X 5 (a) (iii)

Nitrogen concentration in the major grasses of the Derived and Guinea savanna zones of Nigeria in relation to season and site

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The concentration of total Kjeldahl N in above- and below-ground grass samples was monitored at five Nigerian savanna sites over 3 years. Significant variation, even in the same species, was found from plot to plot, with the highest concentrations in the samples from early-burnt Derived savanna and the lowest from northern Guinea samples. This may be related to soil N concentrations as a significant positive relationship was found between soil and plant concentrations. Nitrogen concentration in above-ground grass biomass declined almost exponentially from flushing through the dry season, whereas below-ground N concentration increased with the approach of the dry season. Two shade-favouring grasses, *Andropogon tectorum* and *Beckeropsis uniseta* were found to have the highest N concentrations above-ground.

Keywords: Nitrogen; Grasses; Nigeria; Savanna

The major usable resource of West African savannas is grass which is used as livestock fodder. More than 90% of the cattle and > 60% of the sheep and goats found in Nigeria are managed under traditional nomadic or transhumance systems (Milligan & Sule, 1980) which means that they rely mainly on open or 'natural' savanna as rangeland. This constitutes ≈69% of the land area of northern Nigeria (calculated from data of Milligan & Sule, 1980). Thus the nutritional value of various grass species in relation to site and season is of considerable practical economic importance.

As shown by data assembled by Pratt and Gwynne (1977), the crude protein content of fodder enables an estimate to be made of its nutritional value to livestock, and in this way N analysis of grass can be related to its practical value. Furthermore, N concentration of plants has long been shown to be a good indicator of the nutrient status of the soil (de Wit *et al.*, 1963), often giving a more realistic estimate of nutrient availability than does soil analysis. Nitrogen content of herbaceous material in natural savanna in relation to season is also of interest because of N loss through volatilization at burning. Almost all West African savanna is burnt annually, usually in mid-dry season (January), and all N in ashed material is lost from the system (Isichei & Sanford, 1980). There has been considerable controversy as to how much N is lost in this way, estimates ranging from 28 (Nye & Greenland, 1960) to 13 kg $ha^{-1}yr^{-1}$ (Isichei & Sanford, 1980). How much is actually lost will depend not only on how much material has been burnt but also upon the N concentration of the material at the time of burning. As soil N is so often a limiting factor in primary production in Nigerian savanna (Jones, 1973), the amount lost by burning becomes important.

Therefore, because of the importance of N in the assessment of savanna grasses as livestock fodder, as an indicator of soil N availability, and for estimation of annual burning losses, N concentration of major grasses in the Derived and Guinea savanna were monitored over 3 years (1975-78).

Materials and methods

Study sites

For representation of Nigerian tall-grass humid savanna, five sites were selected: two in Derived or Transition savanna, one in southern Guinea savanna, and two in northern Guinea savanna (savanna zonation *sensu* Keay, 1959). The Derived savanna plots were the 0.17 ha fire investigation plots established in 1929-30 at the Olokemeji Forest Reserve, southwestern Nigeria. These plots have been subjected to controlled annual burning since their establishment, with plot A being late-burnt (March) and plot B, early-burnt (December). The effects of this burning regime on the plots as of 1960 have been described by Charter and Keay (1960) and more recently by Sanford (1980). Brookman-Amissah *et al.* (1980) also discussed the earlier results from the Olokemeji fire experiment. Olokemeji Forest Reserve in general has been extensively studied by Hopkins (1962 and 1970), so that a lot of background information is available.

The other research areas, also in Reserves, were 50 × 50 m (0.25 ha) plots. The southern Guinea site was in the Old Oyo Forest Reserve, near Igbeti, western Nigeria; this Reserve has been studied by Keay (1947). The final two plots were both in the Borgu Game Reserve sector of the Kainji Lake National Park, an area which has been extensively studied (for example, Howell 1968; Ajayi & Hall, 1979; Afolayan, 1977; Isichei, 1979). Of these two, one plot, Oli River, was in open small-tree *Burkea africana-Terminalia avicennioides** savanna and the other in *Isoberlinia-Afzelia* woodland.

Relevant information on the sites is summarized in Table 1.

Sampling and analysis

Grass crop

All standing herbaceous material was clipped at the

*All plant names are according to Hutchinson and Dalziel (1927-1936): *Flora of West Tropical Africa*

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useful feedstuff and would be considered as a medium quality roughage. As *Striga* grows in association with sorghum, usually grown in the summer in the Sudan, the weed will be available during feed scarcity and thus will add to its importance as a feed.

