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Nigerian Man and Biosphere research plots in Guinea savanna: floristics and structure of the vegetation

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Summary

A study was made of the vegetation of three plots used in the Nigerian Man and Biosphere Research Programme for Savanna Studies. The aim is to provide detailed information on the vegetation of the plots which may possibly contribute to an understanding of factors influencing savanna structure and relative abundances of forbs, grasses and woody species. Results show that there are differences in the species composition of the plots. There are more forb species than grass species in each plot. The woody basal areas and crown areas of the plots do not depend entirely on the density but also on the size of the woody species. There are differences in herbage yield in the plots that could be attributed to differences in soil properties, species composition and level of human and animal activities between the plots.

Key words: Man and Biosphere, savanna, Nigeria, vegetation

Résumé

On a réalisé une étude sur la végétation de trois sites du Nigerian Man and Biosphere Research Programme for Savanna Studies. Son but est de fournir des informations détaillées sur la végétation des sites, qui pourraient contribuer à la compréhension des facteurs qui influencent la structure de la savane et l'abondance relative d'espèces d'herbes, de buissons et d'arbres. Les résultats montrent des différences dans la composition en espèces dans les sites. Dans chaque site, il y a plus d'espèces de buissons que d'herbes. Les surfaces arborées, tant au niveau du sol qu'à la cime, ne dépendent pas entièrement de la densité mais aussi de la taille des espèces d'arbres. Il existe des différences dans la production herbeuse des sites, qui peuvent être attribuées aux différences des propriétés du sol, de la composition des espèces et du niveau des activités humaines et animales entre les sites.

Introduction

In 1979, Nigerian Man and Biosphere (MAB) Programme Theme-3 selected ten representative monitoring plots of one hectare each in the Kainji Lake Basin in Northwestern Nigeria for savanna research. The aim of Theme-3 research is to determine the effect of management practices on vegetation structure, floristics, productivity and soil in natural Guinea savanna. The impact of late and early burning, tree density and cover, seeding of native herbaceous legumes and encouragement of nitrogen-conserving grasses and harvesting were investigated with the aim of improving management practices in open rangeland.

While MAB plots have been the sites of ecological studies (Usman, 1981; Sanford, Obot & Wari, 1982; Olaoye, 1985; Ero, 1985), detailed information on the plots is sparse. The present study is undertaken to provide this information.

Study area

The MAB Theme-3 project area is located in the Kainji Lake Basin in North-western Nigeria between latitudes 10° and 13°N, and between longitudes 3°50′ to 5°50′E, and covers an area of about 64,000 km^2. Ten representative monitoring plots of one hectare each, designated MAB plots 1–10, were demarcated within the least disturbed savanna vegetation of the area. Three of these plots, plots 1, 3, and 7 were used for this study; out of the seven remaining plots, plots 2, 8, and 9 were cleared and farmed on by the local population while plots 4 and 5 were inaccessible for most of the year.

The area is within Nigerian Guinea Savanna (Keay, 1959). The mean annual rainfall ranges between 1000 mm and 1200 mm. The rainy season lasts from April to October and the dry season from October to March. Mean temperatures in the area range from an annual mean minimum of 20°C to a mean maximum of 35°C.

The area is underlain by rocks of the Basement Complex, nupe sandstone and by more recent aeolian, alluvial and colluvial deposits (Pullan & de Leeuw, 1964; Klinkenberg & Hildebrand, 1964; Vallette & Higgins, 1967). The soils are classified as ferruginous tropical soils (Nnadi & Balasubramanian, 1982).

Materials and methods

Within each site, the 1 hectare plot was divided into four equal quadrants. Five belt transects (25 m × 5 m) were randomly placed in each quadrant. Every tree and shrub (1 m high and more) within each belt transect was counted and identified to species. The girth was measured at breast height (GBH) for specimens >3 m high and at mid point for those <3 m. The girth measurements were used to calculate the basal area for each species. The height of each individual tree was measured using an Haga altimeter. Tree canopy cover (crown area) was measured by taking two diameters at right angle to each other across the canopy of the plants, one of which was the maximum diameter for the plant. The area of each plant canopy was calculated from the formula πD^2 (m)/4, where D is the average crown diameter.

