Interactions between agronomy and economics in forage legume research

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SUMMARY

FORAGE PRODUCTION *techniques suitable for cultivated and fallow land in the subhumid zone of Nigeria are discussed. Integrating forage legumes into the farming systems benefited both soil fertility and structure. Undersowing, inter-row sowing and fodder banks were found to be suitable methods of establishing forage legumes, requiring minimum inputs. The adoption of undersowing and inter-row sowing was found to depend on the relative values of food grain and fodder. Dry season supplementation with forage legumes from fodder banks markedly improved calf survival and helped reduce animal sales due to nutritional distress. Owners of fodder banks also benefited from increased yields of cereals grown in rotations to combat nitrophilous grasses invading fodder banks over the years.*

INTRODUCTION

Lack of dietary crude protein in natural forage is the most serious constraint to ruminant livestock production in the subhumid zone of West Africa (ILCA, 1979). This constraint could be alleviated by feeding forage legumes, provided that appropriate forage production techniques can be identified. There is no single best technique, because the nature and combination of constraints on forage production in the zone vary. Moreover, even in the same ecological circumstances, forage production techniques have to be adapted to suit the varying economic priorities of the intended beneficiaries.

The International Livestock Centre for Africa (ILCA) has, since 1979, conducted multidisciplinary research at its site in Kaduna, Nigeria, to develop suitable forage production techniques. A summary of ILCA's forage research in the subhumid zone is given in Kaufmann et al (1986). This paper highlights the interactions between agronomy and economics in developing forage production techniques for the two main land-use situations in the zone, cultivation and fallow.

MATERIALS AND METHODS

The target group

There are four production systems in the subhumid zone of Nigeria: the pure pastoral system, with cattle and sheep as the main enterprises; the agropastoral system, where cattle production predominates but some cropping is also done; the multiple enterprise system with mainly cropping and some cattle ownership; and the pure cropping system.

Since the problems associated with working with purely pastoral groups appeared to outweigh the expected benefits (ILCA, 1979), sedentarised agropastoralists were initially chosen as the primary target group for ILCA's forage research. However, because of the close link between agropastoralists and crop farmers, both these groups were eventually included in the study. Forage production interventions tested on cultivated land and fallow are described in Mohamed-Saleem (1986a and b).

Constraint identification

Constraints to forage production were identified through literature review, sociological and economic studies and, most importantly, by interacting with farmers involved in the testing of proposed forage interventions. Adoption of forage techniques was found to be limited by all factors of production.

Land ownership. In West Africa, land is owned by indigenous ethnic groups involved mainly in cropping. They have traditional procedures for allocating land for subsistence cropping to non-indigenes (such as the agropastoralists). The granting of land to an immigrant is a privilege which may be withdrawn even after the person has been resident in the area for a long time. Transient land ownership thus constitutes a major constraint to sustained forage production by agropastoralists.

Labour. Despite their professed greater interest and major investment in cattle, labour for cropping is high on agropastoralists' list of priorities. Demand for labour is greatest during planting. This is so because, although total annual rainfall is fairly reliable in the subhumid zone, the early rains can be very erratic and the soils are prone to surface capping, which makes them virtually impossible to till until the rains have started. Moreover, labour for hire is scarce at planting time, and so all the family labour available is used to plant cereals for subsistence.

Capital. Lack of capital to invest in forage production is another constraint. Compared with farmers, agropastoralists in the subhumid zone of Nigeria are rich, the value of their herds often exceeding US$ 7000. Under a free-access grazing system, owners do not get any benefit by reducing stocking rates. If there are no significant opportunity costs to be realised by reducing herd size, and if, in addition, the rate of inflation is high, then it makes good financial sense to keep animals as long as possible because owners can earn more from price appreciation than from any other investment. The greatest risk owners face is calf and young-stock mortality. However, the mortality of animals which have survived to maturity is low, and there are always butchers ready to buy sick animals before they actually die.

Management. Although agropastoralists are aware of the value of crop residues as supplementary feed, they do not grow plants specifically to feed their animals. They grow cereals and non-cereal crops in rotations, but this is because rotating the crops helps maintain soil fertility and control *Striga hermonthica,* a plant parasite which attacks the roots of cereals.

Agropastoralists are also fully aware of the beneficial effects of fallowing on soil fertility. However, because clearing new land for cultivation is hard work, fallowing becomes less attractive in communities from which many young people have emigrated to towns. The older farmers are prepared to accept low yields, presumably because this gives them a higher return per unit of labour.

