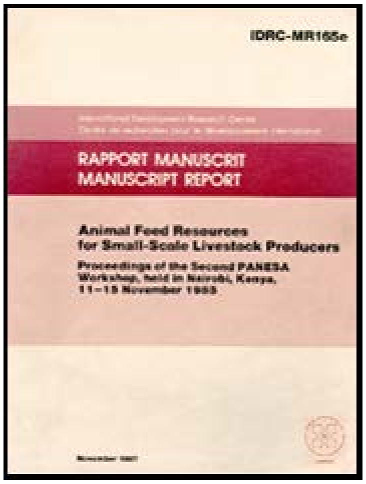
Animal feed resources for small-scale livestock producers - Proceedings of the second PANESA workshop, held in Nairobi, Kenya, 11-15 November 1985



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Edited by

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Inventory of feed resources for the smallholder farmer in Kenya

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Introduction

The use of agro-ecological zone delineation to define areas with similar natural production potentials and constraints has been found to be of considerable value for planning purposes in many countries (FAO 1978). In Kenya a comprehensive field survey of six provinces was carried out during the period 1977-1980 by the Ministry of Agriculture with assistance from the Federal Republic of Germany. This survey resulted in the publication of the Farm Management Handbook of Kenya in which the agricultural areas were classified according to agro-ecological potential (Jaetzold and Schmidt 1982). Maps were prepared for each District at a scale of 1:500,000. Seven major ecozones were identified, very largely on the basis of water availability, with subsidiary classification being based on combinations of altitude, temperature and soil-type parameters (Table 1).

Table 1. Agro-ecological potential zones in Kenya

Zone	Climate type	Water availability (rainfall/Eo)	% of country
1	Humid	>80	5
2	Sub-humid	65-80	5
3	Semi-humid	50-65	5
4	Transitional	40-50	10
5	Semi-arid	25-40	15
6	Arid	15-25	20
7	Pre-arid	>15	40

Eo = Potential evapotranspiration.
Source: Kenya Soil Survey 1982.

Care is needed in the use of such classifications based on average conditions. Variation in the climate in any particular season can shift the effective zone boundaries considerably (Downing et al. 1985). However, using the average classification, the small-farm sector to be considered in the present study lies mainly in zones 2 and 3, although parts of zones 1 and 4 may also be included. The prevailing combination of rainfall, temperature and soils produces good-to-excellent conditions for the growth of plants.

During the period from about 1900 to Independence in 1963 these high-potential areas were occupied either by small-scale African subsistence farmers or, in special reserved areas, by large-scale (mostly European) settler farmers. Prior to Independence the great majority of the commercial agricultural output of the country was derived from the relatively limited number of large-scale farms.

One of the great challenges to the Kenya Government over the last 20 years has been to maintain the increase in cash- and food-crop as well as livestock production needed to satisfy rapidly increasing local food requirements and the export needs of the country while attempting to make land available to more farmers through subdivision of the old settler farms. Over one million hectares have been resettled during this process.

Sub-division of these resettled farms and of the traditional African areas by land sales and family inheritance has resulted in a rapid reduction in farm size. The survey data presented in Table 2 were collected in 1974/75; at that time about three-quarters of all holdings were less than 3 ha. Although no national survey has been reported since that time, there is little doubt that over the last ten years the proportion of farms in the smaller size classes has increased considerably. Irrigation potential over most of the high-potential region involved in the present study is limited due to lack of suitable surface-water sources, difficult topography and the lack of resources needed for pumping from underground sources. Production is, therefore, dependent on natural rainfall.

Table 2. Size classes of smallholdings in Kenya

Size class ha/unit	No. ('000)	% of total	Estimated % pasture/fodder
0.5	208	14	10
0.5-1.0	267	18	20
1.0-2.0	401	27	25
2.0-3.0	223	15	30
3.0-4.0	148	10	40
4.0-5.0	104	7	45
5.0-8.0	89	6	50
>8.0	4	3	55

Source: Stotz 1983.

A mixture of enterprises is usual on these small farms. In the higher-potential wetter areas of zones 1, 2 and 3 cash crops, including tea, coffee, pyrethrum, cotton, wheat, barley, oilseed and cashews, have been encouraged by Government or private marketing agencies. The opportunities for cash cropping in the slightly lower potential areas are very limited due to the lack of suitable crops with an acceptable level of yield. Food crops are grown on all holdings with maize, beans, sorghum, cassava and pigeon peas being the most common. These crops are grown primarily for the subsistence needs of the farm family, but fortuitous surpluses following good growing seasons are frequently sold. Livestock have been estimated to be present on more than 80% of the smallholdings (Stotz 1983), particularly to supply milk for the farm family. The role of smallstock as a readily realizable source of cash has been shown to be very significant in particular areas (Pollard 1981; Rukandema 1981; Stotz 1983).

Table 3 gives the estimated total values for national production of selected agricultural products up to 1983, the last full year for which results are available.

Table 3. Value of agricultural production in Kenya, 1979-1983 (K pounds '000,000)

Sector	1979	1980	1981	1982	1983
Cereals	50.5	35.3	48.0	60.0	81.4
Coffee	105.7	118.9	102.5	122.9	166.2
Tea	67.3	71.5	80.6	93.2	130.3
Sugarcane	23.3	29.5	30.9	29.4	34.3
Slaughter cattle	29.1	33.9	47.9	52.3	51.8
Slaughter smallstock	2.2	1.6	1.4	1.6	1.8
Pigs	1.1	0.9	1.1	1.7	1.9
Poultry and eggs	1.9	1.6	2.8	3.0	1.2
Wool	0.4	0.5	0.4	0.6	0.5
Hides/skins	2.3	2.6	3.7	4.1	4.3
Dairy products	17.5	15.0	22.8	28.5	32.8

Source: Central Bureau of Statistics 1984.

Non-ruminant smallholder farm livestock

Production of poultry and pigs in Kenya is now very largely a commercial undertaking as the home consumption of these products is limited. Commercial production is based on the use of purchased manufactured feeds, with very little on-farm feed production. At present over 60% in value of all manufactured feed in Kenya is fed to poultry (Table 4). Very marked increases in poultry-feed prices, approved by Government, have not been associated with corresponding increases in prices to producers for the animal product so that the initial enthusiasm for poultry as a means of maximizing output per unit area of the land on a smallholding has been dampened. No central marketing organizations exist for eggs or birds and small-scale producers lack the entrepreneurial skills to market their product with an attractive profit.

The problems of the poultry industry do not appear to be a result of lack of feeds as the installed milling capacity is at present underutilized and the distribution network is adequate (Magadi, personal communication). The major disincentives to production are high prices of feeds, variation in feed quality leading to poor conversion rates, and low prices to producers through lack of marketing skills and the low price of competitive products such as beef. The recent formulation of a Kenya Standard for animal feedstuffs, to be supported by the appropriate legislation, should ensure that quality problems are reduced considerably when the required inspection and analytical system is operational. Reduction in feed costs will only be possible when research into cheaper local alternatives to imported components of the rations, such as fishmeal, can confirm their efficacy and adequate supply so that imports can be banned. The lack of such research in the past has undoubtedly been a contributory factor to the apparent reluctance of millers/compounders to make use of some local materials when fortuitous surpluses become available (Ministry of Agriculture 1980b). The producer-price factor mentioned above remains dependent on the beef-price structure, which is at present under direct Government control.

Table 4. Manufactured feed production in Kenya 1978-1983 (K pounds '000,000)

Feed type	1978	1981	1983

Pig	1.3	0.9	0.1
Poultry	8.1	8.5	1.4
Cattle	1.7	1.4	0.9
Other	-	3.9	1.9

Source: Central Bureau of Statistics, 1984.

The problems of the poultry industry with regard to feed prices and end-product value are mirrored in the pig industry. The fall from 40% to 18% in the market share held by the parastatal Uplands Bacon Factory between 1981 and 1983 has been attributed to slow payments, even though the price offered was generally somewhat higher than that from private buyers (Ministry of Agriculture and Livestock Development 1983). The farmers clearly understood the value of a good cash flow.

Although the cost of feed provision is undoubtedly a major constraint to expansion of both the pig and poultry industries in Kenya, the very small farm size and low level of resource availability severely limit the possibilities for on-farm feed production as a means of reducing costs. Neither the quantities of suitable raw materials nor the appropriate technology for production of feeds of the high quality required for good feed conversion ratios appear likely to be available at the farm level.

As Table 3 indicates, the contribution of pigs and poultry to the national agricultural output is small in comparison to that of ruminant products, so the remainder of this paper will concentrate on the feeding of ruminants on the smallholder farm in Kenya.

Smallholder ruminants in Kenya

This livestock class naturally includes sheep and goats as well as cattle. However, the nutrient requirements of smallstock are similar to those of cattle. The estimated ratios of production of smallstock in relation to cattle of 1:12 for value (Table 3) and of 1:8 for biomass (Stotz 1983) confirm the importance of cattle on the small farm.

Table 5 indicates the pattern of cattle ownership in Kenya and Table 6 the contribution of these cattle to the total milk supply. Present beef prices are too low to allow beef production to compete with milk on the small farm in terms of the return per unit farm area. The areas where the proportion of male cattle is highest are those where there is significant use of oxen for cultivation.

Table 5. Pattern of cattle ownership in Kenya, 1983

Cattle Type	Cattle numbers in '000,000 head							
	Numbers and % of cattle on farms							
	Small farms		Large farms		Pastoralists		Total	
Zebu	4.00	(48)	1.50	(18)	2.80	(34)	8.30	(100)
Grade beef[a]	0.04	(11)	0.29	(28)	0.04	(11)	0.37	(100)
Cross-bred								
Dairy[a]	0.80	(89)	0.10	(11)	-	-	0.90	(100)
Grade dairy[c]	1.10	(85)	0.20	(15)	-	-	1.30	(100)

[a] Crosses between local and exotic beef breeds.

[b] Contain less than 75% exotic genotype.

[c]

Contain more than 75% exotic genotype.

Sources: Ministry of Agriculture and Livestock Development 1983; Stotz 1983.

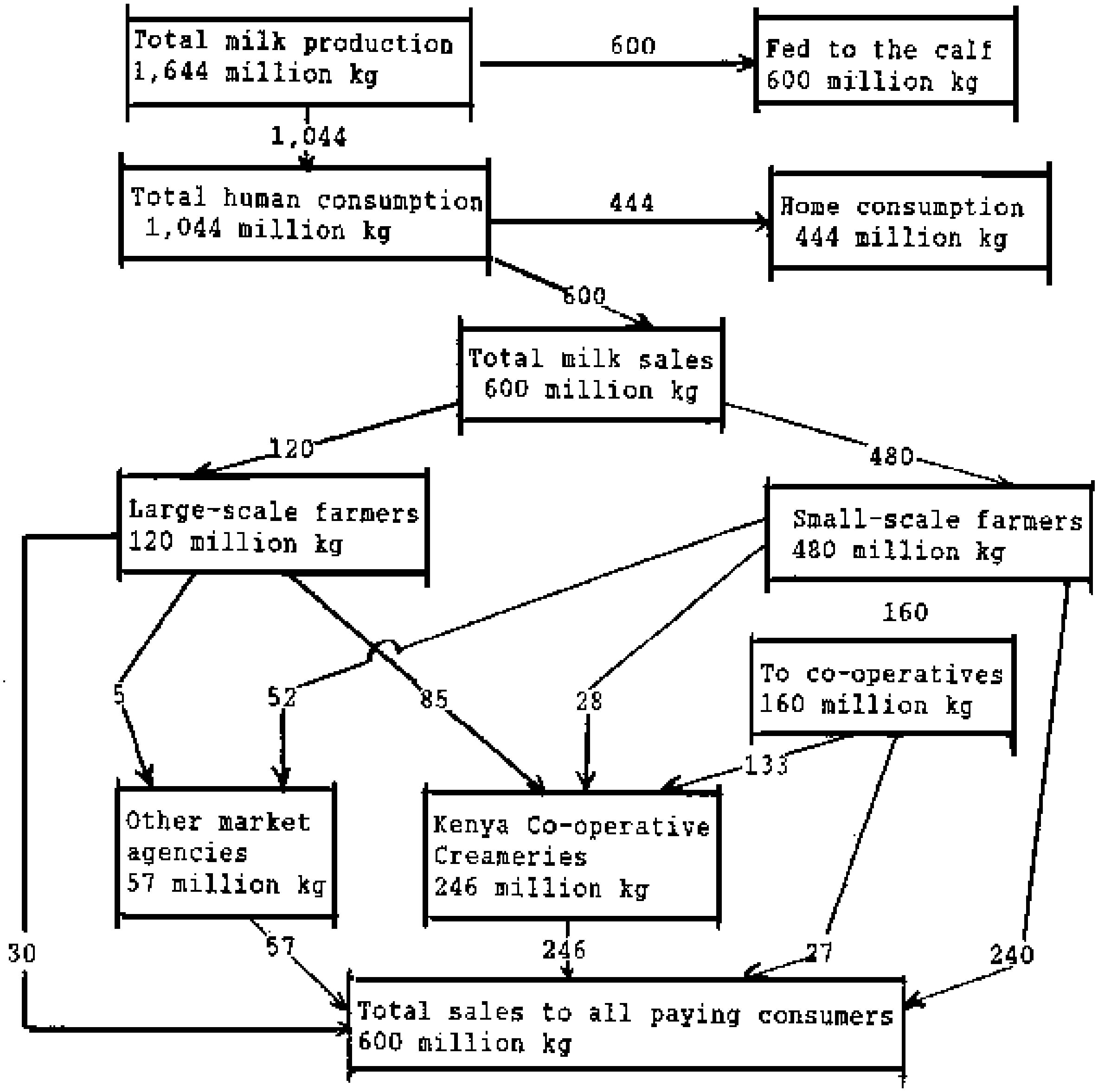
Table 6. Estimated volume of milk production in Kenya, 1983

Origin (type of animal)	Yield (kg/head/yr)	No. ('000)	Total output ('000,000 kg)
Grade cows (+X bred)	800-900	900	890
Zebu cows	50-150	3,900	470
Camels	750	400	260
Smallstock	50	300	14
Total local output			1,644
Powder-milk imports			38
Total availability			1,682

Sources: Ministry of Agriculture and Livestock Development 1983; Department of Customs, Annual Returns 1983; Ministry of Finance and Planning, Nairobi.

Figure 1 is a marketing flow chart for milk production in Kenya for 1983. This chart shows that 80% of the marketed milk is now derived from smallholders. It is, however, clear from Table 6 that though there are almost one million grade dairy cows in the country, their average yield, at less than 1,000 kg per lactation, is far below their genetic potential. Raising the national milk supply to the target required for the country's estimated population in 1990 will depend to a large extent on raising the output of these grade cows by better feeding (Ministry of Livestock Development 1980a).

Figure 1. Marketing flow chart for milk and dairy produce in Kenya, 1983



Source: Ministry of Agriculture and Livestock Development 1983.

Smallholder livestock feeding systems

The national survey data collected for the Farm Management Handbook of Kenya (Jaetzold and Schmidt 1982) from 1977 to 1980 were used to derive Table 7 in which various characteristics of the smallholder livestock sector are presented. The data used in the preparation of the table were derived from sample farm surveys supported by crop-cutting studies of fodder and grazing areas on farms and on relevant research stations. The values presented therefore represent the situation on a "typical" farm in the various Districts, taking into account the range of relevant agro-ecological zones present in the District. A number of points demonstrated in the table are worthy of emphasis.

Resource Base

The farm size is very small and hence overall resource availability is low.

Human Population Density

This is usually high - over 100 per square kilometre. The farm is required to support these people before any saleable surpluses can be considered.

Prevalence of Arable Cropping

The concern to maximize output per unit area of land has led to expansion of the arable area for cash and food generation at the expense of area for providing specific livestock feeds, so that the area available for fodder and grazing is only about one-third of the farm area - typically less than one hectare.

High Stocking Rates

The stocking rates observed are extremely high, considering the potential on-farm feed production resources. The strategy adopted by many pastoral peoples of keeping high stock numbers in conditions of variable feed and water supply, disease, etc., to ensure some survival in adverse conditions (Potter 1981), appears to have been carried into the small-farm situation. Its relevance, particularly considering the high nutritional demands of the grade dairy cow, is now in question.

Level of Forage Supply

Table 7 indicates that the on-farm availability of forage in most areas is very low, typically being less than 5 kg dry matter per head per day. This is partly due to the small area available for forage production, but undoubtedly it is also a result of the lack of use of technology which could support a higher level of forage production. Ignorance of the technology and fears of lack of economic return have limited forage yield at the farm level. It should also be noted that the figures in the table are based on an average year-round forage supply, masking the problems associated with a seasonal pattern of fodder or pasture growth.

The Role of Non-Forage Feed Supply

The low level of on-farm forage supply indicated in Table 7 is completely inadequate for even the maintenance requirements of the dairy animal. That the animals survive at all, albeit to produce milk at a low level, indicates that they must be obtaining feed from other sources. This must be particularly true during the dry seasons (normally two per year) when fodder or pasture growth is reduced.

Future Trends

Whatever the difficulties of providing for the feed requirements of the dairy cow at present, the current rate of human population growth in Kenya of 4% per annum (CBS 1985) will undoubtedly place even more strain on the system as land subdivision is likely to continue reducing effective farm size, with the larger rural and urban population raising national milk requirements. Increase in stock numbers per holding as a strategy to increase farm milk output is clearly not likely to be effective as forage resources are already limiting milk production from the existing animals and the proportion of feed required for maintenance rather than production would increase.

Feed-resource options available to the smallholder

The most recent estimate of on-farm feed resources available to the smallholder was made in 1979 (Table 8). It is perhaps an indication of the low priority attached to animal production in national agricultural policy that since the publication of the National Livestock Development Policy document over five years ago (Ministry of Livestock Development 1980a) no national inventory of livestock-feed resources has been prepared. Figures of areas under fodder or pasture are not available either on a District, Provincial or national basis (ISNAR 1985), although an exercise to gather these vital data has been stimulated by this work (see

Appendix 1).

In the past, programmes related to animal production in Kenya appear to have emphasized the animal-health and breeding aspects with rather less emphasis on nutrition. Table 9, for example, indicates the allocation of resources to the dairy-production section of the Integrated Agricultural Development Programme 1980/81, the first full year of the existence of the Ministry of Livestock Development as a separate Ministry, when it might have been expected that enthusiasm would be high. Without national feed-production data, consideration of the feed options for the smallholder dairy industry must therefore be on the per-farm basis rather than consolidated sectoral output potential.

Table 7. Characteristics of the livestock sector of smallholder farming in Kenya

District	ha farm holding	ha/head (adult equiv.)	Livestock feed resources ha/farm		Stocking rate (LU/ha)	% Grade cattle	% Mature female	On-farm forage production DM kg/year				% Non agric. land
			Fodder	Grazing				Fodder	Grazing	Total	kg/LU per day	
Nyanza Province												
Kisii	3.3	0.6	0.15	1.3	2.5	12	60	1,400	6,200	7,600	5.1	11
S. Nyanza	8.0	1.3	0	3.0	2.3	1	50	-	6,900	6,900	2.7	20
Kisumu	3.1	0.8	0	0.9	4.8	1	60	-	4,750	4,750	2.6	19
Siaya	5.9	1.3	0.2	2.2	2.5	1	50	1,090	5,080	6,170	1.8	17
Western Province												
Busia	5.7	1.4	0.05	2.2	2.1	2	50	450	1,120	5,370	3.1	15
Bungoma	6.6	1.4	0.2	3.1	1.8	7	60	1,510	10,390	11,900	5.5	15
Kakamega	3.9	1.0	0.05	1.8	2.2	16	60	400	5,180	5,580	3.8	18
Eastern Province												
Embu Upper	2.2	0.7	0.1	0.5	9.7	60	75	730	1,540	2,270	2.2)	30
Embu Lower	4.1	1.3	0	2.0	1.7	1	70	0	1,850	1,850	1.5)	
Meru Upper	2.0	0.6	0.15	0.6	4.2	80	85	820	1,850	2,670	2.3)	20
Meru Lower	7.2	1.7	0.1	2.3	2.2	28	80	450	1,850	2,800	1.2)	
Machakos Upper	4.5	1.0	0.2	2.3	1.3	20	40	440	2,150	2,590	2.2)	15
Machakos Lower	5.6	1.5	0	2.7	2.6	7	80	0	3,320	3,320	1.3)	
Kitui Upper	5.2	1.3	0	2.3	2.4	11	65	0	2,660	2,660	1.3	20
Coast Province												
Taita Taveta	1.7	0.5	0.1	0.5	5.7	22	45	400	770	1,170	0.9	25
Kwale	8.2	2.1	0	3.4	0.9	1	65	0	4,180	4,180	3.7	30
Kilifi	6.5	1.4	0	1.5	3.5	1	30	0	1,150	1,150	0.6	40
Rift Valley												
Nandi	10.1	2.6	0.3	6.8	1.9	82	75	1,640	31,390	33,030	6.7	18

Kericho	4.4	1.11	0	2.9	2.8	74	85	0	13,080	13,080	4.4	12
Elgeyo Marakwet	3.7	1.0	0	1.0	4.5	33	75	0	2,310	2,310	0.6	30
Baringo	4.7	1.1	0.1	2.7	2.0	57	75	550	8,310	8,860	4.3	30
Central Province												
Nyandarua	10.4	2.3	0.6	7.0	1.0	79	89	2,910	28,460	31,370	11.3	22
Kiambu	2.6	0.7	0.15	0.3	6.0	73	80	1,090	1,150	2,240	2.3	27
Murang'a	2.6	0.7	0.1	1.1	4.0	60	75	820	4,310	5,130	2.9	18
Nyeri	2.4	0.6	0.3	0.6	4.0	75	93	2,450	2,310	4,760	3.6	21
Kirinyaga Upper	2.6	0.6	0.1	0.4	6.5	55	75	820	1,690	2,510	2.1)	15
Kirinyaga Lower	6.2	1.6	0.1	1.7	3.5	28	65	450	2,620	3,070	1.3)	

Source: Derived by the author from data of Jaetzold and Schmidt 1982.

Note: District values are means weighted for the production of relevant ecozones in each District.