The data from belt transects were used to estimate means and variances for the variables in each quadrant. Plot means and variances were estimated as for stratified sampling (Cochran, 1963).

The herbaceous species composition of each site was described by an analysis at the time for peak biomass of 25 m line transects placed in the belt transects. At every metre point the presence of a species was noted and the total number of individuals of each species was counted for each transect.

Herbage yield

Herbage yield was estimated at peak standing crop in October by randomly placing a 50 cm × 50 cm quadrat in the plots and clipping the herbaceous material at the ground level. The clipped material was sorted into forbs and grasses and oven dried at 80 C to a constant weight and weighed. The oven-dry weights are used to estimate herbage yield. One hundred samples were taken in each plot.

Soils

One hundred soil samples were randomly taken at 15 cm depth in each site to represent the heterogenous conditions within the site. The soil samples were air-dried and passed through a 2 mm sieve. They were analysed for: particle size distribution using the hydrometer method after dispersion with sodium hexametaphosphate; pH in 1:2 soil 1N KCl solution; organic matter content by the Walkley Black method: exchangeable cations (Ca; Mg; K; Na) in 1N ammonium acetate extracts by flame photometry (K; Na) and atomic absorption spectrophotometry (Ca; Mg); total nitrogen by the Kjeldahl method; cation exchange capacity by the neutral magnesium acetate method; and available phosphorus by the Bray 1 method.

Results

Floristic composition of the plots

Herbaceous species. Species nomenclature is in accordance with Hutchinson & Dalziel's Flora of West Tropical Africa (1954-1972). There are 27 herbaceous species (10 grass species; 17 forb species) in plot 1, 43 herbaceous species (15 grass species; 28 forb species) in plot 3 and 26 herbaceous species (9 grass species; 17 forb species) in plot 7. In all the plots the number of forb species is greater than the number of grass species (almost double the number of grass species).

Of the grass species, only *Andropogon gayanus* and *Rottboellia cochinchinensis* are common to all the plots. Plots 3 and 7 have more species common to both of them (*Andropogon schirensis; Hyparrhenia involucrata; H. rufa; Hyperthelia dissoluta; Schizachyrium sanguineum*) than with plot 1.

The most abundant grass species in each of the plots are as follows: plot 1 *R. cochinchinensis, A. gayanus, Setaria pumila* and *Sorghastrum bipennatum*; plot 3- *A. gayanus, Andropogon schirensis, Digitaria argillacea, Hyperrhenia involucrata, Hyperthelia dissoluta* and *Schizachyrium sanguineum*; and plot 7 *A. schirensis, H. involucrata, S. sanguineum* and unidentified species.

Five forb species are common to all the plots, namely *Borreria scabra, Cassia mimosoides, Monechma ciliatum, Pandiaka heudelotii* and *Vigna racemosa*. Plots 3 and 7 have more species in common than either plots 1 and 7 or 1 and 3. The most common forb species in the plots are: plot 1 —*Aspilia helianthoides, Borreria scabra, Cissus rubiginosa, Hibiscus asper, Monechma ciliatum, Stylochiton lancifolius* and *Vigna racemosa*; plot 3 *B. scabra, C. mimosoides, Calcitrapoides praecox, Melantheria eilliptica, Pandiaka heudelotii, P. involucrata, Sebastiana chamaelea* and *V. racemosa*; and plot 7 *Aspilia africana, Crotalaria microcarpa, Indigofera bracteolata, M. ciliatum* and *Tinnea barteri*.

Woody species. There are 19 woody species in plot 1, 27 in plot 3 and 14 woody species in plot 7.

Six woody species (*Burkea africana, Butyrospermum paradoxum, Combretum* spp., *Detarium microcarpum* and *Terminalia avicennioides*) are common to all the plots while plots 1 and 3 have more species in common than either plots 1 and 7 or 3 and 7. Plot 3 has the highest number of woody species followed by plot 1 and plot 7 has the lowest number of species.