SOURCES OF SUPPLEMENTARY FEED

A possible source of crude protein is the agro-industrial byproduct, cottonseed cake, which might be purchased with cash obtained from sales of surplus sorghum. However, agropastoralists do not have sufficient labour and land to produce enough sorghum grain for sale, and cottonseed cake is not readily available. Purchasing supplementary feeds is thus not a practical solution, except for a small fraction of herd owners. Supplementing animals with legume forages grown on cultivated land and on fallows improves their nutrition, and the production techniques developed are within the reach of smaller producers.

Interventions on cultivated land

The first attempt at introducing fodder plants on cultivated land was by way of undersowing the most readily available forage legume, *Stylosanthes hamata cv* Verano, under the most widely grown cereal, *Sorghum bicolor.* The undersowing technique was chosen because it does not require any extra labour for land preparation for the forage.

Ideally, the legume should be planted at the same time as the sorghum so as to minimise labour input, but stylo then fiercely competes with sorghum for light and nutrients. If, however, the legume is planted 3 to 6 weeks after sorghum, reductions in sorghum grain yields are minimal (Table 1).

Table 1. *Break-even sorghum grain:stylo price ratios for different undersowing times, Kurmin Biri, Nigeria, 1980–82.*

Planting pattern	Sorghum		Stylo dry matter (kg/ha)	Available CP[1](kg/ha)	Break-even sorghum grain:stylo CP price ration
	Grain yield (kg/ha	Crop residue (kg/ha)			
Undersowing in 1980					
Sole sorghum	1226	7503	n.a.[2]	180	ng1[3]
Stylo undersown					
With sorghum	357	1303	4010	490	1.00:2.80
3 weeks after	1224	3719	1729	281	1.00:0.02
6 weeks after	1287	4260	702	178	ngl
9 weeks after	1240	3919	408	142	ngl
Undersowing in 1981					
Sole sorghum	2192	8796	n. a	255	ngl
Stylo undersown					
With sorghum	480	2367	4334	592	1.00:5.08
3 weeks after	1550	3524	3215	493	1.00:3.54
6 weeks after	1918	5385	2464	415	1.00:1.71
9 weeks after	1980	7463	456	283	1.00:7.57
Inter-row sowing in 1982					
Sole sorghum	1491	6159	n. a.	188	ngl
Intercropped stylo	1390	5262	1803	410	1.00:0.45

[1] CP = crude protein.

[2] n.a. = not applicable.

[3] ngl = no grain loss.

Source: Adapted from Mohamed-Saleem (1986a).

Whether or not undersowing is adopted depends also on the relative values of crude protein (CP) from grain and stylo. Table 1 shows that undersowing stylo 3 to 6 weeks after sorghum gives as attractive grain: stylo CP price ratios as sole grain production.

The competitive effect of simultaneous undersowing can further be reduced by changing the crop geometry from mixed sowing on one row to planting stylo and sorghum on alternate rows. This technique, known as 'inter-row' sowing, has been tested by ILCA as an alternative to undersowing.

Inter-row sowing is possible because traditional planting rates in the subhumid zone of Nigeria are very low, ranging from 30 000 to 40 000 plants per ha. To increase grain yields under sole cropping, a population density of about 120 000 plants per ha would be required, but such high plant densities cannot be recommended to the farmers because they traditionally intercrop cereals with soya bean. When the grain crop is planted at twice the traditional seeding rate on every second ridge, the total grain plant population traditionally accepted per hectare can be maintained, while freeing alternate ridges for forage legumes. In addition, inter-row sowing (Figure 1) does not affect grain yields per hectare.

