REPRINT

NIGERIAN SAVANNA

Selected Papers from the Man and Biosphere State-of-Knowledge Workshop Sponsored by the Nigerian National Man and Biosphere Committee, U.N.E.S.C.O. and the Kainji Lake Research Institute

Held at
Kainji Lake Research Institute
April 20th - 24th 1980

Edited by
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Published by the Kainji Lake Research Institute. Assisted by the Nigerian Man and Biosphere Committee and the United Nations Educational, Scientific and Cultural Organization.

New Bussa 1982

NITROGEN IN SAVANNA GRASS AND LITTER

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SUMMARY

1. Savanna grasses are low in nitrogen. This is related to the low nitrogen content of the soils: there is decreasing nitrogen in the soil northwards and this is reflected in the grasses.
2. Even in the same environment some species are better accumulators than others. Possible reasons are advanced for this. The *Andropogon* species and *Beckeropsis uniseta* are the best known accumulators.
3. There is a well marked seasonality in nitrogen concentration in grass. The below-ground parts have their highest concentration in the dry season, while in the above-ground parts the highest concentration is at the beginning of growth.
4. Litter is important because it is a major means of nitrogen re-cycling. Its pattern of fall and decay in the savanna is discussed. It is emphasized that most of the litter fall is after the annual fires.
5. Nitrogen content of litter varies from site to site but does not show significant seasonal difference.

CONTENTS

1. Introduction

1.1 Grass

Bradshaw et al. (1964) stated that nitrogen is one of the nutrient elements universally often limiting in natural and agricultural lands; this is particularly true of the tropics. Savanna soils are low in total nitrogen with values ranging from 0.008 to 0.290% with a mean of 0.051% (Jones 1973). (See also Nnadi and Balasubramanian, this volume.) A small proportion of soil total nitrogen is available for uptake by plants; Jones estimates only about 4% annually; Isichei (1979) has estimated only about half this amount.

Often, within rather broad limits, the amount of nitrogen in a plant depends on the amount available in the soil. In the savanna there is a broad relationship between total annual rainfall and plant biomass in the various zones and concomitant with this is an increase in the availability of organic matter for decomposition that eventually results in soil nitrogen. So one would expect a decrease in soil total nitrogen from the Derived to the Sudan zones. This has been shown by some workers, including Jones (1973) and Isichei (1979).

As Bate (1981) has emphasized, the amount of nitrogen available to plants each season is largely a function of the rate at which organic nitrogen is mineralized by soil micro-organisms. In the savanna, moisture is the obvious limiting factor for microbial activity and it would be expected that as soon as the rains come there will be a surge in amount of available soil nitrogen (See Enwezor 1967). It is likely, then, that concentration in grasses may be highest in nitrogen at the beginning of grass growth. This is often so, but the matter is complicated by grass flushing which occurs in the dry season. Grass flush has very high nitrogen concentration drawn exclusively from grass rhizome reserves. As the season progresses and total biomass accumulates, nitrogen concentration decreases even though the total amount of nitrogen continues to increase because of uptake from the soil. So in the savanna a linear decrease in nitrogen concentration with season is often observed.

1.2 Litter

The importance of studying litter production in the savanna stems from its crucial role in nutrient cycling and soil organic matter build-up. Hopkins (1965) is also of the view that litter production is an index of the production of the woody vegetation. In spite of this, very little information is available for West Africa in terms of litter production and its contribution to soil organic matter. Nye and Greenland (1960 p.49) review and discuss in a very general way the role of litter in nutrient cycling in both forest and savanna. Hopkins (1966) concluded that litter does not add much organic material to the soil in savanna regions, since more litter is destroyed by annual fires than is decomposed. On the other hand, Collins (1977), who worked on the border of the Southern and Northern Guinea zones in Nigeria, observed that most of the tree leaf litter falls after the annual fires, so that decomposition and consumption by termites account for much of the litter disappearance. This implies that considerable organic matter, nitrogen and sulphur may be added or returned by way of litter. This is in line with the view of Cornforth (1970), who worked in a tropical rainforest in Trinidad. Isichei (1979) has a similar opinion based on litter collection for a twelve month period in the Derived, Southern Guinea and Northern Guinea zones.

I have observed that while time of leaf fall in savanna varies from species to species in the absence of fire, fire, especially fires in the month of January, bring about complete leaf fall in most species. On the other hand, if one travels through the Southern Guinea zone at this time, one notices new flush of leaves in *Daniellia oliveri* which means that leaf fall occurs before burning in this species. Collins, however, is right in saying that most leaf fall occurs after burning has taken place.