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References

Abou-Akkada, A.R. and El-Shazaly, K. (1958) Studies on the nutritive value of some common Egyptian feeding-stuffs. II. Effect of concentrates rich in protein on cellulose and dry matter digestion. *J. Agric. Sci. Cambridge,* **51** 157-163

Abou-Akkada, A.R. and El-Shazaly, K. (1965) Effect of presence or absence of rumen ciliate protozoa on some blood components, nitrogen retention, and digestibility of feed constituents in lambs, *J. Agric. Sci., Cambridge* **64** 251-255

Annison, E.F., Chalmers, M.I., Marshall, S.B.M. and Synge, R.L.M. (1954) Ruminal ammonia formation in relation to protein with various diets, *J. Agric. Sci. Cambridge,* **44** 270-274

AOAC (1956) *Official Methods of Analysis of The Association of Official Agricultural Chemists.* Washington, DC: AOAC

Bebawi, F.F. and El Hag, G.A. (1980) Ecological studies on *S. hermontheca, Proc. Task Force Meeting on Arid Lands Management,* Institute of Environmental Studies, University of Khartoum

Chalmers, M.I. and Synge, R.L.M. (1954) Ruminal ammonia formation in relation to the protein requirement of sheep. II. Comparison of Casein and herring meal supplement, *J. Agric. Sci. Cambridge,* **44** 263-269

El Hag, G.A. (1976) A comparative study between desert goat and sheep efficiency of feed utilisation, *World Review of Animal Production* III, No 3, 43-48

El Shazaly, K. (1958) Studies on the nutritive value of some common Egyptian feeding stuffs. I. Nitrogen retention and ruminal ammonia curves, *J. Agric. Sci., Cambridge,* **51** 149-156

Hansen, K. (1911) Weeds and their vitality, *Ugeskr. Landm.* **56** 149

Hosmani, M.M. (1978) *Striga* Dharwar, India: University of Agricultural Science

Parker, C., Hitchcock, A.M. and Ramiah, K.V. (1977) The germination of *Striga* species by crop root exudates. Techniques for selecting resistance crop cultivatars, *Proc. 6th Asian Pacific Weed Science Society Conference* Jakarta, 67-74

Tilley, J.M.A. and Terry, R.A. (1963) A two stage technique for the *in vitro* digestion of forage crops, *J. Brit. Grassl. Soc.* **18** (2) 104-111

Table 1 Description of sites (summary)[a]

	Derived savanna plots	Southern Guinea plots	Northern Guinea plots
1. Location	7°25′N, 3°32′E	8°40′N 4°10′E	9°45′N – 10°23′N, 4°32′E – 3°40′E
2. Reserve area (km^2)	71	500	4000
3. Geology and soils			
(a) Parent materials	Basement complex	Basement complex	Undifferentiated basement complex
(b) Soil type	Tropical ferruginous	Tropical ferruginous	Tropical ferruginous
(c) Soil texture and colour	Clayey and brown in colour	Fine grained, gravelly in places, dark brown	Fine grained, brown but reddish in places
(d) Carbon concentration (%) 0—15 cm depth	Late burnt: 1.06 Early burnt: 1.11	0.72	Open savanna: 0.55 Woodland: 0.51
30—45 cm depth	Late burnt: 0.77 Early burnt: 0.91	0.65	Open savanna: 0.57 Woodland: 0.88
(e) Nitrogen concentration (%) 0—15 cm depth	Late burnt: 0.07 Early burnt: 0.08	0.06	Open savanna: 0.05 Woodland: 0.88
30—45 cm depth	Late burnt: 0.06 Early burnt: 0.05	0.04	Open savanna: 0.04 Woodland: 0.05
(f) Soil pH (0—15 cm depth)	Late burnt: 6.53 Early burnt: 6.29	6.29	Open savanna: 6.05 Woodland: 6.34
4. Climate			
(a) Annual rainfall (mm)	1232	1285	Mokwa: 1069.34 Yelwa: 1061.72
(b) Length of rainy season (days)	250	230	170 - 180
(c) Number of rain days	107	109	85
(d) Mean maximum temperature (°C)	29	32.33	Mokwa: 32.99 Yelwa: 34.50
(e) Mean minimum temperature (°C)	21.67	20.82	Mokwa: 20.65 Yelwa: 21.25
5. Vegetation type	Derived savanna	Southern Guinea savanna	Northern Guinea savanna
(a) Tree density (trees > 30 cm in girth at breast height)	Late burnt: 1 tree per 10.20 m^2 Early burnt: 1 per 4.21 m^2	1 per 21.72 m^2	Open savanna: 1 tree per 42.9 m^2 Woodland: 1 per 38.38 m^2
6. Mean maximum herbaceous crop for three years ($g\ m^{-2}$)	Late burnt: 495.58 + 68.13 Early burnt: 400.50 + 48.43	331.15 + 41.75	Open savanna: 323.62 + 49.31 Woodland: 258.72 + 34.24
7. (a) Major grass species and their weights as percentages of all sampling units total	Late burnt: *Andropogon tectorum*, 22; *A. schirensis*, 19; *Schizachyrium* sanguineum, 20; *Monocymbium ceresiiforme*, 19	*Hyparrhenia involucrata*, 31; *S. sanguineum*, 26; *A. gayanus*, 14; *A. schirensis*, 11	Open savanna: *H. involucrata*, 34; *A. gayanus*, 25; *S. sanguineum*, 19
	Early burnt: *A. tectorum*, 66; *S. sanguineum*, 17		Woodland: *H. involucrata*, 38; *A. schirensis*, 15; *H. rufa*, 12; *S. sanguineum*, 10
(b) Percentage contribution of perennial grasses to total weight	Late burnt: 92 Early burnt: 91	66	Open savanna: 60 Woodland: 50
(c) Percentage contribution of non-grass herbs	Later burnt: 0.83 Early burnt: 1.52	3	Open savanna: 6 Woodland: 5

