Crown cover ($m^2 ha^{-1}$)	Density (stem ha^{-1})	Height (M)	Shannon-Weiner diversity index
1	10.72 ± 1.12	47.34 ± 1.79	4556.51 ± 447.09	230.00 ± 12.00	6.44 ± 0.47	1.94
2	9.57 ± 0.74	52.73 ± 7.06	4334.53 ± 290.06	222.00 ± 19.00	7.57 ± 0.94	1.65
3	6.39 ± 0.28	49.50 ± 0.55	2740.92 ± 222.06	196.00 ± 22.00	6.64 ± 0.32	1.52
4	11.37 ± 1.41	52.16 ± 2.69	5458 .78 ± 1060.98	255.00 ± 19.00	7.10 ± 0.32	1.65
5	11.65 ± 1.79	51.25 ± 2.12	5798.78 ± 849.48	206.00 ± 8.00	6.78 ± 0.40	1.65
Significance	(*)	(ns)	(**)	(*)	(ns)	(ns)

Four forb species are common to all woodlands, namely *Aspilia paludosa*, *Indigofera bracteolate*, *Tephrosia elegana* and *Vigna racemosa*. *Aframomum subsericeum*, *Chamaecrista mimosoides* (syn *Cassia mimosoides*) and *Crotalaria comosa* achieve frequencies higher than 9% in the woodlands.

Woodland communities

Figure 3 shows the PCA ordination of the thirty-five woodlands. The most meaning groupings are produced by the first (20.9%) and second (18.2%) varimax rotated axes. The groupings show the existence of five woodland community types. Table 4 shows the distribution of actual woodlands in each community type in each sector of the park. The mean structural properties of these community types are presented in Table 5.

Community 1

This is *Isoberlinia* sp./*Vitellaria paradoxa* community (fig. 3). The dominant species is *Isoberlinia* sp. with the highest basal area and mean height of 12.06m. Co-dominant species is *V. paradoxa* (Table 1) with mean height of 6.44m. *Strychonos spinosa* has the highest stem density in the shrub layer (Table 2) while *Tephrosia elegans* dominates the forb layer (Table 3). This community type has the highest species diversity and ranks second in species density (Tables 4 and 5).

Community 2

Three woodlands are represented in this community type with *Isoberlinia* sp. and *B. africana* as the dominant tree species with mean heights of 12.74 m and 9.41 m, respectively. Emergent like *Daniellia oliveri* has a mean height of 13.50 m. In terms of basal area, *Isoberlinia* sp. dominates (64%) while *B. africana* contributes 11% in this community. *Combretum adenogonium* (syn *combretum ghasalense*) dominates this community type as the only shrub species. In the forb layer *Chamaecrista mimosodes* is the most numerous, closely followed by *T. elegans* (Table 3). The tallest trees are found in this community type which also has the highest canopy cover value (Table 5)