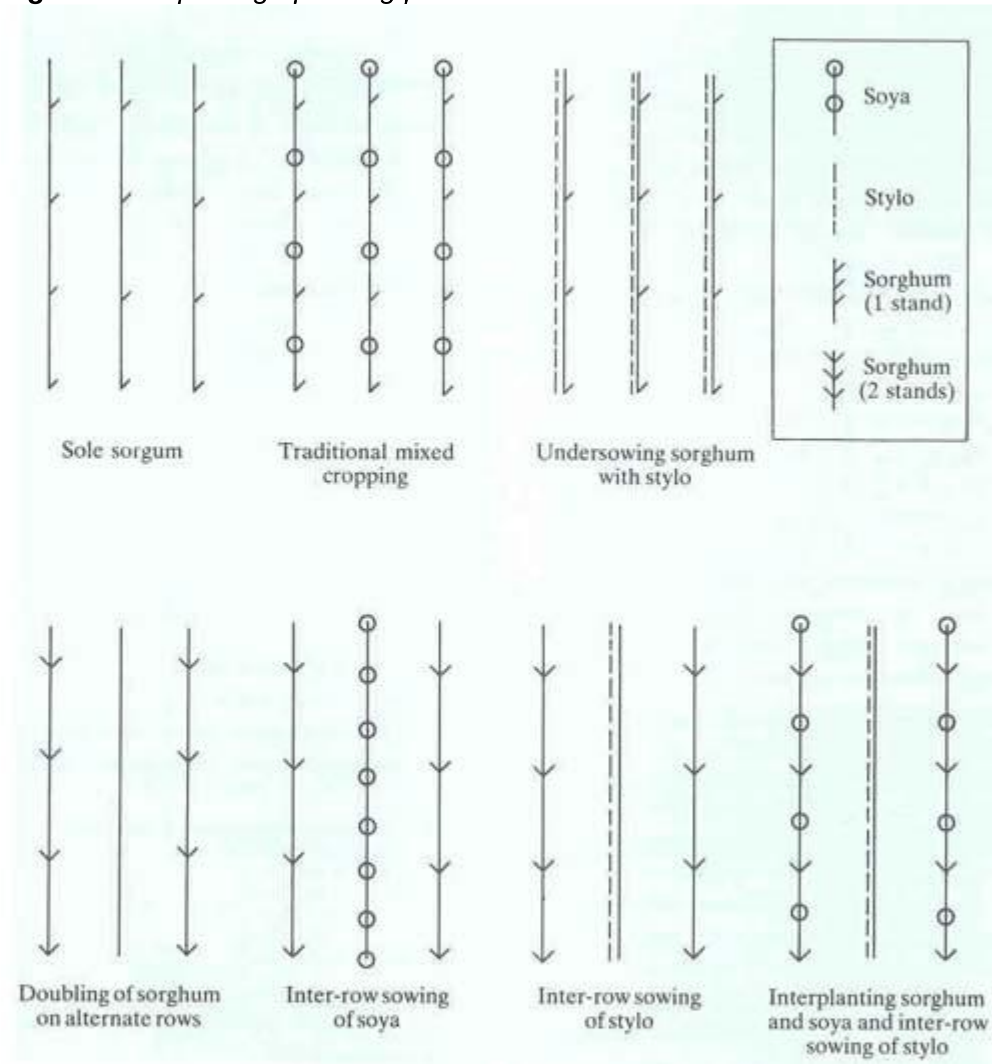
The data in Table 1 suggest that when sole-crop sorghum yields are low, undersowing and inter-row sowing are very attractive techniques, but when, as in 1981, sorghum yields are higher, the additional crude protein from stylo would have to be very valuable for the techniques to be adopted. Undersowing and inter-row sowing would thus appear to be most appropriate in the last year of rotations, when they would have the additional advantage of being a cheap method of establishing legume fallows.

The price ratios given in Table 1 do not include the labour involved in planting stylo. Although the operation is not very laborious, any additional labour demand is unwelcome, especially during the period 3–6 weeks after initially planting sorghum while more sorghum and other crops are still being planted. To overcome the problem of additional labour demands, ILCA conducted trials with other legume species which are less competitive than stylo in the early days after planting. It was found that *Centrosema pascuorum, Alysicarpus vaginalis* and *Macroptylium lathyroides* could be planted simultaneously with sorghum without depressing grain yield.

While crop competition after planting limits the utility of undersowing, interrow sowing is of little interest to the agropastoralists because of the small size of their fields. A typical agropastoralist owns 50 head of cattle and cultivates 1.5 ha of land. Assuming that he can undersow half his cultivated land with legumes, expecting a dry-matter yield of 4000 kg/ha of which 50% may be consumed by cattle, then, if stylo averages 9% crude protein, 2.5 kg dry matter would be required to provide a minimal supplement of 0.25 kg crude protein per head per day. The agropastoralist would thus have produced sufficient food for only 5 animals over the 180-day dry season.

