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Species Composition and Structure of *Isoberlinia* Woodland of Shika, Zaria Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author HB designed the study, wrote the protocol and wrote the first draft of the manuscript. Author AOM managed the literature searches, analyses of the study performed the structural equation modeling and discuss the conclusion. Both authors read and approved the final manuscript.

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ABSTRACT

This study was carried out to investigate the effect of farming activities on *Isoberlinia* woodland. This was achieved by assessing their composition and structural characteristics in two plots, 30 m x 30 m each, the plots were farming plot and a rested plot of minimum anthropogenic impacts (here called disturbed and undisturbed plot respectively). Data were collected from each plot, all woody species were identified and their height, diameter at breast height (dbh), basal area, volume, diversity and biomass were measured. In addition, herbaceous diversity and biomass were also determined. Dominance species were determined by the Importance Value Index (IVI). Soils were augured, collected and analyzed for physico-chemical parameters. A total of 71 species belonging to 36 families were identified. Shannon-wiener diversity index showed that the disturbed plot was 2.441 and equitability of 0.733 had higher diversity when compared to the undisturbed (2.331 and 0.685) respectively. These two plots were 66% similar in vegetal composition. Analysis of the importance value index revealed that the dominant species in the area was *Isoberlinia doka*. The

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total basal area and volume was very low at both plots. The woody biomass for the undisturbed was 0.015 ton/ha for the undisturbed and 0.001 ton/ha for the disturbed plot. The total herbaceous biomass for the undisturbed plot was 70.7 ton/ha and 49.7 ton/ha for the disturbed plot. The soils were characteristically alfisols and much degraded reflecting degrees of vegetal exploitation. The low woody volume and biomass though disturbing but not withstanding had high *Isoberlina* component hence, the woodland can still and better be called degraded *Isoberlinia* woodland.

Keywords: Species composition; woodland; Isoberlinia; soil type.

1. INTRODUCTION

Worldwide, mankind is facing the negative repercussions of global change [1,2]. Recent global forest resources assessment revealed that Nigeria is one of the five countries in the world with the highest annual rate of deforestation for the period 2000 – 2010 [3,4]. A major consequence of global environmental change is an increasing shortage of natural resources, especially the threat to biodiversity [5-7]. The vegetation of any area is inadvertently tampered with by human. At certain level such uses could become detrimental to a sustainable vegetation cover [8,9]. The genus *Isoberlinia* is a woody Caesalpinoideae in the family Fabaceae (legume family) of five species native to tropical Africa, two species are predominant in Nigeria's guinea savanna *I. doka* and *I. tomentosa* [10]. The trees of the Nigeria guinea are on the average, little more than 7-2m tall and also have a less compact special arrangement than the Miomba woodland with which they have similar characteristics [11]. Shika *Isoberlinia* woodlands are used for cropping and livestock grazing [12]. Subsistence farmers also collect fuel wood which may have added effect on degradation of the indigenous woodlands. FAO [12] also advocated for more detailed and standardized data on biomass and structure of vegetation units, in order to parameterize global and regional vegetation maps. Studies linking species composition to environmental parameters are sparse for West Africa savanna systems [13]. Such knowledge is however required in order to expand the understanding of ecosystem processes. This study aimed at assessing the impact of farming activities on the composition and structure of *Isoberlinia* woodlands.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Shika, Zaria, Nigeria. Shika is geographically located between latitude 11°12'N and longitude 7°33'E at an altitude of 640 m above sea level [14]. Shika is located about 20 km along the Zaria -Sokoto road in Kaduna state, North Central, Nigeria. It has three distinct climatic seasons. These are the cold dry season (November –February), the hot dry season (March- May) and the wet season (June – October). The total annual rainfall ranges from 617 to 1365 mm with a 50-year average of 1041 mm. Most of the rains fall between July and September [14]. Area extent of study was approximately 15 hectares of range land under different management strategies. The management types included farmed sections, grazing lots and rested plots (i.e. un grazed and unfarmed) with minimum anthropogenic impact. The study was conducted from June to September, 2006.