2. Nitrogen concentration of savanna grass

2.1 Nitrogen concentration in relation to season and site

Table 1 (adapted from Isichei 1979) - which shows the mean percentage nitrogen concentration for various periods of the year in samples collected from sites in the Derived and Guinea zones - summarizes the trend in nitrogen concentration in the major savanna grasses. Above-ground (the part usually affected by burning) in the dry season, the nitrogen concentration is low but there is an exponential increase in concentration at the flush and early growth periods. Thereafter there is a steep decline. Below-ground, the highest nitrogen concentration is in the dry season. There is a continuous decline as the season progresses with the lowest value at the peak period. This pattern in nitrogen concentration has been reported by Hagger (1970) who worked at Samaru on

Table 1 Mean nitrogen concentrations in above - and below - ground grass samples at various seasons for sites in the Derived, Southern and Northern Guinea zones (± 95% confidence interval)

Season	n	above-ground	n	below-ground
Flush (Feb. - May)	6	0.74 ± 0.18	8	0.53 ± 0.10
Mid-growth (July - Aug.)	9	0.57 ± 0.06	10	0.49 ± 0.08
Peak (Oct. - Nov.)	12	0.47 ± 0.06	12	0.42 ± 0.05
Dry (Dec. - Feb.)	11	0.32 ± 0.11	10	0.58 ± 0.12

Andropogon gayanus , and by Jihad (1976) who worked on *Hyparrhenia* species in Zambia. Hagger obtained a mean above-ground value of 1.04% nitrogen at the beginning of growth and a 0.24% in the dry season; Jihad's above-ground values were 1.15% and 0.35%, respectively. (Figures in both cases are calculated from crude protein figures.)

The pattern of concentration below-ground throughout the year substantiates the opinion (yet to be proved) that there is translocation of nitrogen to the below-ground parts which is again relocated upwards during grass flushing. Egunjobi (1974) indicated this, and Morton (1977) has shown this to happen in temperate species.

Table 2 (from Isichei 1981) shows the mean percentages of nitrogen in oven-dry grass samples over the seasons for the period 1975-1978, above- and below-ground, for five sites in the Derived, Southern Guinea and Northern Guinea zones.

Table 2 Mean percentage nitrogen in above- and below- ground collections 1975-1978 ± 95% confidence interval (from Isichei 1981)

	Seasons	SITES				
		Olokemeji Plot A (late burnt Derived)	Olokemeji Plot B (early burnt Derived)	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

There is significant difference (analysis of variance) between nitrogen concentration above-ground and below-ground ($P < 0.001$) and between the sites ($P < 0.01$) and the seasons ($P < 0.001$); the interaction between seasons and above-ground/below-ground nitrogen concentrations is also significant ($P < 0.001$).

The plot in the Derived zone (Olokemeji Plot B) has the highest mean concentration followed by Olokemeji Plot A and Igbeti. The Borgu plots have the lowest. A casual look at Table 3 (Afolayan and Fafunsho 1978) shows a difference between nitrogen concentration in grasses between the woodland fire plots and the *[illegible] a-botarium* fire plots. The decrease in N concentration with season is also evident from both Tables.

That the grass samples showed a general decrease in N concentration northwards is not surprising because soil total nitrogen decreases northwards (due to decreasing annual rainfall, less vegetation and less soil

Table 3 Seasonal changes in mean nitrogen concentration in three major grass species at Borgu Game Reserve, 1975. (Concentrations calculated from crude protein figures. Afolayan and Fafunsho 1978)

Species	Months				
	August	September	October	November	December
1. *Hyparrhenia smithiana*	1.33	0.99	0.75	0.52	0.43
Beckeropsis uniseta	1.24	1.00	0.78	0.60	0.51
2. *Loudetia flavida*	1.03	0.80	0.63	0.53	0.42
Hyparrhenia involucrata	1.20	0.82	0.59	0.52	0.34

1.= Results from Woodland fire plots

2.= Results from *Burkea/Detarium* open savanna plots

organic matter). Even at the two Olokemeji plots, where the burning regime has affected the soils such that the early burnt plot (Plot B) has a higher mean total soil nitrogen than the late burnt plot (Plot C), when all grass collections from both plots are compared, the early burnt plot samples show significantly ($P < 0.01$) higher mean N concentrations (0.62% and 0.46%, respectively, Isichei 1981). Nitrogen concentration in *Andropogon tectorum*, a grass common to both plots, is higher in collections from Plot B than in collections from Plot A, with respective mean concentrations of 0.64% and 0.45% (significantly different at $P < 0.005$) (Isichei 1981).