[a]Borgu Game Reserve does not have a well established weather station so figures from nearby stations at Mokwa (9° 18′ N, 5° 5′ E) and Yelwa (10° 50′ N, 4° 44′ E) have been used

various growth periods of the year called the 'flush' (February-May), 'mid-growth' (July-August), 'peak crop' (October-November) and 'dry' seasons (December-February). The clipping was done ≈ 1.5 cm from the ground from ≈ 20 randomly placed 0.25 m^2 quadrats. Each quadrat clipping was sorted into species, immediately oven-dried at 80°C to constant weight, ground through a 1.5 mm mesh and analysed. During 1975-1976, for example, 106 quadrat clippings were made from plot A, 80 from plot B, 97 from the Igbeti plot, 101 from the Oli River site and 100 from the Tungan Giwa site. Total N was determined by the Kjeldahl method.

At the time of biomass clipping, a few plants (3-5 individuals) of each of the major grasses were dug up carefully and divided into above- and below-ground portions. Digging was usually only to a depth of ≈ 20 cm, and some of the fine fibrous roots may have been lost, although Cesar and Menaut (1974) have shown that most of the below-ground grass biomass lies between 0 and 10 cm. After washing, these samples were oven-dried, ground and analysed in the same way as the clipped samples.

Soil

Soil samples were collected at 8-week intervals for one year starting in October, 1975. Five samples were randomly taken from each plot using a soil auger with a scoop 17 cm high and 8 cm in diameter Sampling was done at two depths, to bring out the soil from 0-15 cm and 30-45 cm cores.

Each soil sample was put in a polythene bag and air-dried. Dried samples were sieved through a 2 mm mesh and analysed for total N by the Kjeldahl method.

Results

Nitrogen concentration in relation to site

Mean N concentrations for the total grass crop are given in Table 2. For site comparison, it is necessary to consider the N concentrations at comparable stages of growth as well as above- and below-ground. However, most livestock move out of the southern (Derived and Guinea) savanna regions by late June because of tsetse flies and because the grasses soon become fibrous and relatively unpalatable; they return to the south in December-January when food and water in the Sudan areas are exhausted. Considering livestock fodder, therefore, the most important periods are flush, mid-growth and dry season which fall into the months of March-May, July-August and December-March, respectively. The early flush of grass occurs shortly after burning in the dry season and is uniformly relatively high in N. This N probably comes from the underground store in the roots and rhizomes rather than from the soil, and significant variation among the plots cannot be shown. By the mid-growth period, however, statistically significant differences ($P < 0.001$) among the sites can be shown, with the early-burnt Derived savanna plot and the southern Guinea plot showing the highest mean N concentration and the northern Guinea Woodland showing the lowest; there is decreasing N concentration northwards. Dry season N concentration is highest in the Derived and southern Guinea plots and lowest in the northern Guinea plots.