2.2 Vegetation Sampling

A strategy of simple random sampling was used as the vegetation appeared on inspection to be homogeneous in structure and flourishes. The sampling unit was a plot of 30 m x 30 m (900 m^2). Two plots were sampled for each of the woodland.

2.3 Identification of Species

Species were identified on the field from recognition while critical species were determined by comparing with types and use of flora in the herbarium unit of Biological sciences Department, Ahmadu Bello University, Zaria, Nigeria.

2.4 Parameters Evaluated on Vegetation

2.4.1 Height and diameter

With each 30 m x 30 m plot, the height and dbh of all individual trees was measured in order to characterize tree structure of the plot.

2.4.2 Calculation of Tree cover and volume

For each tree individual in 30 m x 30 m plot, the basal area was calculated using πr^2 (m^2) and volume was calculated using $\pi r^2 h$ where π=22/7, r=radius, h=height of trees were measured.

The species composition of the plots was described using Importance Value Index [15].

The following parameters were measured:

1. Relative dominance = (total basal area for a species/total basal area of all species) x 100.
2. Relative density = (number of individuals of a species/total number of individuals) x 100.
3. Relative frequency = (frequency of a species/sum of all frequencies) x 100.
4. The importance value index (IVI) = relative dominance + relative density + relative frequency.

In general the relative dominance, relative frequency, and relative density vary in the range 0 – 100%, so the species and importance value indices

(IVI) vary between 0 and 300%.

2.4.3 Woody biomass

Woody biomass was calculated after Schongart (2003) as stated in Orthman [16] given the equation below:

Woody biomass=

$$\frac{\text{height(m)}}{2} \times \frac{\text{dbh}(m^2)}{2} \times \pi \times \text{wood density } (t/m^3)$$

Wood density defined as the over-drymass per unit of green volume (tons/m^3) for tropical tree species were given by Brown [17]. Data on wood density were not available for all sampled tree species. Brown [17] gives wood densities for many Africa tree species within the range of 0.5-0.79 (tm^{-3}) taking into account only those in the studied area, a mean value of 0.65 (tm^{-3}) was calculated.

2.5 Sampling of Herb Layer Data

2.5.1 Species composition

Vegetation surveys were conducted in the 5 m x 5 m (25 m^2) plot in each of woodland. The species were identified and their numbers determined in the 1 m x 1 m quadrants.

2.5.2 Herbaceous biomass

The herbs in the 1 m x 1 m quadrant were harvested with sickle for above ground biomass determination. The harvested herbs were weighed as grass and forbs separately. Harvesting was done in September at the peak period of flowering grass species. Samples were oven dried to constant weight. Dry matter yield was calculated using the formular below:

Percentage dry matter (%Dm)

$$= \frac{\text{sub sample of dried matter weight} \times 100}{\text{sub sample of fresh weight}}$$

Dry matter yield = $\frac{\%Dm \times \text{fresh weight}}{100}$(g/$m^2$)

2.6 Data Analysis

Vegetation data were analysed using the mathematical index of Shannon –wieners [18] as stated in Tiseer and Smith [19]. The Shannon Diversity Index and equitability was computed as

(H’ = ∑Pi*ln Pi) where Pi=ni/N.
H’ is the index of diversity,
Pi is the importance value of a species as a proportion of all species.
ni’ is number of individual species.
N’ is Total number of individual species.
Equitability J=H/InN.

Microsoft Excel 2007 package was used for data analysis.

3. RESULTS

A total number of 71 species were recorded in 36 families. The families represented by the greatest number of species were Fabaceae (12 species), Combretaceae (7 species), Poaceae (7 species), 39 species were trees and shrubs while 33 herbaceous species were recorded. The predominant woody species was *Isoberlinia doka* with 307 individuals in the undisturbed plot and 224 individuals in the disturbed plot. The dominant herbaceous genus was *Setaria barbata* with 300 individuals per hectare in the undisturbed plot and *Fadogia pobeguini* with 501 individuals per hectare in the disturbed plot. A single stands of *Entada africana*, *Strychnos spinosa* has the highest height of 5.5 m and 4.5 m respectively. While *Isoberlinia doka* has the height of 2.5 m in the undisturbed plots. In the disturbed plot all height measurement was less than 2.5 m. In undisturbed plot *Lannea schimperi* contributed the highest girth of 40cm as showed in Table1b.