The dominant woody species in each of these plots in terms of density are: plot 1– *Acacia* species (*Acacia gourmaensis; Acacia hockii, Acacia nilotica*), *Anogeissus leiocarpus, Combretum* spp., and *Prosopis africana*; plot 3: *Acacia gourmaensis, Bridelia ferruginea, Butyrospermum paradoxum, Combretum* spp., *Gardenia erubescens, Isoberlinia tomentosa, Lannea acida, Maytenus senegalensis, Terminalia avicennioides*, and *Ximenia americana*; plot 7: *Annona senegalensis, Butyrospermum paradoxum, Combretum* spp., *Detarium microcarpum* and *Terminalia avicennioides*.

Sorensen index of similarity between the plots shows that plots 3 and 7 (IS_s = 56·36%) are more similar than either plots 1 and 3 (IS_s = 48·28%) or 1 and 7 (IS_s = 37·21%) when all the species (herbaceous and woody species) or herbaceous species alone are considered. But when only woody species are considered, plots 1 and 3 (IS_s = 56·52%) are more similar than either plots 1 and 7 (IS_s = 42·42%) or 3 and 7 (IS_s = 53·66%).

Plot 3 has the highest number of species (70), followed by plot 1 (46) and plot 7 has the lowest (40).

Structure and physiognomy

Woody species density, basal area, crown area and girth size distribution.

The density and basal area of the woody species are shown in Table 1. In plot 1, *Combretum* spp. have the highest density of 158 ± 18 plants ha^{-1} while *Crossopteryx febrifuga, Detarium microcarpum* and *Entada abyssinica* show the lowest density of 4 ± 2 plants ha^{-1} each. In plot 3, *Combretum* spp. still have the highest mean density of 82 ± 16 plants ha^{-1} and *Boswellia odorata, Daniellia oliveri, Khaya senegalensis* and *Sterculia setigera* have the lowest mean plant density of 4 ± 2 plants ha^{-1} each. In plot 7, *Terminalia avicennioides* has the highest plant density of 302 ± 20 plants ha^{-1} followed by *Detarium microcarpum* 212 ± 18 plants ha^{-1} while *Daniellia oliveri, Strychnos spinosa* and *Trichilia emetica* have the lowest. Though plot 7 has the least number of woody species, it has the highest mean plant density of 742 ± 34 plants ha^{-1} of all the plots followed by plot 3, 484 ± 29 plants ha^{-1}. Plot 1 has the lowest plant density of 458 ± 26 plants ha^{-1}.

Anogeissus leiocarpus contributed the largest mean basal area of 4·25 ± 0·59 m^2 ha^{-1} (26%) in plot 1, *Isoberlinia tomentosa* 3·56 ± 0·27 m^2 ha^{-1} (38%) in plot 3 and *Burkea africana* 2·01 ± 0·22 m^2 ha^{-1} (38%) in plot 7 (Table 1).

Plot 1 has the highest mean basal area of the plots even though it has the lowest woody density. There is a preponderance of stems in girth sizes 1–20 cm and 21–40 cm in all the plots (Fig. 1). Plot 1 has a higher number of trees in the largest girth size than the other plots (girth size > 100 cm; plot 1, 50 ± 8; plot 3, 25 ± 6; plot 7, 10 ± 4 trees ha^{-1}). The occurrence of big trees such as *A. leiocarpus, B. africana, Entada africana, Prosopis africana* and *Pterocarpus erinaceus* in plot 1, has contributed to the larger basal area.

Table 2 shows the mean crown cover of each species in the three plots. In plot 1, *A. leiocarpus* and *P. africana* provide over 50% of the mean crown horizontal area. In plot 3, *Bombax costatum*, *I. tomentosa*, *Lannea acida* and *P. erinaceus* provide over 44% of the crown area. In plot 7, *B. africana* alone provides over 27% of the mean crown area. A comparison of crown area contribution per girth size class (Fig. 2) with the density of plants in the girth class (Fig. 1) in each plot highlights the influence big trees can exert on the environment irrespective of their density.

Plot 1 has the highest mean crown area followed by plot 7 and plot 3 the lowest (Table 2). The ground area covered by mean crown horizontal area in each plot is greater than one hectare. This is mainly due to the vertical packing of some species.