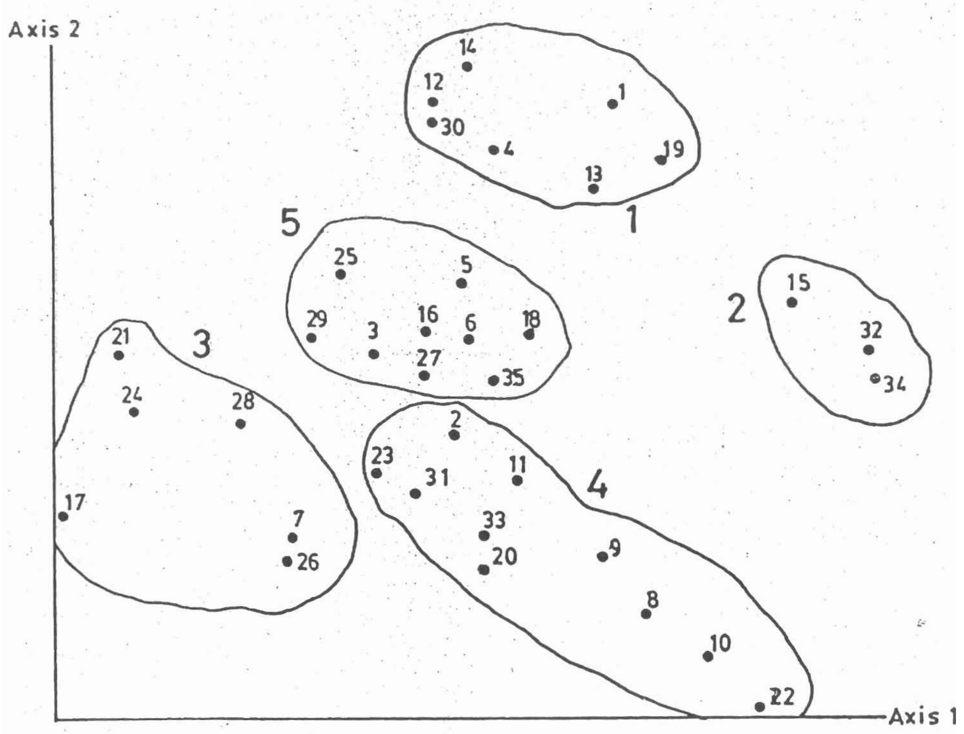

Fig 3: Ordination by principal component analysis (varimax rotation) of *Isoberlinia* woodlands of northwestern Nigeria with defined community types. For woodland distribution see Table 4.

Community 3

This community type (*Isoberlinia* sp./*Monotes kerstingii*) is represented by six woodlands. The most numerous tree species are *Isoberlinia* sp.and *M. kerstingii* with mean heigths of 10.53m and 4.94m, repectively. *Maytenus senegalensis* dominates the shrub layer (Table 2), and *Crotalaria comosa* and *Andropogon tectorum*, the forb layer (Table 3). This is a community type with the lowest value of all structural properties except species height (Table 5).

Community 4

This is *Isoberlinia sp./ Daniellia Oliveri* complex. It is represented by ten woodlands. The respective mean height of *Isoberlinia* sp. and *D. Oliveri* are 11.18m and 12.25m. *Maytenus senegalensis* is the dominant shrub species (Table 2) while *Vigna racemosa* is the dominant forb species. *Andropogon tectorum, H. fillipendula* and *Aframomum subsericeum* are also numerous in

Table 6. Means ± SE of significant (ANOVA test) soil factor determinants of woodland community types (*): P =0.05; (***): P=0.001

Woodland type	Al^{+3} (me/100g)	K^{+} (me/100g)	Ca^{+2} (me/100g)	Mg^{+2} (me/100g)	Fe^{+3} (me/100g)	Org. C (%)	Sand (%)	Silt (%)
1	0.07+0.03	0.15+0.07	2.69+1.03	1.11+0.48	0.14+0.02	0.78+0.24	71.74+7.20	15.20+3.94
2	0.03+0.01	0.28+0.06	3.09+0.99	1.82+0.44	0.11+0.04	0.64+0.20	59.31+12.79	20.85+7.88
3	0.08+0.05	0.20+0.11	1.84+0.78	0.70+0.23	0.09+0.03	0.82+0.28	52.70+9.80	24.87+8.01
4	0.14+0.10	0.22+0.05	1.98+0.89	0.91+0.54	0.14+0.02	0.90+0.26	57.74+11.92	21.74+6.63
5	0.05+0.07	0.34+0.16	2.95+0.44	1.52+0.54	0.06+0.69	1.06+0.69	45.79+8.04	21.48+2.36
Significance	(*)	(*)	(*)	(***)	(***)	(***)	(***)	(***)

this community (Table 3). This community ranks first in species density and second in species height and coverage values (Table 5)

Community 5

Nine woodlands are representatives of this community type (Fig. 1). It is an *Isoberlinia* sp./ *Detarium microcarpum* community. The highest mean basal area is achieved by *Isoberlinia* sp., followed by *D. microcarpum* (Table 1). In the shrub layer, *M. senegalensis* is the most numerous and most important. Table 3 shows that the forb layer is mainly composed of *A. tectorum* and *H. filipendula*. The highest values of basal area and crown cover are achieved in this community type.