Importance value index (IVI) provides knowledge on important species of a plant community. Based on IVI *Isoberlinia doka, Sechium idule, Dichrostachys cineria, Ochna afzeli, Detarium microcarpum* were the dominance species in undisturbed plot whereas *Isoberlinia doka, Securidaca longepedonculata, Pilostigma thonningii, Hymenocardia acida, Dichrostachys cineria* were dominance in the disturbed plot. As showed in Table 2.

Table 1a. Plants diversity for undisturbed and disturbed *Isoberlinia* Woodland

S/no	Species	Families	Undisturbed		Disturbed	
			Woody	Herb	Woody	Herb
1.	*Isoberlinia doka*	Fabaceae (c)	307		224	
2.	*Adenodolicus paniculatus*	Fabaceaes (p)				159
3.	*Khaya senegalensis*	Meliacece	-		8	
4.	*Butryospermum paradoxum*	Sapotaceae	18		23	
5.	*Vitex doniana*	Verbenaceae	6		1	
6.	*Securidaca longepedonculata*	Polygalaceae	20		35	
7.	*Afxelia Africana*	Fabaceae (c)	-		10	
8.	*Entada Africana*	Bignoniaceae	10		26	
9.	*Stereosperrmum kunthiana*	Fabaceae (m)	-		6	
10.	*Detarium microcarpum*	Fabaceae (c)				
11.	*Cussonia barteri*	Araliaceae				
12.	*Annona senegalensis*	Annonaceae	11		16	
13.	*Piliostigma thonningii*	Fabaceae (c)	17		48	
14.	*Azadirachta indica*	Meliaceaa	-		-	
15.	*Dicrostachy scineria*	Fabaceae (m)	122		38	
16.	*Bridelia ferruginea*	Euphorbiaceae	9		1	
17.	*Lannea schimperi*	Anacadiaceae	8		10	
18.	*Terminalia avvicinoides*	Combretaceae	1		8	
19.	*Fadogia pobeguini*	Rubiaceae		16		501
20.	*Ximenia Americana*	Olaceae	-		3	
21.	*Maerua crassifolia*	Capparidaceae	-		2	
22.	*Cissus cornifolia*	Vitaceae		4		2
23.	*Vernonia kotschyana*	Asteraceae				
24.	*Cochlospermum tinctorum*	Cochlespermaceae		38		23
25.	*Phyllantus muellerianus*	Euphorbaceae	-		1	
26.	*Gardenia Aquila*	Rubiaceae	6		2	
27.	*Guiera senegalensis*	Combretaceae	2		3	
28.	*Swartzia madagascariensis*	Fabaceae (c)				
29.	*Lippia multiflora*	Verbenaceae		196		72
30.	*Strychnos spinosa*	Loganiaceae	15		12	
31.	*Astrosolen marcrozhia*	Thymelaceae				69
32.	*Costus afer*	Zingiberaceae				102
33.	*Andropogon gayana*	Poaceae		80		80
34.	*Stylochiton hypoqea*	Araceae		36		23
35.	*Setaria pallidefusca*	Poaceae		47		12
36.	*Xyris sp*	Xyridaceae		14		36
37.	*Heckhloe sp*	Poaceae		130		60
38.	*Setaria barbata*	Poaceae				
39.	*Aspilia Africana*	Asteraceae		25		189
40.	*Eragrostic atrovirens*	Poaceae		35		21
41.	*Hypharrhenia rufa*	Poaceae		52		
42.	*Gutenbergia cordifolia*	Asteraceae		3		74
43.	*Cyperus michellus*	Cyperaceae		120		4
44.	*Paspalum arbrculare*	Poaceae				25
45.	*Heeria insignis*	Anacardiaceae		6		
46.	*Aselepias gurassavica*	Asclepiadaceae				5
47.	*Waltheria indica*	Sterculiaceae		27		58

