Some Aspects of Rangeland Improvement In a Derived Savanna Ecosystem

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Abstract

Natural rangelands carry the bulk of ruminant livestock in the tropics of Nigeria. However, the productivity of such ecosystems is low. Some improvement of the rangelands' productivity is, therefore, needed and in this experiment the effects of fertilizers, legume oversowing, and harvesting management were evaluated. Dry matter yield increased from 3,400 kg/ha with zero fertilizer to 6,600 kg/ha with a combination of 200kg N, 44kg P, and 83kg K per hectare. NPK × 6 weeks cutting interval gave the highest dry matter yield. Crude protein concentration and botanical composition of the herbage as well as the site's soil chemistry were altered by the treatments. Application of NPK fertilizers and harvesting every 6 weeks were, at least for this ecological zone, the best way of improving the rangeland and sustaining the improvement for long-term productivity.

Nigeria has about 57 million hectares of rangelands (McKell and Agboola 1966). The types vary from the derived savanna (a transitional zone between the rain forests and the true grasslands with its tall and tufted grass species mixed with forest tree species) to the low-producing scrublands of the Sahel savanna. The vegetation is similar in all of West Africa. In this region and elsewhere in the tropical world, much of the ruminant livestock is produced on natural rangelands of this type. Apart from a few established pastures aimed at supplementing the range, there has been very little improvement of this natural rangeland.

Fertilizers have been utilized to improve both rangelands and established pastures elsewhere (Henzel 1962, Smith 1964, Saleem and Chheda 1972). Nitrogen fertilizer indicated highly significant herbage yield increases along with changes in botanical composition of rangelands (Rogler and Lorenze 1957). Phosphorus fertilizer, especially in combination with nitrogen fertilizer, also improved forage yield particularly when applied to soils inherently low in phosphorus. Additional improvement in the herbage yield and quality was obtained in the Northern Great Plains of the United States, where potassium fertilizer along with nitrogenous fertilizer was applied (Rogler and Lorenze 1957).

Further improvement has been obtained both by adopting more suitable management practices and by variations in the botanical composition of the sward. Garden et al. (1978) reported increases in yield, but not in quality, of an Australian native pasture as the harvesting increased from 2 to 8 weeks. Similar effects have been reported even in sown pastures (Oyenuga 1959, Omaliko 1980). Alteration of the botanical composition, through oversowing with productive species, especially the legumes, has helped to improve range productivity. For instance, improvement in a Hyparrhenia dominant grassland oversown with *Stylosanthes guyanensis* has been reported (Hagger 1971). The added advantage of this is the low cost of improvement, as use of N-fertilizer is minimized.

The objective of this study was to assess the effects of fertilizer application, legume oversowing, and harvesting frequency on the rangeland site, forage yield, and quality.

Materials and Methods

The experimental site was the Faculty of Agriculture farm, University of Nigeria, Nsukka. The location is a humid tropical site on a fine sandy loam (an oxisol). Soil properties are shown in Table 1. Ten-year average precipitation for the farm site is 1,547 mm, of which 1,455 mm is recorded between April and October, the rainy season. The rangeland has not been cropped for the past 15 years and was randomly grazed by livestock in addition to occassional burning. The botanical composition of the sward at the beginning of the study is shown in Table 2. *Panicum maximum* and *Anthephora ampulacea* accounted for about 67% of the herbage yield.

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Table 1. Soil properties of the experimental site[1].

Profile depth (cm)	Fine sand	Coarse sand (%)	Silt	Clay	pH	CEC (meq 100g$^{3-1}$)	Ca	Mg (g kg^{-1})	K	Na
0 - 15	21	58	3	18	4.8	6.4	0.48	0.12	0.36	0.18
15 - 30	18	64	1	17	5.0	6.8	0.30	0.10	0.10	0.35
30 - 45	18	60	2	20	4.9	4.3	0.20	0.00	0.10	0.30

[1]Source: Soils of the University of Nigeria, Nsukka Farm.
Mimeograph, Department of Soil Science, University of Nigeria, Nsukka.

Table 2. Pre-treatment frequency of occurrance and composition of plant species on the experimental site.