2.2 Nitrogen concentration in relation to species

2.2.1 Genetically based variation among species

Some species are better accumulators of nitrogen than others and so tend to have higher nitrogen concentrations than others when growing in the same environment. Thus Bradshaw et al. (1964) stated: "An awareness of difference in response to nitrogen between economically important species underlies much present-day grassland management, and certain specific experiments suggest that differences between species may be considerable." This is no less true and very important for Nigerian savanna grasses, because low nutrient content - mainly in terms of nitrogen and phosphorus - is one of the major constraints facing the livestock industry today (Brinckman and de Leeuw 1979). The differences in efficiency of accumulation by different species is at times so glaring that Beauchamp et al. (1976), in a study on maize genotypes, observed that "there appears to be some potential for the screening and development of hybrids capable of accumulating relatively large quantities of nitrogen or using nitrogen more efficiently through translocation from various parts." The work of Opakunle (1978) showed differences between *Andropogon gayanus* and *Schizachyrium sanguineum*. He grew wild rhizomes of the two grasses at three different nitrogen concentrations (210, 420 and 630 ppm N). Higher concentrations of nitrogen were found in *S. sanguineum* at the lowest concentration medium, while at the higher N-levels *A. gayanus* accumulated more. The implication for this is that *Andropogon gayanus* may be outcompeted in N-poor soil. The differences in accumulation by species is further illustrated by Hagger (1975). While testing the yield of *A. gayanus* in response to nitrogen applications that ranged from 0 to 896 kg N ha^{-1} he found that when rates exceeded 500kg N ha^{-1} *A. gayanus* decreased in abundance and began being replaced by "less desirable species".

2.2.2 Variation in species composition and form of nitrogen utilised in relation to successional position

Even in the same environment uptake may depend on whether a species is especially adapted to such an environment in terms of whether the ecosystem is 'seral' or 'climax'. (In natural habitats undisturbed for a long time such as in game reserves one would assume that species found there are the 'climax' species.) Bate and Heelas (1975) found that nitrate uptake by the 'seral' grass, *Sporobolus pyramidalis* was 20% higher than uptake by 'climax' grass *Hyparrhenia filipendula* in Zimbabwe. This is in line with the observation of Rice and Pancholy (1972) that as a succession approaches 'climax' there is increasing utilization of ammonium nitrogen and decreased nitrate-nitrogen uptake. The implication of these observations for nitrogen uptake depends on the form of nitrogen that is more abundant in the habitat. From the standpoint of energy conservation in the ecosystem and prevention of nitrogen loss through denitrification and leaching, ammonium nitrogen uptake is obviously advantageous.

2.2.3 Maximum nitrogen accumulators among species occurring in Nigeria

That some species are better accumulators than others has been shown in Nigerian savanna (Isichei 1979). Tables 4 - 8 compare the nitrogen content of various grass species found at various sites in the Derived, Southern Guinea and Northern Guinea zones at various times of the year. Results of analysis of variance and paired comparison of means indicate which species are good accumulators of nitrogen in natural savanna and which are not. In summary, the *Andropogon* species, namely *A. gayanus*, *A. schirensis* and *A. tectorum*, have been identified as the best accumulators of nitrogen. *A. gayanus* and *A. schirensis* are more widely distributed; *A. tectorum* is very often restricted to shade. *Beckeropsis uniseta* (also favouring shade) is a fairly good accumulator in poor soil. The annual, *Hyparrhenia involucrata*, which is sometimes the most abundant species at the peak crop period in the Northern Guinea zone is a poor accumulator both above- and below-ground.