S/no	Species	Families	Undisturbed		Disturbed	
			Woody	Herb	Woody	Herb
48.	*Crotolaria lanchnosuma*	Fabaceae (p)				1
49.	*Latana camara*	Verbenaceae				6
50.	*Pericopsis laxiflora*	Fabaceae (c)				
51.	*Gmelina arborea*	Verbenaceae			1	
52.	*Terminalia mollis*	Combretaceae	22		6	
53.	*Pavetta corymbosa*	Rubiceae	2		4	
54.	*Ochna afzelii*	Ochnaceae	102			
55.	*Combretum lamprocarpum*	Combretaceae				
56.	*Ficus thonningii*	Moraceae	3			
57.	*Sechium edule*	Cucurbitaceae	145			
58.	*Scoparia dulcis*	Scrophalariaceae		4		
59.	*Tephrosia pedicellata*	Fabaceae (p)		60		
60.	*Stylosanthes auretta*	Fabaceae (p)				
61.	*Ipomea aquatic*	Convolvulaceae	`	32		
62.	*Ekebegia senegalensis*	Meliaceae	1			
63.	*Diospyros mespiliformis*	Ebenaceae				
64.	*Psorospermum senegalense*	Hypericaceae				
65.	*Asperagus Africana*	Liliaceae				
66.	*Hymenocardia acida*	Euphorbiaceae	2		48	
67.	*Maranthes polyandra*	Rosaceae		8		
68.	*Terminalia lanceolatum*	Combreteceae			10	
69.	*Danielia oliveri*	Fabaceae (c)	1			
70.	*Securinega virosa*	Euphorbiaceae	38			
71.	*Tacca involucrate*	Taccaceae				4
Total			941	611	1622	1546

letters in bracket represent the sub-families of fabaceae, (c- ceasalpinioideae, p- papilionoideae, m - mimosoideae)

Table 1b. Summary of species composition and structural characteristics for each Woodland type

Diversity measure	Undisturbed		Disturbed	
	Woody	Herb	Woody	Herb
No of family	18	17	15	15
No of species	30	25	28	25
Average dbh (m)	0.1±0.5		0.02±0.06	
Mean height (m	2.24±1.4		0.7±0.05	
Basal area (m^2)	0.43		0.05	
Volume (m^3)	9.53		0.68	
Biomass (tons)	0.54	70.7(g/m^2)	0.02	49.7(g/m^2)
Shannon index	2.33	2.63	2.44	2.68
Equitability	0.69	0.82	0.73	0.83

dbh-diameter at breast height, N- 30 and 28 for woody average in undisturbed and disturbed plot respectively, herbaceous biomass were measured in g/m^2

In Table 3 below, the textural class of the soil in the farmed plot is loam with 45% sand, 34% silt and 21% clay. The physicochemical parameters shows average low organic matter in the farmed plot which had correspondingly high Nitrogen content of 0.53 g/kg^{-1}, other macro elements were low except for Magnesium (0.78 cm/kg). The undisturbed plot was texturally sandy loam with 49% sand, 34% silt and 21% clay. The organic carbon at 0.97 g/kg^{-1} was low. The nitrogen content of the soil at 0.53 g/kg^{-1} was high. Other element were low except again for magnesium at 0.63 cmg/kg^{-1} in all cases the sodium content 1.8 cm was low which removes any fears of solidification. The available phosphorous was low in the undisturbed and the disturbed plot.

4. DISCUSSION

There is variation in the species composition and structures of the disturbed and undisturbed plots of the woody and herbaceous layer. Mishra [20] observed greater diversity of herbs in disturbed forest than in undisturbed ones. The composition is similar to that described [21] in the central border Nigeria *Isoberlinia doka* being the most dominant and numerous giving a monospecific picture of the woodlands gives reason why it was called *Isoberlinia* woodlands [10].