That the difference in mean N concentration of the standing crop among the sites is not due solely to difference in species composition is shown by comparing N concentrations in species common to the two Derived savanna plots. Here, *Andropogon tectorum* samples simultaneously collected from the early- and late-burnt plots throughout the year showed significantly higher N concentrations ($P < 0.005$) in the samples from the early-burnt plot, with respective mean concentrations of 0.64 and 0.45%; N concentration was also higher in *A. schirensis* samples from the early-burnt plot.

In another pair of matched samples of *Monocymbium ceresiiforme* the N content was higher in the samples from the early-burnt plot. Overall, the mean concentration in all the early-burnt plot species samples was 0.62% ($n = 28$) whereas in the late-burnt plot it was 0.46% ($n = 55$); this difference is significant ($P < 0.001$). Matched collections of *Andropogon schirensis* and *Schizachyrium sanguineum* showed significantly lower N concentrations in samples from the northern Guinea plots than in samples from the Derived and southern Guinea plots in every case.

Nitrogen concentration in relation to season

In all sites N concentration of above-ground grass declined almost exponentially as the growing season advanced from flush to dry season. However, below-ground N declined through the peak standing-crop period, then abruptly increased in the dry season (see Fig. 1).

Nitrogen concentration in relation to species

Nitrogen concentrations in above-ground grass samples for the dry season and at peak standing-crop are shown in Table 3. The tendency for higher concentrations in samples from the Derived and southern Guinea plots may be discerned. Above-ground, *Andropogon tectorum* and *Beckeropsis uniseta* had the highest N concentrations. The same relationship holds for below-ground biomass, particularly in the Derived and southern Guinea zones.

Table 2 Mean percentage N in above - and below - ground collections 1975-1978 (±95% confidence interval)

	Seasons	Sites				
		Olokemeji plot A (late-burnt Derived savanna)	Olokemeji plot B (early-burnt Derived savanna)	Igbeti (southern Guinea)	Borgu Oli River (northern Guinea open)	Borgu Tungan Giwa (northern Guinea woodland)
Above-ground	Flush	1.04±0.08	1.16±0.09	1.01±0.41	1.40±0.40	1.04±0.42
	Mid-growth	0.64±0.09	0.72±0.08	0.70±0.06	0.64±0.06	0.56±0.08
	Peak	0.46±0.04	0.56±0.04	0.50±0.04	0.39±0.02	0.40±0.04
	Dry season	0.45±0.08	0.52±0.11	0.48±0.06	0.21±0.02	0.20±0.02
Below-ground	Flush	0.53±0.07	0.69±0.47	0.50±0.08	0.45±0.07	0.37±1.01
	Mid-growth	0.55±0.07	0.56±0.08	0.45±0.04	0.44±0.09	0.52±0.13
	Peak	0.48±0.06	0.62±0.24	0.39±0.06	0.31±0.02	0.37±0.02
	Dry season	0.55±0.06	0.69±0.47	0.70±0.18	0.50±0.09	0.46±0.09

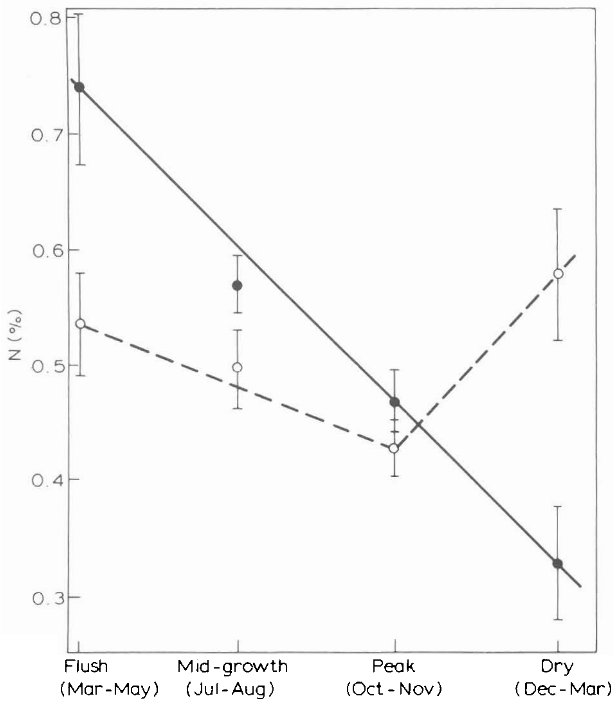

Fig. 1 Mean seasonal concentrations of nitrogen in grass samples collected from all the sites. ●, above-ground concentration; ○, below-ground concentration. Standard errors about each point are shown