Significant variation occurs in tree species dominance among the community types. For example, *Lannea schimperi* shows significant ($p = 0.01$) occurrence in the community types with basal area ranging from 0.05 m^2 ha^{-1} in community 1 to 1.97 m^2 ha^{-1} in community 2. Similarly, *Terminalia schimperiana* with basal area which ranges from 0.06 m^2 ha^{-1} in community 5 to 0.47 m^2 ha^{-1} in community 1, also shows significance ($p = 0.01$) in distribution within the community types.

Variations in stem density in the shrub species are shown in table 2. *Maytenus senegalensis* is highly represented in community 3 and highly significant ($p = 0.001$). *Annona senegalensis* shows significance ($p = 0.01$) with no representation in community 2 but highly represented in community 4. Total shrub density does not show any statistical significance.

Some forb species vary significantly across the communities (Table 3). *Vigna racemosa* varies significantly at $p = 0.01$ and *R. cochinchinensis* at $p = 0.05$. Total forb density also varies significantly ($p = 0.05$).

Basal area, crown cover and density of species show significant variations in the community types (Table 5).

Soil properties

The woodland communities show contrast in their soil properties (Tables 6 , 7). The soils are medium acid to neutral in reaction. pH ranges from 5.94 ± 0.42 to 6.54 ± 0.34. Soils associated with community 5 are less acidic than those of community 4.

Organic carbon contents vary significantly ($p = 0.001$) among the communities with highest values associated with community 5 and lowest with community 2. High sand and silt concentrations, which vary significantly ($p = 0.001$) among the woodlands, are associated with community 1 and low values with community 3 (Table 6). Calcium and magnesium vary significantly ($p = 0.05$, $p = 0.001$) in the communities. Both have high values associated with community 2 and low values with community 3. High contents of iron are associated with communities 1, 4 and 5 (Table7). Other soil properties, though varied in their concentrations among the communities are not statistically significant (Tables 6, 7).

Soil - Vegetation relationships

Variation in species and soil properties among the woodland communities was achieved through the use of analysis of variance. Of the sixteen soil properties fed into the analysis, only eight gave significant values. Table 6 presents the significant soil factor determinants of these community types.

The community types show contrasts with the soil properties. Soils associated with woodlands co-dominated by *Vitellaria paradoxa* have high level of Fe and low level of K. The substrate has high sand content. High Ca and low Al values are associated with *Isoberlinia*/*Burkea africana* woodland soils. Moderate organic carbon values and low Mg concentrations are found in soils associated with *Isoberlinia*/*Monotes kerstingii*. These woodland soils contain high silt contents. Aluminium concentrations are highest in woodland soils co-dominated by *Daniellia oliveri* while soils of *Detarium microcarpum* are associated with high contents of K and organic carbon and low sand values.

Spearman rank correlation of the significant soil properties with the first three PCA ordination axes revealed that Axis 1 has greater correlation than other axes (Table 7). Axis 1 emphasizes the importance of Iron, Magnesium, Organic carbon, Potassium and Silt while in Axis 2, Aluminium and Calcium are important. Along Axis 3, the nature of substrate in terms of sand and silt are emphasized.

Table 7. *Spearman rank correlation of soil properties along three principal component axes for Isoberlinia woodlands*

	Isoberlinia woodland ordination		
	Axis 1	Axis 2	Axis 3
Soil properties			
Aluminum	-0.12	0.59***	0.17
Calcium	-0.003	0.52**	0.08
Iron	0.81***	-0.10	-0.06
Magnesium	-0.36*	0.16	0.26
Organic Carbon	0.48**	0.16	0.10
Potassium	0.46**	0.11	0.02
Sand	-0.08	-0.16	0.49**
Silt	0.51**	0.31	-0.54**