2.2.4 N_2-fixation in the grass rhizosphere

One likely reason why some species show indications of better accumulation than others is the observation that some tropical grasses,

Table 4 Comparison of nitrogen concentration in some grass species during the dry season of 1975-1977 in the Derived and Southern Guinea Zones+ (from Isichei 1979)

Species	Mean ± 95% Confidence Interval			
	n	Standing crop	n	Below-ground
Andropogon tectorum	9	0.51 ± .008	4	0.51 ± .003
A. schirensis	6	0.54 ± .03	4	0.63 ± .03
Beckeropsis uniseta	7	0.43 ± .008	2*	0.80 ± 0.80
Hyparrhenia (Perennial spp.)	8	0.60 ± .02	8	0.61 ± .02
H. involucrata	5	0.48 ± .05	4	0.33 ± .004
Schizachyrium sanguineum	19	0.46 ± .000	9	0.55 ± .01

*Some analytical results missing

+ The difference between the species is statistically significant below-ground but not above-ground

Table 5 Nitrogen concentration in some species compared at the peak growth period in the Derived and Southern Guinea zones*

Species	Mean ± 95% Confidence Interval			
	n	Standing crop	n	Below-Ground
Andropogon tectorum	35	0.57 ± .003	6	0.39 ± .006
A. schirensis	19	0.44 ± .001	8	0.41 ± .002
Beckeropsis uniseta	6	0.51 ± .01	4	0.60 ± .03
Hyparrhenia involucrata	15	0.41 ± .005	2	0.35 ± .14
Monocymbium ceresiiforme	18	0.42 ± .001	3	0.37 ± .04
Schizachyrium sanguineum	21	0.44 ± .002	6	0.43 ± .003

*Here the differences among the species was significant both above- and below-ground.

in association with the bacterium *Spirillum lipoferum* , fix nitrogen in their rhizosphere (see for example, Dobereiner and Day 1976). No work on this has been reported in Nigerian savanna. Balandreau (1975) estimated that 10kg N ha^{-1} is fixed in Andropogoneae rhizosphere in the Ivory Coast in an environment similar to the Derived/Guinea Savanna regions of Nigeria. Day (1977) gives a list of laboratory grown grasses from Brazil, Nigeria and Ivory Coast that have been studied for rhizosphere fixation and the list includes *Andropogon gayanus* (from Nigeria) with a nitrogenase activity of 5-90 nanomoles of nitrogen per gram root per hour. Further reports of nitrogen fixation in grass- *Spirillum* systems were made in Florida, U.S.A. (Smith et al. 1976), but some doubt was expressed concerning the results presented (Rogerson 1977). Day (1977) shows that nitrogen fixed in the rhizosphere is incorporated into the plant.

Table 6 Comparison of mean % nitrogen in oven-dry samples of *Andropogon spp.*, *Hyparrhenia spp.* and *Schizachyrium sanguineum* at various seasons at the southern Guinea site*

	% nitrogen ± 95% Confidence Interval											
	Andropogon spp.				*Hyparrhenia spp.* (perennial)				*Schizachyrium sanguineum*			
	n	Above-	n	Below-	n	Above-	n	Below-	n	Above-	n	Below-
Flush	10	1.77 ± .25	10	0.50 ± .07	7	0.94 ± .26	8	0.55 ± .25	18	1.11 ± .2	9	0.48 ± .09
Mid-growth	8	0.66 ± .09	8	0.51 ± .09	4	0.66 ± .01	4	0.41 ± .05	1	0.69 ± .06	1	0.33 ±
Peak-growth	7	0.46 ± .09	5	0.45 ± .13	7	0.45 ± .09	5	0.36 ± .05	3	0.46 ± .06	4	0.33 ± .10
Dry season	5	0.36 ± 19	3	0.63 ± .50	7	0.49 ± .17	5	0.56 ± .24	8	0.35 ± .09	7	0.72 ± .48

*Significant difference between above- and below- ground (P < 0.025), between the seasons (P < 0.005) and species (P< 0.005).

Table 7 Concentration of nitrogen in some grass species in the Northern Guinea zone in the dry season 1976-1977*

Species	% nitrogen in oven-dry tissue ± 95% Confidence Interval			
	n	Above-ground	n	Below-ground
Andropogon gayanus	15	0.19 ± .001	3	0.60 ± .03
A. schirensis	4	0.20 ± .02	2	0.40 ± .002
Hyparrhenia involucrata	14	0.22 ± .001	3	0.41 ± .02
Hyparrhenia (perennial) *spp*	12	0.20 ± .001	1	0.28 ± .003
Schizachyrium sanguineum	12	0.20 ± .002	2	0.36 ± .003

*The species show a significant difference in below-ground nitrogen concentration only ($P<0.025$)

Table 8 Comparison of N concentration in some species in the Northern Guinea zone at peak growth (November)