Nitrogen concentration in relation to soil

Mean soil N concentrations are shown in Table 1. Correlation of these values with N concentration of grass standing-crop is significant ($P < 0.05$) at both the peak standing-crop period and during the dry season ($r = 0.89$ and 0.88, respectively). A direct relationship between soil N and crop N is also indicated by comparing N concentrations for the same species collected at the same time in different plots, as already mentioned.

Discussion

Nitrogen concentrations of Derived and Guinea savanna grasses are generally very low. Even at flush, the concentration is only ≈ 1/3 of that considered minimal in temperate zone grasses (de Wit *et al.*, 1963). *Beckeropsis uniseta* and *Andropogon tectorum* are shown to have significantly higher concentrations of N both above- and below-ground. Both of these species favour some shading by high tree canopy, whereas the less nutritious and less palatable *Hyparrhenia* spp. and *Schizachyrium sanguineum* favour full exposure, and may even be replaced by the shade-favouring species under tree canopy (Sanford *et al.*, 1982). In all species, N concentrations decline from flush to the dry season and during the dry season. Whereas they are the highest at flush, the quantity of grass at this time is too little to sustain livestock (Milligan & Sule, 1980). Nitrogen concentrations at the mid-growth period (≈ 3-3½ months after the start of the rainy season) are 135-150% of the concentration at peak standing-crop. It would appear ideal, therefore, to utilize grass either for graze, hay or insilage at this time when bulk is considerable and N concentration still relatively high.

Clearly, much of the plant N has left the above-ground biomass by the time of burning, and more has left at late burning (March) than at early burning (December). The data imply considerable transfer of N below-ground. While this suggests the advisability of late burning from the standpoint of N conservation, a much greater amount of material is burned in late fires. Therefore, the usual time of mid-dry season burning appears more reasonable. In reviewing herbaceous production in Nigerian and Ghana savanna, Sanford (1980) could not find significant difference between early-burnt and mid-dry-season-burnt plots. Control of burning time, to a large extent, also controls the canopy density and height (Sanford, 1980) and thus is instrumental in the control of grass species distribution. By such control of canopy, the shade-favouring species mentioned previously can be encouraged.

Nitrogen of the herbaceous standing-crop and of the soil appear positively correlated and, if the same species are collected at comparable times, plant analysis may give a better indication of available soil N than would soil analysis. As Cornforth (1974) has remarked, 'The amount of nitrogen in the soil depends on vegetation, rainfall and soil drainage and the supply of nitrogen available to plants frequently depends on rainfall and on the base status of soils rather than on the total amount of nitrogen present. This implies that laboratory tests for nitrogen-supplying potential have little value.'

Table 3 Mean concentration of N in standing crop of various grass species at the peak crop period (October - November) and in mid-dry season (December - February) at various savanna sites in western Nigeria

Species	Savanna type	Percentage nitrogen (±95% confidence interval)			
		Peak crop period (Oct-Nov)	(*n*)	Mid-dry season (Jan)	(*n*)
Andropogon gayanus	Northern Guinea	0.38 ± 0.002	(11)	0.19 ± 0.001	(15)
A. pseudapricus	Northern Guinea	0.35 ± 0.003	(9)	—	
A. schirensis	Derived and Southern Guinea	0.44 ± 0.001	(19)	0.54 ± 0.03	(6)
A. tectorum	Northern Guinea	0.41 ± 0.001	(29)	0.20 ± 0.02	(4)
	Derived and Southern Guinea	0.57 ± 0.003	(35)	0.51 ± 0.008	(9)
Beckeropsis uniseta	Derived and Southern Guinea	0.51 ± 0.01	(6)	0.43 ± 0.008	(7)
Hyparrhenia perennial spp.	Derived and Southern Guinea	—	—	0.60 ± 0.02	(8)
	Northern Guinea	0.30 ± 0.03	(4)	0.20 ± 0.001	(12)
H. involucrata	Derived and Southern Guinea	0.41 ± 0.005	(5)	—	
	Northern Guinea	0.37 ± 0.000	(38)	0.22 ± 0.001	(14)
Schizachyrium sanguineum	Derived and Southern Guinea	0.44 ± 0.002	(21)	0.46 ± 0.000	(19)
	Northern Guinea	0.39 ± 0.003	(7)	0.20 ± 0.002	(12)