Table 8. On-farm feed resources for smallholder farm livestock, 1979 (estimate)

Source	Total area (ha)	Remarks
Permanent pasture	1,900,000	Unsuitable for arable crop use
Grass leys	2,100,000	Includes regenerating fallows
Fodder crops	240,000	Especially Napier grass
Food crop residues	2,100,000	Especially maize stover

Source: Stotz 1983

Table 9. Resource allocation to dairy development in the Integrated Agricultural Development Programme, Ministry of Livestock Development, 1980/81

Sector	Funds allocation (%)
Tick control	73
A.I. services	11
Animal production extension	14
Animal production research	2

Source: Ministry of Livestock Development, Work Plan 1980/81.

The options open to the smallholder for feed for his livestock can be summarized as follows:

1. Fodders and pastures;
2. On-farm by-products;
3. Industrial by-products;
4. Bought-in roughages;
5. Concentrates.

These will be discussed in turn.

Fodders and Pastures

Although official estimates of the overall area under fodders and pastures do not appear to have been made since Stotz's 1979 work, there is little doubt that the area of folders, particularly Napier grass, has considerably increased since then at the expense of grazing area. As the results of Jaetzold and Schmidt (1982) indicate, in most areas the forage yield of planted or natural pastures is likely to be only about half that of Napier grass, depending on the level of technology actually used on the farm. The value of the yield increase from a switch to folders in the smallholder's attempt to maximize output per unit area of land has been confirmed in the rapid rise in Napier-grass area. However, the effective exploitation of the higher potential of feed availability from the fodder has required that the farmer switch to some form of "cut-and-carry" or stall-feeding system to reduce the wastage that occurs from trampling and soiling by dung and urine during grazing. This switch has a number of management implications, especially with regard to the need for a continual supply of labour and feed as the animal can no longer find feed for itself.

The switch away from pasture use has also been encouraged by the lack of animal-production research data on the limited range of locally available pasture grasses - whose seeds are in any case extremely expensive at more than KSh. 50 per kilogram. Establishment of planted pastures, especially essential early attention to weeding, is also difficult for the small farmer who is tied up with his arable crops at the same time in the season. Natural pastures containing grasses long known to be of high nutritional value (Strange 1963), such as star and Kikuyu grasses, though available in some areas, are losing ground to folders, particularly Napier grass, due not only to their lower yield potential but also to the desire of farmers to adopt the widely publicized technology of zero-grazing. Although off-farm grazing, and even cutting of grass from outside the farmstead do occur throughout the area under study, especially in Districts with higher proportions of non-agricultural land, increasing land pressure will undoubtedly reduce the availability and reliability of this supply (Potter 1982).

Napier grass has been mentioned frequently as the example of a fodder crop in the smallholder regions of Kenya and it is at present by far the most common in terms of its contribution to the national on-farm feed supply. Production data collected by the Dairy Development Project team from co-operating farmers (Wouters 1985) and from the Muguga research programme (Potter and Anindo 1985) have indicated that forage yields per unit area can be raised considerably from the levels observed by the Jaetzold and Schmidt (1982) surveys. The use of relatively inexpensive and simple management improvements, involving plant spacing, weeding, cutting systems and application of farmyard manure, as outlined in the technical bulletin recently published by the Kenya Agricultural Research Institute (1985), can help significantly to remove the lack of knowledge noted as an important constraint to the effective use of fodder (Stotz 1975; Nkanata 1984).

With regard to other fodders, including sweet-potato vines, giant Setaria, sorghums, brassicas, etc., information is much more limited. Although standing-crop estimates of these materials have been made on-farm (Goldson 1977), an examination of persistence, long-term yield and quality characteristics under regular harvesting, as required in an actual production system, has not been carried out. Animal feeding and production studies are almost completely absent for these materials. Such studies may be extremely desirable, not only because these materials may have growth characteristics which could supplement the already established Napier grass, but also because the long-term wisdom of dependence on a single forage crop as the basis of the dairy industry in Kenya appears questionable.

The nutritive value and growth characteristics of Napier grass, and other folders, will be considered in some detail in a later paper in this workshop. Local research data do indicate close correlations between chemical composition of the forage, intake and animal performance (Karanja 1985; Njogah and Kamande 1985; Potter and Anindo 1985; Wouters 1985). With an appropriate field-production and feeding system material palatable enough to be consumed at the rate of 65 kg fresh forage per head per day has been demonstrated to support a milk output of up to 10 litres per day without concentrates (Potter and Anindo 1985). The technical basis for supporting an increase of milk output from fodder appears therefore to exist.

Present evidence suggests that above about 10 kg-milk-per-day production levels (about three times the present national daily average for the grade cow), Napier grass is unable to supply an adequate balanced supply of protein and energy (Potter and Anindo 1985; Wouters 1985). Legume enrichment, for example with Desmodium species or siratro, has been suggested as a possible method of improving forage quality. Studies in both western and central Kenya have so far failed to lead to the identification of a practical on-farm management system capable of maintaining the legume at a proportion high enough to have any effect on overall forage nutritive quality while at the same time maintaining total dry-matter yield. At the farm level the reason for the low milk yield is much more the result of lack of feed quantity than quality.

Conservation of either fodders or pasture material is extremely uncommon in the smallholder areas at present. The availability of surpluses is extremely limited given the high stocking densities on the farms. In addition, the technology for making hay or silage on a scale appropriate to the actual farm-resource level has not yet been identified, although promising results have been obtained from preliminary studies in Napier grass silage production by the Dairy Development Programme in Coast Province (Voskuil, personal communication).

On-Farm By-Products

As mentioned above, all of the farms in the smallholder area grow crops, with up to two-thirds of the farm area being under arable crops grown either for food or for sale. Many of these crops have residues which have potential value for livestock feed. Table 10 gives the arable by-products most commonly available in the smallholder areas, together with some comments regarding their potential value.

Table 10. On-farm arable by-products available to the smallholder farmer in Kenya

Crop	Residue	Remarks
Maize	Stover	Est. 7.5 m tonnes available p.a. Requires protein supplement for effective digestion
Cob spindle		Est. 2.8 m tonnes available p.a.
Sweet-potato	Vines	No availability estimate High water content limits value
Sorghum	Stover	No availability estimate Requires protein supplement for effective digestion
Legumes	Haulms	No availability estimate Good roughage if available
Bananas	Leaves/Stalks	No availability estimate High water content limits value
Rice	Straw	Est. 39,000 tonnes available p.a. High silica/low protein limit value
Cassava	Tops	No availability estimate Very high quality if not too woody

Source: Compiled by author from various sources.

No accurate estimate has been made of the quantities of these materials used or available to the smallholder either on a per-farm, District or national basis, but widespread use of them has been recorded (Chudleigh 1974; Kevelenge 1978; Nkanata, personal communication). Use of these byproducts is somewhat haphazard as often there are no suitable storage facilities and the farmer has no way of determining the most effective feeding regime to incorporate these roughages into a year-round feed budget. Although basic chemical-composition data have been available for many of these by-products for many years (Dougall 1960), data on availability and from controlled animal-feeding studies are limited (Said 1976; Kevelenge 1978).

Factors which have been identified as limiting the nutritive value of these materials include:

1. Low crude-protein content;
2. High cell-wall content (fibre);
3. Low effective in vivo digestibility (Kevelenge 1978).

To these may be added low dry-matter content, as with sweet-potato vines and banana leaves or pseudostems.

Some research has been carried out in Kenya on the treatment of a number of these crop residues with chemicals such as urea, ammonia and alkalis in an attempt to increase their nutritive value (Kevelenge 1980). Although some improvements in parameters such as digestibility have been reported, the relevance of such techniques to the small-farm situation remains unclear, especially when the toxicity of some of the materials is considered. Of the materials suggested, urea, with its possible additional role as a non-protein nitrogen source, deserves further investigation.

Further studies of the availability, especially as affected by seasonal factors, and animal-production characteristics of these byproducts appears highly desirable due to the universal occurrence of arable crops on the farms and the need to maximize total on-farm feed-resource use. Recent studies of the use of fresh maize leaves derived by defoliating the growing plant have indicated that a tonne of dry matter of forage per hectare may be obtainable over a three-month period without any drop in grain yield (KARI 1985). Such studies of methods of integration of the crop and animal components of the small-farm operations can only be beneficial to the farm-feed budget, and finally to farm output.

Agro-Industrial By-Products

Almost all of these materials are derived from the processing of arable crops. They are distinguished from the previous class by having an off-farm origin, although small quantities may be available on the farm. Table 11 presents some of the characteristics of the more common materials involved.

Estimates of the total quantities of these materials likely to be available have only been made for a few of them, partly because the processing is often done on a relatively small scale by many different units with variable rates of recovery. Many of the comments regarding feeding value made in regard to the on-farm by-product are also valid in respect of the industrial products. The nutritional value of some of these materials is notably higher than that of most roughages, with the value of materials such as brewer's waste (machicha) having been recognized widely. Materials such as pyrethrum marc and poultry waste have levels of protein which enable their use in the formulation of concentrate rations, or for raising the feeding value of roughages such as silage (Odhuba 1984).

Table 11. Agro-industrial by-products useful for animal feed

Source	Residue	Remarks
Coffee	Hulls	No availability estimate High fibre reduces digestibility

	Pulp	No availability estimate High water content/low palatability
Sisal	Pulp	Est. 41,000 tonnes available p.a. High water content/low palatability
Coconuts	Copra/meal	Est. 33,000 tonnes available p.a. High fibre/low digestibility
Cashew	Waste	Est. 20,000 tonnes available p.a. High fibre/low digestibility
Pineapple	Waste	No availability estimate High water content/low protein
Pyrethrum	Marc	No availability estimate High protein feed, good quality
Barley	Brewer's grains (Machicha)	No availability estimate Excellent roughage when available
Sugarcane	Tops/waste	No availability estimate High energy content but high fibre
Cereals	Milling residues	No availability estimate Quality varies according to fraction
Poultry	Waste	No availability estimate High protein content from faeces source and possibly sanitization
Cattle	Abattoir waste	No availability estimate Quality variable from high (blood) to roughage (rumen contents)

As with the on-farm by-products, there is a clear need for further evaluation of the availability and animal-production-support capability of the agro-industrial materials. The quantity of material, cost of purchase and transport to the farm will be a highly site-specific combination, but general principles regarding the incorporation of such materials into the whole farm budget may be clarified by research.

Bought-in Roughages

During the severe drought experienced over much of the smallholder area of Kenya in the first ten months of 1984, it became very common to see piles of grass, hay or other roughages for sale by the side of the road around Nairobi. Prices up to KSh. 2 per kilogram were being asked, often for material of rather dubious nutritional value. Livestock owners had little option but to pay the prices asked as the supply of feed on their own holdings was virtually nil. This material had been collected from swamps, forest areas, road sides and other non-individually owned areas. This represented a type of commercial venture for the vendors which had not been observed previously to any extent. It remains to be seen if this type of feed provision becomes a significant component of smallholder feed resources. The cultivation of small areas of Napier grass outside regular farm boundaries on land that would have been previously planted with arable crops has significantly increased over the last year, reflecting a demand for the forage. To what extent the purchase of this forage is being supported by the higher returns smallholders are able to obtain by selling milk direct to the consumer requires investigation as results from such a study would have implications for Government policy on official milk pricing and marketing, through, for example, the parastatal Kenya Co-operative Creameries.

Concentrates

Table 4 gives the estimated total value of commercial animal feeds produced in Kenya in 1983 and comment has already been made regarding the prices of such materials. Table 12 gives the quantum and price indices for livestock feeds over the past five years. The very steep increase in costs noted for 1984 was the result of the need to import most of the raw materials as drought conditions severely limited local supply, particularly of maize which makes up about 60 per cent of most rations. In spite of the almost doubling of price the quantity produced and sold increased in 1984 over 1983, no doubt due to the shortage of other feeds for livestock.

Table 12. Commercial feed production Kenya, price and quantum indices, 1980-1984 (1982 =100)

	1980	**1981**	**1982**	**1983**	**1984**
Quantum index	88	128	100	111	116
Price index	108	108	100	89	156

Note: Total feed output in 1982 was estimated at 120,000 tonnes
Source: Central Bureau of Statistics 1984, 1985.

No estimates are available of the proportion of smallholder farmers feeding concentrates. The national average milk output of 3-4 kg per day for the grade cow appears to indicate that even if feeding of concentrates does occur it does not generally provide for the high milk output potential of the grade animal. In many cases the purchased material will be of value to the animals only in terms of supplementing the inadequate roughage supply so that little more than maintenance requirements are met. Considerable ignorance is also apparent as to what is regarded as a concentrate (Nkanata, personal communication). Bran, brewer's waste and sweet-potato vines have all been considered as concentrates. The use of these products may in fact lead to an increase in milk output at the farm level, but it is clear that this is mainly through improving roughage supply. As pointed out above, a roughage-only diet of Napier grass may be able to support a milk output of 10 kg per day if supply is adequate.

The exact role of commercial concentrates on the smallholding depends to a very great extent on the relationship between milk price and the cost of concentrate. At the present time 1 kg of commercial dairy meal costs approximately Ksh 2.50 on the farm, while 1 litre of milk marketed through a co-operative is worth about Ksh 2. Direct to the consumer about Ksh 3.50 may be obtained. Economic evaluation of the use of concentrates in relation to roughages has not been carried out adequately. The Dairy Development Project is carrying out some economic analysis of their co-operating farms and initial results will be available shortly (Valk 1985).

It is, however, abundantly clear that the price paid and marketing efficiency of the milk industry will greatly influence concentrate use. An increase in the Government-controlled producer price paid by the parastatal Kenya Co-operative Creameries, with its legal monopoly over much of the smallholder region, or expansion of direct sales to consumers at higher prices, would provide considerable incentive to the producer to intensify production, with a greater use of concentrates. The feed-compounding industry has adequate capacity for the near future, at least to provide a sufficient quantity of feeds for national requirements, and the formulation of feeds of acceptable quality is not a technical problem.

The possibility of production of home-made concentrates on the small farm appears to be very limited given the farmer's labour and land constraints. The legume sweet lupin does, however, appear to offer some promise as a high-protein crop which is capable of being intercropped successfully within a maize crop in a manner similar to that already practiced with beans. There is some evidence that the legume may benefit the maize crop as well as providing a valuable protein source (KARI 1983).

Conclusions

The dairy industry in Kenya is at present in a highly critical state. Demand for milk is expanding rapidly due to a population growth rate of over 4% per year, increasing urban incomes, and the requirements of the Presidential-sponsored school milk scheme aimed at supplying free milk to all primary school children in the country. The development over the last 20 years of a small-holder-based commercial dairy industry may well be a forerunner of future trends in other African countries as land pressure increases. The transfer of technology developed in Kenya to other countries is a clear possibility. Within Kenya itself, increase in national output on the small farm appears possible using technology already available, but more research is needed to ensure that adequate material is available for the year-round feed budget, especially as the pressure on land reduces farm size in the drier regions of the smallholder zone. The role of milk marketing, including pricing, is central to the economic applicability of any proposed new technology.

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Appendix 1

As mentioned in the text a survey is currently under way to obtain estimates of the area of fodder and/or pasture in the smallholder areas. Some results are already available, as shown in the table below.

District	Area (ha)			
	Pastures		Fodders	
Nyeri	Planted		Napier grass	10,464
	Natural	45,000	Sweet potato	3,913
			Lucerne	157
Baringo	Chloris gayana	230	Napier grass	164
	Setaria sphacelata	231	Misc. folders	200
	Natural	66,000		
Bungoma	Rhodes	66	Napier grass	145
Murang'a	All	16,875	Napier grass	9,925
Uasin Gishu	Chloris gayana	5,000	Napier grass	1,250
	Setaria sphacelata	1,000		
Siaya	Chloris gayana	91	Napier grass	154

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An inventory of livestock feed resources in Tanzania

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Abstract

The main feed resources in Tanzania can be grouped into natural grasslands, established pastures, cereals and root crops, and agricultural by-products.

The main limitations of the natural grasslands are their characteristic seasonal productivity, low production of dry matter, the low quality of herbage and the low level of range management. Planted pastures play a limited role as a feed resource and are confined to the intensively cultivated areas. The poor link between pasture research and extension and a shortage of pasture seed have also contributed to the underdevelopment of this resource.

Cereals and root crops are produced primarily for human consumption, although the potential exists for increased production to meet both human and livestock needs.

Agricultural by-products contribute significantly to livestock feeding. Improvements in handling, processing and transportation of the by-products, as well as integration between livestock and crop production, could greatly increase the utilization of this feed resource.

Introduction

Tanzania has one of the largest livestock populations in Africa with 13.5 million head of cattle, 5.5 million goats, 3.6 million sheep, 0.4 million pigs and 23.2 million chickens (Ministry of Agriculture 1982b). Most of the cattle are indigenous Tanzania Shorthorn Zebu (TSZ) and the rest (estimated at 30,000 head (Lohay 1977) are exotic dairy animals and crosses with the TSZ). The bulk of the livestock are under traditional production systems in which the animals are expected to fend for themselves to a large extent and to contend with the environmental stresses imposed on them by nature.

Livestock are an important resource in Tanzania. They:

> (i) are the direct source of cash income and livelihood for an estimated 10% of the population (Ministry of Agriculture 1982a);
>
> (ii) are the major source of animal protein throughout the country;
>
> (iii) provide farm power in some areas in the country;
>
> (iv) play an important role in some traditional cultural activities (for example, payment of brideprice);
>
> (v) provide raw materials for industry (for example, tanning and leather industries).

The direct contribution of livestock to the total exports of the country was estimated at 13.2% in 1971 (Ministry of Agriculture 1982a).

In spite of the large population, livestock in the country have a low productivity (see Table 1). In a review of the livestock situation in 1982, the Ministry of Agriculture (1982b) noted with concern:

It is generally agreed that inadequate nutrition is one of the main factors accounting for the low productivity of livestock in the country (Calo 1976; Ministry of Agriculture 1982a; Mwakatundu and Mpatwa 1977). Ruminant livestock obtain adequate feed from grazing during the rainy season, but are on the verge of starvation during the dry season. In some years they die from starvation by the thousands. Reproductive performance of less than 50%, mortality rates of 15% from birth to weaning and over 5% from weaning to market, are thus the rule rather than the exception (Calo 1976). Pigs and chickens, which in traditional production systems are left to scavenge around the homestead, often do not obtain an adequate or balanced diet.

Table 1. Estimates of cattle population and productivity in Tanzania 1982

Cattle population ('000)	Beef and veal ('000 head slaughtered)	Carcass weight (kg/animal)	Fresh milk ('000 tonnes)	Cow milk (kg/animal)
13,150	1,351	102	376	160

Source: FAO 1983.

(i) The small number of cattle sold, resulting in slaughter plants operating below capacity;

(ii) The decline in the average weight of beef carcasses from 250 kg in 1971 to 180 kg in 1981;

(iii) The country's high demand for dairy products which exceeded local production, forcing the Government to import them at an average annual value of TSh 80 million;

(iv) The inability of the country to export beef and meat on account of the poor quality of these products and, hence, their non-competitiveness on the world market.

Livestock feed resources

In Tanzania livestock feed resources can be grouped into four main categories, namely, natural grasslands, established pastures, cereals and root crops, and agricultural by-products. The following account attempts to describe them and assess their potential.

Natural Grasslands

Natural grasslands are the most important feed resources for ruminant livestock in Tanzania. It has been estimated that the country has 451,903 square kilometres (or 51% of the total land-area) of natural pastures which support over 90% of the total ruminant livestock population (UNDP/FAO 1967; Ministry of Agriculture 1982a). These areas, which correspond to ecological-climatic zones IV and V of Pratt, Greenway and Gwynne (1966), are represented by grazing lands on the low eastern plateau between the coastal plains and the eastern rift valley, and on the central plateau. They are characterized by low and seasonal rainfall (usually 760 mm or less annually) and high evapotranspiration potential (over 1,800 mm). The vegetation is characterized by the dominance over most areas of Themeda and Hyparrhenia grass species and the conspicuously meagre content of herbaceous forage legumes (Thomas 1973).

A basic shortcoming of natural grasslands as a source of feed for ruminant livestock is their low production of dry matter due to a combination of the negative effects of inadequate rainfall and the dearth of available soil nitrogen on plant growth (Russell 1966; Wigg, Owen and Mukurasi 1973). The seasonality of plant growth, which is a reflection of the annual rainfall distribution pattern, further restricts the availability of herbage for the grazing animal to four or five months of the wet season over most of the natural grasslands.

Another shortcoming of the natural grassland is the low quality of the herbage. Results from an investigation in which Karue (1974) determined the nutritive values of grass species from similar grasslands in Kenya showed that, for most of the grasses, available energy and crude protein fell short of the animal's (Boran cattle) nutritional requirements during both the dry and wet seasons. In a review of the nutritional value of tropical grasses and folders, French (1957) observed that: (i) irrespective of area in the tropics, or of grass species under consideration, the highest crude-protein values are recorded during the wet season; and (ii) tropical grasses often develop not only a high proportion of carbohydrates but also a high lignin content at an early vegetational stage and the lignin reduces the overall digestibility of the grasses. French (1957) presented data to show that the fast growth of tropical grasses was associated with a rapid decline in their mineral content, especially of phosphorus and sodium. The combined effects of the small quantities and the low quality of herbage from natural grasslands is to reduce drastically their carrying capacity. Pratt and Gwynne (1977) estimated that 4-12 hectares of similar grasslands in Kenya were required to support one livestock unit. Other factors, for instance the presence of game in some areas, annual burning during the dry season, tsetse infestation in some areas and uneven distribution of water supplies, further reduce the effective carrying capacity of the natural grasslands.

Considering both their size and their role as the source of feed for most of the country's ruminant livestock population, national grasslands are, nevertheless, an important resource in Tanzania. Their improvement through better management and utilization, bush and tsetse control, increasing the content of forage legumes (including suitable browse species), and provision of adequate water supplies could, by themselves, considerably raise the production efficiency of ruminant livestock in the country.

Planted Pastures

There is a lack of information on the area of planted pastures in the country, but it comprises a very small proportion of the total land area under cultivation. These pastures are found on dairy farms and units mainly in areas of high crop-production potential. Table 2 shows the various types of planted pastures and the plant species grown. Overall, they are much more productive than natural grasslands and form the basis of the nontraditional dairy industry in the country.