Species	% nitrogen in oven-dry tissue 95% Confidence Interval			
	n	Above-ground	n	Below-ground
Andropogon schirensis	29	0.41 ± .0006	18	0.34 ± .0003
A. pseudapricus	9	0.35 ± .003	5	0.28 ± .008
A. gayanus	11	0.38 ± .002	9	0.33 ± .01
Aristida kerstingii	5	0.42 ± .008	5	0.34 ± .002
Hyparrhenia involucrata	38	0.37 ± .0004	20	0.35 ± .004
H. smithiana	4	0.30 ± .03	4	0.35 ± .004
Schizachyrium sanguineum	7	0.39 ± .003	5	0.30 ± .001

*The species do not show significant difference either above- or below-ground.

2.2.5 Nitrogen loss from annual burning

Table 9 is a follow-up of the information in Tables 4 - 8: it shows the nitrogen concentration in the major grass species of sites in the Derived, Southern and Northern Guinea zones at the various seasons, the mean N-content of all herbaceous plants (mainly grass) per unit area through one year (October 1976 to November 1977). (The dates have been grouped according to seasons. For reference purposes the standing crop figures obtained on these dates are inserted with the nitrogen figures.) The Table gives a picture of the amounts of nitrogen in herbaceous biomass at various times of the year and allows evaluation of nitrogen loss as a result of savanna burning which is of prime importance.

Nitrogen lost through burning is a loss to the system since no nitrogen is left in the ash (Isichei and Sanford 1980). Hence the importance of the amount of nitrogen in the below-ground part of the herbaceous biomass - which is not usually burnt. At late burning in February/March, the amount of nitrogen above-ground is about half the amount in December when grass drying starts. This obviously suggests translocation.

3. Nitrogen in litter

3.1 Nitrogen in litter in relation to site and season

3.1.1 Range of nitrogen concentration

Cornforth (1970), working in a tropical rainforest in Trinidad, found nitrogen concentration in leaf litter to be between 0.80 and 0.90%. Table 10 presents total Kjeldahl nitrogen concentrations in leaf and wood litter as obtained by Isichei (1979) in the Derived, Southern Guinea and Northern Guinea zones. Nitrogen concentration in litter ranges from 0.50% in wood to 1.22% in leaves.

3.1.2 Variation among sites

A significant difference among the sites is indicated when an *a posteriori* test is applied. Results show that N-concentration in leaf litter at Oli River (N. Guinea) is less than concentration at Igbeti; Oli River litter also had significantly less nitrogen in the November period than either Igbeti or Tungan Giwa. No significant difference is indicated among the seasons.

3.1.3 Litter production in West African savanna

Table 11 integrates litter production and nitrogen concentration and gives an idea of the amount of nitrogen returned to the soil when burning loss is excluded. Known litter production figures for West African savanna are presented in Tables 12a and 12b.

3.2 Nitrogen in litter in relation to species

Isichei's (1979) result shows that litter prodction is related to density of trees and that nitrogen concentration is related to the proportion of leguminous trees. He analysed cores taken from legume and non-legume trees and found that legumes had significantly higher N-concentration ($P < 0.05$, $n = 26$).

3.3 Litter as a source for organic matter build-up in the soil

Litter could contribute significantly to the build-up of organic matter if it is not burned. Isichei and Sanford (1980) found that at the Olokemeji plots only about 18.54%, 11.71% and 36.84% of the annual leaf, wood and fruit litter production, respectively, are burned. It is certain that the amount of litter burned is subject to year-to-year and place-to-place variation, but the important fact is that the litter-fall peaks are outside the burning periods in most places. Isichei (1979) observed two litter fall peaks - one in August, during the little dry season (Hopkins 1966), and in the late dry season after burning must have taken place. (See also Collins 1977).