The general height distribution of woody species in the plots can be grouped as follows: trees above 7 m high, those 3–7 m and others less than 3 m.

Thus the vegetation of the plots consists of a ground layer made up of grasses and forbs, a tree layer with trees >7 m high making up 33·62% 7·64% 2·70%, a 3–7 m tree layer, 28·6% 45·25% 45·61% and <3 m layer, 37·77% 47·11% 51·69% in plots 1, 3 and 7, respectively. Plot 1 has a higher percentage of trees above 7 m in height (33·62%) than plots 3 and 7 (plot 3, 7·64%, plot 7, 2·70%). All the plots have more trees in the less than 3 m height class than in any other height class.

Herbage yield

The mean maximum standing crop in the plots is $316{\cdot}85 \pm 28{\cdot}93$ g m^{-2}, $246{\cdot}08 \pm 30{\cdot}27$ g m^{-2} and $221{\cdot}57 \pm 20{\cdot}08$ g m^{-2} in plots 7, 3 and 1, respectively (Table 3). Grass species contribute 75·33%, 93·08% and 94·31% of this in plots, 1, 2 and 7, respectively, while forb species contribute the balance in each of the plots.

Soils

Table 4 shows the physical and chemical attributes of the soil in the study plots. The soils of the plots are slightly acid. Differences in soil particle size are most pronounced in the percentage sand and silt contents of the plots.

Discussion

Species composition

There are more herbaceous and woody species in plot 3 than in either plot 1 or plot 7. Dominance is less pronounced in plot 3 than in the other two plots. This is very clearly shown by the woody species composition of the plots where two species together contribute 48% and 69% to woody densities in plots 1 and 7, respectively. The difference in species composition is likely to depend on differences in soil properties and other factors which affect species composition. The closer similarity in woody species composition between plots 1 and 3 is because they are physically closer to each other than to plot 7. The highest species diversity obtained in plot 3 could be attributed to the greater disturbance than in the other two plots. More of grazing activity by domestic animals goes on in the plot.

Woody plant density, basal area and crown area

Woody plant basal area and crown area of the plots do not depend entirely on the density of the woody plants in the plots but also on the size of the trees. This is most

Table 1. Mean basal area and density of woody species ±95% confidence interval in three study plots in the Guinea savanna zone of Northwestern Nigeria (1985–1986)

Species	Basal area (m^2 ha^{-1})			Density (ha^{-1})		
	Plot 1	Plot 3	Plot 7	Plot 1	Plot 3	Plot 7
Acacia gourmaensis	0·2665±0·0913	0·0845±0·0066	—	32±7	18±6	—
Acacia hockii	0·1304±0·0239	0·0488±0·0087	—	28±7	10±4	—
Acacia nilotica	2·3119±0·0407	0·0199±0·0051	—	60±10	12±4	—
Afrormosia laxiflora	0·0029±0·0009	0·0907±0·0165	—	6±3	8±3	—
Afzelia africana	—	0·6033±0·1193	—	—	8±3	—
Anogeissus leiocarpus	4·2462±0·5947	—	—	40±8	—	—
Annona senegalensis	—	0·0286±0·0099	0·0568±0·0048	—	10±4	40±8
Bombax costatum	—	0·6226±0·1263	—	—	6±3	—
Boswellia odorata	—	0·3643±0·1270	—	—	4±2	—
Bridelia ferruginea	0·0379±0·0114	0·1244±0·0161	—	8±3	28±7	—
Burkea africana	0·9359±0·2598	0·0512±0·0379	2·0135±0·2224	8±3	18±6	34±7
Butyrospermum paradoxum	1·1165±0·2831	0·2114±0·0139	0·0086±0·0017	14±4	12±4	8±3
Combretum spp.	1·1871±0·0988	0·3222±0·0299	0·6833±0·0855	158±18	82±16	68±10
Crossopteryx febrifuga	0·0020±0·0007	0·1570±0·0303	0·2600±0·0744	4±2	10±4	8±3
Daniellia oliveri	—	0·2408±0·0839	0·0249±0·0087	—	4±2	4±2
Detarium microcarpum	0·0733±0·0256	0·1426±0·0282	1·3446±0·611	4±2	8±3	212±18