The temperate pastures deserve special mention because of their high potential for improving dairy production in the high altitude areas. Presently only 12,000 ha out of a total of 29,000 ha of available land in Kitulo are under planted pasture with a carrying capacity of 1 ha/livestock unit* yielding, on average, 8 kg milk per day (TISCO 1983). TISCO also estimated (1983) that with good management and utilization the same pastures could support 1 livestock unit/0.5 ha, yielding an average of 10 kg milk per day.

* 1 livestock unit = a mature TSZ animal weighing 350 kg.

A major constraint to the development of planted pastures is the shortage of pasture seed. There is no proper pasture-seed production programme and consequently the country has had to rely on imported seed (Lwoga 1979).

Another constraint has been the failure to bring pasture research results to the point of application, even though much research on pasture has been conducted in Tanzania (Lwoga 1979).

Cereals and Root Crops

Tanzania produces substantial amounts of cereals and root crops (see Table 3). Because of their high content of readily digestible carbohydrates, they are valuable feeds for livestock, especially the monogastrics. However, they are produced primarily for human consumption and most of them are in short supply in the country. In addition, some of them are used in the brewing industry and others (especially cassava) are likely to be used in the starch industry in future (Kategile and Urio 1982). Appreciable quantities of sorghum are exported (Ministry of Agriculture 1979). Changes in priorities have to be made to reduce the quantity exported and channel part of the produce into livestock production (Kategile and Urio 1982), but quantities are likely to diminish with improved storage.

Table 2. Types of planted pastures and plant species grown

Pasture type	Grass species	Legume species
Temperate pastures	Perennial ryegrass	White clove
	Lolium perenne	
	Dactylis glomerata	
	Festuca arundinacea	
	Avena sativa	
Sub-tropical pastures	Chloris gayana	Desmodium intorum
	Panicum maximum	Desmodium sandwicense
	*Pennisetum purpureum	Neonotonia wightii
	*Setaria splendida	*Medicago sativa
	*Tripsacum laxum	
	*Zea mays	
Tropical pastures		
(a) Humid-sub-humid	Chloris gayana	Purераria phaseloides
	Setaria anceps	Neonotonia wightii
	Panicum maximum	Desmodium spp.
	*Pennisetum purpureum	
	*Tripsacum laxum	
	*Zea mays	
	*Sorghum	
(b) Sub-humid to semi-humid	Chloris gayana	Stylosanthes gracilis
	Cenchrus ciliaris	Centrosema pubescens
	Cynodon plectostachus	Rynychosia sennarenis
	Panicum maximum	

*Mainly fodder
Sources: Madallali 1974; Mwakatundu and Mpatwa 1977; TISCO 1983

Table 3. Cereal and root-crop production 1970/71-1979/80 ('000)

Year	Maize	Paddy	Wheat	Sorghum/millet	Cassava	Potatoes	Sweet potatoes
1970/71	870	192	60	413	3,444	74	248
1971/72	850	202	77	367	3,209	67	229
1972/73	980	178	67	409	3,189	120	234
1973/74	750	193	49	423	3,388	165	296
1974/75	750	141	32	280	3,688	101	302
1975/76	825	157	46	440	3,800	87	320
1976/77	897	180	58	390	3,900	92	330
1977/78	968	203	35	390	4,000	96	335
1978/79	1,000	260	38	410	4,450	85	330
1979/80	900	250	30	380	4,550	85	330

Source: Ministry of Agriculture 1982.

Given the above situation, it is unlikely that cereals and root crops will become a major source of livestock feed in the country in the near future. With improved production, however, they could contribute significantly to livestock feed requirements in the future.

Agricultural By-Products

Apart from natural grasslands, agricultural by-products offer great promise as a source of ruminant livestock feed in Tanzania. Table 4 presents estimates of the production of these materials in the country.

Farm Residues

These include materials from annual crops (for instance, various types of stover, straw, maize cobs, cassava peelings and groundnut haulms and hulls) and "wastes" from perennial crops (for instance, coffee pulp and hulls, sugarcane tops, bagasse, molasses, sisal pulp, and cashew fruit and kernel powder). Collectively, the annual production of farm residues in the country has been estimated at 13 million tonnes dry matter, having, on average, 3.0% digestible crude protein and 1.90 Mcal ME/kg which, if fully utilized, could support 6.6 million head of 200 kg animals at maintenance level for one year (Calo 1976).

Annual crop residues are routinely fed to ruminant livestock, either in situ, where farmers keep large herds, or in stalls where farmers keep a few animals for milk production. In the main cropping areas of the country, however, these materials are either left to rot or burnt in the fields after harvest (Kiangi 1979).

Perennial crops generate large quantities of residues. On plantations, the presence of these materials makes possible the establishment of large-scale livestock feeding operations. Few plantations in the country, however, have livestock enterprises. In most cases the materials are used as mulch (e.g. coffee and sisal pulp), burnt to produce power for processing plants (e.g. bagasse), used as raw materials in other industries (e.g. molasses for the production of alcohol), or exported (e.g. molasses).

Considerable research has been carried out in Tanzania and elsewhere on means of improving the nutritive value of crop residues (Kategile et al. 1981; Kiangi and Kategile 1981; Urio 1981). As elsewhere, the improvement in feeding value involved the use of chemicals such as sodium hydroxide and ammonia which proved to be expensive and their supply to be unreliable. The current trend is to improve utilization of the residues through better handling and transportation and supplementing for those nutrients which are most limiting. Traditional in situ grazing has long been known to be wasteful (French 1943).

Milling By-Products

Milling by-products are an important group which, along with oilseed cakes, form a key raw material in the production of feeds for various classes of livestock in the country. Unfortunately, the majority of farmers in the rural areas have access neither to the by-products nor the feeds since most of the milling and feed manufacturing operations are carried out in the large urban centres (Kategile and Urio 1982). In addition, the quantities of feeds produced are far below existing demand, and there is a lack of an efficient distribution system in the country (Ministry of Livestock Development 1983; Mwakatundu and Mpatwa 1977).

Oilseed By-Products

These products are, perhaps, the most important group because of their high content of protein, the most deficient nutrient in natural grassland herbage and in the other agricultural by-products. Used as supplementary feeds they could help not only to increase the overall productivity of the animals but also to make more efficient use of protein-deficient feed resources. Calo (1976) estimated the potential supply of this group to be of the order of 167,000 tonnes of dry matter, with an average content of 25.7% digestible crude protein and an energy content of 2.71 Mcal ME/kg, which if fully utilized to supplement natural grassland grazing could add an extra 42,000 tonnes of beef without increasing the offtake.

At present, substantial quantities of cotton-seed cake are exported (Kategile and Urio 1982). As in the case of milling byproducts, the lack of an efficient distribution system is a constraint to the utilization of oilseed cakes where they are most needed.

Other By-Products

Other by-products are produced in small quantities and their supply is often unreliable. Nevertheless, they deserve mention because of their high protein content which makes them particularly good supplementary feeds for pigs and chickens. They include brewery by-products (see Table 4), fishmeal, bonemeal and meatmeal. The brewery waste produced by the Arusha brewery is almost exclusively and fully utilized by smallholder dairy and pig farmers around Arusha. There has also been some attempt to produce pelletized dairy feed using brewers waste by private feed manufacturers in Moshi, but the limited supply of this byproduct has been a major constraint to this effort.

Table 4. Estimates of the annual production of major crop residues and processing by-products in Tanzania

Crop	Dry matter ('000 tonnes)	Digestible crude protein ('000 tonnes)	Metabolizable energy (million Mcal)
Maize			
Stover	3,509.5	155.9	6,844.5
Cobs	1,269.0	2.8	2,527.2
Germ meal	65.0	10.4	191.8
Bran	44.0	2.7	85.9
Sub-total	4,887.5	171.8	9,649.4
Rice			
Straw	604.0	10.2	923.4
Hulls	15.0	0.1	22.3
Bran	10.0	0.5	18.5
Sub-total	629.0	10.8	964.2

Sorghum			
Stover	1,875.0	14.5	3,283.4
Threshed heads	150.0	4.5	270.6
Bran	10.0	0.5	19.0
Sub-total	2,035.0	19.5	3,573.0
Millet			
Stover	1,352.0	16.9	2,580.5
Bran	5.0	0.5	15.5
Sub-total	1,357.0	17.4	2,596.0
Wheat			
Straw	573.0	16.0	1,011.2
Bran	18.0	1.8	39.8
Sub-total	591.0	17.8	1,051.0
Cassava			
Peelings	88.0	0.9	238.0
Waste-meal	230.0	0.0	678.0
Sub-total	318.0	0.9	916.0
Groundnuts			
Haulms	112.0	10.8	220.5
Hulls	10.0	0.2	7.1
Sub-total	122.0	11.0	227.6
Coffee			
Pulp	11.3	0.7	31.4
Hulls	3.3	0.2	6.4
Sub-total	14.6	0.9	37.8
Sisal			
Pulp	300.0	0.0	615.0
Sugarcane			
(a) Plantation			
Tops	36.5	0.9	71.7
Bagasse (50%) used for fuel	24.1	0.0	29.6
Molasses	46.6	0.6	127.5
(b) Small-farm			
tops	47.3	1.2	92.8
Sub-total	154.5	2.7	321.6
Cashew			
Fruit (dehydrated)	382.1	25.2	1,250.3
Kernel powder	6.5	1.1	13.6
Sub-total	388.6	26.4	1,263.9
Pyrethrum flowers			
Marc	2.8	0.3	8.4
Sunflower seed			
Cake	3.7	1.6	10.1

Hulls	1.8	0.1	3.1
Sub-total	5.5	1.7	13.2
Cotton seed			
Cake	110.0	37.9	347.7
Hulls	42.0	0.1	65.3
Sub-total	152.0	38.0	413.0
Sesame seed			
Cake	5.2	2.3	14.1
Copra			
Cake	3.9	0.9	11.2
Kapok			
Cake	0.18	0.1	0.4
Brewery by-products			
Brewery grain (wet)	1.8	0.3	4.3
Brewers yeast	0.4	0.2	1.3
Sub-total	2.2	0.5	5.6
Grand total	10,969.0	323.0	21,681.4

Source: Calo 1976

Conclusion

It is clear from above that Tanzania has a considerable reserve of livestock feed resources which, if fully exploited, could help to increase the level of production from its large livestock population. It is worth drawing attention to some of the factors that have contributed to the underutilization of livestock feed resources.

Development planners have long regarded livestock and crop production as mutually exclusive activities that compete for the same resource (i.e. land). Consequently, development plans have often failed to integrate the two activities resulting, in turn, in the underutilization or wastage of agricultural by-products which could otherwise be made available to livestock. Large crop-production schemes are frequently established without consideration being given to the use of crop residues as a livestock feed. Similarly, the lack of transport and handling facilities between the major crop and livestock areas blocks the flow of crop by-products to where they could be fed to livestock.

Unco-ordinated, and sometimes wrong, decisions have often deprived the country of the opportunity to supplement and alleviate grazing pressure on natural grassland with agricultural by-products. The export of such byproducts as molasses, cotton-seed cake and bonemeal has meant the country exporting materials to feed livestock in other countries and importing dairy products at high prices.

Finally, improvements in the management and utilization of natural grassland have not been given due attention in some livestock-improvement schemes. Overemphasis on veterinary services, dips and water supplies was, for instance, shown to result in increased livestock populations with the consequent overuse and deterioration of rangeland in Maasailand and in central Tanzania.

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Feed resources in Ethiopia

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Introduction

Ethiopia lies in the horn of Africa between 3° and 18° north and 33° and 48° east and has a land area of approximately 1.23 million km². It borders on the Sudan in the north and west, Kenya in the south, Somalia in the southeast and Djibouti and the Red Sea in the east.

Out of the total land area, 846,100 km² is agricultural land of which 137,000 km² is cultivated land 651,000 km² pastureland, and 88,000 km² forests. Swamps cover 57,800 km² are barren land and 120,000 km² water and water courses.

The topography consists of a high central plateau ranging in altitude from 1,800 to 3,000 m, the Rift Valley that divides the country from south to north with altitudes ranging from 1,000 to 1,800 m, and the extensive lowland plain areas to the south and south-east with varying altitudes but often less than 1,000 m. These are the areas occupied by nomadic people.

The soils vary from black cotton soils (vertisols) and red soils (artisols) to desert sands. Vegetation cover varies from rain forest to savanna. The originally fertile soils of the high and medium altitudes have been intensively cultivated for centuries and are now degraded in some places.

There are several large rivers such as the Blue Nile, Wabe Shebele, Omo, Baro and Gibe, and many smaller rivers, streams and lakes whose potential is as yet untapped.

Large parts of the country have adequate rainfall which has a bimodal pattern. The small rains occur from March to May and the big rains from late June until the end of September in the high and mid-altitudes. The rainfall pattern is different in the lowland areas for there the rains start in early July and end in early September. Temperatures vary with altitude, ranging from less than 10°C in alpine areas to 35°C and higher in lowland areas.

Agriculture is the backbone of the country's economy with the raising of crops being the major activity. Coffee is the major exportable agricultural commodity and it earns the largest proportion of foreign exchange. Livestock also play an important role in Ethiopia's economy being the second largest earner of foreign exchange after coffee.

Present livestock production systems

Domestic livestock herds and flocks include 29 million cattle, 24 million sheep, 18 million goats, 1 million camels, 7 million equines and 53 million poultry, distributed throughout the country. The greatest concentration occurs in the highland where 70% of the human population live. Although there are few data on the animal population, it is generally accepted that there are about 5 livestock units (LU)* of grazing animals per capita in the lowlands and 1 LU per capita in the highlands. In addition, almost all rural households, with the exception of nomadic ones, own some chickens.

*1 LU is equivalent to a 250 kg animals

The heterogeneity of Ethiopia's topography, climate and cultural conditions make it difficult to generalize about livestock production systems in the country. The following are the major livestock production systems in the country, however.

Highland Livestock

Here animals are part of a mixed subsistence farming complex. Animals provide inputs (draught power, transport, manure) to other parts of the farm system and generate consumable or saleable outputs (milk, manure, meat, hides and skins, wool, hair and eggs).

Lowland Livestock

Where animals are kept by pastoralists they do not provide inputs for crop production but are the very backbone of life for their owners, providing all of the consumable saleable outputs listed above and, in addition, representing a living bank account and form of insurance against adversity.

Parastatal and Commercial Livestock

Commercial livestock are mainly held by state farms, co-operatives and some private individuals and produce milk and eggs for local sale and meat for export. Only a very small proportion of the animals in Ethiopia fall into this category.

Feed resources and status

In Ethiopia livestock obtain feed from:

1. Grazing and browsing on natural pastures;
2. Crop residues and agro-industrial by-products; and
3. Cultivated pasture and forage-crop species.

Grazing and Browsing

The availability and quality of native pastures available to livestock vary with altitude, rainfall, soil type and cropping intensity. The total area of grazing and browsing is 62,280 million hectares, of which 12% is in the farming areas (more than 600 mm rainfall) and the rest around the pastoral areas (Tables 1 and 2).

Afro-alpine vegetation, found at altitudes above 3,000 m, is characterized by heaths and Lobelia with cold-resistant short grasses. Much of this area is overgrazed. The highland areas (between 2,200 and 3,000 m) as characterized by grass and legume pastures with the legume component decreasing with decreasing altitude. The area available for grazing is determined by the intensity of annual cropping and in southern Ethiopia, by the areas sown to coffee, Ensette (pseudo-banana, a carbohydrate source), and chat (Cata edulis, a narcotic leaf which is chewed). There are extensive grassland plateaux and areas of seasonally waterlogged soils. Active plant growth is restricted to periods during the short rains, where these occur, and to one or two months after the small rains. Pastures are generally overgrazed and many areas are invaded by Pennisetum spp. Overgrazing is less severe in areas with lower cropping intensity. The lower-altitude farming areas are characterized by grass-dominant pastures and production varies with rainfall, which in some areas is poor and erratic overgrazing is common in settled farming areas.

The higher rainfall areas of the pastoral zone (300-600 mm rainfall per annum), are characterized by dense thornbush with a low carrying capacity and more open vegetation with understory grasses having a higher carrying capacity. Open desert with annual rainfall below 300 mm is characterized by sparse vegetation, including early maturing annual grasses. Carrying capacities vary from 8 to 15 ha per LU.

In the farming system, permanent pastures provide 85% of the feed resources available to livestock and in the pastoral areas grazing and browsing provide 100% of such resources. (Table 1 and 2).

Productivity studies indicate that in the lowland areas native pasture yields 1 ton dry matter ha^{-1} or less in intermediate and high areas on freely drained soils yields are 3 tons dry matter ha^{-1} and in seasonally waterlogged fertile areas 4-6 tons dry matter ha^{-1}.

Table 1. Feed Resources Available Annually to Livestock in the Highlands

Feed source	Area (millions ha)	Availability	
		dry matter	Total dry matter
Grazing	7.280	4.50	32.760
Cereals	4.607		
Crop residues		1.40	6.500
Aftermath grazing		0.40	1.843
Pulse residues	0.808	0.50	0.404
By-products			0.150
Total			41.657

Table 2. Feed Resources Available to Livestock in Pastoral Areas

Rainfall zone (mm)	Area (millions ha)	Availability	
		Dry matter h^{-1}	Total dry matter (million t)
500-700	9.90	1.00	10.007
300-500	8.10	0.64	5.153
<300	22.50	0.35	7.970
Thorn bush areas	14.50	0.53	7.685
Total	55.00		30.815

Sources: Tables 1 and 2, Ministry of Agriculture, 1984

Vegetation

The highlands are rich in pasture species, particularly indigenous legumes. The proportion of legumes tends to increase with increasing altitude and particularly above 2,200 m there is a wide range of annual and perennial Trifolium spp. and of annual Medicago spp. At lower altitudes native legumes are less abundant and commonly have a climbing or sprawling growth habit which renders them more susceptible to loss through grazing. There is a large variation in the range and density of legumes in wet bottomlands, and this appears to be only partly due to edaphic differences.

Common species

Areas above 3,000 m

The most common grasses are species of Poa, Fectuca, Agrostis and, to a less extent, Andropogon. In the wetter areas, sedges of the genera Carex, Eleocharis, and Mariscus occur. Of the perennial legumes, the most important are the deep-rooted Trifolium burchellianum (var. oblongum and var. johnstonii) and Trifolium acaule which extends to over 4,000 m. Trifolium polystachyum extends to at least 3,500 m and of the annuals Trifolium tembense is the most significant, though it occurs only in the lower range. Of the shrubs, Erica arborea and Hypericum revolutum are common.

Areas from 2,000 to 3,000 m

The most common grasses are species of Andropogon, Cynodon and Pennisetum. Other common ones are species of Setaria, Themeda, Eragrostis, Sporobolus, Brachiaria, Paspalum, Phalaris and Festuca aurindinacea. The only significant annual grass is Snowdenia abyssinica. Productivity may be extremely high during the later part of the wet season but there is little growth after early October. Legumes are prolific in this zone. The most common perennial is Trifolium semipilosum, and other frequently occurring ones are Trifolium burchellianum var. johnstonii, Trifolium, polystachyum, Lotus sp., Trifolium rueppellianum, Trifolium decorum, Trifolium steudneri, Trifolium quatinanum and Vigna sp. are the most widespread of the annuals. In the extremely wet bottomlands sedges are common. Of the legumes, Trifolium tembense is prolific. Arable land left fallow usually has a dense weed cover initially, but with heavy grazing there is always an invasion of grasses, including Digitaria scalarum, Cynodon dactylon and Phalaris paradoxa. With longer-term fallows Cynodon dactylon and Pennisetum sp. become more common. Trifolium semipilosum and Trifolium burchellianum are also found in such areas. Of the browse Erythrina sp. is common.

Areas from 1,800 to 2,000 m

This zone is characterized by tall grasses and a higher proportion of climbing/sprawling legumes, especially in less intensively settled areas. The most common grasses are of the genera Chloris, Cenchrus, Hyparrhenia, Setaria, Paspalum, Cynodon, Pennisetum, Eleusine, Eragrostis, Cymbopogon and Andropogon. The perennial legumes include Neonotonia wightii, Indigofera spp., Crotolaria sp., Desmodium sp., Rhynchosia sp., Vigna sp. and Trifolium semipilosum which grows down to about 1,500 m in wetter western areas and commonly to 1,800 m in central areas. Stylosanthes fruticosa is found in scattered sites, mainly below 1,800 m, and may be common in degraded areas where few other species thrive. Of the annuals, Trifolium steudneri, Trifolium reupellianum and Medicago polymorpha are quite frequent above 1,700 m. Of the browse species, Albizia sp. is common and Sesbania is also prolific on wet lake margins.

Areas below 1,800 m

These areas, which include the Rift Valley, are covered with Acacia woodland. Today much of the Acacia has been removed as the demand for charcoal has increased in urban centres. Heavy grazing and low-productivity farming have followed the cutting of trees. Common grasses include Chloris pycnothrix, Hyparrhenia anthistiriodes, Setaria acromelana, Aristida keniensis, Cynodon dactylon, Panicum atrosanguineum, Microchloa kunthii, Hyparrhenia dregeana, Cenchrus ciliaris, Heteropogon sp. and Bothriochloa insculpta. Of the legumes, Neonotonia wightii and the less valuable Indigofera spicata are common. Browse species are dominated by Acacia etbaica, Acacia nilotica subsp. leiocarpa and Acacia seyal var. seyal.

Crop Residues and Agro-Industrial By-Products

Cereals and Pulses

Cereal straw from teff, barley and wheat is the largest component of livestock diet in the intermediate and highland areas that is not obtained in situ. Straw is stacked after threshing and fed to animals during the dry season, as are pulse-crop residues (e.g. horsebeans, chickpeas, haricot beans, field peas and lentils). At lower altitudes in the highland areas maize, sorghum and millet stovers occur to a greater extent than at higher altitudes. Teff is grown at intermediate altitudes and barley replaces wheat at the higher altitudes, where pulses are also grown to a great extent. The nutritive values of the different residues vary. Whereas teff straw is equivalent to medium-quality hay, the residue of other cereal crops is only of poor to fair quality. On the other hand, pulse haulms are high-quality roughage with 5-8% protein.

By-Products from Sugar

The sugar industry in Ethiopia has factories at three sites (Wonji, Shoa and Methara). The present area of cane is 13,000 ha and the estimated yield of cane tops is 6 tonnes dry matter per hectare or 78,000 tonnes dry matter per year. Production of molasses in 1981/82 was 51,100 tonnes of which 29,000 tonnes were exported. At present the use of a molasses/urea mixture as a drought-relief feed has been started in a pilot scheme run jointly by the Ministry of Agriculture, the Ministry of State Farms and ILCA.

