Relationship of woody plants to herbaceous production in Nigerian savanna

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Evidence is presented that a light, high tree canopy leads to greater production of grasses in the Nigerian Guinea savanna than either full exposure or dense canopy. Furthermore, some shading provides a micro-environment where such favoured species as the Andropogons replace such undesirable species as *Schizachyrium sanguineum* and *Hyparrhenia* species. The role of trees in open rangeland in relation to mineral cycling and soil maintenance is briefly discussed. It is recommended that the common practice of clearing all trees to improve rangeland is stopped and a low density of large trees, preferably legumes, be maintained.

Keywords: Trees (plants); Grasses; Density; Management

A critical problem in African savanna is the management of 'natural' or open rangeland for the production of livestock fodder. Uncultivated savanna in Nigeria alone amounts to ≈ 60 million hectares (de Leeuw, 1974), much of which will remain unsuitable for cultivation or monoculture and so will continue to serve as rangeland. One crucial question in managing such land is whether or not to eliminate all the woody plants to achieve maximum grass yield. However, a number of trees and shrubs have been shown to provide excellent browse (de Leeuw, 1979; Pratt and Gwynne, 1977) and, grass production has been reported to be inversely related to woody vegetation (de Leeuw, 1978; Rose Innes and Mansfield, 1976). Hence either a choice or a compromise must be made in savanna management.

In this paper, evidence is presented from research in Nigerian Derived and Guinea savanna on the relationships between herbaceous production and grass species distribution and tree canopy cover, tree density and size which will help in making such management decisions.

Research sites and methods

Research sites

The main research has been carried out over 1 year in 10 one hectare plots which were demarcated and monitored by the Nigerian Man and Biosphere (MAB) savanna research team in the Kainji Lake Basin area, northwestern Nigeria (Fig. 1). These plots lie within 9°11′ and 11°52′ N and 3°7′ and 5°28′ E. Annual rainfall in the region ranges from > 1000 mm in the northern part to > 1200 mm in the south, with mean temparatures ranging from an annual mean minimum of 20°C to a mean maximum of 34.5°C. Elevation above sea level varies from 400 to 600m. The southern part of the area (Fig. 1, plots 1,2,3) is largely over Nupe Sandstone, whilst crystalline acidic rocks of the Basement Complex are dominant in the central area (plots 4,5,6,7). In the north (plots 8,9,10), sandy drift over the Basement Compex is prevalent. The soil is ferruginous tropical in the southern and west central region and undifferentiated ferrisols in plots 4 and 5. The soil is ferrugionous tropical also in plots 8,9,10 (Nnadi and Balasubramanian, 1980). The vegetation has been classified as Northern Guinea by Keay (1959), although Clayton (1957) has termed the northern area Sub-Sudan. The area of plots 1,2,3 is considered close to Keay's concept of Southern Guinea, but the whole region may best be termed humid Tall-grass Guinea savanna. The major grass species are the perennials† *Andropogon schirensis*, *A. gayanus*, *A. africanus*, *A. tectorum*, *Schizachyrium*

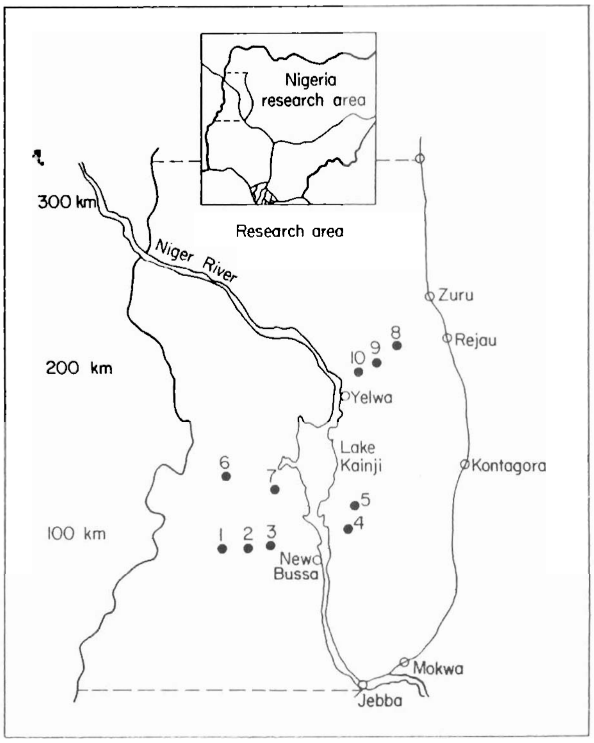

Fig. 1 The Nigerian Man and biosphere Savanna Research area, northwestern Nigeria