Entada abyssinica	0·0005 ± 0·0002	—	—	4 ± 2	—	—
Entada africana	1·4917 ± 0·4994	0·0459 ± 0·0120	—	8 ± 3	8 ± 3	—
Gardenia erubescens	—	0·1869 ± 0·0174	0·0412 ± 0·0077	—	54 ± 10	10 ± 4
Grewia mollis	0·4409 ± 0·0091	—	—	20 ± 5	—	—
Isoberlinia tomentosa	—	3·5569 ± 0·2662	—	—	32 ± 7	—
Khaya senegalensis	—	0·0118 ± 0·0032	—	—	4 ± 2	—
Lannea acida	—	0·7826 ± 0·0955	0·0536 ± 0·0132	—	24 ± 6	6 ± 3
Lannea kerstingii	0·7054 ± 0·1645	—	—	8 ± 3	—	—
Maytenus senegalensis	—	0·2305 ± 0·0224	0·1237 ± 0·0177	—	44 ± 7	24 ± 8
Piliostigma thonningii	0·0146 ± 0·0020	—	0·0325 ± 0·0051	8 ± 3	—	18 ± 5
Prosopis africana	2·5248 ± 0·3422	0·0704 ± 0·0226	—	24 ± 6	10 ± 4	—
Pseudocedrela kotschyii	—	0·3686 ± 0·0795	—	—	10 ± 4	—
Pterocarpus erinaceus	0·6183 ± 0·1515	0·3148 ± 0·0673	—	16 ± 6	10 ± 4	—
Sterculia setigera	—	0·4972 ± 0·1733	—	—	4 ± 2	—
Strychnos spinosa	—	—	0·0509 ± 0·0168	—	—	4 ± 2
Terminalia avicennioides	0·2073 ± 0·0364	0·1031 ± 0·0116	2·0890 ± 0·0898	8 ± 3	30 ± 6	302 ± 30
Trichilia emetica	—	—	0·0046 ± 0·0016	—	—	4 ± 2
Ximenia americana	—	0·1226 ± 0·0191	—	—	16 ± 5	—
Plot mean	16·3141 ± 0·9928	9·4036 ± 0·3886	6·7872 ± 0·2738	458 ± 26	484 ± 29	742 ± 34

(—) against a species in a plot indicates absence of the species in that plot.

Table 2. Mean crown horizontal area $\pm 95\%$ confidence interval of the woody species in three one hectare study plots in the Guinea savanna zone of Northwestern Nigeria (m^2 ha^{-1})

Species	Plot 1	Plot 3	Plot 7
Acacia gourmaensis	473·74 ± 71·87	6·61 ± 1·62	—
Acacia hockii	485·70 ± 71·49	62·33 ± 10·84	—
Acacia nilotica	802·69 ± 85·69	43·26 ± 7·75	—
Afrormosia laxiflora	192·50 ± 24·01	66·31 ± 14·66	—
Afzelia africana	—	162·40 ± 24·10	—
Anogeissus leiocarpus	3160·28 ± 271·52	—	—
Annona senegalensis	—	3·80 ± 0·93	77·43 ± 5·01
Bombax costatum	—	289·64 ± 70·95	—
Boswellia odorata	—	179·14 ± 43·88	—
Bridelia ferruginea	13·93 ± 3·16	72·56 ± 8·34	—
Burkea africana	239·55 ± 42·98	121·51 ± 26·02	1206·54 ± 208·20
Butyrospermum paradoxum	256·71 ± 40·24	109·9 ± 17·91	28·45 ± 6·36
Combretum spp.	920·55 ± 69·54	233·78 ± 26·22	377·12 ± 38·58
Crossopteryx febrifuga	19·64 ± 4·81	3·43 ± 0·58	125·14 ± 20·78
Daniellia oliveri	—	—	12·73 ± 6·24
Detarium microcarpum	22·49 ± 5·51	154·00 ± 37·72	868·12 ± 43·81
Entada abyssinica	22·49 ± 5·51	—	—
Entada africana	10·81 ± 2·64	55·55 ± 10·70	—
Gardenia erubescens	—	126·96 ± 15·28	25·33 ± 5·14
Grewia mollis	15·63 ± 2·26	—	—
Isoberlinia tomentosa	—	428·53 ± 86·86	—
Khaya senegalensis	—	6·70 ± 1·64	—
Lannea acida	—	356·75 ± 41·01	10·18 ± 2·49
Lannea kerstingii	9·63 ± 2·36	—	—
Maytenus senegalensis	—	193·51 ± 37·90	9·78 ± 6·36
Piliostigma thonningii	12·98 ± 2·24	—	60·13 ± 9·36
Prosopis africana	1489·68 ± 166·12	45·98 ± 11·26	—
Pseudocedrela kotschyii	—	16·33 ± 3·74	—
Pterocarpus erinaceus	151·60 ± 22·64	423·94 ± 96·84	—
Sterculia setigera	—	95·94 ± 23·50	—
Strychnos spinosa	—	—	5·31 ± 1·30
Terminalia avicennioides	39·61 ± 9·70	47·96 ± 5·54	1701·44 ± 205·40
Trichilia emetica	—	—	36·33 ± 17·78
Ximenia americana	—	137·20 ± 15·31	—
Plot mean crown area	8340·21 ± 501·35	3444·02 ± 176·18	4544·03 ± 299·24