Species	Frequency of occurrance[1] %	Composition[2] %
Panicum maximum	100	47
Anthephora ampulacea	70	20
Sporobulus pyramidalis	40	10
Loudetia simplex	40	7
Cynodon nlemfuensis	60	4
Andropogon gayanus	20	4
Digitaria horizontalis	50	3
Hyparrhenia rufa	10	3
Eupatorium odoratum	10	1
Centrosema pubescens	10	1

[1]Values are based on 40 quadrats (50 × 50 cm)
[2]Values are on dry-matter basis.

The legume species contributed 1% of the total herbage, similar to the findings by Ezedinma et al. (1979) in which only 1% of the herbage was legumes.

In July 1978, the site was mowed and plots (6.1 × 1.5m) marked out in a randomized complete block design and replicated 4 times. In 1979 and 1980, initial harvests were on May 7 of each year. The treatments consisted of all possible combinations of 3 harvesting intervals, 4 improvement methods, and a control. The harvesting was done every 4, 6, or 8 weeks. Improvement methods were nitrogen fertilizer only (N); nitrogen and phosphorus fertilizers in combination (NP); nitrogen, phosphorus, and potassium fertilizers in combination (NPK); phosphorus and potassium fertilizers plus legume oversowing (PKL); and finally a control that received neither fertilizer nor the legume oversowing. The fertilizer rates were 200kg N/ha, 44 kg/ha phosphorus, and 83 kg/ha potassium applied as ammonium sulphate, triple superphosphate, and muriate of potash, respectively. One-half of the nitrogen and all of the phosphate and potash fertilizers were applied at the beginning of the experiment in May of 1979 and 1980. Fifty kgN/ha was applied after 6 and 12 weeks of starting the annual harvesting. *Stylosanthes hamata* cultivar Verano was the legume used.

Harvesting lasted between July and November in 1978 and between May and November in both 1979 and 1980. At each harvest date, the entire plot was harvested and total fresh weight taken soon after the cutting. Two representative samples (600g each) were taken. One was dried at 65° C for 48 hours for dry matter determination. The second sample was used for determination of botanical composition. Each sample was sorted into (a) *Panicum maximum*, (b) *Anthephora ampulacea*, (c) *Stylosanthes hamata*, and (d) all other species. These samples were dried as in dry matter determination.

After weighing, the first samples were ground in a laboratory mill and preserved for crude protein (N × 6.25) determination. In March 1981, soil samples were collected from each plot at 15-cm intervals to a maximum depth of 45 cm using a 5-cm diameter corer. Soil samples were air dried before being analysed for N, P, and Ca percentages. Nitrogen concentration was determined by kjeldahl method (Jackson 1962); phosphorus photocolorimeterically by the Bray No. 1 Method (Bray and Kurtz 1945); and calcium by flame photometry (Black 1965). Data were statistically analysed and differences between treatments were tested for significance with least significant difference at 5% level of probability (Steel and Torrie 1960).

Results and Discussion

Herbage Yield

The first year's as well as the second and third years' average dry matter yields are shown in Table 3. Harvesting either every 4 or 6 weeks significantly improved the dry matter yield when compared to the 8-week interval. These findings contradict the results

Table 3. Total dry matter (1000 kg/ha) of swards as influenced by harvesting intervals and improvement methods.

Harvesting intervals (weeks)	Improvement methods[1] N	NP	NPK	PKL	Control	Mean[2]
			1st year			
4	6.65	7.83	8.66	5.46	5.92	6.90^c
6	7.20	7.25	7.81	4.79	3.99	6.21^b
8	4.70	7.08	6.14	4.00	2.84	4.95^a
Mean$^+$	6.19^c	7.39^d	4.75^b	4.25^a		
			2nd and 3rd years' average			
4	5.25	5.95	6.88	5.29	4.09	5.49^b
6	5.40	5.54	6.92	4.71	3.39	5.19^b
8	4.28	5.57	5.91	4.99	2.79	4.78^a
Mean$^+$	4.98^b	5.69^c	6.57^d	5.00^b	3.42^a	

[1]N = nitrogen only applied
NP = nitrogen plus phosphorus applied
NPK = nitrogen, phosphorus and potassium applied
PKL = phosphorus and potassium applied in addition to legume oversowing
Control = received neither nutrient nor legume - oversowing.
[2]Improvement methods means or harvesting interval means followed by the same letter are not significantly different at 5% level of probability.