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† Plant names are according to the Flora of West Tropical Africa by Hutchinson and Dalziel, 1954-1972

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Table 1a Herbaceous standing crop dry weight and tree density estimations from 9 one hectare plots of Guinea Savanna, Kainji Lake Basin, 1979

MAB plot number	Herbaceous crop, ($gm^{-2} \pm 95\%$ confidence interval)	Tree density (m^{-2})		Trees with ≥ 30 cm girth (%)
		≥ 1 cm girth	≥ 30 cm girth	
1	520 ± 200	0.0263	0.0137	38
2	422 ± 132	0.1111	0.0213	19
3	465 ± 122	0.0333	0.0120	45
4	342 ± 107	0.0169	0.0125	69
5	338 ± 75	0.0526	0.0278	40
6	633 ± 312	0.0053	0.0033	83
7	—	0.0476	0.0263	38
8	118 ± 24	0.0625	0.0078	23
9	152 ± 38	0.0909	0.0100	15
10	84 ± 43	0.0909	0.0213	23

sanguineum, Hyperthelia dissoluta, Beckeropsis uniseta, Loudetia spp., *Hyparrhenia smithiana;* the annual-perennial *Hyparrhenia involucrata-H. subplumosa* complex (see Olorode (1980) for a discussion of the genetics and distribution of this complex); the annual grasses are *Pennisetum pedicellatum, P. subangustum, Brachiaria* spp, *Aristida kerstingii*.

Several other plots, although part of a different study, have provided data for this paper. The two fire-plots in the Olokemeji Forest Reserve of western Nigeria (7°25′N, 3°32′ E) were studied over 3 years. These plots, subject to controlled annual late- and early-burning since 1929, have been extensively described by Charter and Keay (1960), Hopkins (1962) and Isichei (1979). The vegetation is Derived savanna: i.e., the area lies on the edge of the lowland rainforest area (Keay, 1959) but has become savanna through anthropic interference. Major grass species are *Andropogon schirensis, A. tectorum, Schizachyrium sanguineum, Hyparrhenia spp.* and *Monocymbium ceresiiforme*. Also considered was a 1 ha plot in Old Oyo Forest Reserve, western Nigeria (8°40′N, 4°10′E), previously described by Keay (1947), with climate, soil and vegetation similar to the southernmost MAB plots (1,2,3), and two plots in the Borgu sector of the Kainji Lake National Park physically similar to MAB plots 6 and 7.

Study methods

At the end of the growing season (time of maximum standing crop) — late October at Olokemeji, November elsewhere — the herbaceous crop was estimated by random sampling of each plot (except MAB 7 which was burned before sampling could be completed) with 20 m^2 quadrats within which all the herbaceous material was clipped at ground level and sorted into species. The material was oven-dried and weighed. Tree density was estimated at various times by plotless sampling, point-centred quarter method (Cottam and Curtis, 1956) and by enumeration within belt transects. The girth at breast height (or at the mid-point of trees < 3 m in height) of all the trees encountered was measured. Tree canopy cover was recorded above the randomly placed quadrats for herbaceous crop sampling. The canopy was also recorded at every metre point along the central line of belt transects for overall plot estimation. Subjective cover estimates of major grass species were usually made around the points of plotless samplings.

Where soil C estimates were made, the analytical method was by weight loss with ignition (350°C for 18 h); total N was estimated by the Kjeldahl method.

Results

Mean dry weights of the herbaceous standing crop and tree densities for 1979 of the MAB plots are shown in Table 1a. Data from the other five plots (Table 1b) are not strictly comparable, as crop estimates are means for 1976-1978 and tree density was estimated for all trees ≥ 3m in height.

An indication of a possible relationship between woody plants and herbaceous production is given by correlation analysis, as shown in Table 2.

These relationships strongly suggest that whereas small woody plants decrease herbaceous production, larger trees either do not affect it appreciably or actually increase production.