(—) against a species in a study plot indicates absence of the species in the plot.

clearly shown in plot 1 which has the lowest wood density but the highest woody basal and crown area of the three plots.

The woody species densities of 458 ± 26, 484 ± 29 and 742 ± 34 plants ha^{-1} for plots, 1, 3 and 7, respectively, from this study agrees with 400, 453 and 739 plants ha^{-1} for plots 1, 3 and 7, respectively, obtained by Sanford *et al.* (1982). Thus, this result tends to support the argument of Sanford *et al.* (1982) that besides annual selection by fire, which imposes considerable uniformity on species composition (via fire resistance) of savanna vegetation and tends towards stabilization within broad climate and soil ranges, there is selection by competition especially via the mechanism of shading. Thus the few fire and drought resistant species that do

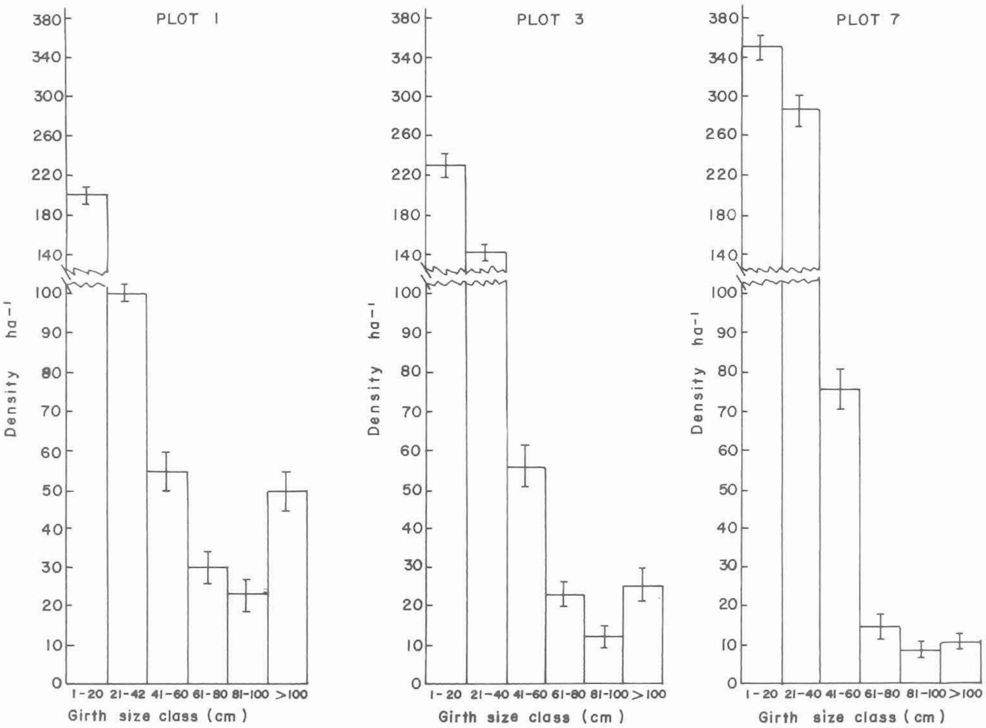

Fig. 1. Density of woody plants in various girth size classes in three study plots in the Guinea savanna zone of Northwestern Nigeria. Vertical lines (I) indicate $\pm 95\%$ confidence intervals.

exist here are limited by density. If these limits are such that juvenile and young mortality is balanced against old tree mortality, continual regeneration will occur and the savanna woodland will change little over the years.