Table 4. Crude protein concentration (g per kg dry matter) of herbages, as influenced by harvesting intervals and improvement methods.

Harvesting intervals (weeks)	Improvement methods[1]					
	N	NP	NPK	PKL	Control	Mean[2]
4	119.3	113.7	105.4	79.1	83.4	100.2[c]
6	98.4	101.8	92.0	74.4	76.1	88.5[b]
8	88.4	76.6	79.8	80.3	66.2	78.3[a]
Mean[2]	102.[e]	97.4[d]	92.4[c]	77.9[b]	75.2[a]	

[1]N = nitrogen only applied
NP = nitrogen plus phosphorus applied
NPK = nitrogen, phosphorus and potassium applied
PKL = phosphorus and potassium applied in addition to legume oversowing
Control = received neither nutrient nor legume - oversowing.
[2]Improvement methods means or harvesting interval means followed by the same letter are not significantly different at 5% level of probability.

reported by Garden et al. (1978) from a study in Wales, Australia, in which increasing the harvesting interval from 2 to 8 weeks apparently increased the herbage dry matter yield. In an earlier study in the same ecosystem, the more frequent 4-week harvesting interval was superior to the 8-week interval at the second half of the year (Omaliko 1980). These reduced yields of the longer intervals compared to those of shorter intervals was attributed to reduced floral development in this season and, therefore, more dry matter accumulation by the more frequently cut sward. In this study, the major portion of the harvesting was carried out between June and November, thus this may account for the apparent superiority of the 4-week over the 8-week interval.

Dry matter production was highest in the plots receiving N, P, and K fertilizers in combination and lowest in those receiving neither fertilizers nor legume oversowing. Furthermore, each treatment effect was superior to the control. However, the inability of the oversown sward to yield as much as the fertilized plots 3 years after initiating the treatment is of concern. The legume species, especially *Stylosanthes guyanensis,* are often used to improve both the yield and quality of similar rangelands (Foster 1961), as well as to reduce rangeland improvement costs, especially in a developing agricultural system where fertilizers are both scarce and expensive. Further improvement in the performance of legume oversown plots may be attained through the use of more productive legume species. There is a need to screen the adapted species for ability to improve dry matter yield at least to levels attainable with NPK treatments.

Individual P and K fertilizer effects were not assessed but the results demonstrate that the addition of P fertilizer, either alone or in combination with K, improved herbage yield more than N alone. Additional 15% increase in dry matter yield was obtained by using NPK combination instead of NP combination. Applying the N fertilizer alone significantly increased dry matter production compared to control but had the same effect as oversowing with legume in addition to P and K fertilizer application. Significant fertilizer × harvesting interval interactions existed (LSD 0.05 = 0.61 and 0.44 for the 1st year and 2nd/3rd year averages, respectively). Applying NPK fertilizers and cutting every 6 weeks resulted in the highest dry matter yield and agrees with similar results reported in the manipulation of this ecosystem (Omaliko 1980). However, the nitrogen rate to be used requires further investigation as the apparent nitrogen fertilizer recovery from the NPK treatment was 30% indicating that 200kg N/ha was too high. The lowest yields were from the control plots under the 8-weeks harvesting interval. Increasing the interval from 6 to 8 weeks also depressed the yields of swards receiving NPK treatment, while this is a contraindicated on those under PKL treatment. This due to the increased regrowth capability of legumes, which results in greater dry matter yield of the sward. Therefore, different harvesting schemes need to be adopted for different improvement programmes if such an improvement is to be sustained over time.

Herbage Quality

Each fertilizer regime significantly improved the crude protein (CP) content of the herbage compared to the control (Table 4). The CP content of herbage from sward oversown with legume was also significantly lower than each of those receiving fertilizer. A higher increase in herbage CP content than the values presented was expected from the PKL treatment. The possible atmospheric nitrogen fixed by the legume may not have been available to the grass at the same quantity as for swards receiving fertilizer N, hence a lower N content. Therefore, the possible effects of initial application of N (at a rate to be determined) to plots receiving legume oversowing need further investigations.

Botanical Composition of Herbage

The botanical compositions of herbage from the improved swards in the first and third years of the study are shown in Tables 5 and 6. *Panicum maximum* remained the dominant species at the conclusion of the 3-year study except in swards oversown with legume. Proportionately (averaged over all improvement methods)

Table 5. Fertilizer treatment and harvesting interval effects on botanical composition (%) of the sward in the first and third years of improvement.