Another problem is selecting the animals which should be supplemented. Agropastoral herds are management units owned collectively by several members of a household, and any management practice proposed must be acceptable to all those who have a vested interest in the herd. In the circumstances it would be invidious, if not socially impossible, for the nominal head of the household to select just a few animals for supplementation. And since the small fields of the agropastoralists cannot possibly supply enough forage for all their animals, agropastoralists would probably continue to depend on crop residues produced on the much larger and more numerous farmers' fields.

Figure 1. *Crop forage planting patterns.*



Farmers have not shown much interest in undersowing and inter-row planting, because they do not gain any financial benefit from growing forages. In parts of the subhumid zone where cattle are still rather scarce and competition for crop residues is not yet keen, farmers pay agropastoralists to bring their cattle to the fields to deposit manure and clear stubble and weeds. How ever, this is likely to change as population pressure builds up and competition for land intensifies. In all heavily cultivated areas, cattle owners are obliged to pay for crop residues produced on farmers' fields, which makes undersowing or intercropping forage legumes more attractive to farmers.

INTERVENTIONS ON FALLOW LAND

According to Young and Wright (1980), at least 30% of the land in the subhumid zone should be under fallow to restore fertility and sustain crop yields. Natural grasses and forbs are not very good fallows because they do not grow vigorously. The soil tends to be exposed to high surface temperatures and surface erosion for long periods, and the grass roots are not very effective in maintaining sufficient levels of organic matter in the soil. In addition, the poor grazing value of indigenous grasses limits the economic use of the land during the fallow period.

Soil fertility and the quality of grazing could be improved by introducing forage legumes into natural fallows. Early during the testing of the technique the question arose whether or not stands of forage legumes sown on fallows should be enclosed. ILCA's first attempt to produce forages without fencing failed, and so did government range improvement schemes. Then, when the idea of fencing was introduced, there were doubts as to whether agropastoralists would be permitted to erect fences round improved fallows, as this would convey a certain degree of permanence and suggest private ownership. However, it soon became apparent that deciding on how big an area should be enclosed was more crucial than fencing itself.

The area of fallow set aside for forage production would, naturally, depend on the pressure on land for cultivation but, in general, it was assumed to be no greater than about twice the area of land traditionally cultivated by landowners. Given an average farm size of about 2.5 ha (Powell, 1986), the effective limit on even large areas of unused fallow would thus appear to be about 4 ha.

Besides the size of enclosures there were two other critical management issues to be resolved - land preparation for the forage crop and grass control. Potential solutions to these problems were found by observing the behaviour of herds. For example, animals confined in a kraal overnight destroy vegetation with their hoofs and break the surface of the land, and this gave the researchers the idea of using cattle to prepare land for forage crops. Also, cattle's preference for grass over young legume plants could be exploited for the control of fast-growing grasses that tend to smother young legumes (Otsyina et al, 1987).

Based on these observations, confined units of intensive forage production, also known as fodder banks, were designed to meet the following economic objectives of agropastoralists:

- increased cow productivity and calf survival
- increased total herd welfare and elimination of distress sales
- increased crop yields, and
- increased security of tenure.

The cost of establishing and maintaining a 4-ha fodder bank are shown in Table 2. A comparison of the recurrent cost of producing 1 kg of crude protein from fodder banks with the market price of an equivalent amount of crude protein in cottonseed cake showed that crude protein from fodder banks is cheaper (Table 3). Besides, depending on cottonseed cake is riskier than depending on fodder banks, because the supplement is not always on the market and its price is subject to inflation.

Table 2. *Capital and recurrent costs of a 4-ha fodder bank with metal fencing, subhumid Nigeria, 1989.*

Input	Establishment			Maintenance	
	Unit	Cost/unit (₦[1])	Total cost (₦)	Requirement	Cost (₦)
Fencing	800 m	5.50	4400.00	10% replacement	440.00
Seed	40kg	15.60	624.00	25% reseeding	156.00
Fertilizer	600 kg	1.20	720.00	600 kg	720.00
Labour	40 man-days	5.00	200.00	20 man-days	100.00
Total cost			5944.00		1416.00

[1] ₦= naira; US$ 1 = ₦ 7.3 (1989).
Source: ILCA (International Livestock Centre fog

Table 3. *Costs of obtaining crude protein from a 4-ha fodder bank and from cottonseed cake, subhumid Nigeria, 1989.*