Oil-Cake

Oil cakes are an excellent concentrate feed for ruminant livestock. Ethiopia grows most of the temperate and sub-tropical oilseed plants such as linseed, groundnuts, rape, sesame, sunflower and cotton. Neug or niger, a native annual composite, which produces niger seed for oil, is also grown. The processing of oilseeds is widely practiced on a family basis or in small village mills. In some areas (the northwest) neug cakes are currently being wasted rather than being properly used.

Milling By-Products

The various milling by-products obtained through processing wheat are of great interest as livestock feed for state farms, city dairy holders, and to a lesser extent for some dairy co-operatives. Wheat grain is processed in big mills, whereas in the case of teff, barley, maize and sorghum the whole grains are processed and used for food.

Slaughter Products

Large numbers of livestock, mainly cattle, sheep and goats, are slaughtered every year. Of these, only a small proportion of the cattle are slaughtered in abattoirs with processing facilities. The Addis Ababa Municipality, which is responsible for the abattoirs, produces meat, bonemeal and blood. At present most of the meat and bonemeal is exported.

Brewery By-Products

Brewer's grains are traditionally valued for lactating cows because of their palatability and milk-producing property. In addition to commercial beer production at the two breweries in Addis Ababa and one each in Asmara and Harare, small-scale home brewing is also practiced.

Other By-Products

Sisal waste is produced in the southern part of the country. Studies indicate that it has a low protein and high fibre content. Coffee pulp and hulls (about 30,000 tonnes per year) can also be used as a minor feed source in the coffee-growing areas. Since coffee-residue production is seasonal, storage is a problem.

Cultivated Pasture and Forage-Crop Species

Research on cultivated pasture and forage-crop species was initiated in the late 1960s. The leading organizations conducting research were the Institute of Agriculture Research (IAR), Arsi Rural Development Project (ARDP, ex-CADU), and lately the International Livestock Center for Africa (ILCA) and the Forage Network in Ethiopia (FNE). The development programmes were partially executed by the Extension Promotion and Implementation Department (EPID) and the Livestock and Meat Board (LMB), but since 1979 the Ministry of Agriculture, Animal and Fisheries Resources Development, Main Department, has been responsible for the execution of the national programmes. Within the same Ministry, the Department of Soil and Community Forests and the Third Livestock Project are also running development programmes. The Ministry of State Farms, especially the Animal Resources Development Department, has large-scale dairy and beef farms.

Cultivated pastures and forage crops, with the exception of alfalfa and Rhodes grass, have not been used on significant areas outside government stations, state farms and farmer's demonstration plots. Fodder crops are commonly grown for feeding dairy cattle, with oats and Vetch mixtures, alfalfa, Rhodes grass and fodder beet being the most common. There has been widespread acceptance of the use of fodder following an intensive rural development programme; and both an oats/Vicia mixture and fodder beets have been used to a limited extent for draught oxen. Fodder crops have had minimal use in non-dairy production, perhaps partly because seed has been imported and available only in limited quantities. In suitable areas yields of oats/Vicia mixtures are commonly 8-12 tons dry matter per hectare. Introduced fodder trees (Leucaena, Sesbania sp.) have been used only within the soil-erosion control programme and around farmers' homesteads. Due to land scarcity and a crop-dominated farming system there has been no significant introduction of cultivated species into traditional grazing areas.

Key recommendations for plant species to be grown in the different zones are shown in Table 3.

Feed development constraints

Undernutrition and malnutrition are major factors constraining animal production in Ethiopia. Nutritional stress causes low growth rates, poor fertility and high mortality, which is compounded by diseases. About 85% of feed intake is used to meet the animals' maintenance requirements and only 15% is utilized for production. Utilization of the feed resources is therefore highly inefficient. The area of improved pastures and fodder crops is insignificant and natural pastures are overgrazed causing invasion of inferior species. Seasonal feed deficiencies cause the loss of weight gains made during more favourable periods, while fodder conservation to help eliminate seasonal feed-supply fluctuations is rarely practiced. Generally, all stock are grazed together with no attempt to provide special treatment for different classes of stock. Controlled breeding is rarely practiced so that seasonal variation in feed supply and demand are not synchronized. Agro-industrial by-products are often wasted or poorly utilized and crop residues are fed without treatment or supplementation. Transport problems often prevent by-products being moved to areas where they can be utilized effectively. The incidence and effects of mineral deficiencies are poorly understood, although there is an overemphasis on concentrate feeding, even though the supply of concentrates is unreliable. Dairy calves receive poor weaning rations which lead to poor growth.

Table 3. Major Recommended species for different environments

Altitude (m)	Rainfall (m)	Major Species
<2,000	600-900	Buffel, Rhodes grass, Stylosanthes spp., Siratro, green panic, Sorghum almum, Leucaena, pigeon pea.
	>900	Rhodes grass, Panicum maximum, elephant grass, Desmodium uncinatum, Siratro, Stylosanthes spp. alfalfa, Leucaena, Sesbania, pigeon pea.
2,000-2,400	All	Rhodes grass, Panicum maximum, Panicum coloratum, Setaria, tall fescue, Phalaris, vetch, Desmodium, Medicago, alfalfa, oats, Sesbania, pigeon pea.
2,400-3,000	<1,200	Tall fescue, Phalaris, indigenous clovers, Medicago, vetch, oats, fodder beet.
	>1,200	Tall fescue, Phalaris, rye grass, cocksfoot, indigenous clovers, Medicago, vetch, oats, fodder beet, Erythrina sp.

In pastoral areas, feed shortages during drought cause high mortality. There are increasing signs of range deterioration including erosion, bush encroachment and loss of species diversity. Better management of the rangeland is badly needed.

Strategy for feed development

A strategy for feed development/improvement would incorporate reduction of livestock numbers improvement of feed availability and quality, and improvement in the efficiency with which feed supplies are used. A reduction of livestock numbers would concentrate initially on the intensively cultivated highlands where the stocking pressure is greater. The destocking would be accompanied by increased utilization of working oxen bred in the rangeland areas and eventually by mechanized cultivation.

Strategies to improve the efficiency with which feed supplies are used include disease control so that animals can realize the benefits of improved nutrition, and improved feeding management techniques such as rotational grazing, fodder conservation, feeding fresh forage using the cut-and-carry method, and regulating the intake by different categories of stock. The introduction of seasonal calving and lambing would help to synchronize fluctuations in feed supply and demand. Dry-season supplementation with protein-rich feeds would help reduce seasonal losses. Improved use of crop residues and agro-industrial by-products would also be useful. Mixing cereal residues with legumes would be the preferred method of improving the efficiency of utilization of the residues, rather than chemical treatments which would be difficult to apply in Ethiopia. Some agro-industrial byproducts such as cane tops, coffee pulp, oilseed meals, and molasses are currently underutilized or wasted and the scope exists for improving their utilization. Prepared feeds could also be improved by up-grading the existing feed-milling facilities.

Measures to improve the availability and quality of feed include establishment of grass/legume-based permanent pasture, fodder crops, forage intercropping, oversowing, undersowing, use of fodder trees and seed production.

Feed resources for small-scale livestock producers in Zimbabwe

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Abstract

Small-scale livestock producers in Zimbabwe include both small-scale commercial and communal land farmers. The latter, in particular, occupy a large proportion of the area of Zimbabwe with low agricultural potential. Cattle are the main livestock type, supplying draught, milk, manure and meat to their owners. Goats and donkeys are important in the lower altitude areas, especially where tsetse occur.

Crop residues form an important source of winter feed for stock and are either grazed in situ or are harvested and stored. Maize is the dominant crop in the high- and medium-potential areas and is grown both as a cash and food crop. In the very dry areas sorghum and millets are grown instead of maize.

Natural pastures form the main feed source for the small-scale livestock producer, but massive overstocking has led to severe degradation over large areas. Grazing schemes incorporating simple grazing rotations appear to offer a potential measure to halt this degradation of the environment, but few are in operation at present.

Some methods of alleviating the present situation of critical feed shortages are suggested.

Introduction

Small-scale livestock producers in Zimbabwe fall into two distinct groups:

Small-Scale Commercial Farmers

These are producers on land in the former African Purchase Areas who have full and sole rights to the arable and grazing land within a defined area. In 1983 there were 8,563 farm units, with a total area of 1.07 million ha.

Communal-Land Farmers

These are farmers in the former Tribal Trust Lands who have individually-allocated arable plots but whose grazing is used by the whole community. There are about 850,000 landholders and the communal lands cover a total of 16.20 million ha.

Statistics relating to the crop and livestock production of small-scale commercial farms are published annually. Corresponding data for the communal lands as a whole are difficult to locate and are at best estimates. However, detailed surveys carried out recently in the communal lands do help to give deeper insight into conditions and practices in those areas.

Geographical distribution of small-scale farmers in Zimbabwe

Vincent and Thomas (1961), modified by Surveyor-General (1980), defined five natural regions (NR) in Zimbabwe each with differing agricultural potential and suited to differing agricultural potential and suited to different farming systems. These regions are defined as follows:

NR I: Specialized and Diversified Farming Region

Rainfall is high (900 + mm) normally with some precipitation in all months of the year. The region is one of high-altitudes and mountainous so temperatures are relatively low leading to high rainfall efficiency. The main farming activities are afforestation, orchard crops and tea and coffee plantations. Supplementary irrigation of these tree crops may be required for maximum yields. There is also some intensive livestock production, particularly with dairy cattle.

NR II: Intensive Farming Region

Rainfall is confined to the summer months (November to March) and is moderately high (750-1,000 mm). Two sub-regions have been defined:

Sub-region IIa receives an average of at least 18 rainy pentads per season, normally enjoys reliable rainfall conditions and rarely experiences severe dry spells in summer. The region is suitable for intensive systems of farming based on crop and/or livestock production.

Sub-region IIb receives an average of 16-18 rainy pentads per season and is subject either to rather more severe dry spells during the rainy season or to rather short rainy seasons. In either event, crop yields in certain years will be affected but not sufficiently to change the overall utilization by intensive systems of farming.

NR III: Semi-Intensive Farming Region

Rainfall amounts are moderate (650-800 mm) but effectiveness is reduced by intense storms and high temperatures. Rainy pentads average 14-16 per season, and fairly severe mid-season dry spell alone are common. Suitable farming systems are therefore based on livestock production. The region is, therefore, marginal for enterprises based on crop productions (assisted by the production of fodder crops) with cash-crop production on soils of high available moisture potential.

NR IV: Semi-Extensive Farming Region

Fairly low rainfall (450-650 mm), periodic seasonal droughts and severe dry spells during the growing season make this region generally unsuitable for cash cropping. The farming system should be based on livestock production but it can be intensified to some extent by growing drought-resistant fodder crops.

NR V: Extensive Farming Region

Low and erratic rainfall precludes the growing of even drought-resistant crops and livestock production based on the veld alone is the most suitable farming system.

The proportions of the various land-tenure categories which fall within each of the Natural Regions are shown in Table 1. This table is derived from pre-Independence data and does not include the resettlement schemes which have been set up in former large-scale commercial farming (LSCF) areas.

Table 1. Percentage of each natural region falling into the various land tenure categories

Land-tenure category	Natural region					% of Zimbabwe
	I	II	III	IV	V	
National and unreserved	16	6	12	18	23	16.8
Large-scale commercial	71	69	45	28	26	37.3
Small-scale commercial	-	4	4	4	2	3.8
Communal land	13	21	39	50	49	42.1
% of Zimbabwe	1.8	15.4	18.5	37.4	26.9	

Source: Chavunduka et al 1982

From Table 1 it is clear that LSCF occupies a disproportionately large proportion of the land in the more intensive regions, that small-scale commercial farming (SSCF) areas are fairly uniformly distributed and that communal land (CL) is mainly in the more extensive regions.

Livestock holdings

Cattle are the main domestic livestock in Zimbabwe and have this dominant role in both the commercial farming areas and the communal lands. In LSCF areas cattle are kept for the commercial value of their products (meat, milk or breeding stock). In SSCF areas the position is more mixed, with sales in 1982 equivalent to about 18% of cattle numbers, but oxen also form the main source of draught power on most farms. In CL the role of cattle is diverse with the main benefits being derived from arable inputs (draught and manure), a substantial benefit from home consumption of milk and meat and only a small benefit from the sale of stock (Dackwerts, no date; PTASC 1982). The social values of livestock in CL cannot be ignored.

To some extent these different roles of cattle in the farming economy can be detected in the ratios of the different sex and age classes of cattle in LSCF, SSCF and CL herds. The smaller percentage of steers/oxen in LSCF herds (Table 2) is a reflection of the fact that these animals are slaughtered when relatively young rather than kept until too old to work. There is also a greater proportion of cows in the LSCF herd. The calving percentage in the Chibi data is very low because these figures were collected after three years of drought.

Table 2. Demography of cattle herds in large and small-scale commercial farming areas and in various communal lands. Percentages of cattle herd in each class

	LSCF[a]	SSCF[a]	CL		
			ZCUM[b]	Mangwende[c]	Chibi[a]

Calves (12 months)	20.7	19.7	27.7	11.0	5.1
Heifers	16.7	15.8		12.0	17.6
Cows	37.7	32.0	34.6	34.1	28.4
Bulls	2.1	4.9	3.5	4.4	11.3
Steers/oxen	21.5	27.6	-34.2	27.2	26.0

[a]. CSO 1982a

[b]. Zvimba, Chirau, Umfuli and Magondi communal lands, Gubbins and Prankerd 1983

[c]. Mombeshora et al 1985

Numbers of cattle in Zimbabwe have increased steadily since the rinderpest epidemic of 1896 and after the war in 1980. For most of this period the LSCF and CL herds have been roughly the same size but there are now considerably more cattle in the communal lands. SSCF holdings form only a very small percentage of the total.

Small-Scale Commercial Farming Areas

In order to examine the effect of environment on livestock holdings, groups of farming districts falling entirely within each NR were taken and the mean size of herd, the calving percentage and the percentage of the herd made up of draught animals calculated. The results are presented in Table 3.

It is noticeable that nearly all the farms have cattle, irrespective of NR. The size of farm increases as farming becomes more extensive and the farms are very much larger in NR V. Stocking rate decreases as farming becomes more extensive and is very low in NR V. These stocking rates would be regarded as reasonable by LSCF standards, except perhaps for NR IV, and it may be significant that NR IV is the only one with a calving rate below 60%. Mean herd size was roughly constant in NR II to IV but was very much greater in NR V. The high proportion of draught animals in the herds emphasizes the importance of ox traction on these farms. Although the percentage of draught animals was lower in NR V than in the other regions, the actual number of draught animals per farm remained roughly constant.

Table 3. Small-scale commercial farms grouped by natural region to examine effects on various cattle-holding parameters

NR	Farms in sample	% farms with cattle	Mean size (ha)	Cattle per	Ha per head	Calving rate	% draught animals
IIa	1,015	95.9	92.8	27.0	3.44	60.3	18.5
IIb	446	88.6	78.0	20.3	3.84	67.3	18.5
III	831	93.3	100.6	21.7	4.64	62.3	20.8
IV	572	97.7	111.7	25.3	4.42	57.7	22.0
V	54	100.0	835.5	62.3	13.14	63.1	7.7

Source: CSO 1982a

The percentage of farms in each NR with sheep, goats and pigs and the mean size of flock is shown in Table 4. These data were derived from the same sample of farms used for Table 3.

Table 4. Percentage of small-scale commercial farms in each natural regional with sheep, goats or pigs and the flock size of each

	Sheep		Goats		Pigs	

	% farms	No. Flock	% flock	No. Flock	% farm	No. herd
IIa	12.8	8.1	25.5	10.4	9.2	3.8
IIb	17.4	6.9	20.1	5.3	7.7	8.9
III	21.6	5.5	43.4	8.0	-	-
IV	82.4	7.5	40.2	8.5	22.4	2.7
V	48.0	9.7	80.0	14.4	44.0	7.3

Source: CSO 1882a.

The percentage of farms with each class of livestock increases as farming becomes more extensive, but there is no clear effect on flock size except for the much larger flocks of goats in NR V. It is unfortunate that donkeys were not included in these statistics as they form an alternative form of draught power in the drier areas. These figures emphasize clearly the subordinate role that other classes of livestock play to cattle in Zimbabwean agriculture.

Communal Lands

The estimated numbers of the different classes of livestock in the communal lands over the past 20 years are shown in Table 5. There was a steady increase in cattle numbers to a peak in 1977, followed by a decrease until 1980. This was largely due to the prevalence of tick-borne diseases following the cessation of dipping over large parts of Zimbabwe during the Independence struggle. It is estimated that approximately one million head of cattle died during this period (Chavunduka 1984). The communal-land cattle herd then increased until 1982 after which the effects of three successive years of drought resulted in the death of about a quarter of a million head and further reduction in numbers (Chavunduka 1984). Despite these fluctuations, a linear regression fitted to cattle numbers over this period indicates a mean annual increase of approximately 76,300 head.

Table 5. Communal land numbers of cattle, sheep, goats and pigs at end of each year ('000 head)

	Cattle	Sheep	Goats	Pigs
1964	1,916	186	579	66
1965	1,844	182	599	51
1966	1,714	215	778	71
1967	2,183	263	851	72
1968	2,036	278	975	82
1969	2,315	336	1,291	100
1970	2,451	387	1,504	99
1971	2,600	392	1,689	101
1972	2,691	403	1,813	90
1973	2,847	444	1,877	94
1974	2,936	466	1,909	89
1975	3,123	494	1,872	96
1976	3,183	440	1,694	85
1977	3,388	451	1,748	99
1978	2,950	494	1,872	96
1979	2,860	400	1,300	-
1980	2,869	214	935	39

1981	2,895	297	1,203	84
1982	3,240	247	858	76
1983	3,105	241	1,013	74
1984	3,087	260	1,409	94

Source: CSO 1985

The numbers of sheep increased to a peak of about 500,000 in 1978 but numbers have since decreased to approximately half that figure. Goat numbers increased steadily from 1964 to 1974 but then remained roughly constant until 1978. Numbers then decreased dramatically until 1982, but there are signs that they are now increasing. There were no clear trends in the number of pigs (which are of little importance) with numbers fluctuating irregularly between 39,000 and 100,000. It is noticeable that with pigs, too, the lowest population was recorded at the end of 1980. It is unfortunate that donkeys are not included in this table but Vaughan-Evans (1984) states that there were 256,000 donkeys in the communal lands in 1982.

A total of 3,240,000 cattle and approximately 850,000 households in 1982 implies an average of 3.81 cattle per household, but the pattern of stock owning is obviously not as simple as that. This is illustrated by the reports of the Zimbabwe National Household Survey Capability Programme (ZNHSCP 1985a, b) which cover the communal lands of Mashonaland East and West.

From Table 6 it can be seen that more than half the households in Mashonaland East and nearly 40% of those in Mashonaland West own no cattle at all and a further 38% in Mashonaland East and 45% in Mashonaland West own herds of ten head or less which are unlikely to be self-sustaining in terms of draught requirements.

Table 6. Mean household sizes and cattle holdings in Mashonaland West and East Provinces

			% households with	
	Persons per household	**Cattle per household**	**No cattle**	**>10 Cattle**
Mashonaland West	5.6	5.1	38.9	45.2
Mashonaland East	4.7	3.0	54.5	37.8

Source: ZNHSCP 1985 a, b.

The same survey also recorded the numbers of households in each province owning other classes of livestock, although unfortunately numbers of smallstock were not recorded. These figures are presented in Table 7, which also contains the data of Mombeshora, Agyemang and Wilson (1985) for Mangwende (in Mashonaland East) and Chibi communal lands.

Table 7. Percentage of households in different areas owning different classes of smallstock

	% of household with					
	Goats	**Sheep**	**Pigs**	**Donkeys**	**Poultry**	**Others**
Mashonaland West	45.0	8.5	2.6	1.8	68.1	2.8
Mashonaland East	18.4	5.4	10.5	0.7	61.1	3.5
Mangwende CL	27.8	1.8	4.6	4.6	87.0	10.2[a]
Chibi CL	51.9	5.3	6.1	29.8	79.4	2.3[a]

[a] Rabbits only quoted in this reference.
Sources: ZNHSCP 1985 a, b; Mombeshora et al 1985.

Poultry were very common, being owned by the vast majority of households. Goats were the most common ruminants and were kept especially in the drier parts of Mashonaland West (Gubbin and Prankerd 1983) and in Chibi. Donkeys made up a significant part of the "other stock" holding only in Chibi.

Now that we have categorized the livestock holdings of small-scale farmers in Zimbabwe, we should turn our attention to the feed resources available for their nutrition.

Arable cropping

The percentage of land cultivated or fallow in each NR in each of the three agricultural land tenure categories is presented in Table 8.

In each land-tenure category there is a decrease in the percentage of the land cropped as the NR becomes more suited to extensive farming. In each NR the intensity of cultivation follows the order LSCF<SSCF<CL. The intensity of cultivation in the communal lands is frightening. In NR IV, a region best suited to semi-extensive farming, almost a quarter of the land is either cultivated or fallow and in NR V, best suited to extensive livestock production, almost one-sixth.

Table 8. Percentage of area in each natural region and land-tenure category which is cultivated or fallow

Natural region	LSCF	SSCF	CL
I	7.0	31.5	38.4
II	29.3	32.0	42.4
III	10.6	12.6	33.1
IV	4.5	15.4	23.1
V	2.8	12.0	17.1
Mean	12.2	20.7	24.7

Source: Whitlow 1979.

In terms of livestock production, land used as arable has a dual consequence: it reduces the area available for grazing in summer when the crops are growing, but the residues of the crops become available as feed during the dry season. These crop residues are often of higher feeding value than the natural grazing. Small-scale farmers, both SSCF and in the CL, do not use arable land to grow crops specifically for livestock.

Small-Scale Commercial Farming Areas

In order to examine the effects of NR on patterns of cropping, the same group of farms as used in Tables 3 and 4 were taken and the percentage of arable land under each of the major crops was calculated (Table 9).