References

Afolayan, T.A. (1977) *Savanna structure and productivity in relation to burning and grazing regimes in Kainji Lake National Park*, Ph.D. Thesis, University of Ibadan, Nigeria

Ajayi, S.S. and Hall, J.B. (1979) An ecological management Plan for the Kainji Lake National Park, in: *Wildlife Management in savannah Woodland*, (Eds. Ajayi, S.S. and Halstead, L.B.) London: Taylor and Francis, pp. 205-213

Brookman-Amissah, J., Hall, J.B., Swaine, M.D. and Attakorah, J.Y. (1980) A re-assessment of fire protection experiment in north-eastern Ghana savanna, *J. Appl. Ecol.* **17** 85-99

Cesar, J. and Menaut, J.C. (1974) Le peuplement végétal des savanes de Lamto (Côte d'Ivoire), *Bulletin de Liason des Chercheurs de Lamto*. Numéro special, fascicule II

Charter, J.R. and Keay, R.W.J. (1960) Asessment of the Olokemeji fire-control experiment (Investigation 254) 28 years after institution, *Nigerian Forestry Information Bulletin (New series)* **3** Federal Government Printer, Lagos

Cornforth, I.S. (1974) A review of work on Nitrogen in West Indian soils, *Trop. Agric. (Trinidad)* **51** 145-152

de Wit, C.T., Dijkshoorn, W. and Noggle, J.C. (1963) Ionic balance and growth in plants, *Verslagen Van Het Landbouwkundig Onderzoekingen in Nederland* **69** p.69

Hopkins, B. (1962) Vegetation of the Olokemeji Forest Reserve, Nigeria, I. General features of the Reserve and the research sites, *J. Ecol.* **50** 559-598

Hopkins, B. (1970) The Olokemeji Forest Reserve, III. Natural History, *Nigerian Field* **35** 54-78

Howell, J.H. (1968) The Borgu Game Reserve of Northern Nigeria, Part I. *Nigerian Field* **33** 99-116; and Part 2, 147-165

Isichei, A.O. (1979) *Elucidation of stocks and flows of nitrogen in some Nigerian savanna ecosystems*, Ph.D. Thesis, University of Ife, Nigeria

Isichei, A.O. and Sanford, W.W. (1980) Nitrogen loss by burning from Nigerian grassland ecosystems, in: *Nitrogen cycling in West African ecosystems*. ed. Rosewall, T. Swedish Academy of Sciences pp. 325-331

Jones, M.J. (1973) The organic matter content of the savanna soils of West Africa, *J. Soil Sci.* **24** 42-53

Keay, R.W.J. (1947) Notes on the vegetation of Old Oyo Forest Reserve, *Farm and Forest* **8** 36-47

Keay, R.W.J. (1959). *An Outline of Nigerian Vegetation*, Third Edition, Lagos: Government Printer

Milligan, K. and Sule,B. (1980) Natural forage resources and their dietary value, in: *Nigerian Savanna: State of Knowledge*. Proceedings of the Unesco/Man and Biosphere Workshop, 1980, (Eds. Sanford, W.W., Yesufu, T.M. and Ayeni, J.S.) (in press)

Nye, P.H. and Greenland, D.J. (1960) *The Soil under Shifting cultivation*, Technical Communication No. 51, Commonwealth Bureau of soils, Bucks., UK

Pratt, D.J. and Gwynne, M.D. (1977) *Rangeland Management and Ecology in East Africa*, London: Hodder and Stoughton

Sanford, W.W. (1980) Effects of seasonal burning in the savanna, in: *Nigerian Savanna: State of Knowledge*. Proceedings of the UNESCO/Man and Biosphere Workshop 1980. (Eds. Sanford, W.W., Yesufu, T.M. and Ayeni, J.S.) (in press)

Sanford, W.W., Usman, S., Obot, E.A. Isichei, A.O. and Wari, M. (1982) Relationship of woody plants to herbaceous production in Nigerian savanna, *Trop. Agric* (Trinidad) **59** 315-318.