Due to the less ability of *Isoberlinia sp* to regenerate after over exploitation for fuel wood or clearing of the woodland during farming, other competitive species such as *Adenodolichos penniculatus Detarium microcarpum*, *Daniella oliver, Vitex doniana, Annona senegalensis* etc comes into the woodland. The diversity of plant in all plots was high. However this was higher in the disturbed plots, this may be due to the resilient nature of most savanna plants which have a phyrophytic behavior and regenerate from buds on their below ground parts. The consequence is that cutting during farm clearing operation serve to multiply regenerating stocks. This proves a case of disturbance induced diversity [22,23].The maximum population of species of 39 in the plots is also appreciable given the area sampled. The consequence is that diversity at the level of this interference is not too adversely affected. An earlier report of sample size larger than 900 square meters, yield a total of 42 plants species [24]. The plots were also of 66% similar meaning that subsistence farming did not account for gross disappearance of species in this case. Also important value index in Figs. 1 and 2. Shows that *Isoberlinia doka* appears to be dominant in both plots. These results disclose that, the most important species in the plots have high diversity in the scale of Shannon-Weiner Index of Diversity. The IVI rank species in a way as to give an indication on which species come out as important element of the woodlands [25].

Isoberlinia doka, though dominant in numerical value had awfully low basal area plant has of late been highly exploited for fuel to the extent that yearly regrowth are even harvested. Indeed these appear to be a high skew to biomass in all plots in favor of grass and forbs. While figure for this are alarmingly high, the biomass estimate for wood are very low. The implication are that, the vegetal conditions typified by this plots can no longer supply wood either for rough construction or timber, there is progressive turning of the woodlands of Shika into an open range which favour grassing more than any other form of land use. The high herbaceous biomass cannotes high danger of annual fires which can exacerbate the degradation of the range. *Isoberlinia* species has been recorded as an endangered species [26]. The ridiculously very low volume in the plots indicated the wanton exploitation which is not pursued with conservation, indicates that no regard is given to sustainability and perpetuity. As poverty increase and population increase, the range will no longer cope with the demand for fuel wood and farm land. This may reach a catastrophy that can result to ecosystem collapse [27,28].

Table 2. The five most abundant woody species in each Woodland type according to decreasing order of the species importance value index (IVI)

Species	Undisturbed IVI(%)/200		Disturbed IVI(%)/200	
	Woody	**Herb**	**Woody**	**Herb**
Isoberlinia doka	39.9		42.3	
Sechium idule	15.4			
Dichrostachys cineria	13.1		6.5	
Ochna afzeli	12.9			
Detarium microcarpum	8.0			
Other woody species	110.7			
Securidaca longepedonculata			29.1	
Pilostigma thonningii			9.8	
Hymenocardia ocida			7.8	
Other woody species			104.5	
Setaria babarta		19.9		
Stylosanthes qurretta		17.4		
Lippia multiflora		12.8		
Heckloea sp		8.4		
Cyperus michellus		7.7		
Others herbs		133.8		
Fadogia pobeguini				32.4
Cochlospermun tinctorium				14.6
Aspilia Africana				12.0
Adenodolicus peniculatus				6.6
Other herbs				122.2