Maize is the dominant crop, being grown both as a cash crop and as a food for home consumption, and occupies roughly three-quarters of the arable area in NR IIa, IIb and III and over half in NR IV. Only in NR V was a greater area of other crops sown, with a preference for the drought-resistant sorghum. One noticeable feature is the diversity of cropping - a wide range of crops is grown, even though many are grown only on small areas.

Communal Lands

The main crops planted in the communal lands, and their estimates yields, over the period 1976-1986 are shown in Table 10.

Again maize is the most widely-grown crop, although it does not dominate to quite the same extent as in SSCFA. It must be remembered, though, that the figures in Table 10 were from the pre-Independence period before the massive incentive price rise for maize in the 1980/81 season. One point of interest is the importance of munga (Pennisetum americanum) which was hardly grown in the SSCFA.

Table 9. Percentage of arable area planted to major crops on SSCF in different natural region

		Natural region				
		IIa	IIb	III	IV	V
Farms in sample		1,015	446	831	572	54
Mean size (ha)		92.8	78.0	100.6	111.7	835.5
Area cropped (ha)		12.20	7.58	6.21	7.96	11.67
% of arable sown to:						
	Maize	72.20	78.9	79.3	56.3	40.0
	Sorghum	1.7		0.6	3.7	46.5
	Munga[a]			1.4	1.0	
	Groundnuts	6.7	10.7	9.4	11.8	7.6
	Sunflower	0.7	2.8	0.4	7.0	3.5
	Nyimo[b]	0.2	1.2	0.9	2.3	1.0
	Beans	0.1	0.8	0.1	0.8	0.3

[a]. Pennisetum americanum
[b]. Voandzeia subterrana
Source: CSO 1982 b

Table 10. Main crops planted in communal lands 1976-1980

	Area (ha)	% of total	Yield (kg/ha)
Maize	738,400	43.7	695
Munga	339,800	20.1	385
Groundnuts	250,000	14.8	481
Sorghum	152,400	9.1	493
Rapoko[a]	116,500	6.9	493
Cotton	33,800	2.0	722
Beans	29,500	1.7	304
Sunflowers	29,400	1.7	401
Total	1,698,800		

[a]. Elensine coracana
Source: Chavunduka et al 1982

Obviously there are likely to be major differences in the cropping patterns in the different regions, but figures are not readily available. However, even within four adjoining communal lands Gubbins and Prankerd (1983) showed clear trends (Table 11).

Maize was the dominant crop throughout but its importance decreased successively from Zvimba to Umfuli. Cotton played a valuable role as a cash crop in the latter two areas. Areas of arable per household corresponded closely with the mean holding of 2.10 ha in Mashonaland West (of which these communal lands form a part) and 1.82 ha in Mashonaland East (ZNHSCP 1985a, b).

Table 11. Cropping and other data for four communal lands in Mashonaland West

	Zvimba	Chirau	Magondi	Umfuli
Natural region	**IIa**	**IIb**	**III**	**III/IV**
Total area (ha)	48,800	32,500	46,000	100,000
Arable not cropped	4,070	2,920	660	1,200
Arable cropped	7,250	6,800	2,870	4,270
% of arable sown to:				
Maize	83.2	73.8	67.9	63.2
Cotton	0.3	9.1	23.0	29.0
Groundnuts	11.2	4.7	-	-
Others	5.4	12.4	9.1	7.7
Households	3,960	2,890	1,810	1,560
Arable ha/household	1.83	2.35	1.59	2.74

Source: Gubbins and Prankerd 1983

Similar trends are obvious the data presented in Table 12, for communal land districts in Mashonaland East Province. Maize occupies a smaller percentage of the arable land in the drier areas and munga becomes an important grain crop. Cotton formed a large portion of the "other crops" in Murewa and UMP but not in Mudzi, and it seems likely that the most important "other crops" in the latter area were drought-resistant grain crops.

Table 12. Percentages of arable land sown to various crops in communal land districts of Mashonaland East Province

District	N.R[a]	% of arable sown to					
		Maize	G'nuts	Rapoko	Munga	Beans	Others
Goromonzi	IIa	86	6	4	-	0.6	3.4
Harava	IIb	72	17	4	-	5.0	2.0
Rudhaka	IIb, IIa	72	14	8	-	4.0	2.0
Wedza	IIb, III	72	16	11	0.5	0.5	-
Murewa & UMP[b]	IV IIa IIb III	40	12	8	21.0	10.0	9.0
Mudzi	IV	36	11	3	19.0	1.0	30.0

[a] Where more than one NR occurs within a district, they are listed in order of importance.
[b] Uzumba, Maramba and Pfungwe communal lands.
Source: PTACS 1982

Over the years the area under cultivation in the communal lands has increased. Phillips et al

(1962) estimated the area of cultivated land as 1,166,500 ha, compared with the figure in Table 10 (from Chavunduka et al 1982) of 45% over a period of less than 20 years. But the increase in total area cultivated has not meant an increase of 1,689,800 ha: an increase in area per household as the number of households has increased even more dramatically - from 359,300 in 1961 to 850,000 in 1982. The mean area of arable per household therefore fell from 3.25 ha in 1961 to 1.99 ha in 1982. Vaughan-Evans (1984) states that the-ratio of arable to grazing land fell from 1: 10.8 in 1965 to 1: 6.4 in 1982. Over the same period the number of cattle per cultivated hectare fell from 1.7 to 1.5.

Once the crops have been reaped stock are allowed access to the arable area to graze on crop residues and on the grass on contour ridges, roadways and waste areas. The crop residues remain the property of the landholder, however, and if he wishes to harvest and store them for his own stock he is at liberty to do so. In the survey of Mombeshora Agyemang and Wilson (1985) 96% of the stockowners in Chibi harvested and stored their crop residues, compared with only 17% in Mangwende. These authors say that the reason for this marked difference is not clear, but it is almost certainly a result of the very successful pen-feeding scheme "pushed" by extension staff in the Masvingo Province in the early 1970s (Danckwerts, no date). In Chibi grain stover is mostly used as feed for stock but in Mangwende it is mainly used for bedding. In both areas legume stover is mostly used for bedding (Mombeshora, Agyemang and Wilson 1985). Because of its generally higher crude-protein content legume stover is likely to be a particularly valuable feed during the dry season and its use as bedding seems wasteful.

Communal farmers recognize differences in the acceptability of the stover of different crops to livestock. As an example, Billings et al (1984) record that farmers in the Siabuwa valley of the Sebungwe area reported that stock do not readily graze millet stover. They considered that this was because the millet leaves were very tough and were covered with hairs.

Natural grassland or veld

Veld forms the most important source of feed for small-scale livestock producers in Zimbabwe, especially during the growing season.

The natural vegetation over most of Zimbabwe is woodland with a sparse understorey of herbs and grasses. The dominant tree species vary widely, according to rainfall, altitude and soil type. In the high-altitude high-rainfall areas Brachystegia spiciformis is the most common tree, with Julbernardia globiflora and Brachystegia boehmii more important at slightly lower altitudes. In lower rainfall areas Acacia spp. dominate on heavy soils while Terminalia sericea is characteristic of the granite sands. The Kalahari sands carry a woodland in which Baikiaea plurijuga is the most prominent species. In the low-rainfall low-altitude areas mixed tree/shrub associations occur. Colophospermum mopane is widespread and is associated with soils of poor infiltration. In most regions broad drainage areas (vleis) occur which are clear of trees and are dominated by grasses (often of low grazing value) and sedges.

In many communal lands, especially those near major centres of population, cultivation and felling of trees for fuel and poles has changed large areas of woodland into grassland. Rattray (1957) classified the grasslands of Zimbabwe into seven types ranging from mountain grassland in the eastern highlands to Aristida-Dactyloctenium-Eragrostis veld in the driest parts of-NR V. A knowledge of these grassland types, and of the successional changes likely to occur in them, is of great value to anyone dealing with grazing land in Zimbabwe.

Small-Scale Commercial Farming Areas

There are very few published data on the grazing resources of these farms. In drawing up Table 3 stocking rate was calculated as hectares of total farm area per head of cattle because cattle have access to the crop residues during the dry season. The arable forms only a small proportion of the farm and the figures are very similar when calculated on a grazing-area-only basis. Stocking rates are very similar to those on equivalent LSCF areas and no particular problems seem likely.

Communal Lands

Vincent and Thomas (1961) presented a suggested carrying-capacity range for each NR and sub-region defined in their agro-ecological survey. Using the upper limit of the Vincent and Thomas range and the area of CL in each sub-region, the total carrying capacity of the communal lands was calculated as 2,385,000 livestock units. (A livestock unit (LU) is equivalent to 500 kg of grazing ruminant.) Vaughan-Evans (1984) calculated the present livestock holding in the CL as 2,642,724 LU, which represents 10% overstocking - not really a very horrific situation.

Reality, however, points to a rather more gloomy interpretation because, as usual, averages tell us very little. Some portions of CL are grossly overstocked, others (usually in tsetse-affected areas) are virtually unused. Cleghorn (1966) reported on a survey of the condition of grazing areas in CL which gives scant ground for complacency. Grazing land was divided into four condition classes and the proportions of these in each NR are presented in Table 13.

Table 13. The proportions of communal land in each natural region falling into four veld-condition categories

NR	Veld condition			
	Bare	Very overgrazed	Moderate	Good
I	-	21.4	76.7	1.9
II	-	65.5	18.0	16.5
III	-	68.2	12.9	18.9
IV	4.8	29.7	16.6	48.9
V	39.1	26.3	9.8	24.8

Source: Cleghorn 1966

This report makes depressing reading and authors such as Sandford (1982) and Whitlow (1980) have been quick to point out that the communal land herd of 1,916,000 in 1964 has increased tremendously subsequently. They argue that the 70% increase in cattle numbers between 1964 and 1982 is hardly commensurate with the position outlined by Cleghorn. Unfortunately, data for individual CL are not available and it is not possible to be sure how much of the increase was due to expansion into areas which were virtually unstocked at the time of Cleghorn survey. However, it is almost certain that some of the areas classed by Cleghorn as bare or very overgrazed were carrying considerably more stock in 1982 than they were in 1964. On the other hand, those were the areas where the greatest stock losses were experienced during the 1982-1984 drought.

The communal lands are carrying their high cattle population at the expense of ecological stability, and erosion of the grazing areas is now considered to pose a greater threat than erosion of the arable land. Siltation of rivers is just one example of the consequences which follow this exploitative grazing.

One approach to halting the degradation of the grazing area is by the application of some form of grazing management. During the early 1970s "grazing schemes" were widely instituted in Masvingo Province (Froude 1974). Normally these schemes were planned on the basis of five paddocks which were grazed in rotation for 14 days and then rested for 56 days. No accurate data on veld condition were recorded in these schemes but observations by grazing specialists indicated a definite upward trend with an increase, for instance, of Hyparrhenia spp. This was confirmed by the comments of tribesmen involved in the schemes (Danckwerts no date). Unfortunately nearly all these grazing schemes foundered during the liberation struggle and the fencing was removed and used for other purposes. The major limitation to the reinstitution of these schemes today is the lack of capital for fencing. It is true that grazing could be controlled by herding the cattle in particular areas, using seasons to demarcate the "paddocks", and even simple schemes of this kind have been shown to lead to improvement (Robinson 1961). This is being done now in a few instances but the feasibility of herding is reduced by the attendance of the young males (the traditional herders) at school. However, in some cases adults are taking it in turns to herd the cattle of the whole village. Several communities are now making plans to institute some form of management on their grazing area and if these prove successful the practice will spread rapidly.

The way ahead

For the agricultural scientists, suggesting possible solutions to the problems of the communal areas in Zimbabwe is both fascinating and frustrating. Fascinating because there seem to be no end of beneficial interventions, frustrating because the agricultural economy of the CL is tightly interwoven and an intervention here is likely to lead to a reaction there, and soon the matter gets beyond the stage of mere technology and involves political or sociological changes as well. Quite obviously there can be no lasting solution to the problems inside the CL without major external changes as well. One such is the creation of a voracious employment market so that those who have no desire to be cultivators of the soil can find other ways of earning a living. Those who then remain in the CL will be those who have chosen to farm (rather than those who were forced to through lack of alternatives), and would regard farming as a career. Such a situation is far in the future: let us confine ourselves to the situations here and now and to technical aspects alone.

Grazing Areas

Barnes and Clatworthy (1976) suggested four possible ways by which the grazing areas in CL could be stabilized and their carrying capacity increased. An essential preliminary to the application of these steps was the demarcation of grazing areas so that each village knew the extent of its grazing and would have some incentive to maintain or improve it.

Development of Stock-Watering Facilities and the Application of Rational Grazing Procedures

In some places, particularly in the drier parts of Zimbabwe, the number and distribution of watering points limits the use of grazing. Grazing near the water point is overused and degraded, that further away is underutilized. If watering points were spread more widely, the utilization of the grazing would be more uniform and more efficient.

Another way of increasing the uniformity of utilization is by some form of rotational grazing. Under uncontrolled grazing, favoured areas and palatable plants are continuously defoliated without adequate rest. With rotational grazing they have a chance to grow out and increase in vigour. Five paddocks seem to be the minimum number which accords with both the technical and the physiological needs of rotational grazing systems and, as has already been pointed out, this was the number used in the grazing schemes of Masvingo Province. Claims have been made that rotational grazing will lead to massive increases in carrying capacity. These claims have not been borne out by the results of research in Zimbabwe and it is preferable to regard the main benefit of rotational grazing as being increased ecological stability. Other benefits could flow from this. Dams, for instance, would not be so subject to siltation and a programme of small-dam construction would be more easily justifiable.

The Use of Sheep or Goats in Combination with Cattle

Because of their different feeding habits, the use of smallstock with cattle can lead to more uniform utilization of the grazing and to greater production. We have already seen that smallstock are common in CL, especially in the drier areas. What is needed is greater control of their grazing as uncontrolled smallstock can be enormously destructive, and perhaps better marketing facilities so that stock in excess of local requirements can be profitably sold.

The Selective Thinning or Clearing of Tree and Shrub Growth

The natural vegetation over most of Zimbabwe is woodland and the trees can compete with and drastically reduce the grass understorey. Clearing the tree cover has been shown to lead to marked increases in grass yields. In the higher rainfall areas few of the trees have much browse value and clearing of the trees, perhaps leaving shelter belts, seems justifiable. In the lowveld many of the trees and shrubs form useful browse and selective thinning is preferable. In all cases follow-up operations after felling are essential. Uncontrolled cutting can lead to coppice regrowth much denser than the original tree cover.

The Introduction of Legumes into the Veld

Nitrogen is the main nutrient limiting the productivity of grassland and, even in the drier areas of Zimbabwe, applications of nitrogen have been shown to lead to marked increases in yield (Mills 1966). Nitrogen applications to veld are not economically justifiable, especially under CL conditions. The other way of adding nitrogen to the ecosystem is through the use of nodulated legumes and in NR II and III veld reinforcement has been shown to be feasible on commercial farms. This topic is dealt with in a separate paper at this workshop. So far the technique has been little used in CL but it does seem to offer one means of increasing the productivity of grazing above natural levels. However, it should form the final step in the ladder of improvement of the communal grazing areas and be undertaken only when the preceding steps have been negotiated.

Arable Lands

There appear to be two means of increasing production from the feed resources of arable land: firstly by utilizing fully what is already grown, secondly by growing new crops or exploiting presently unused areas. These will be discussed under four headings.

The Harvesting and Controlled Feeding of all Crop Residues

The use of crop residues, and especially legume stover for bedding in cattle kraals seems very wasteful. These crop residues have a relatively high feed value and should be used as feed. Feeding legume hay or residues with grain crop residues may increase the utilization of the latter and there may also be a role for feeding small amounts of purchased supplementary protein as well as salt and minerals if necessary. In view of the power limitations on CL farms, processing of crop residues (e.g. milling) before feeding seems unlikely to happen. It is desirable that the herd be subdivided and kraaled separately at night and the residues rationed to the most important classes of stock, probably the draught animals and the cows with calves.

Bedding in the kraals is important, both for the well-being of the stock and the production of compost, but dry grass is the most suitable source.

Growing Perennial Forage Plants, Especially Legumes, on Contour Ridges or Waste Areas

There is always a considerable area of land within the cultivated fields that is otherwise wasted and which could be sown with forage plants to offer considerable scope for increasing production. If the plants are left for winter grazing in situ, there is a need to select ones which retain their leaves well and tree legumes may be especially suitable. Possibly the best way to use herbage produced from these areas may be to cut it and feed it as hay.

Multiple Use of Land or Multi-Purpose Crops

Under present conditions maize is likely to retain its pre-eminent position in higher-rainfall CL areas because of its interchangeable role as food and cash crop. Overall production from maize lands could perhaps be increased by intercropping with a grain or forage legume. Similarly, in choosing grain legume crops, the fodder value of the stover could be taken into account. Because of the widespread protein deficiency in CL, both in humans and in livestock, as much emphasis as possible should be placed on the pulses.

Increased Use of Non-Ploughed Arable Land

The report by Gubbins and Prankerd (1983) showed that a considerable proportion of the arable is not ploughed every year. This land could be included in some form of rotation which should incorporate a legume/grass fey. This would have the dual function of contributing to livestock productivity as well as restoring the fertility of the soil.

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Inventory of livestock feeds in Malawi

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Introduction

The livestock industry of Malawi comprises a large traditional sector and only a small but important commercial sector. For example, about 96% of the nation's cattle are in the traditional sector (MOA 1969). The cattle population is about one million and growing at 5% per annum (DAHI 1982). The offtake rate from the traditional sector is estimated at 9%, but the total marketed offtake passing through the rural markets and the Cold Storage Company (CSC) is estimated at 25%. The populations of goats and sheep are 630,000 and 157,000, respectively, and the growth rates are 1.5% for goats and negligible for sheep (MOA 1982). The offtakes are estimated at 40% and 19% for goats and sheep, respectively. Pigs, poultry and fish are also important sources of animal protein in the nation.

The annual per capital consumption of meat is 3.2 kg. This low figure is a result of low livestock numbers combined with low productivity per animal. The major constraint to the livestock industry in Malawi is poor animal husbandry, the chief component being feeding. The traditional sector is plagued with multiple social and economic constraints to both crop and animal production. In order to improve livestock production from this sector, significant extension efforts towards better grazing management and utilization of crop residues need to be emphasized.

This paper is intended to give information about the feed resources available to livestock producers in the country and, where possible, the expected levels of animal production if these feeds were given.

Grazing resources

Malawi's ruminant carrying capacity has been estimated as ranging from 877,000 to 1,279,000 livestock units (LU)* (Booker Agriculture International Limited 1983). Table 1 shows the carrying capacity for cattle alone.

* 1 LU is equivalent to 340 kg live weight

Table 1. National carrying capacity from grazing for cattle

	High estimate	Low estimate
Total carrying capacity (LU)	1,279,000	877,000
Less sheep/goats (head)	802,190	802,190
= Lu[a]	160,438	160,438
Balance available to cattle (LU)	1,118,562	716,562
= Head[b]	1,454,131	931,531
Present cattle population	949,833	949,833
Surplus (deficit) carrying capacity head of cattle	594,298	(18,302)

[a] Average 5 head per LU
[b] Average 1.3 head per LU
Source: Booker Agriculture International Limited 1983

Using the Lower estimate, there is a deficit in carrying capacity of 18,302 head. This deficit might be reflected in the observed low productivity of traditional livestock. Improvements in the carrying capacity of ruminants might come from planted forage and fodder crops, improved utilization of crop residues and increased use of supplements/concentrates.

Planted forage and fodder crops

Although the technology for pasture production is available in Malawi, its adoption by the traditional sector is poor. The technology is presently adopted by the commercial sector, which uses Rhodes grass in tobacco rotations, and some smallholder dairy producers. Pasture improvement in the traditional sector is difficult because (1) grazing is by customary right with everybody having free access to the grazing areas; (2) improved pastures are expensive to establish, maintenance requires regular fertilizer applications and fencing might be necessary to control grazing; and (3) the average holding in Malawi is small and does not allow the farmer to establish a significant area of pasture on his own land unless it can provide him with a greater return than that from crap production. Dairying might justify pasture establishment in the traditional sector but not beef production.

The available technology for pasture production is described in the Pasture Handbook of Malawi. A summary of the dry-matter yields, crude-protein values and organic-matter digestibility of prominent pastures in the nation is given in Tables 2, 3 and 4.

Table 2. Dry-matter production of some selected forages in Malawi

	Type of forage	Dry-matter production (kg/ha/annum)
Natural grassland		
	Unimproved "dambo"	3,220
	Unimproved dryland	1,050
	N-fertilized dryland	1,585
	Stylo-improved dryland	3,960
Fertilized improved pastures		
	Common Guinea grass	10,075
	Ntchisi panic grass	17,075
	Bushmine panic grass	9,965

	Biloela buffel	9,170
	Giant Rhodes grass/Silverleaf	11,140
	Giant Rhodes grass/Siratro	11,680
	Silverleaf (pure sward)	9,846
	Siratro (pure stand)	9,655
	Gold Coast Napier grass	21,860

Source: MOA 1983

Table 3. Crude-protein contents of natural grasslands and improved forage species in Malawi

Species		Crude-protein content (%) (Dry-matter basis)
Natural grasslands		
Dryland grass	- wet season	11.0
	- dry season	2.0
"Dambo" grass	- wet season	6.0
	- dry season	3.0
Improved grasses		
Rhodes grass	- Young	13.8
	- Mature	4.2
Green panic	- Young	14.4
	- Mature	4.1
Ntchisi panic	- Young	12.3
	- Mature	4.1
Improved legumes		
Tinaroo Neonotonia	- Young	23.1
	- Mature	14.4
Siratro	- Young	19.4
	- Mature	12.1
Endeavour stylo	- Young	19.4
	- Mature	13.6
Leucaena leaf	- Grade A	26.0
	- Grade B	14.2

Source: MOA 1983

The crude-protein content of young and improved grasses is higher than that of unimproved forages (Table 3) and that of legumes is even higher. Therefore the inclusion of legumes in grass pastures would improve the overall nitrogen content of hays. The digestibility of improved grasses is also much higher than that of unimproved grasses (Table 4).