With the exception of the mean basal area of plot 7, the mean basal area reported in this work falls within the range of $10{\cdot}9 \pm 1{\cdot}9$ to $26{\cdot}2 \pm 10{\cdot}3$ reported by Ramsay & de Leeuw (1965) for vegetation developed on soils derived from different parent materials in Nigerian savanna.

Herbage yield in the plots

The end-of-season herbage yields of natural rangelands in the subhumid zone of West Africa are reported to range from 1500 to 18,000 kg ha^{-1} depending upon local site conditions (ILCA, 1979), although yields between 2000 and 6000 kg ha^{-1} would be more typical (Milligan & Sule, 1982). The yield of 2216 to 3168 kg ha^{-1} obtained in these plots falls within this range. Sanford *et al.* (1982) reported mean herbaceous standing crop as 520 ± 200 g m^{-2} and 465 ± 122 g^{-2} for plots 1 and 3 respectively, but had no value for plot 7. Their values for these plots are higher than those obtained in this study. This difference may be accounted for by variation in rainfall through the years and increasing human and animal activities in these plots manifested by the camping of nomadic herdsmen with their livestock in the plots from the beginning of dry season to the beginning of rainy season and gathering firewood (source of fuel) from the plots. However, the peak biomass of

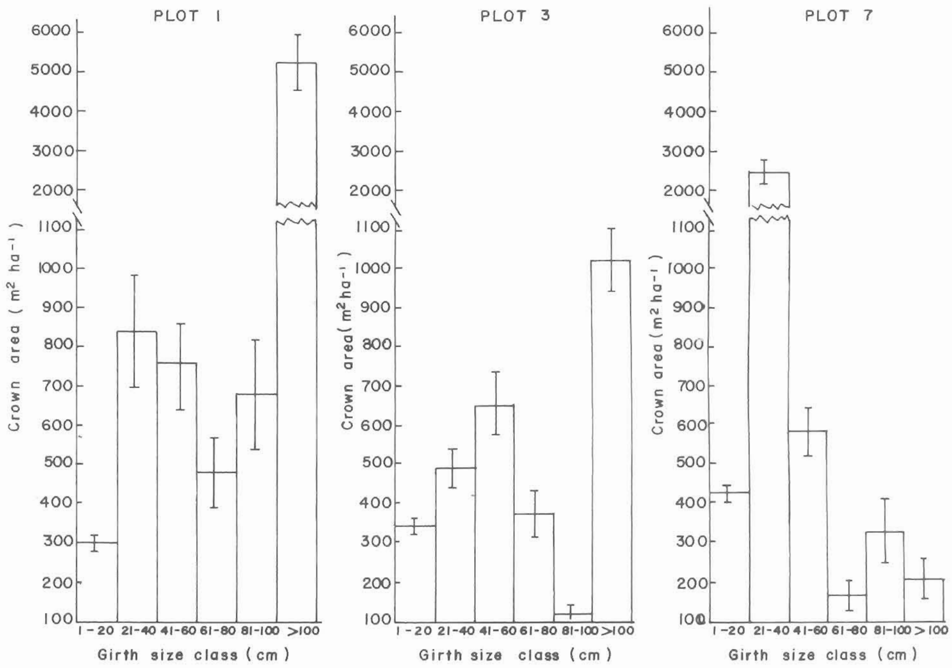

Fig. 2. Mean crown area of woody plants per girth size classes in three study plots in the Guinea savanna zone of Northwestern Nigeria. Vertical lines (I) indicate ±95% confidence intervals.