Another approach for assessing the relationship between herbaceous yield and woody plants is to compare the yields under different canopy classes. Canopy above each square metre from which standing crop was clipped was ranked as 0, <½, ≥½ canopy, with canopy considered only from trees >3m in height. Instead of using the weight of the her-

Table 1b Herbaceous standing crop dry weight and tree density estimations of five plots of Derived and Guinea savanna, 1976-1978

Site	Herbaceous crop, ($gm^{-2} \pm 95\%$ confidence interval	Density of trees ≥ 3m in height (m^{-2})
Olokemeji Forest Reserve Fire Plots (Derived savanna)		
Late-burnt	496 ± 68	0.0983
Early-burnt	400 ± 43	0.2378
Igebiti (Old Oyo Forest Reserve) (S. Guinea Savanna)	331 ± 42	0.0460
Kainji Lake National Park (N. Guinea Savanna)		
Olli River-Open savanna	324 ± 49	0.0233
Tungan Giwa-woodland	259 ± 34	0.0261

Table 2 Correlation analysis of woody plants and herbaceous production

Variables compared	Coefficient of correlation, r	Significance
MAB plots		
Herbaceous crop and density of trees ≥ 1 cm in girth	−0.63	$P < 0.10$
Herbaceous crop and density of trees ≥ 30 cm in girth	−0.22	Not significant
Herbaceous crop and percentage of trees ≥ 30 cm in girth	+0.68	$P < 0.05$
Other plots		
Herbaceous crop and density of trees ≥ 3 m high	+0.53	Not significant

baceous crop from each square metre, this weight was divided by the mean weight per square metre for the plot. This allowed evaluation of the effect of canopy without the effect of plot-to-plot yield variation. Results of this analysis are shown in Table 3. Whereas statistical significance cannot be shown because of high and unequal group variances, the trend is clear: slightly better herbaceous production may be achieved under light canopy (< ½) than under 0 canopy; the lowest production is achieved under heavy canopy (≥ ½).

When the same type of analysis is used for data of grass yield alone with further separation of canopy categories, the results obtained are shown in Table 4. These suggest further the probable advantage of light canopy to herbaceous production.

Such canopy rankings are very approximate; however, it should be noted that any sort of canopy categorization fails to provide information as to how much of the day any particular patch of ground is in shade. Such information can only be approximated by considering both tree density and canopy cover. The actual percentage of the ground directly beneath trees > 3m high in the ten MAB plots ranges from ≈ 25 to 40%. This canopy cover may be approximately divided into two strata: canopy A, > 7m above the ground and provided by such trees as *Anogeissus leiocarpus, Butyrospermum paradoxum, Isoberlinia doka, I. tomentosa, Pterocarpus erinaceus, Acacia hockii, A. gourmaenis* and a second stratum of canopy < 7m above the ground, provided by trees such as *Annona senegalensis. Combretum* spp., *Piliostigma thonningii, Maytenus senegalensis* and *Crossopteryx febrifuga*. The data collected so far indicate a strong positive correlation between herbaceous yield and percentage of the canopy made up of stratum A trees.

As important as the relationship between tree canopy and amount of herbaceous yield, is the relationship between canopy and type of yield, i.e. grass species distribution in relation to shading. The highest mean yield was obtained from quadrats under light (< ½) canopy in five MAB plots and under 0 canopy in three plots; equal yield under light and 0 canopy was obtained in one plot. All of the three northern plots (8,9,10) achieved the greatest yield under canopy. Of the more southern plots, plot 6, with the highest yield under light canopy, *Andropogon* species were dominant (43% of the dry weight yield). In the other southern plot with the highest yield under light shade (plot 1), *Hyparrhenia* spp. were dominant (68% dry weight). In this latter plot, species other then *Hyparrhenia* constituted 19% of the standing crop from quadrats under 0 canopy, 31% under < ½ canopy and 46% under ≥ ½ canopy. In MAB plot 2, with highest yield under 0 canopy, appreciable *Andropogon tectorum* occurred, but this species constituted only 15% of the grass yield under 0 canopy, yet contributed 38% of the dry weight under light canopy. These results suggest that in locations where andropogons are found, they favour some shade, whereas *Hyparrhenia* spp., tolerant to both partial shade and full exposure, out compete them under full exposure.

It is interesting that in the three southern MAB plots (1,2,3), the percentage of plot canopy cover is very similar, ranging from 30 to 36%, but variation is considerable in the proportion of the canopy provided by A stratum trees. This variation appears to be related to herbaceous yield. In plot 1, the canopy is 87% A stratum and grass yield is highest under light canopy; in plots 2 and 3, 67 and 73% respectively, of the canopy is provided by A stratum trees and grass yield is either the same under light canopy and 0 canopy (plot 3) or more under 0 canopy (plot 2).