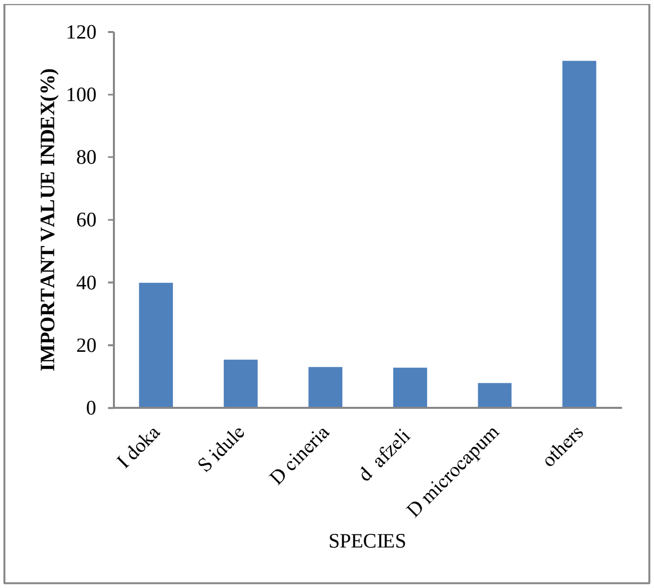

Fig. 1. Important dominants woody species in the undisturbed woodland

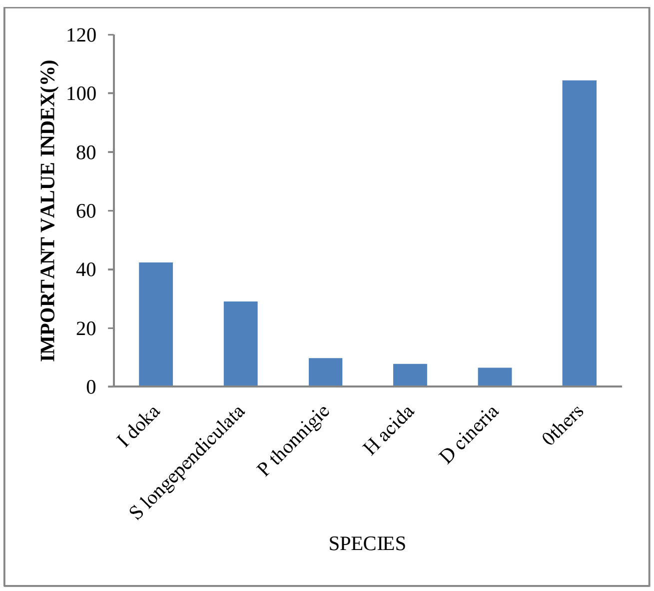

Fig. 2. Important dominants woody species in the disturbed woodland

Table 3. Physico-chemical parameters of soil in the investigated plots

Woodland type	Texture class	%o.c g/kg^{-1}	N g/kg^{-1}	P ppm	Ca cm/kg^{-1}	Mg cm/kg^{-1}	K cm/kg^{-1}	Na cm/kg-1
Undisturbed	Sandy loam	0.97	0.53	0.79	1.00	0.60	0.12	1.8
Disturbed.	Loamy	0.75	0.53	0.63	1.7	0.78	0.19	1.65

**o.c-organic carbon, N- Nitrogen, P - Phosphorus, Ca – Calcium, Mg – Magnesium, K- potassium, Na- Sodium*

The soil presented mixed parameters which indicate at best progression on the part of degradation. Some normal situation ware noted such as P^H at 5.8-6.0 range for the soil. The low sodium entails that no immediate solidification problems are envisage with soils. The low phosphorus level is characteristics of alfisol of the guinea savanna [29]. The low organic matter and relatively high Nitrogen could suggest that rapid mineralization occurs in the soils. Perhaps the soil nitrogen level is not commensurate the rapid organic carbon loss. Reduction in nitrogen and available phosphorus showed that the major soil nutrient has been noted to be limited in disturbed soil compared to undisturbed [30]. The low organic matter carbon status could also be due to lack of replenishment of soils with organic matter as crop residues are used as fuels. The rapid removal of trees can also be another factor in the low soil organic Carbon. This loss of fertility in either the undisturbed or the farmed plots can note a situation where plants regeneration and production will be painfully slow and low. With unabated use of such lands perhaps with fertilizer practices, the consequences would be degradation. This may aggravate the already poor vegetal state and escalate/set stage for desertification [31].

5. CONCLUSIONS

This study revealed that deforestation problem in Shika, zaria has attained a critical level which can no longer be ignored. Any forms of anthropogenic activity detrimental to biodiversity need to be checked against background of sustainability. The prevailing trends of exploitation certainly connote danger in the not too distance future given emerging trends of desertification, drought and global warming. Therefore proper vegetation management should be adopted in order to maintain a balance ecosystem and a sustainable resources base for the benefit of the present and future generations.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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