Table 3. Mean herbage yield ($g\ m^{-2}$) ±95% confidence interval in three one hectare study plots in the Guinea savanna zone of Northwestern Nigeria

Plot	Herbage component yield ($g\ m^{-2}$)		
	Grass	Forb	Total herbage
1	169·12±18·97	52·45±4·63	221·57±20·08
3	229·05±39·05	17·03±3·50	246·08±30·27
7	298·82±28·65	18·03±4·05	316·85±28·93

316·85 $g\ m^{-2}$ obtained in plot 7 which is within the Kainji National Park compares favourably with 315 $g\ m^{-2}$ obtained for late burned plot in Burkea/Deterium savanna in Borgu Game Reserve physiognomically similar to plot 7 reported by Afolayan (1977).

The variation in yield among the plots may be due to soil texture, species composition and level of human and animal activities in these plots. It would have been expected that plot 1, with more fertile soil than the others, would have had a higher yield than the others but this was not the case. This may be a reflection of the influence of soil texture on water availability and production. Frost *et al.* (1986) reported that different patterns of plant production on clayey and sandy soils occurring along rainfall gradients or in response to fluctuations in annual rainfall at a site clearly illustrates the influence of soil texture on water availability and

Table 4. Soil properties of three study plots in the Guinea savanna zone of Northwestern Nigeria (mean values ± 95% confidence interval)

Soil property	Plots 1	3	7
% Sand	54·89 ± 1·46	73·66 ± 0·94	76·37 ± 0·65
% Silt	32·28 ± 1·09	18·06 ± 0·89	15·47 ± 0·51
% Clay	12·81 ± 0·76	8·28 ± 0·51	8·15 ± 0·47
pH (KCl)	5·05 ± 0·26	5·79 ± 0·17	5·69 ± 0·11
% Organic matter	2·30 ± 0·14	1·28 ± 0·13	1·08 ± 0·06
% Total nitrogen	0·085 ± 0·007	0·061 ± 0·002	0·048 ± 0·002
Soil available phosphorus (μg/g)	1·74 ± 0·24	4·46 ± 0·80	2·99 ± 0·26
Calcium (me/100 g)	2·80 ± 0·44	2·79 ± 0·22	1·55 ± 0·18
Magnesium (me/100 g)	1·79 ± 0·16	1·17 ± 0·08	0·64 ± 0·10
Potassium (me/100 g)	0·26 ± 0·05	0·26 ± 0·04	0·15 ± 0·01
Sodium (me/100 g)	0·23 ± 0·02	0·22 ± 0·01	0·11 ± 0·02
Total exchangeable bases (me/100 g)	5·06 ± 0·55	4·44 ± 0·26	2·45 ± 0·28
Cation exchange capacity (me/100 g)	9·33 ± 0·39	7·41 ± 0·41	4·78 ± 0·33
% Base saturation	54·62 ± 3·59	62·71 ± 2·93	51·32 ± 5·86

production. When rainfall is low, production on clays may be as low as or even lower than that on sandy soils under the same rainfall, despite the generally higher nutrient status of clays (Frost *et al*., 1986). According to Dye & Spear (1982), coarse-textured sandy soils allow for a greater infiltration and deeper percolation of rainwater than heavier textured soils with a consequent increased moisture storage in the subsoil. Sandy soils enhance less capillary movement of moisture than clayey soils, therefore have a lower opportunity for evaporative loss, thereby buffering the soil moisture available for plant growth against effects of erratic rainfall (Dye & Spear, 1982). This seems to be the situation with yield in these plots though none of the soils in these plots could be described as being clayey; however, plot 1, which has the lowest yield, has the highest clay and lowest sand content. Plot 7 with the highest herbaceous yield is located within the Borgu Sector of the Kainji Lake National Park which is protected from human and livestock activities but subjected to only wildlife activity. Plots 1 and 3 are located outside the Park. Plots 3 and 7 are composed of tall grass species such as *A. gayanus, A. schirensis, H. dissoluta, H. involucrata, R. cochinchinensis* and *S. sanguineum* which give high yields per unit area while only two of these are found in plot 1, namely *A. gayanus* and *R. cochinchinensis*.

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