*Significant at p= 0.05; ** significant at P= 0.01 *** significant at P= 0.001

DISCUSSION

There is variation in the species composition of the woodlands especially in the shrub and herb layers. The composition is similar to the *Isoberlinia tomentosa* - *Annona senegalensis* - *I. Doka* Association described by Kershaw (1968) in central northern Nigeria. *Isoberlinia* sp. is the most dominant and numerous, giving a monospecific picture of the woodlands. Due to less ability of *Isoberlinia* sp. to regenerate, other competitive species e.g *B. africana*, *D. oliveri* and *V. paradoxa* come into the woodlands especially in gaps created by fallen dead individuals of the species. Hence variation in species density and dominance show that the woodlands structure and physiognomy are defined by few species such as *Isoberlinia* sp., *B. africana*, *M. kerstingii* and *V. paradoxa*. The trees are low, less dense and few exceed 100cm in girth or 10m in height. The canopy depicts a continuous upper storey (Table 5) except where *D. oliveri* and *P. erinaceus* are present and constitute the emergents, especially in Zugurma sector.

The low taxonomic diversity of shrubs and herbs in the woodlands may be linked to almost closed canopy formed by the upper storey species, and shading. Certain species occurrence and their associations are limited. For example, *Acacia hockii*, *Grewia mollis*, *Strychnos spinosa* and *Pandiaka heudelotii* are absent and form no association in community type 2 probably due to high canopy cover (Tables 2 and 3). This illustrates that these species are either heliophytes or that they are unable to achieve the level of competition and adaptation existing within the community type(s). Species such as *M. senegalensis*, *A. tectorum* and *V. racemosa* are able to compete, adapt or tolerate environmental conditions and therefore have high density in the woodlands.

Principal component analysis produced five woodland community types suggesting that factors other than those measured affect species distributions in the woodlands. However, since the community types cannot be identified with physiography, soil factors are important ecological factors that control woodland distribution. Hence woodland vegetation and soil composition are highly interrelated as shown by the magnitude and significance of the correlation between soil properties and vegetation principal components. Therefore plant - soil relationships need be studied in detail for a better understanding of the ecology of *Isoberlinia* woodlands.

The dominance of species in the community types determine their ecological optima and consequently the level of competition and adaptation in which they achieve. But analysis of the community types reveals overlap in species niche relationships. This is, species are not restricted to specific soil conditions and community types although communities tend to show niche relationships to some soil properties. Thus these soil properties serve as indices for differentiating woodlands. For example high organic carbon contents are associated with communities dominated at the tree layer by *Isoberlinia*, *D. microcarpum*; at the herb layer by *G. ternifolia* and *M. senegalensis*, and at the herb layer by *Chamaecrista mimosoides*, *A. tectorum* and *H. filipendula*. Dead and decomposed fibrous root system of Isoberlinia (which is extensive), addition of litter by the trees, shrubs and tall grasses could increase the organic carbon content of the soils. High sand concentrations occur in communities co-dominated by *V. pardoxa*. These are large trees, which accumulate aeolian materials under their canopies (Isichei and Muoghalu, 1992). Highest values of Fe are found in soils of *Isoberlinia* communities co-dominated by *V. paradoxa D. oliveri* and *D micocarpum*,, while lowest values are found in soils associated with *M. kerstingii*. Iron concentrations correlate with spatial extrusions of plinthite and quartzite ridges. While V. paradoxa, *D. oliveri* and *D. micocarpum* are luxuriant at the feet of these extrusions and ridges, M. kerstingii is dominant close to water-logged grounds.

This study has shown the variation in the species composition and structure of *Isoberlinia* woodlands and the factors which influence species distribution. Mature woodlands have a considerable economic value. As many individuals reach maturity, their harvest as timber and fuel wood is probable unless managed. There is evidence of destruction of the woodlands outside the Park for the purpose of cultivating the land. Since ecological conservation is not observed, continuous felling will result in the loss of recreation as these woodlands are resting places for wildlife. Therefore scientific studies to maximise timber yields of *Isobelinia* should also be considered to ensure efficient use of the species and maintenance of the land.

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