Soil analyses were carried out for the five non-MAB plots and the percentage of total N at the 0-15 cm depth was significantly positively correlated ($P < 0.05$) with the tree density; soil C at the 30-45 cm depth was positively correlated with tree density but with a significance level of $P < 0.1$.

Discussion

Whereas the preference of certain highly nutritious grasses for partial shade has been pointed out previously (eg Pratt and Gwynne, 1977, concerning *Beckeropsis uniseta;* Isichei, 1979, on *Andropogon tectorum* and *A. gayanus*; Milligan, 1979), overall increase in grass production under light shade has not been claimed before. Rather, grassland yield has been held generally to be inversely proportional to woody cover (de Leeuw, 1978; Rose Innes and Mansfield, 1976). Milligan (1979) suggests that the effect of woody vegetation on species composition may have opposite results on favoured yield. The results of the present paper indicate that in Guinea savanna herbaceous production is not inhibited and is probably enhanced by light, high canopy. This enhancement is more pronounced in regions of low soil fertility and high temperatures. This is suggested not only by the results of the three northern-most MAB plots studied here (8,9,10) but also by the positive correlation between tree density and soil C and N. This agrees with the results reported by Brookman-Amissah *et al.* (1980) for the Red Volta fire plots in northeastern Ghana. Here, the highest grass yield was found in the early-burnt plots with a tree density slightly over twice that of the late-burnt plots. The yield of forbs in the two sets of plots was appreciably the same. The fire-protected plots, after 27 years, had a slightly higher grass yield than the late-burnt plots. These plots are on the border of Northern Guinea and Sudan savanna and so are comparable approximately to the presently studied MAB plots 8,9,10.

Table 3 Comparison of herbaceous standing crop yield under three canopy classes in the Southern, Central and Northern MAB research areas, N. Guinea savanna, Kainji Lake Basin, 1979

MAB plot numbers	Percentage of mean plot yield achieved in lm² samples under the canopy classes: 0 canopy	< ½ (light canopy)	≥ ½ (moderate to full canopy)
1, 2, 3	1.03	1.18	0.51
4, 5	1.02	0.95	1.25
6	1.05	1.28	—
8, 9, 10	0.93	1.28	0.84
Mean	1.01	1.17	0.87

Table 4 Comparison of grass standing crop dry weight under five canopy classes in all MAB research plots combined, N Guinea savanna, Kainji Lake Basin, 1979.

Grass crop under each canopy class (% ± 95%) confidence interval)	0	< ½ (light)	Canopy class ½ (moderate)	½ (heavy)	Total
	91 ± 0.7	114 ± 1.8	85 ± 1.8	75 ± 5.1	71 ± 4.1

Furthermore, a negative correlation (−0.89, $P > 0.05$) is obtained for the relationship of herbaceous crop and mean maximum temperature in the five non-MAB plots. It is probable that large trees with high canopies at moderate density (25-50 trees > 29 cm in girth per hectare) not only improve the soil by control of erosion, addition of organic matter, improved mineral cycling and possible N addition by N_2-fixation in the Leguminosae, but also ameliorate the effects of high temperature. The latter would be beneficial in reducing herbaceous transpiration and respiration. Such a light, high canopy apparently allows enough light to reach the understorey of grasses for adequate photosynthesis, at least of such preferred species as the andropogons and *Beckeropsis uniseta*.

However, small trees appear to have an adverse effect on grass yield, especially in the more southern, humid savanna. This may be explained by direct competition for space and nutrients, and by the deeper shading of a low canopy. Furthermore, such small woody plants would not be as effective in temperature amelioration, mineral cycling and addition of C to the soil as would larger trees.

Several *Andropogon* species, including *A. gayanus* and *A. tectorum*, and *Beckeropsis uniseta* have been shown to contain more N than other Guinea savanna grasses such as *Hyparrhenia* and *Schizachyrium* (Isichei, 1979) and to be more palatable to livestock as well (de Leeuw, 1979; Milligan, 1979).

The amount of shading which is optimal is clearly related both to species of grasses available and to soil and climatic condition. In Nigerian Guinea savanna in general, however, where temperatures are often high, soil N and organic matter low and moisture limiting, for part of the year, a low to moderate density of larger trees (A canopy stratum) appears optimal. Such a condition is often favoured by annual burning, with the time of burning tending to be later in the Southern savanna than in the Northern.

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