Table 4. Digestibility of some natural grassland species and improved forage species

Type of forage	Organic-matter digestibility at the end of wet season (% of DM)
Natural grasslands	
Hyparrhenia sp.	31
Sporobolus sp.	30

Improved forage (grass)	
Giant Rhodes grass	63
Ntchisi panic grass	61
Common guinea grass	62
Bushmine panic grass	65
Mature forage (standing hay)	
Buffel grass	35
Rhodes grass	40
Napier grass	35
Joint vetch	58
Siratro	47
Neonotonia	52

Source: MOA 1983

Dry-matter production, crude protein and organic-matter digestibility are all higher for improved pastures than for natural pastures. Thus, an increase in the establishment of improved pastures alone would be expected to more than double the present ruminant carrying capacity (based on dry-matter production in Table 2). Gold Coast Napier grass and Ntchisi Panic grass are particularly high yielding (Table 2) and could be better utilized under the cut-and-carry systems of livestock production. Since these forages are capable of high yields, a farmer could plant them near his homestead thereby avoiding the need for fencing whilst restricting the use of the forage to his own animals.

Crop residues

Estimates of crop-residue production are given in Table 5 and the available total digestible nutrients (TDN) are shown in Table 6. Crop residues provide valuable grazing from April to August. From September to November ruminants thrive on scanty supplies of crop residues, overgrazed river basins, browse, and coarse standing hays. Rampant bush fires reduce the quantity of standing hays even more. The available TDN from crop residues could support an additional 861,137 LU per year (Table 6). Since crop residues are available only during the dry season, their utilization is restricted to that season. Therefore they would be best utilized for maintaining stock during the dry season and not to support extra stock. The utilization of crop residues might be enhanced by improving their intake and feeding value through some convenient means of treatment.

Table 5. Basic statistics on production of crop residues and crop by-products

Crop	Area planted (ha)	Kernel production (tonnes)	Crop-residue[a] production (tonnes)	Bran/cake[b] (tonnes)	Husks[c] (tonnes)
Cereals					
Maize	1,144,850	1,355,200	2,710,400	433,664	-
Rice	20,807	34,265	34,265	3,426	8,566
Sorghum and Bulrush millet	50,138	32,700	65,400	-	-
Wheat	1,126	787	787	197	-
Oil crops					
Groundnuts	135,966	62,240	62,240	31,140	-

Pulses	-	5,573	-	-	-
Sunflower	3,513	1,544	-	-	-
Cotton	51,059	30,545	-	9,209	-

[a]. Based on kernel-to-residue ratios of 2:1 for maize, sorghum and bulrush millet, and 1:1 for rice, wheat and groundnuts.

[b]. Based on kernel-to-bran/cake-yield ratios of 3.1:1 for maize, 10:1 for rice, 4:1 for wheat, 2:1 for groundnuts, and 3.3:1 for cotton seed.

[c]. Based on paddy rice-to-husk ratio of 4:1.

[d]. Pulses purchased by Agricultural Development and Marketing Corporation.

Concentrate feeds

The Grain and Milling Company was established in 1971 to provide balanced feedstuffs from local raw materials, and to reduce imports of animal feeds. The volume of animal feeds produced by Grain and Milling Company ranges from 500 to 1,500 tonnes per month. The large range in monthly production is not necessarily a response to demand at the time. It is indicative of the unpredictable nature of the supply of concentrate feeds. Most of the concentrates produced are used by commercial animal producers.

Minerals and supplements are also supplied by the Grain and Milling Company but other companies such as Shell Chemicals and Malawi Pharmacies also supply them.

Table 6. Available TDN from crop residues and by-products

Residue	Dry matter (%)	TDN of residue (%)	TDN available (tonnes)[a]
Maize stover	90	59	575,689
Maize bran	90	74	288,820
Rice straw	90	35	10,793
Rice bran	90	68	2,097
Sorghum and bulrush millet	90	57	33,550
Groundnut tops	90	64	35,850
Wheat straw	90	48	340
Wheat bran	90	63	112
Equivalent to 1.1 tonnes TDN LU per year			947,689
			861,137 LU

[a]. Calculated from the estimated yields given in Table 5

Utilization of feed resources

The research work conducted on animal production in Malawi is usually geared towards small-scale livestock production. The main feeds evaluated are crop residues (maize stover and groundnut tops), maize bran and Rhodes grass (mainly for fattening steers).

The performance of steers grazed on Rhodes grass pasture is given in Table 7. Cattle performance per LU declined with increasing stocking rate, although total gain increased per hectare. The situation in Malawi favours the 2.5 stocking rate due to short supplies of fattening stock, and hence high individual animal performance is desired.

Table 7. Effect of stocking rate on animal production (Rhodes grass pasture)

Parameter measured	Stocking rate	LU/ha
	2.5	5.0	7.5
Number of grazing days	159	123	91
Animal gain/ha (kg)	369	525	539
Mean gain/LU (kg)	148	105	72

Source: Addy and Thomas 1976b

Since smallholder farmers rarely make hay, the performance of steers grazed on Rhodes grass aftermath was investigated and the results are shown in Table 8. During bad rainfall years (1973) aftermath grazing nearly met maintenance requirements of the animals. During good rainfall years (1974/75) aftermath grazing gave some gains, although at high stocking rates weight losses were experienced (Table 8).

Table 8. Performance of steers grazed on Rhodes grass aftermath

Year	Cattle breed	Stocking rate (LU/ha)	Change in Livestock July to mid-October (kg)	
			Nil supplement	Supplement
1973	MZ	3.25	-13	22.8
1974	MZ	3.25	42	55.3
	Friesian	3.20	67	124.9
	MZ and F x MZ	3.75	-38	-
	Friesian	3.50	-70	-3.5

Source: Addy and Thomas 1976 b

Maize stover and ground tops are the main crop residues produced in the nation, and most of them are grazed in situ. Table 9 shows the performance of steers grazed on maize stover. The stover used was obtained from crops yielding 6,250 to 7,500 kg/ha grain. Maize stover was able to meet the maintenance requirements of the type of cattle used in these trials (Table 9).

Table 9. Performance of yearling cattle grazing on maize stover

Cattle breed	Treatment	Grain in 8 weeks days (kg)	LU grazing per ha
MZ	Grazed maize Stover + 0.73 kg CP/day	12	108
MZ and F x MZ	Grazed maize stover only	7	103

The performance of steers fed different types of crop residues and supplements is shown in Table 10. The table demonstrates the value of including either groundnut tops, Leucaena leaf or cottonseed cake in maize stover/maize bran-based diets. Both daily gain and conversion efficiency of the maize bran is improved by the inclusion of groundnut tops, Leucaena leaf and cotton-seed cake, all of which are higher in crude protein content than maize.

Table 10. Performance of steers fed different types of residues and supplements

Cattle type	Maize stover	Feed consumption (kg/ha)					
		Leucaena		leaf	CSC[a]	Mean daily gain (kg)	C.E.[b] of concentrate
		Groundnut tops	Maize bran				
MZ[c]	Appetite	-	3.6	-	-	0.37	9.9
MZ	Appetite	-	5.2	-	-	0.63	8.3
MZ	Restricted	-	6.4	-	-	0.63	9.3
MZ	Appetite	Appetite	3.6	-	-	0.68	5.3
MZ + MZ x F[d]	Appetite	Appetite	6.3	-	-	0.89	7.1
MZ + MZ x F	Appetite	-	2.3	-	1.2	0.75	4.7
MZ + MZ x F	Appetite	-	2.3	1.8	-	0.77	-

Conclusion

The potential carrying capacity of ruminant animals in Malawi has almost been reached. Increased production per animal needs to be emphasized more than increasing the numbers of animals. Such an improvement in production per animal will result from increasing the utilization of crop residues to minimize liveweight losses of animals during the later months of the dry season. Good range management, through controlled grazing and bushfires, will also contribute significantly to increased feed supplies for the animal during the dry season. Emphasis should be put on teaching the traditional sector simple practical animal husbandry techniques, conservation of rangelands, and proper rationing of the available feed resources to last a whole year.

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Inventory of animal feed resources in Burundi

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Abstract

Natural grazing lands are becoming scarce and more degraded every year because of the population explosion. Since the livestock production methods practiced today no longer enable the animals to realize their full production potential there is a need to adopt other methods such as the cultivation of fodder grasses and legumes. The fodder types would be sufficiently productive and adapted to each of the country's natural regions. The rational use of field-crop residues and processing of agro-industrial by-products will also be important in increasing livestock productivity.

Introduction

An improvement in animal feeding and the livestock breeding environment are basic conditions for the intensification of animal production. The improvement of animal feeding means rational management of natural pastures, the establishment of fodder crops and the availability of concentrates in sufficient quantities. The traditional method of livestock production is based on extensive grazing where animals feed exclusively on the natural grazing lands. The traditional system may be improved by ranching. In this system seasonal fluctuations in quality and supplies adversely affect livestock productivity. In fact, it is recognised that food problem is most responsible for poor animal performance. The genetic factor is only of secondary importance. Therefore, adequate and good quality feed supplies should get first priority genetic improvement. This presentation will deal with the rational exploitation of natural pastures, agro-industrial byproducts and concentrate supplements.

Natural Pastures

The natural pastures of Burundi, even though they are subject to continuous deterioration, will remain the mainstay of animal feeding for a long time to come. In order to make some improvement in our pastures, and especially to avoid further deterioration of cover vegetation and soil, we recommend the practice of very late bush fires in October after the commencement of the long rains 50 to 100 mm of rainfall. In cases where there is a possibility of mowing (on the commercial farms) three-year burnings followed by grazing restriction and then mowing, would be advisable. In order to apply this method, the grazing lands are sub-divided into paddocks whereby about one-third is mown annually and another one-third is burnt. Burning should be done in paddocks which were mowed the previous year.

Some experiments have also been carried out to determine the potential grazing capacity, which varies according to the type of vegetation in each natural region of the country and according to the season of the year. The grazing capacity also depends on the quantity of the fodder produced and the quality available to the animal so that they can support satisfactory animal performance.

The most precise method consists in determining the value of the pasture through estimates of the recorded animal-husbandry performance of a given grass, that is the weight of livestock that the grass can sustain and the performances realized by the animals.

The agro-industrial by-products produced in Burundi include brans from cereals, oil meals and brewer's wastes. For a long time cottonseed cake was the only by-product offered on the market. Lately others have been introduced including rice bran, plam-kernel cake and wheat and maize brans. With the exception of wheat bran, the amount of the by-products available each year depends exclusively on the national production of cotton, palm kernels, rice and maize. Recent production statistics are shown in Table 1.

Table 1. National concentrate production and prices

Concentrate	Production		Maximum factory capacity (tons)	Price per kg (FBu)
	1982	1983		
Wheat bran	595	1,554	2,000	7
Maize bran	194	42	1,200	9
Rice bran	770	1,000	1,500	7
Brewer's waste	-	4,050	-	-
Cotton-seed cake	1,520	800	3,000	10
Palm-kernel cake	1,475	1,500	1,500	7
Groundnut cake	-	17	-	-

Wheat bran is produced by the Muramvya Flour Mills, the major part of the wheat being imported. Intensification in wheat growing will make it possible to increase the production of wheat bran that is so essential for food and animal production. The extraction yield is about 23%. The maximum production capacity is 2,000 tons per year, of milled wheat depending on the demand for wheat flower for bread making. Maize bran is also produced at Muramvya Flour Mills, the milling yield being 17% bran. The maximum annual capacity is 1,200 tons. The production of maize bran is almost exclusively dependent on the purchases of the Brarudi (Burundi's brewery) the availability of maize bran is, therefore, erratic. It is also very dependent on the maize offered on the market and sales are limited to only a few months in the year. The rice bran is produced at the rice fields of the Imbo Societe Regionale de Developpement (SRDI). These are residues resulting from the polishing of rice grain produced in the Imbo Valley.

Brewer's wastes are produced by the Brarudi Breweries. The present installations only allow for delivery of wet wastes to each brewer. The setting up of a pressing and drying machine will make it possible to deliver the wastes in bags and consequently to widen the geographical area from which they can be collected. The recent opening of the Gitega Brewery will make it possible to increase the availability of fresh brewer's wastes, and particularly make them available in the areas surrounding Gitega. Cottonseed cake is produced by RAFINA, from cotton grains delivered by COGERCO. The extension of cotton cultivation to other areas (Move) will make it possible to increase the amounts of cotton-seed cake produced. Sunflower-seed cake is also produced by RAFINA, using sunflower seeds from the Kivoga plantations. Production is, however, limited to about 30 tons per year. Palm-kernel cake is produced by several small factories whose main final product is soap. The extension of palm-kernel cultivation undertaken in the Rumonge Region by the Societe Regionale de

Developpement will increase the production of palm-kernel cake.

Chemical Analysis of Agro-Industrial By-Products

The chemical composition of the agro-industrial by-products given in Table 2 are averages for five years for the cakes and three years for the brans. In general, the composition of the various concentrates does not differ substantially from that reported in the literature.

However, the cotton-seed cake produced in Burundi has traces of gossypol in it and the fat content of the local palm cake is about 20% of dry matter. The high level of fat in the palm-kernel cake is due to the method of extracting the palm oil. The high rate of fat is a disadvantage as it greatly reduces the preservation period of the feed. All the byproducts have imbalances in the phospho-calcium ratio. It is, therefore, advisable to rectify the mineral balance by adding some chalk.

The palatability of the different by-products is variable, both within each species and between different test animals. Cotton-seed cake and the brans are the most relished by all classes of livestock, while the palm-kernel cake is the least accepted, with the exception of pigs. In order to avoid dustiness in brans it is advisable to feed it wet, although humidity somewhat modifies the smell.

The storage of the agro-industrial by-products does not pose serious problems if they are used within a short period. Storage of palm-kernel and groundnut cakes and of rice bran is limited to one month: beyond that, there is a serious risk of it becoming rancid.

How can these agro-industrial by-products reach the livestock farmer? While livestock keepers in the vicinity of the factories can obtain the concentrates directly from the factories, those farther away buy them from veterinary centres. As is to be expected the prices are higher at these centres being one franc more per kilo than the factory price.

Table 2. Chemical composition of agro-industrial by-products

Composition (% DM)	Cotton-seed	Palm-kernel cake	Wheat bran	Rice bran	Maize bran	Brewer's wastes	Groundnut cake	Rice straw
Dry matter content (% of total)	90.8	91.1	88.5	88.9	87.6	91.5	91.7	91.5
Protein	45.2	14.6	15.5	11.1	11.6	4.5	41.6	4.5
Cellulose	7.3	27.3	9.3	12.7	6.7	33.5	6.5	33.3
Ash	6.5	3.5	5.2	11.8	2.9	17.2	3.6	17.2
Fat	8.2	20.2	4.3	13.1	5.7	0.8	27.1	0.8
Non-azotic extract	32.8	34.4	65.7	51.3	73.1	-	-	-
Calcium (mg/kg)	1,703	1,825	898	5,511	390	2,900	375	-
Phosphorus mg/kg	11,589	4,948	10,439	9,519	3,135	4,800	4,648	-
FBu/kg	1.0	0.7	0.75	0.75	0.8	-	-	-

Burundi is faced with an ever increasing population resulting in an increase in the amount of arable land at the expense of grazing land. Intensive animal production can only develop through a really intensive farming system based on the use of fodder crops. According to a 1970 SEDES study there were 1,477,000 ha of pastoral land in Burundi. That area is now reduced to 810,000 ha (1983-1987 Five-Year ISABU Development Plan).

The intensification of fodder-crop cultivation is already a subject of study at ISABU and is a practice which is starting to spread here and there in the country. But there is still a long way to go. At present 1,708 ha (1982 agricultural census) of fodder crops have been established in the rural areas, made up as follows: 463 ha started by the development projects (for demonstration), 1,129 ha started by the livestock farmers themselves, and 116 ha through community development works using stem cuttings and root fragments produced by ISABU and given to the various extension centres in the rural areas. These fodder crops are mainly Tripsacum laxum and Setaria sphacelata in the low- and medium-altitude regions and Setaria splendida in the high-altitude regions. Pennisetum purpureum is grown in all regions.

ISABU is carrying out research on improvement of the grazing lands, the development of artificial pastures (with the emphasis on fodder-crop cultivation), the preservation of fodder, and the collection of agro-industrial by-products with the aim of integrating agriculture with livestock breeding. We must choose the most adaptable and productive of the available fodder-crop species, whether local or imported.

Inventory of feed resources for small-scale livestock producers in Madagascar

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Introduction

The Malagasy small-scale farmer is both a rice producer and a cattle owner. This means that in most cases a mixed animal-crop system is used. The main outputs required from livestock, particularly Zebu cattle, are manure and draught power for paddy cultivation.

Estimated livestock populations (MPAEF 1984) are: 10,363,000 cattle, 1,379,000 pigs, 1,340,000 goats, 550,400 sheep and 14,486,000 poultry.

Feed requirements for all these animals vary widely, but over the last two decades no feedstuff has been imported except for micro-ingredients such as vitamins, antibiotics, trace minerals and amino acids.

Generally speaking, there is no special fodder for the small-scale producer, but the use of any particular feed depends mainly on its availability and its price. Feed resources can be divided into three classes:

1. Pastures;
2. Agro-industrial by-products and crop residues; and
3. Agricultural products.

Pastures

Natural grazing land occupies the largest part of the island and artificial pastures are very localized.

Natural Grazing Lands

Of the 587,000 km² total surface area of Madagascar, nearly 58%, or approximately 340,000 km², are occupied by natural grassland. Four main zones can be identified (Granier, Lahore and Dubois 1968; Bosser 1969; Morat 1972).

The Western Region

This is the largest region where the prevalent grasses are Hyparrhenia dissoluta, Heteropogon contortus and Chrysopogon serrulatus.

The Southern Region

In this region the main grasses are Aristida congesta, Cenchrus ciliaris and Heteropogon contortus.

The Mid-Western Region

This region is dominated by Hyparrhenia rufa, Heteropogon contortus and Aristida rufuscens.

The Highland Areas

These are defined as all land above 1,000 m, and the most common grasses are Aristida similis, Aristida rufescens and Ctenium coucinuum.

The common features of these grazing lands are, on the one hand, the absence of productive indigenous legumes and, on the other, their very low nutritive value during the dry period which lasts 5-8 months according to region. Uncontrolled burning, even if it limits bush encroachment, leads to a reduction of useful grass species (Granier 1969).

Zebu cattle are raised on these grazing lands without receiving supplements. Generally, animals are on pasture day and night, but recently, because of an increase in cattle thefts, they have been kraaled at night.

Animal production on natural pastures were studied particularly in the mid-western region (Granier, Lahore and Dubois 1968; Granier 1969; Sarniget et al (1969); de Reviers 1970; Granier and Gilibert 1976; Rasambainarivo et al 1984).

Annual liveweight gains range from 41 to 98 kg per animal. The most important problem is the quality and availability of dry-season fodder. Crude-protein content of the pasture may be as low as 2.5% dry-matter and the loss of weight may reach 60 kg per animal. Calf mortality is high.

Artificial Pastures

More than 70 species and varieties have been introduced to Madagascar during the last three decades. They have been tested in more than 50 localities. Among these introduced species, ten are in common use in the highland and mid-western regions by small-scale dairy producers.

No pasture irrigation is practiced. The most cultivated species are Pennisetum purpureum, Tripsacum laxum, Chloris gayana and maize. Perennial grasses (Pennisetum purpureum and Tripsacum laxum) are cultivated alone, not in association with legumes. They are used as green fodders which is cut and carried to the herd. Chloris gayana is established for hay making. Three to five cuts can be realized and the annual dry-matter yield may reach 12 t/ha. Maize (Zea mays) is mainly grown for silage for dairy cattle. In the mid-western region dry-matter production ranges from 15 to 20 t/ha. Maize silage was tested as the basal ration for fattening cattle and the daily liveweight gain was about 0.7 kg (Rasambainarivo, Rakotoarivelo and Rakotozandrindrainy 1980).

Oats (Avena saliva) is cultivated on rice fields just after the rice harvest (Granier and Razafindratsila 1970). It produces well and may be the only green cattle fodder available during the dry season. In the mid-western and western areas Stylosanthes guianensis and Stylosanthes hamata are cultivated and used in the late rainy season and in the first part of the dry season (Granier 1970; Rasambainarivo et al 1983). In the southern region, spinny, Opuntia ficus, is cut, burnt and distributed to some lactating Zebu cattle.

Annual liveweight gains on artificial pasture ranges from 81 to 602 kg/ha (Rasambainarivo et al 1984).

Even when pastures are cultivated, cattle graze for a part of the day on natural grassland or crop residues. So it is difficult to estimate the potential stocking rate on artificial pasture under this system. It is observed that when farmers grow artificial pasture, they also give some supplements to their cattle during the dry season, and if the artificial pasture is not sufficient, they buy some green forage cut in the lowlands.

Agro-industrial by-products and crop residues

Rice is the Malagasy staple food and annual consumption is estimated at 135 kg per capita. Consequently the most important agro-industrial by-products and crop residues are those which come from rice, followed by those from cotton and groundnuts. Other crop residues are available in relatively small quantities and they are not produced throughout the year.

Rice Brans

Three main grades of rice bran can be identified: soft, roughed and mixed (De Riviers and Gaulier 1970; Laurent 1975). There is no clear standardization in milling processes, so there is great variability in these feedstuffs between mills. Mongodin, Lobry and Pergent (1980) reported that the total amount of rice bran available is approximately 376,000 t (Table 1). It is noteworthy that the highest yield comes from many small and widely scattered manual mills. Under these conditions the bran is not commercialized but fed directly to poultry and pigs. The commercial rice brans come from a variety of mills. They produce a total of about 46,000 t per year. Rice polishings and rough rice brans are produced by large mills (rizeries) and the mixed bran by small mills (decortiqueries) and hand mills. Rice polishings have a high fat and crude-protein content up to 17 and 14% dry matter, respectively. Meanwhile, rough and mixed brans are lower grade and contain more crude fibre, as high as 22% DM (Table 2).