Nitrogen content of the herbaceous biomass in g m^{-2} + 95% confidence interval (October 1976 to November 1977)

Date	SITE									
	Olokemeji A		Olokemeji B		Igbet		Borgu Oli Rive		Borgu, Tungan Giwa	
	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below
2 Oct. 1976	----------	----------	----------	----------	1.25 ± .13 (254.22 ± 47.70)	3)	----------	----------	----------	----------
16 Oct. 1975	----------	----------	----------	----------	----------	----------	1.26 ± .34 (359.54 ± 88.07)	(.64)	0.73 ± .18 (183.08 ± 42.01)	(0.39)
13 Nov. 1976	1.72 ± 46 58.02 ± 133.01)	(0.68)	3.11 ± 1. (431.39 ± .01)	(0.42)	----------	----------	----------	----------	----------	----------
14 Dec. 1976	----------	----------	----------	----------	1.86 ± .38 (300. ± 145.70)	(1.14)	The Borgu Plot we e burned in ea ly January 1977			
16 Dec. 1976	----------	----------	Olokemeji B was burned on this date after which collection was made from the plot 0.37 ± .08 (70.046 ± 59.57)	----	----------	----------	----------	----------	----------	----------
11 Jan. 1977	----------	----------	----------	----------	The Igbeti plot was burned in early Jan. 1977		0.21 ± .02	(0.82)	0.10 ± .02 49.44 ± 30.51)	(.44)
25 Feb. 1977	----------	----------	----------	----------	0.22 ± .04 (45.44 ± 40.19)	----	----------	----------	----------	----------
	Plot was burned in the 1 st week of Febru 1977									

Table 9 (Continued

Date	SITE									
	Olokemeji A		Olokemeji B		Igbeti		Borgu, Oli River		Borgu, Tungan Giwa	
	Above	Below	Above	Below	Above	Below	Above	Below	Above	Below
30 June 1977	----------		----------		----------		0.60 ± .09 50.94 ± 36.73)	(0.92)	0.85 ± .00 (93.72 ± 37.02)	---- ----
25 Aug. 1977	1.15 ± .37 (196.55 ± 90.77)	(0.39)	0.49 ± .05 (60.59 ± 27.02)	(0.12)	----------		----------		----------	
28 Aug. 1977	----------		----------		----------		0.51 ± .07 (64.94 ± 31.82)	(0.32)	1.01 ± .10 (152.12 ± 46.33)	(0.66)
1 Sept. 1977	----------		----------		1.38 ± .45 (177.12 ± 66.38)	(0.64)	----------		----------	
28 Oct. 1977	----------		----------		----------		1.44 ± .07 (287.74 ± 52.02)	(0.53)	1.45 ± .16 (334.48 ± 140.54	(0.80)
4 Nov. 1977	----------		----------		1.57 ± .12 (376.68 ± 105.43)	(0.65)	----------		----------	
10 Nov. 1977	2.75 ± 1.07 (687.28 ± 347.18)	(0.82)	278 ± .59 (480.28 ± 127.13)	(0.41)	----------		----------		----------	

*Above-ground values are based on nitrogen contained in species in quadrat clippings while below-ground values are based on nitrogen contained in below-ground parts of up-rooted grass samples and on mean ratios of below-ground to above-ground biomass as estimated from up-rooted plants. Below-ground values here are thus crude estimates. The ratios vary with season and increase from the Derived to the Northern Guinea Zones.

Table 10 Nitrogen concentration in litter ± 95% confidence limits (values are percentages)

Sites	% Concentration in Leaf Litter	% Concentration in Wood Litter
Olokemeji A (late burnt Derived savanna	0.95 ± 0.20	0.50 ± 0.14
Olokemeji B (early burnt Derived savanna)	0.97 ± 0.80	0.58 ± 0.10
Olokemeji C (fire protected Derived savanna)	0.95 ± 0.10	0.61 ± 0.16
Igbeti (southern Guinea savanna)	1.22 ± 0.18	0.61 ± 0.16
Oli River (open Northern Guinea savanna)	0.81 ± 0.12	0.55 ± 0.02
Tungan Giwa (Northern Guinea woodland)	0.97 ± 0.10	0.58 ± 0.04

Table 11 Total annual nitrogen content, in grams, of leaf wood and fruit litter per square metre of site area

	Nitrogen g m^{-2} oven-dry litter ± 95% confidence interval			
Sites	Leaf litter	Wood litter	Fruit litter	Total litter
Olokemeji A	0.65 ± .04	6.49 ± .65	0.00	7.14 ± .22
B	4.50 ± .08	1.15 ± .08	0.13 ± .04	5.95 ± .02
C	5.50 ± .12	1.26 ± .06	0.10 ± .02	6.86 ± .04
Igbeti	1.25 ± .07	4.39 ± .46	0.19 ± .09	5.83 ± .10
Borgu				
Oli River	1.16 ± .05	0.38 ± .08	0.02 ± .01	1.56 ± .02
Tungan Giwa	2.27 ± .92	1.02 ± .11	0.11 ± .11	3.40 ± .46

3.4 Litter disappearance

What certainly happens is that a considerable amount of litter is consumed by termites which abound in the savanna (See Ohiagu, this volume.) This represents an accelerated breakdown of litter but whether the nitrogen contained in the litter is denitrified before plants can absorb it is not known.