	Panicum maximum		*Anthephora anthephora*		Other species	
	Year 1	Year 3	Year 1	Year 3	Year 1	Year 3
Fertilizer treatment						
N	65	52	7	17	28	31
NP	69	38	5	22	26	40
NPK	68	31	9	35	24	33
Control	52	49	12	9	36	42
L.S.D. (0.05)	7.1		3.2		5.4	
Harvesting interval (weeks)						
4	63	54	9	16	27	31
6	55	52	10	20	35	38
8	65	29	12	27	22	55
L.S.D. (0.05)	8.5		3.9		8.4	

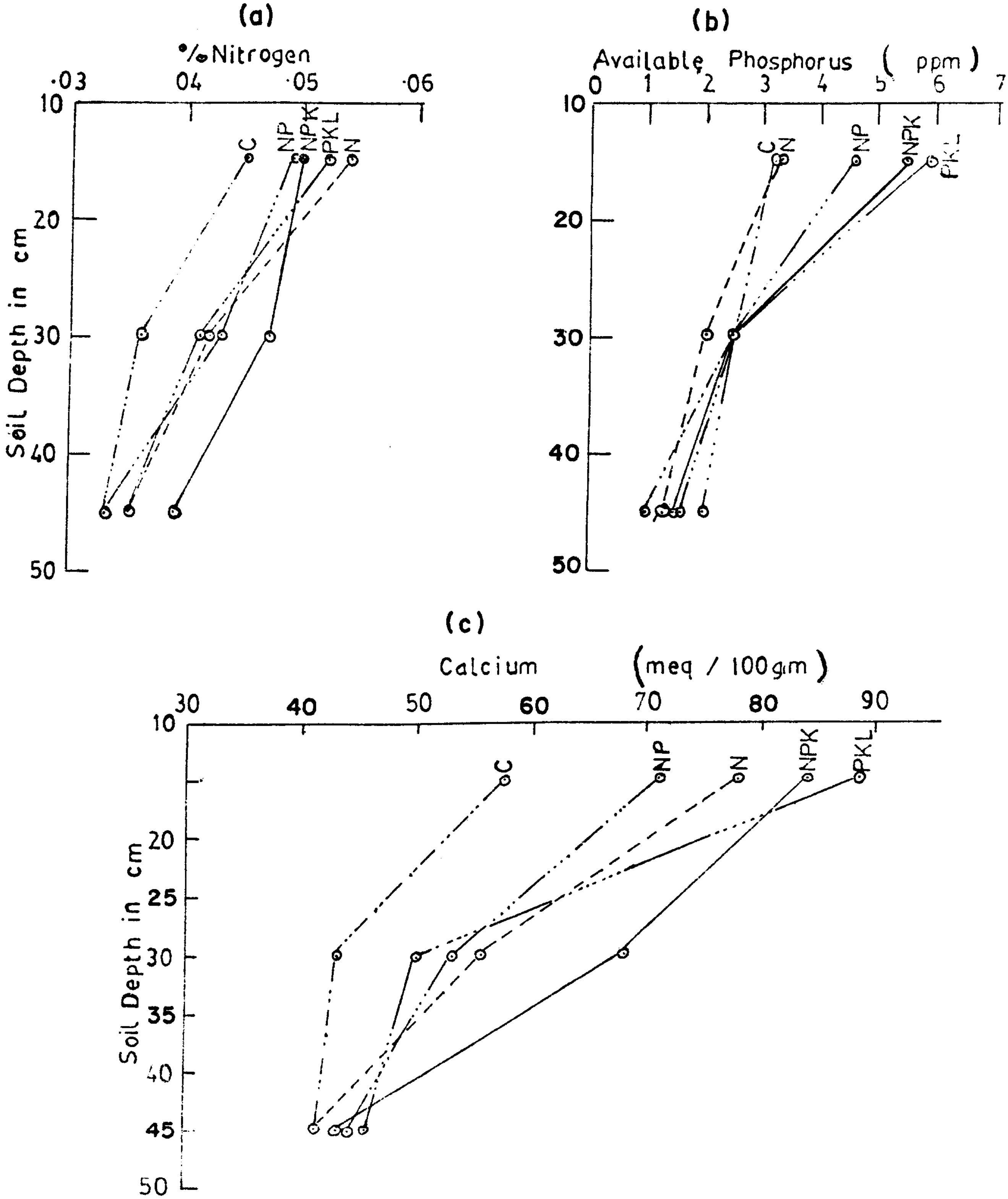

Fig. 1. *Effects of different improvement methods on site's (a) nitrogen, (b) available phosphorus, and (c) calcium content of the soil at the end of the 3rd year.*