Table 1. Extraction rates of rice brans in different milling processes

	Large mills		Small mills		Hand milling	
Rice		70%		60%		60%
Rice bran	Rice polishings	3%	Mixed bran	25%	Mixed bran	15%
	Rice bran	4%				
Rice husk		23%		15%		25%
Total bran available	13,000 tonnes		33,000 tonnes		330,000 tonnes 376,000 tonnes	

Table 2. Chemical composition of rice brans (% DM)

Sample	Dry matter	Ether extract	Crude protein	Crude fibre	Ash
Rice polishings (n=54)	89	15.6	12.0	6.9	9.2
Rice bran (n=36)	91	5.9	8.1	18.9	17.4
Mixed rice bran (n=22)	92	5.3	6.0	22.4	16.0

Source: Laurent 1975

Rice brans are used for all farm animals. They may be the only component of pig and poultry diets, but, generally, 80% rice bran is combined with 15-20% seed cake and minerals (Tillon 1972). A recent review of Zebu-cattle fattening shows that a ration of 0.4-0.8 kg/100 kg liveweight gave a daily gain ranging from 0.5-0.8 kg (Rasambainarivo and Rakotozandrindrainy 1985). The best gain was obtained with a ration consisting of rice polishings and molasses (Serres et al 1971; Meissonnier and Godet 1972). Rice brans were also combined with cassava and gave high liveweight gains (Godet 1971).

Rice straw

Rice straw is extensively used for Zebu cattle and particularly for draught and lactating animals. National rice production is estimated at 2 million tonnes and if we assume a 1:1 straw/grain ratio, the total yield of rice straw is equivalent to the total yield of grain. The straw is all cut and dried before threshing, then the straw is left to the cattle for ad libitum consumption without any treatment. There is a high level of wastage. Experiments are now being conducted to see if the nutritive value of this straw can be improved by the addition of ammonia.

Cotton-seed cake

Cotton-seed cake is the most common seed cake used for animal feeding. In 1983 cotton-seed cake production was estimated at 5,000 t. It is produced principally in the western region, but it is extensively used for all livestock. For growing and finishing pig diets (Tillon 1971) recommended no more than 10% of cotton-seed cake in the complete feed. For beef feed-lot fattening up to 1 kg of cotton-seed cake is essential if the basal ration is maize silage. With this use of cottonseed cake the liveweight gain may reach 0.72 kg (Rasambainarivo et al 1980).

Cotton-seed

The use of whole cotton seed prevents weight loss in Zebu grazing dry-season pasture. A daily ration of 1.5 kg per animal leads to 0.075 a liveweight gain ranging from 0.75 kg to 0.191 kg in mature animals. For young animals 0.5 kg of cotton seed seems sufficient and gives a daily liveweight gain of between 0.21 and 0.31 kg (Rasambainarivo and Rakotozandrindrainy 1985).

Groundnut cake

Groundnut cake is highly valued and together with rice bran constitutes a regular ingredient of poultry and pig rations (Daumas 1963; Gaulier and Serres 1971). Generally the groundnuts are not decorticated, crude fibre content is relatively high (up to 18% dry matter) and there is a constant risk of aflatoxin-induced diseases.

Although here attention has been focused on rice, cotton and groundnut by-products, other by-products such as wheat bran, soybean cake, coconut cake and brewer's grains are also used.

Livestock by-products

Four well-equipped abattoirs are operational, but the numbers of animals slaughtered in them represent only 15-20% of the total number of slaughtered animals. The majority are not slaughtered in these abattoirs and the byproducts are not recovered. The estimated data on available livestock byproducts are presented in Table 3. The majority of these by-products come from Zebu cattle. A 300-kg animal produces around 1 kg of dry bloodmeal (Raveloson 1980) and 25 kg of bonemeal (Ranaivoson 1985). Meatmeal quantity is variable and is estimated at a total of 855 t (Mongodin, Lobry and Pergent 1980).

Fish Products

Dried fish is produced in the western region and at Alaotra Lake. The fish are generally sun dried or smoked, but there are no industrial facilities. Consequently, the dried fish are sold whole and without any removal of oil or heads. Total dried fish available varies between 1,000 and 2,000 tonnes per year.

Table 3. Estimated production of animal processing by-products

By-product (tonnes)	Annual production
Meatmeal	855
Bloodmeal	98
Bonemeal	147
Fish	1,500
Waste shrimp meal	200

Source: Mongodin, Lobry and Pergent 1980

Waste shrimp meal comes principally from processing plants on the north-western Malagasy coast. Production is estimated at about 200 t per year (Mongodin, Lobry and Pergent 1980). All of these animal byproducts are commonly used in pig and poultry rations.

Crops used as livestock feeds

When rice brans became scarce, the research and extension services proposed the use of maize and cassava (Serres, Zebrowska and Sejourne 1966). The former is mainly used in pig and poultry diets and the latter is used for all livestock except for the extensively raised Zebu (See Table 4).

Table 4. National production and animal consumption of root tubers

	Cassava		Sweet potatoes (tonnes)	Potatoes (tonnes)	Maize (tonnes)
Estimated national production	Fresh	1,322,355 (40% DM)	333,000	132,190	100,040
Estimated for live-stock feeding	Dry	599,000	32,700	19,000	
Percentage used for livestock feeding		10-15	10-15	10-15	30-60

Source: Mongodin, Lobry and Pergent 1980

Maize

National maize production is approximately 100,000 t, of which 60% is for animal feeding.

Cassava

Cassava is the only agricultural product traditionally distributed to cattle and particularly to lactating female, fattening and draught cattle. It may be distributed green or dried, with quantities distributed ranging from 3 to 5 kg per day. A feed-lot review indicates that if the quantity of cassava increases without any corresponding increase in protein sources, the Zebu's liveweight gain may be low.

Other Agricultural by-products

Potatoes, sweet potatoes, Colocassia and Canna edulis are in some cases fed to pigs and Zebu cattle in some areas. Rejected banana fruit are commonly fed to growing and fattening pigs.

Conclusion

Numerous feed resources are available in Madagascar. It is clear, however, that protein deficiency is a major problem. Dry-season pasture does not meet the maintenance requirements of ruminants and leads to a loss of weight and mortality in young animals. Protein seed cakes are produced but they are expensive and not always available. Zebu and dairy cattle suffer from a second major nutritional deficiency caused by a shortage of phosphorus. In addition, transport costs are a bottleneck for wider utilization of these various feedstuffs.

Intensive research is needed to increase our knowledge on the use of locally available raw materials. Information is required on yields nutritive value and management of pastures and multipurpose fodder trees. Studies on the use of crop residues and non-conventional feeds should continue. The tendency seems to be to maximize the use of available feedstuffs to meet the nutritional requirements of livestock and reduce the input cost. To this end, an interdisciplinary approach, at national and international level, is needed to improve the small-scale farming system of Madagascar.

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An inventory of animal feed resources for small-scale livestock producers in Botswana

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Abstract

With an estimated livestock population of 3.8 million, Botswana produced 903,905.1 tonnes of agro-industrial by-products in 1984. Currently, very little of these by-products is used to meet the nutritional requirements of livestock.

Because of the fodder deficit, the Government imported 5978.6 tonnes of roughage from neighbouring countries in 1984. Despite these efforts, livestock mortality was still as high as 20%.

Crop residues are not utilized efficiently as livestock feed, but could play a significant role in livestock feeding. The major quantities are cereal residues while legume residues are marginal.

Milling by-products are from cereal sources as there is no factory producing oilseed cakes or the equivalent. Major animal byproducts consist of bone, blood and carcass meals and chicken litter. These can be used by the dairy industry which is still in its infancy. There is endless competition for bonemeal by the cattle, pig and poultry subsectors.

There are two sources of industrial by-products and all of them are used by the dairy industry.

It is suggested that future research address itself to inventory, documentation and dissemination of information on available feed resources.

Introduction

The livestock population in Botswana is estimated at 2.7 million cattle, 0.9 million goats and 0.2 million sheep (ASU 1984). These are kept under two production/management systems, namely the commercial system and the communal system. About 85% of the national herd is found in communal areas, where the majority of farmers are small/livestock producers. Botswana has an area of 576,000 km² of which 77% is grazing land.

Livestock in Botswana have customarily been maintained on feedstuffs that come from natural rangeland. Rangeland utilization within the communal zones is uncontrolled, while the commercial system follows "reasonably acceptable levels of management" (APRU 1980). Unfortunately, there is considerable evidence to indicate that the productivity of the range is declining rather than increasing to match the steadily increasing livestock population. In 1978 the average stocking rate in communal areas was 14.4 ha/LU (Field 1978) which by 1983 had decreased to 11.0 ha/LU*. Large grazing areas have lost their plant cover as a result of overgrazing and the four-year-old drought. It is perhaps now evident that the country's current rangeland production under the two management systems may not provide the animal feedstuffs required by small livestock producers as well as the entire national herd.

*The figure was arrived at by dividing the total communal grazing land area (41,290,000 ha) by the estimated number of livestock units (= 3.75 million) derived from multiplying the number of cattle (= 3.0 million) by a factor of 1.25 LU per 350 kg animal.

It is therefore, inevitable that some districts in the country will soon have to resort to agro-industrial by-products to augment the disappearing range resource and to meet feed requirements of their livestock.

To achieve efficient utilization of the available feed resources, it is essential to have a good knowledge of their production and availability. With this in mind, this inventory has been undertaken to ascertain the national production of animal feed resources available for utilization by the small livestock producer other than from the natural rangeland.

Drought relief measures

Botswana's livestock industry is one of the heavily subsidized sectors in the country. There has been an intensified drought-relief programme geared to providing fodder from the livestock industry. Lucerne, pandamatenga grass, **nyle grass of Acroceras macium teff, maize and sorghum stover have been provided at subsidized prices (Table 1). Peak demand period is from mid-winter to mid-summer. Sale of these feedstuffs has fluctuated since the inception of the programme in 1983. The 1984/85 sale estimates are shown in Table 1.

**A bale containing a mixture of Hyparrhenia spp., Setaria sphacelata and Ischaemum brachyatherum

During this period, livestock mortality was 20% and this amount of fodder did not have a significant effect on reducing mortality.

Agro-industrial by-products

There are large amounts of by-products which can be used as feed for ruminants. They result from the processing of food crops and as animal byproducts.

Table 1. Drought-relief sales in 1984/85

Feed type	Production sales (tonnes)
Pandamatenga grass	568.6 (locally produced)
Nyle grass	1,180.9
Lucerne	367.5
Teff	877.1
Wheat straw	18.0
Millet stover	136.2

Peanut stover	148.2
Maize stover	1,649.5
Sorghum stover	1,601.2
Total	6,547.2

Source: Livestock Advisory Centre, Gaborone

Crop Residues

Maize and sorghum are the major cereal crops in Botswana, followed by millet, beans and groundnuts. They provide considerable amounts of grain and crop residues. With a cattle population of 2.7 million and each animal consuming about 2.5 tonnes of dry-forage equivalent per year, crop residues could play a major role in supplementing natural grazing. A previous study (Mosimanyana 1983) revealed substantial residue-production levels per hectare (Table 2).

Table 2. Dry-matter yields and dry-matter digestibility of sorghum, millet and maize residues

Type of residue	DM yield range (tonnes/ha)	Average DM yield (tonnes/ha)	Dry-matter digestibility (%)
Sorghum	0.60-10.40	5.50	60.93
Millet	1.15-4.95	3.05	55.65
Maize	1.66-5.81	3.73	63.60

Source: Mosimanyana 1983.

It was concluded that a herd of 50 cattle could be maintained for at least two months on the residues from 6 hectares. It was also concluded that dry-matter yield of the plant residue decreased by 28.34% and dry-matter digestibility by 11.17% from April to May. This means that early harvesting would result in higher quality fodder.

Average residue-production values per hectare (Table 2) were used to compute the 1984 production estimates (Table 3), given the area planted (ASU 1984).

Table 3. Estimated 1984 season sorghum, maize, and millet crop residues*

Type of residue	Area planted (000 ha)	Total production (000) tonnes
Sorghum		
Traditional	107.6	591.8
Commercial	6.8	37.4
Maize		
Traditional	43.9	163.8
Commercial	4.0	14.9
Millet		
Traditional	16.6	50.6
Commercial	0.1	0.3
Total	179.0	858.8

*1984 was a drought year.

Under traditional husbandry considerable quantities of crop residues are left to be trampled by livestock or ploughed under (Table 3). These could have an important impact on animal production if they were preserved as soon as possible after grain harvest when both the yield and nutritive value are relatively high (Mosimanyana 1983).

Though there are several options open to small-scale producers on how to utilize crop residues for livestock, in Botswana the popular method is to have them grazed by uncontrolled animals. The current extension packages emphasize cutting the residues during grain harvest and drying and transporting to a safe place next to a kraal from where they can be fed to a selected group of animals.

Legume Residues

Production of legumes in Botswana is primarily done on a commercial basis, therefore these crops do not play a significant role in small-scale livestock production systems. The few small-scale producers who do grow legume utilize them by grazing livestock after harvest.

Milling and Animal By-Products

As energy resources become scarcer, there is an ever-increasing need for efficient utilization of food by-products and animal and plant waste. Because techniques of integrating them into animal-feeding systems are often unknown or uneconomic, millions of tonnes of potentially valuable feed are discarded annually. Both concentrate and roughage by-product feeds are available in Botswana, though utilization by small-scale producers is very limited.

Milling By-Products

There are a number of sorghum-milling factories in Botswana. A recent inventory revealed the existence of one large milling factory in the south, one medium-sized factory in central Botswana and about ten smaller units scattered throughout the country.

Since Botswana is not yet self-sufficient in food grain production, there is heavy reliance on grain imports. Over the past two years, Botswana imported about 19,000 tons of sorghum represented about 3,800 tons of additional sorghum bran that could be used as feed.

The figures in Table 4 were arrived at by adding the estimated production levels of milling factories to 20% of sorghum grain imports. Wheat bran production figures were provided by producers. The third source of sorghum bran relates to individual household production. This level of production has not been estimated, though the production capacity cannot be discounted. The high-energy feeds produced include rice and wheat bran.

Table 4. Estimated production levels of milling by-products

Type of by-product		**Estimated production (tonnes/year)**
Sorghum bran (moroko)		
	Local	11,000
	Imports	3,800
What bran		6,000
Total		20,800

Wheat bran is produced by the flour milling company in the south, while rice bran is localized in the north-western part of Botswana (Ngamiland).

Considerable but undocumented quantities of glumes (moko) are wasted annually during threshing. These are generally disposed of by burning-another untapped source of livestock feed.

Animal By-Products

Recycling animal waste as livestock feed is a well established practice. Broiler or layer-house litter is currently being used as a protein and energy substitute in other parts of the world. Botswana has an estimated 770,000 mature birds (broilers and layers) producing 6,183.1 tonnes of chicken litter per year - based on 0.022 kg dry-matter production per day by a 1.8 kg bird (North 1978). Currently Botswana does not use chicken litter for livestock feeding but occasionally as fertilizer.

The Botswana Meat Commission has three slaughter and canning factories which currently produce bonemeal, meatmeal and bloodmeal. Production levels vary from year to year depending on the number of animals slaughtered. Table 5 gives the 1984 production levels of the three animal processing byproducts.

Bonemeal is highly subsidized to encourage small livestock producers to utilize it, though supply is below national requirements. The cattle, pig and poultry sub-sectors are currently competing for the scarce bonemeal feed. Fish meal is imported in small quantities for pig production.

Table 5. Production of animal by-products in 1984

Type of by-product	Production (tons/year)
Chicken litter	6,183.1
Bonemeal	2,528.0
Meatmeal	4,361.0
Bloodmeal	533.0
Total	13,605.1

Source: Botswana Meat Commission 1984

Brewery By-Products

There are at least three sources of brewer's grains in Botswana. On average both Kgalagadi and Chibuku Breweries produce 700 tons of dry matter per year. Brewer's grains have 20-25% crude-protein content on a dry-matter basis (Huber 1980).

Concentrate Feed Production

Like most of the developing countries, Botswana often experiences a shortage in grain production for human consumption. Concentrate feeding is therefore not practiced in Botswana except for one feedlot and a handful of commercial farmers. On average there is production of 10,000 tons of hominy-chop, maize bran mixed with coarse particles of grain, which is also utilized by the growing pig industry. Nutrient values for some of the agro-industrial products mentioned are given in Table 6.

From Table 6, it can be seen that some agro-industrial byproducts have adequate crude protein but cereal stovers are marginal to deficient.

Table 6. Nutrient values for some agro-industrial products

By-product	CP	CF	Ca	P
Groundnut hulls	10.11	20.32	2.36	0.077
Rice bran	12.63	-	0.202	0.531
Sorghum bran (Moroko)	12.00	6.17	0.038	0.036

Sorghum stover	6.35	31.46	0.35	0.11
Maize stover	8.54	30.85	0.35	0.10
Millet stover	3.98	37.02	0.19	0.03
Brewer's grains	12.15	43.94	0.77	0.46
Bonemeal	45.80	-	5.67	0.49
Bloodmeal	90.51	-	0.004	0.005
Meatmeal	59.52	0.17	11.34	7.84

Source: APRU (unpublished data), Gaborone.

Suggestions on future research priorities

Forage from natural rangeland in Botswana is of very how nutritive value, being characterized by high crude fibre, low crude protein, low dry-matter digestibility and low calcium and phosphorus values at all times except for the immature herbage produced after the first rains. Consequently beef cattle and range research in Botswana has concentrated on improving the utilization of extensive natural rangeland and thus the nutritional status of the grazing ruminant. There is, therefore, a need to focus research priorities on other sources of livestock feeds. With this in mind, the following priorities are suggested:

1. Documentation of total production (traditional and commercial) and availability of agro-industrial by-products, and the designing of suitable utilization methods under both the communal and commercial systems;

2. Characterization of nutritive value and inventory of local feed resources;

3. Production of continuous publications/handouts on nutritive values of such by-products for extension staff.

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A year-round feeding plan for the livestock owner in Swaziland

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Introduction

Swaziland has a total land area of 17,365 km² and is divided into four distinct topographical regions: the highveld, middleveld, lowveld and lumbombo, each running roughly north to south. Just over half of the country's area is vested in the King in trust for the Swazi nation and parts of it are allocated by chiefs to individual Swazi families. This sector is known as Swazi Nation Land (SNL). The agriculture in this sector is mainly subsistence in character.

The rest if the land is known as Individual Tenure Farms (ITF) and is owned on freehold or concessionary title. It includes commercial forests as well as farms, estates and ranches, and land owned by the Swaziland Government. The agriculture of the ITF is highly modernized and most of the country's cash production is derived from it.

Livestock have traditionally been an important component of the agricultural industry in Swaziland. Table 1 shows the population of ruminant livestock according to the most recent census.

Table 1. Ruminant livestock population in Swaziland

Class of livestock	Total in country	Number on SNL
Cattle	636,036	502,000
Goats	320,398	286,000
Sheep	40,138	26,000
Equines (mules, horses, donkeys)	16,975	14,000

Source: CSO 1982

The majority of the herd is owned by the subsistence farmers in SNL (Table 2).

Table 2. Swaziland land-use figures for 1981/82 (hectares)

Land-use category	Whole country	SNL	ITF
Cropland	135,974	97,260	52,341
Natural pastures	1,046,620	861,895	184,725

Improved pastures	96,259	0	98,259
Commercial forest	100,916	0	100,916
Other	341,846	5,925	320,294
Total	1,721,615	965,080	756,535

Source: CSO 1982.

Several features of Swaziland's grazing resources may be discerned from Table 2. Firstly, improved or cultivated pastures contribute less than 10% of the total grazing resource. They are established exclusively on ITF. Secondly, native pastures or veld occupy some 90% of SNL while they form only a small proportion of title-deed land.

Under Swaziland's system of conversion, the total livestock population presented in Table 1 is equivalent to 617,000 livestock units which gives a crude stocking rate of 1.7 hectares per livestock unit on native veld, the major grazing resource. This value is undoubtedly well above the estimated carrying capacity of much of the veld and is reflected in the observed low animal productivity and degraded range condition, especially on SNL (Ions and Kidner 1967).

Another important feature of Swaziland's pastures, whether natural or planted, is their relatively low nutritive value for most of the year. Many forage species grow very rapidly as soon as the rains commence in early summer (October). At this time leaf production is high and crude protein content and digestibility are satisfactory (Ogwang 1985b). By the end of the wet season (March), the plants develop tall flowering stems which are low in protein and high in fibre. These conditions place severe restrictions on livestock production, particularly during the dry season which can be as long as seven months. The present paper discusses some of the strategies that could be used to minimize the winter-feed problem thereby improving overall livestock production throughout the year.

Pattern of pasture production in Swaziland

Pasture production is usually related to seasonal rainfall distribution which in Swaziland is restricted to only a few months of the year. Consequently stock owners who rely exclusively on pastures experience periods of excess forage in the wet months alternating with periods of scarcity in winter. In order to sustain uninterrupted livestock production, the stockowner should be able to adjust to this fluctuating feed supply. To some extent this could be achieved through seasonal disposal and purchase of livestock while the winter feed deficit could be improved by a number of measures, as described below.

Irrigation

Pasture production can be extended into the dry winter months through irrigation, subject to limitations of light and temperature. Cool-season grasses such as oats, rye grass and triticale have been grown successfully for dairy production in some parts of the country. It has also been shown that the yield and the feed value of the grasses can be considerably enhanced by the inclusion of temperate legumes such as vetch or red clover (Whitmarsh 1977). Approximately 37,000 hectares of land are currently irrigated in Swaziland of which 1,200 hectares are on SNL and the rest on individual farms and company estates. While the cotton, rice and sugarcane, opportunities for pasture establishment could be investigated.

Use of Fertilizers

In terms of quantity, by far the most important farm input used, particularly on SN, is fertilizer. An estimated 46,500 tonnes of fertilizer were used in Swaziland during the 1980/81 season (Anonymous 1983a). This represented an average application rate of 320 kg per cropped hectare. At present the bulk of the fertilizer used on SNL is reserved for maize and cotton and very little appears to be used for pasture establishment. While the cost of pasture fertilization may appear unattractive, possibilities for strategic application of small quantities just before the end of the growing season need to be investigated. Fertilizers could extend the period of pasture production into the dry season and any surplus will remain in the soil during the winter months to stimulate active growth with the new rains in spring.

Use of Drought-Tolerant Species

Pasture species capable of growing out of season can be planted to prolong the period of good-quality forage. Drought-tolerant legumes can be particularly useful in this regard. They can benefit ruminants through their high productivity, high protein content and high mineral status. That the use of legumes is not widespread in Swaziland probably reflects the limited knowledge of their agronomic characteristics and adaptability to the local environment. Some success has been recorded with a few legumes such as Desmodium and stylo (Whitmarsh 1975) and the need to explore more of them was recently emphasized by Ogwang (1985a).