Item	Quantity or amount
Fodder bank (4 ha)	
Dry matter produced	16 000 kg
Dry matter available	8 000 kg
Crude protein (CP) content[1]	720 kg
Capital cost	5 944 ₦[2]
Recurrent cost	1.96 ₦/kg CP
Cottonseed cake	
Crude protein	720 kg
Required dry matter at 30% crude protein content	2 400 kg
Capital cost	0
Recurrent cost [3]	2.27 ₦/kgCP

[1] Assumes 9 % crude protein content in available dry matter.
[2] ₦=naira; US$1=₦7.3 (1989).
[3] Calculated as ₦680/t of cottonseed cake, at 30%crude protein.
Source: ILCA (International Livestock Centre for Africa), Kaduna, Nigeria, unpublished data.

A more complete financial appraisal of fodder banks required that their capital and recurrent costs be compared over time with the value of improvements obtained in animal productivity due to dry-season supplementation. The benefits realised were determined in a 5-year study of more than 2000 head of cattle in 40 cooperating agropastoral herds (Table 4). Forty per cent of the herds had access to fodder banks of reasonable quality and were classified as supplemented. The rest of the animals were classified as unsupplemented, although owners may occasionally have purchased feeds and their animals may have had occasional access to fodder banks.

Table 4. *Effect of dry-season supplementation on the productivity of Bunaji cattle under traditional management, subhumid Nigeria, 1979–84.*

Character	Unsupplemented herds	Supplemented herds	Improvement (%)
Cow survival (%)	92.2	96.0	4.1
Calving rate (%)	53.8	58.1	8.0
Calf survival (%)	71.8	86.3	20.2
Calf weight (kg)	98.1	103.4	5.4
Milk offtake/lactation (kg)	300.2	312.5	4.1
Productivity index[1] (kg)	51.5	69.1	34.2

[1] Productivity index = weight of 1-year-old calf + liveweight equivalent of milk/cow/year.
Source: ILCA (International Livestock Centre for Africa), Kaduna, Nigeria, unpublished data.

Dry-season supplementation had a major effect on calf survival through increased milk production. The low increase in milk offtake for consumption suggests that the first priority of the owners was indeed increased calf survival, not milk for human consumption. The 8% improvement in calving rate is remarkable considering that the increased fertility of dry cows was counteracted by the protracted lactational anoestrus of the cows whose calves would have died if the dams were not supplemented. However, Otchere (1986) found a lengthening of the calving interval 2 years after supplementation was started, indicating that the fertility response took longer to manifest itself than the lactational anoestrus effect.

Early in the study it was observed that participating herd owners were not following the management strategies recommended by researchers. In particular, they did not restrict fodder banks to pregnant and lactating cows, which had been identified in the pre-study modelling as the best strategy to increase herd productivity. The use of fodder bank was restricted to a few hours per day during the dry season, but all animals were allowed on the fodder bank at the same time. This 'equal treatment' was at first attributed to the complex ownership patterns among agropastoralists, but analysis of herd offtake showed that owners with fodder banks were less likely to have to sell distressed animals than those without.

The initial constraint analysis had not revealed the fact that, each year, animals had to be sold due to nutritional distress. Since avoiding this problem appeared to have a more immediate benefit than, for instance, increased calf survival which could be realised in cash terms only after several years, the economic role of feed supplementation had to be reassessed.

The analysis also has to take into account the fact that fodder banks tend to deteriorate over the years. This is so because increasing soil fertility encourages an invasion of nitrophilous grasses and forbs that compete with stylo. The invasion could be combated by rotational cropping with cereals, which would have the added benefit of increasing crop yields which must be compared with the cost of foregone stylo.

The economic viability of fodder banks has been appraised using a model which, despite problems of collecting data on agropastoral herds, can simulate fairly well the consequences of supplementation on livestock productivity over time (von Kaufmann et al, ILCA, Kaduna, Nigeria, unpublished data). The model accounts for important factors which are time-related to animal productivity, and is, therefore, more useful than such economic tools as gross margins and linear programming. It was validated by comparing predicted and actual offtake from the herds, recorded by scientists other than those who designed the model.

The analysis was based on 1989 market prices, with the price for milk being rather conservative to ensure that the model applies to rural producers who, because of their remoteness from urban markets, cannot sell milk at the best price obtainable. Its results indicated that fodder banks could be attractive investments (Table 5). Owners of fodder banks could benefit from reduced forced sales and increased crop yields. Stylo regenerates under the crop, so it is possible to have a rotation, whereby cropping continues around the fodder bank. In addition, stylo makes the soil easier to work, thus reducing labour for tilling (Tarawali et al, 1987).