Table 13 presents calculated litter disappearance rates at various sites in the savanna (Isichei 1979). 'Disappearance' is used because the rates reported include consumption by termites and natural microbial decomposition which is affected by climate, especially moisture availability.

Table 12a Summary of known litter fall results, g m^{-2}

Location and Zone	Leaf fall	Wood fall	Total	Source
Near Mokwa (Southern Guinea)	238.7	139.1		Collins (1977)
Zaire (Miombo)	290	440	-	
Lamto, Ovory Coast (Derived Savanna)	-	-	480	"
Fete Ole, Senegal (Sahel Zone)	-	-	160	"
Olokemeji, Nigeria (Derived Savanna)	90		160	Hopkins (1966)

Table 12b Mean annual leaf, wood and fruit litter fall in grams oven-dry litter m^2 (From Isichei 1979)

Site	g oven-dry fall m^{-2} ± 95% confidence interval		
	Leaf Fall	Wood Fall	Fruit Fall
Olokemeji A	62.88 ± 9.80	986.95 ± 641.27	0.80 ± 0.41
B	316.79 ± 32.04	223.07 ± 27.04	14.73 ± 2.10
C	582.13 ± 48.62	207.79 ± 42.32	10.04 ± 0.88
Igbeti	118.21 ± 27.84	671.87 ± 299.45	15.52 ± 8.26
Borgu			
Oli River	148.19 ± 46.64	69.65 ± 47.62	1.46 ± 4.86
Tungan Giwa	240.66 ± 27.06	175.89 ± 81.07	27.47 ± 4.86

The rates presented in this table agree well with those reported by Hopkins (1966) and Madge (1960).

It has very often been stated that nutrient contents of tropical ecosystems are held in the biomass. Litter is therefore a very important means of nutrient re-cycling. This makes it imperative that range developments which start with clearing of trees be reviewed. Isichei (1979), in a nitrogen balance study, has shown that most of the nitrogen in the savanna ecosystem is held in the woody biomass instead of in the herbaceous biomass. Apart from sparing the trees for litter production, there is also the advantage of enhanced growth of particularly nutritious grasses, especially *Andropogon tectorum* and *A. gayanus* and *Beckeropsis uniseta*.

4. Discussion

It is evident that many grasses have fairly high nitrogen concentrations at early stages of growth. This concentration dwindles sharply as the season and growth progress. It is also evident that particular species from the beginning of growth to maturity have higher N concentration than others. The high N-concentration species need to be systematically screened for each zone of the savanna. The work of Brinckman and de Leeuw

Table 13 Litter decomposition rates per year (from Isichei 1979)

Site	Litter Component							
	Leaf				Wood			
	*k	1/k	50%	95%	k	1/k	50%	
	Disappearance (yr)				Disappearance (yr)			
Olokemeji A	2.32	0.43	0.30	1.3	0.32	3.13	2.2	9.4
B	2.51	0.40	0.28	1.2	-	-	-	-
C	2.69	0.60	0.41	1.8	-	-	-	-
Igbeti	1.68	0.60	0.41	1.8	-	-	-	-
Borgu								
Oli River	2.52	0.40	0.28	1.2	1.16	0.86	0.60	2.6
Tungan Giwa	4.62	0.22	0.15	0.65	0.37	2.72	1.9	8.1

*The decomposition parameter, K, has been calculated from the differential equation,

$N_t = N_o e^{-kt}$, where N_t is the litter remaining after time t and N_o is the litter at the beginning of time interval length t. (After Olson 1963). (k has been calculated per year).

(1979), which also included browse plants, is very welcome in this regard. I believe such studies will provide the key to effective savanna management for livestock production.

Litter studies have so far reported only production figures. It cannot be ascertained what effective role litter plays in organic matter build-up since it is possible that most organic matter in the savanna may result from decaying roots and rootlets. It will also be interesting to see how decomposition processes affect N-concentration in litter.

Quantification of the role of litter in organic matter build-up and nutrient cycling will affect savanna management practices, because it seems that many people are not yet convinced of the desirability of planting trees in rangelands.

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