this species increased from 47% at the beginning of the experimental period to 62% at the end of the first year. In the third year it was reduced to an average of 41% for all plots receiving fertilizers only (Table 5) and to 15% for plots oversown with the legume (Table 6). The proportion of *Anthephora ampulacea* decreased the first year but returned to its pre-improvement value in the third year. Despite these changes the 2 species combined still constituted about 60% of the total herbage in the third year, compared to 67% at the beginning of the experiment. Addition of either NP or NPK fertilizers reduced the proportion of *P maximum* in the sward due to concurrent increases in proportions of both *A. ampulacea* and the other species. These changes in proportion of the main species may also help account for the decrease in quality of the herbage from swards under either NP or NPK compared to those under N only.

Harvesting interval also influenced the herbage composition, especially in the third year. There were significant species × harvesting interval interactions. Harvesting the improved sward either every 4 or 6 weeks for the 3 years maintained the proportion of *P. maximum* while the 8-week interval greatly reduced its proportion. The reverse held for *A. ampulacea* in both the first and third years and for the other species in the third year mainly.

Table 6. Botanical composition (%) of the sward in the first and third years of improvement as influenced by legume oversowing and harvesting interval.

	Harvesting interval (weeks)			
Sward age	4	6	8	$LSD_{(0.05)}$
	Panicum maximum			
1 year	63	55	65	12.2
3 years	17	15	13	
	Anthephova ampulecea			
1 year	10	10	12	5.5
3 years	14	22	17	
	Sprobulus hamata cv. Veranao			
1 year	5	9	15	8.4
3 years	38	40	43	
	Other species			
1 year	22	26	7	11.9
3 years	31	23	27	

When the sward was improved by legume oversowing (Table 6), proportion of *P. maximum* and *A. ampulacea* was reduced to about 30% irrespective of the harvesting interval. The legume component of the sward substantially increased over the years and generally with increasing harvesting interval. These increases are of interest as they were expected to at least theoretically improve the quality of the sward. However, this expectation was not observed; rather, both yield and quality were lower than for swards receiving NPK fertilizers. On a large scale the economic advantages of legume oversowing will need to be established before deciding on what treatment or combinations of treatment to adopt. It is also possible that the use of other adapted legume species and cultivars may improve the sward.

Soil Component

Available phosphorus, nitrogen, and calcium content at soil depths of up to 45cm are shown in Figure 1. Only at the top 15 cm did fertilizer treatments show differences in P content. All plots receiving P, had higher P content than those with N or the control. For soil N, differences ($P = 0.05$) existed at 0–15, 15–30, and 30–45 cm depths. At the 2 lower depths NPK had significantly higher soil N than any other treatment, while at the top 15 cm it was superior only to the control.

Nitrogen fixation by the legume species left as much N in the soil as those from inorganic N application. However, as indicated earlier, organic N was low and not available to the plants, hence the reduced herbage yield by PKL plots. The slightly higher N observed at the 15-cm layer with either N or PKL compared to NPK may be due to lower plant growth and development which then left more of the N unabsorbed. NPK and PKL at the top 15 cm and NPK and N at 15–30 cm significantly improved the calcium content of the soil.

Summary

The productivity of the derived savanna grassland in terms of the dry matter yield can be at least doubled by the addition of NPK fertilizers without adversely affecting the biotic or soil components of that ecosystem. The use of inorganic fertilizers to improve rangeland productivity is expected to add an extra financial burden to pastoralists. Therefore, much more may be achieved, on a long-term basis, by compromising some yield for lower cost by use of legumes. The development of a more productive legume which could improve the yield and quality of the rangeland would be feasible. However, whatever improvements that may be achieved will need to be sustained by the application of a judicious harvesting interval.

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