Table 5*. Economic returns on fodder banks in subhumid Nigeria over 10 years*[1]*.*

	Net present value[2] (₦[3])	Internal rate of return (%)	10th-year herd value		10th-year incremental net revenue (₦)
			Without fodder bank (₦)	With fodder bank (₦)	
Improved herd productivity (IHP)	1 414	22.5	49 907	90 833	4 950
IHP plus reduced forced sales	7 538	34.1	49 907	90 833	7 138
IHP plus increased crop yields	9 395	36.3	49 907	90 833	8 544

1 In 1989 prices.
2 Calculated at 20 % discount rate.
3 ₦ = naira; US$ 1 = ₦7.3 (1989).
Source: ILCA (International Livestock Centre for Africa), Kaduna, Nigeria, unpublished data.

CONCLUSION

Cattle productivity in the subhumid zone of Nigeria can be improved by supplementing animals during the dry season with crude protein. Growing forage legumes on the farm was perceived to be more advantageous than purchasing cottonseed cake and other protein supplements on the market, because they are costly and their supplies are highly erratic. But apart from this, incorporating forage legumes into the prevailing farming system has the advantages of increasing soil fertility and improving soil structure so that tilling becomes less laborious.

Although ecologically suitable forage production techniques were developed for both cultivated land and fallows, the adoption of these techniques depended on their economic viability. An economic evaluation of undersowing and inter-row sowing showed that these techniques are profitable if used in the later stages of crop rotations when grain yields are low. They were more likely to be adopted by farmers in highly populated areas where the numbers of livestock are high and the competition for crop residues is keen.

Establishing fodder banks on fallows appears to lie a particularly attractive investment. Based on recurrent costs, crude protein produced in fodder banks is cheaper than protein purchased in the form of cottonseed cake. Dry-season supplementation of animals has a long-term financial benefit in the form of increased animal sales due to increased calf survival. It also helps reduce nutritional distress, thereby reducing financial losses due to forced sales. Owners of fodder banks also benefit by increased crop yields due to the increased soil fertility in fodder banks.

REFERENCES

ILCA (International Livestock Centre for Africa). 1979. *Livestock production in the subhumid zone of West Africa: A regional review.* ILCA Systems Study 2, ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 184 pp.

von Kaufmann R, Chater S and Blench R M (eds). 1986. *Livestock systems research in Nigeria's subhumid zone.* Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October – November 1984. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 484 pp.

Mohamed-Saleem M A. 1986a. Integration of forage legumes into the cropping systems of Nigeria's subhumid zone. In: R von Kaufmann, S Chater and R M Blench (eds), *Livestock systems research in Nigeria's subhumid zone.* Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October – 2 November 1984. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 304–325.

Mohamed-Saleem M A. 1986b. The establishment and management of fodder banks. In: R von Kaufmann, S Chater and R M Blench (eds), *Livestock systems research in Nigeria's subhumid zone.*Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October–2 November 1984. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 326–350.

Otchere E O. 1986. The effects of supplementary feeding of traditionally managed Bunaji cows. In: R von Kaufmann, S Chater and R M Blench (eds), *Livestock systems research in Nigeria's subhumid zone.* Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October –2 November 1984. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 204–212.

Otsyina R M, von Kaufmann R R, Mohamed Saleem M A and Suleimann H.1987. *Manual on fodder bank establishment and management.* ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 27 pp.

Powell J M. 1986. Cropping systems in the subhumid zone of Nigeria. In: R von Kaufmann, S Chater and R M Blench (eds), *Livestock systems research in Nigeria's subhumid zone.* Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria, 29 October – 2 November 1984. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. pp. 243–267.

Tarawali G, Mohamed-Saleem M A and von Kaufmann R. 1987. Comparison of labour requirements for cropping maize on land previously used for *Stylosanthes* fodder banks and on adjacent fallows in the subhumid zone of Nigeria. *ILCA Bulletin* 26:36–39. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia.

Young A and Wright A C S. 1980. Rest period requirements of tropical and subtropical soils under annual crops. In: *Land resources for populations of the future.* Food and Agriculture Organization of the United Nations, Rome, Italy. pp. 197–268.