Shrub legumes such as pigeon peas and Leucaena have been successfully established around homesteads and grass strips in other sub-tropical countries. They are not only drought resistant but also offer a variety of domestic uses besides being important dry-season feeds. Their potential for Swaziland needs to be investigated.

Conservation of Excess Forage as Silage

The production of silage is currently practiced on a limited scale in Swaziland. Small quantities of maize silage are produced on a number of dairy farms around the country. Both bana grass and Napier grass have been shown locally to have higher yields than maize (Whitmarsh 1977). If cut with a forage harvester before they become too mature these giant grasses are no more difficult to ensile than maize, although they do have a higher protein content necessitating the addition of a carbohydrate supplement such as molasses. There is a need to re-examine the potential limitations of silage making under Swaziland conditions.

Conservation of Excess Forage as Hay

In Swaziland, hay making is practiced on livestock breeding stations and in a number of ranches. The production of hay from natural as well as improved pastures can be an easy and cheap method of conserving forage. Its present lack of popularity emphasizes the need for more research on the quality of the various forage species available, appropriate techniques for cutting, drying and storing the hay, and the socio-economic viability of such technologies.

Conservation of Forage as Standing Hay

Where a decline in quality can be tolerated, forage can also be stored as standing hay. This is generally the cheapest way of conserving forage. On fenced grazing land, standing hay may be conserved by leaving one or two areas/paddocks ungrazed during the last part of the growing season. It can then be utilized during the dry season when forage from other areas is no longer available in adequate quantities. Even on communal grazing land, certain areas could be reserved during the growing season and grazed later.

Crop Residues

A wide variety of arable crops is grown both on SNL and ITF for subsistence. Many of these crops have residues which can form an important source of livestock feed. Yields of some of the common crops grown are presented in Tables 3 and 4 respectively.

Table 3. Area and production of major crops grown on SNL, 1981/82

Crop (tonnes)	Area	Production
Maize	58,936	52,267
Sorghum	2,168	720
Cotton	11,575	8,445
Beans	2,071	404
Groundnuts	1,665	481
Sweet potatoes	910	1,192

Source: CSO 1982.

Tables 3 and 4 indicate the potential variety and abundance of crop residues that could be used for livestock feeding in Swaziland. The contribution of such residues to total available feed resources has been reported to vary from 6% in some regions to 2% in the Rural Development Areas (Anonymous 1983b).

Table 4. Area and production of major crops grown on ITF, 1981/82

Crop	Area (ha)	Production (tonnes)
Sugarcane	30,819	3,249,659
Cotton	not available	5,810
Pineapples	1,552	33,150
Citrus	not available	58,492
Oranges	not available	33,249

Sources: Central Statistics Office; Sugar Association; Swaziland Citrus Board

Yields of cereal stover may be expected to vary depending on season, inputs and skill of the farmer. Maize stover, for example, has a digestible CP content of 2.3% on a dry-matter basis and a TDN of 57%. This compares with 2.5% DCP and 52% TDN for very good quality veld or poor quality Eragrostis curvula hay. Opportunities for improving the quality of dry cereal crop residues through treatment with chemicals such as urea, NaOH and NH_3 could be investigated.

Whenever available, grain legumes such as groundnuts and beans should provide good-quality roughage after the crops have been harvested.

The most important vegetables grown in Swaziland include sweet potatoes, pumpkins, cabbages, tomatoes and onions. The non-marketable parts of sweet potatoes and cabbages can provide feed of high value compared to dry-crop residues. They are difficult to store and would therefore be more suitable for daily feedings.

It has been shown in other countries that sugarcane can be used as the basis of intensive animal production systems. In the Philippines, for example, a number of sugarcane producers experimented with fattening cattle using sugarcane tops as basal diets. Their results showed average daily weight gains per cow of 0.5-0.7 kg (Guzman and Lee 1978). Sugarcane is the most important export crop in Swaziland and the tops could form an important feed source for animals raised around sugarcane growing areas. Molasses is another feed which is being used very extensively in other countries.

Pineapple and citrus wastes may be regarded as high-energy feed for livestock. They are high in sugar, low in protein and fairly high in fibre. Swazican produces a large quantity of these wastes at Malkerns but they are largely thrown away due to the lack of appropriate technology and economic methods of utilization. Suitable methods of conservation could be devised. The addition of formic acid and urea to ensiled pineapple waste has been shown to significantly improve the digestibility of the nutrients (Lebbie, personal communication).

Agro-industrial By-Products

Potential agro-industrial by products for livestock feeding include molasses, bagasse and cotton-seed cake. About 138,000 tonnes of molasses were produced in 1982 in Swaziland (CSO 1982). This could be used to supply energy in conjunction with poor-quality forage in the dry season. Bagasse, another sugar-processing by-product, is generally of low quality due to high content of fibre and Lignin. However, the quality can be significantly improved through heat or alkali treatment.

At present no oilseeds are produced as a primary commodity in Swaziland. Cotton seed is exported mainly to South Africa where oil is expressed from it for domestic use. There is some potential for making good-quality animal feed if the seeds could be processed locally.

Concentrate Supplementation

Cereal grains such as maize and sorghum have a high feed value. They can contribute significantly to animal output. However, most of the grains grown in Swaziland are primarily for human consumption. This, together with the high cost of concentrates, renders them inappropriate as livestock feed unless very high yielding animals are used.

In conclusion, it should be pointed out that there is considerable opportunity for increasing pasture production and the availability of non-conventional feedstuffs in Swaziland. Veld improvement can be effected through bold policies such as destocking, fencing and bush clearing. Planted pastures need considerable inputs such as fertilizers and, although the economics of such undertakings have often been questioned, the possibility of strategic application of small quantities could be explored. The inclusion of both herbaceous and shrub legumes in the cropping systems can significantly cut such production costs. Considerable opportunities also exist for the use of crop residues and agro-industrial by-products. What is needed is a comprehensive inventory of the feed sources coupled with appropriate technologies for improving their nutritional values.

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Inventory of feed resources for small-scale livestock production in Mozambique

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Introduction

The principal form of livestock in Mozambique is cattle, which are raised traditionally in an extensive manner on natural pastures. Most of the national herd is concentrated in the relatively tsetse-free southern fifth of the country south of the Rio Save (Figure 1). Although concentrated, the cattle numbers are not so high as to cause large areas to be overgrazed. This is partly due to the reasonable rainfall and productive pastures of much of the zone.

Mozambique has a low cattle population considering its size (1.77 cattle/km² and population (0.1 cattle/habitation (UDC 1981)). Indeed, it is one of the lowest in Africa. This can be explained by the presence of tsetse, large areas of woodland unsuitable for grazing, and no tradition of livestock raising among much of the population.

Other important livestock for small-scale producers are goats, sheep, pigs, ducks, chickens and, increasingly, rabbits.

The principal activity of the estimated 1984 population of 13.3 million is agriculture, which employs 3.5 million economically-active people, mostly in the form of crop raising for subsistence. This is done on small plots, which are nearly all on light soils and cultivated by hand.

Agricultural activity is commonly divided into four sectors: state farms, private farms, co-operatives and the family sector. The family sector can be further divided into those practicing traditional methods of agriculture (hereafter termed traditional farmers), and smallholders. Smallholders are mostly concentrated in areas close to the major towns (the "Zonas Verdes") and practice improved forms of management with higher inputs. Their attitude is somewhat or wholly commercial, but the area cultivated and number of animals kept remains small. The family sector possesses 76% of the national cattle herd (Table 2) but in terms of commercialized offtake provides only 23% of the national total (Dionisio 1985). The co-operative sector is of little significance with regard to cattle.

Table 1. Agricultural areas in use by sector (1980 data)

Sector	Area of land utilized (ha)	%
State farms	250,000	10.5
Co-operatives	75,000	3.1
Private farms	65,000	2.7
Family farms	2,000,000	83.7
Total	2,390,000	100

Table 2. Livestock population by sector, 1980

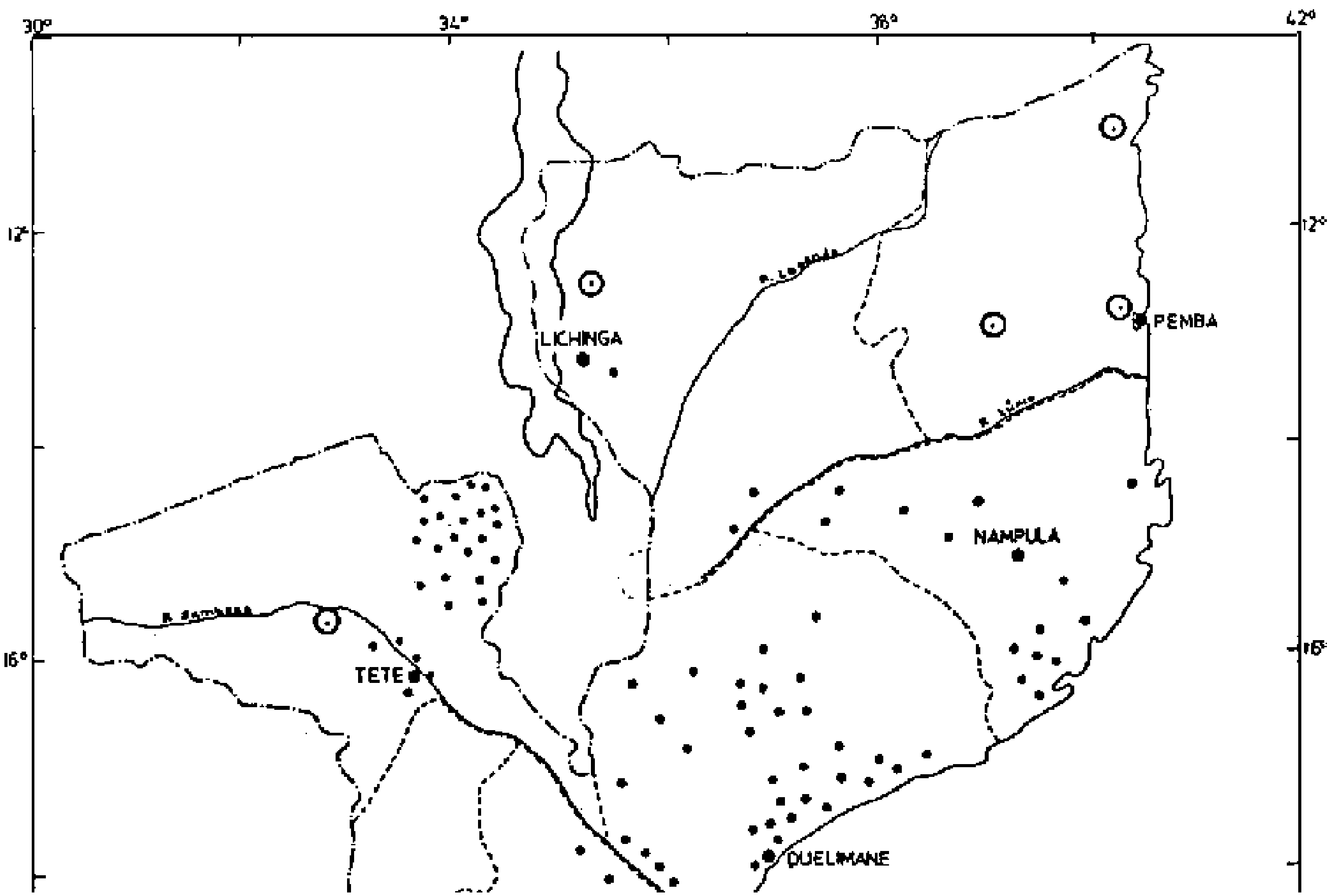
Animal	Sector	No. of Head

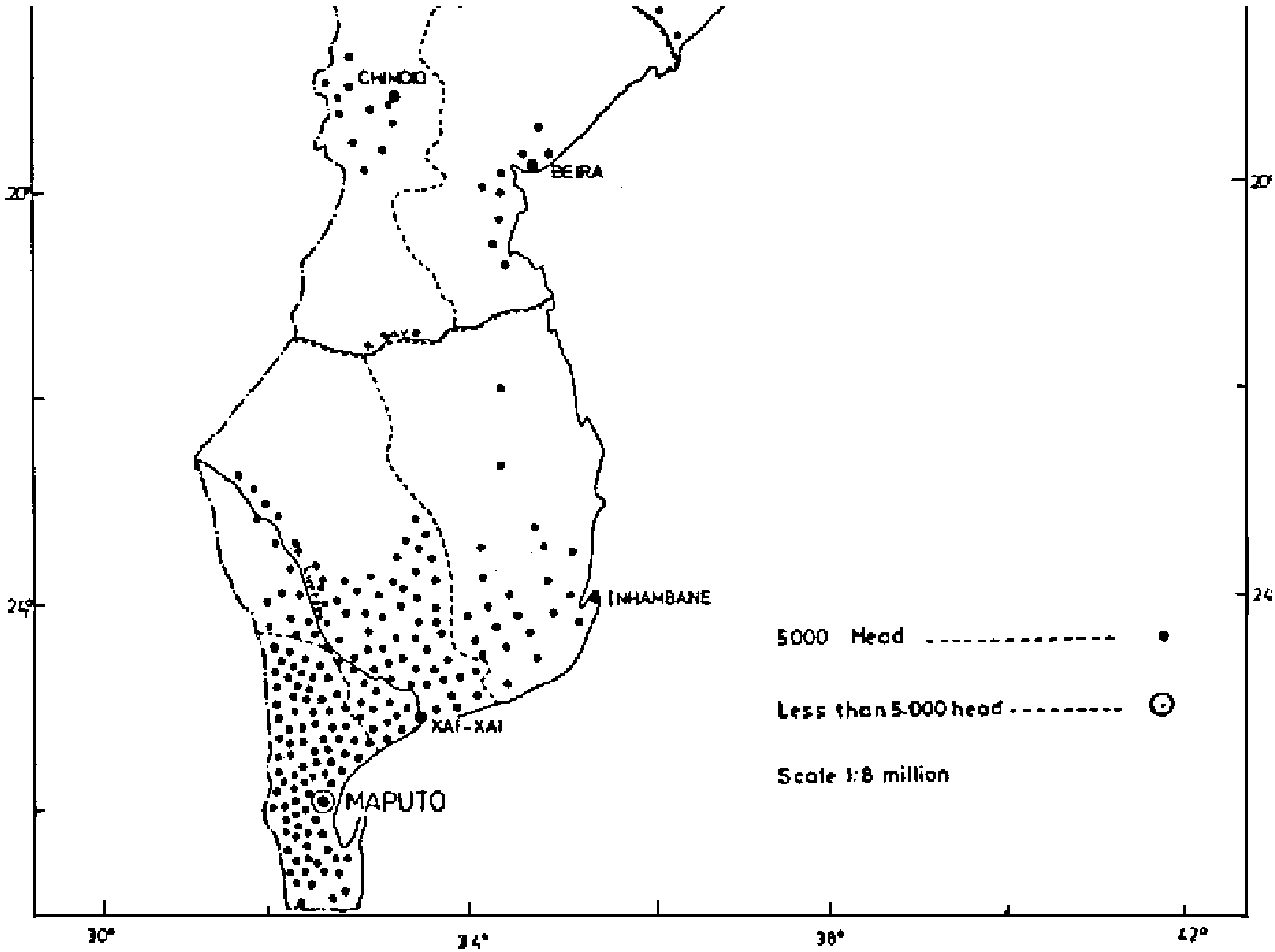
Cattle	Family[a]	1,001,813
	Commercial[b]	383,155
Total		1,384,968
Goats and sheep[c]	Family	413,280
	Commercial	12,558
Total		425,838
Pigs	Family	176,599
	Commercial	41,240
Total		217,839
Rabbits[d]	Family	1,800[e]
	Commercial	18,000
Total		19,800

[a]. Peasant owned.
[b]. State farms and private.
[c]. Not recorded separately, but in 1974 16% of total in family sector were sheep.
[d]. Pavesi 1985.
[e]. Estimated minimum
Source: FAO 1982a and others

Due to reasonable climatic and soil conditions over much of the country the natural potential for pasture and feed production is high. But there is still no tradition of provision of feed to small ruminants and cattle in the traditional sector; all grazing is from natural pastures and, locally, crop residues. The necessity to cultivate feeds for pigs, chickens and rabbits, when feed requirements exceed the feed and scraps that can be collected locally, is a severe limitation to future expansion of production.

Fig. 1 - Cattle distribution in Mozambique in 1975





Des: Maciel/PED/8418

A brief description of Mozambique

Mozambique covers an area of 799,380 km² between 11° and 27°S latitude, and ranges in altitude from 1,600 m to sea level, with an extensive (2,800 km) coastline along the Indian Ocean. Much of this area is under 200 m and consists of coastal plains of sedimentary deposits between the Zambezi and Limpopo Rivers. Three major rivers cross the country - the Zambezi, the Sare and the Limpopo. The valleys and flood plains of the Zambezi, Limpopo and Incomati rivers provide fertile soils, and it is here that a large proportion of the country's cattle are found.

Mean annual rainfall ranges from 350 mm near the Mozambique/Zimbabwe/South Africa border to 2,000 mm in the highlands of Zambezia. North of the Rio Save the rainfall is more concentrated with a long dry season, except in parts of the coast. South of this, rainfall is less concentrated in distribution and winter rains can be encountered in areas closer to the coast. The range of climate, topography, geology and vegetation gives a very diversified environment.

Livestock and livestock-production systems

Livestock numbers in the country and in the family sector are shown in Table 2.

Cattle

Until Independence in 1975 cattle numbers had been growing at about 2% per annum (Dionisio 1985). At Independence many of the colonial farms were abandoned and many cattle found their way into the family sector. Following the decrease in total numbers after independence there was an increase of about 2.3% per annum until 1981. In the last few years the cattle population has been decreasing substantially in all sectors due to drought and problems associated with reduced security in rural areas.

Cattle in the family sector are almost exclusively of the Nguni type (called Landim in Mozambique) in the south, and of the Angoni type (the same as the Malawi Zebu) in Angonia close to Malawi. A few improved crossbred dairy cattle are raised by smallholders in some areas.

Cattle are kept in a traditional manner and for the traditional reasons of status, brideprice, as a means of storing and acquiring capital, risk-reduction in mixed-farming systems, draught power, for home consumption, for meat production and milk production. Draught power is very important on the heavier soils of the Limpopo and Incomati river basins and on the sandy soils of coastal Inhambane. Less than 100,000 ha is ploughed by animals out of a total of 2 million ha cultivated by smallholders throughout the country (FAO 1982b). Average herd size is around 10 head, and the herd is usually grazed on communal pastures or fallows during the day and gathered in kraals at night.

There is no supplementary feeding and by the end of the dry season in some places cattle have to walk 20-30 km to drink and only drink every two days.

In 1979 the average commercial offtake from the national herd was 4% with a family-sector offtake of 2.2%. However, this does not consider local slaughter, and a more realistic estimate of family-sector offtake would be 5% per annum (FAO 1982b).

Goats

Goats and sheep are more evenly distributed over the country and appear to be the principal form of livestock in drier parts of the north. Virtually all are of the local Landim breed (southern African small-eared type) and are kept close to the villages. Many are tethered in semi-urban areas. Normally no supplements are given. Postnatal is an important factor, but otherwise disease mortality incidence is unknown. Given their size and reproductive rate goats represent a valuable form of livestock production for smallholders.

Pigs

Pig numbers in the smallholder sector increased substantially after Independence. In the traditional sector pigs are mostly left to forage, but smallholders tend to raise them in enclosures and provide feed. Generally only one or two pigs are kept per family due to problems with provision of feed. Many fruit are used, e.g. pawpaws and mangoes, along with locally-collected green feed.

Poultry

Chickens are commonly kept around homesteads and fed on scraps and winnowings, but there is as yet no commercialization of smallholder production. Attempts are being made to encourage production in cooperatives using locally-mixed rations, and to encourage the use of local plants. Ducks are quite common too, and are fed on locally-collected fresh green feeds.

Rabbits

Production of rabbits in the smallholder sector, particularly those around urban centres ("Zonas Verdes"), has been actively encouraged in recent years. Pregnant females are provided by state breeding farms and raised in housing constructed from local materials. At this level of production feeding can be adequate using locally collected grasses and other plants. But beyond a population of 10-15 animals this becomes too difficult. This form of livestock production has shown some success in the smallholdings surrounding the major towns, particularly Maputo, where sufficient extension services are available.

Natural pastures

Practically all of the cattle and goats in the smallholder sector are raised on natural pastures. Average stocking rates in the two main livestock raising-provinces of Maputo and Gaza are around 9 ha/LU* and 26 ha/LU respectively (1981 data). Overgrazing is not generally a problem, although it can be quite marked and severe around water sources. There is thought to be still room for expansion in cattle numbers, perhaps of the order of 20%, in these provinces.

Pastures in Mozambique can be divided into sweet and sour types. Sweet pastures are those found in the drier or more variable climatic zones, particularly on heavier soils, and are usually dominated by Themeda triandra, Panicum maximum, P. coloratum, Digitaria eriantha and Eragrostis spp. They can support grazing throughout the year. Sour pastures are found in the higher rainfall areas and are usually dominated by Hyparrhenia spp., Hyperthelia dissoluta, Andropogon spp. and Heteropogon contortus. They show high levels of plant production, but protein content falls rapidly on flowering and cannot support cattle production through the year without supplementary feeding. Most of the smallholder cattle are concentrated in areas of sweet or semisweet pastures. Browse is an important dry-season feeding resource in these areas (Walker 1980). The major species are Colophospermum mopane (xanate or mopane), Acacia spp. and some species of Combretum.

Very few data exist on actual or potential carrying capacities on the different pasture types. However, accepted estimates for ranching are of the order of 3-4 ha/LU on Themeda pastures on fertile soils in the 700 mm rainfall zone with some winter rains, to 8 ha/LU on the mixed Themeda pastures on seasonally flooded soils of the Limpopo Valley in the same rainfall zone. In mopane bushland or open woodland in the 400 mm rainfall zone estimates for the family sector in the major cattle-raising district of Magude, have been put at between 4 and 6 ha/LU (FAO 1983). A comparison of the available natural resources, e.g. climate, soil, fertility, pasture species, distribution of water, and accepted carrying capacities in different parts of Maputo Province would suggest that accepted values for the family sector are higher than those for commercial ranching in similar areas. This requires further investigation and would be of great importance in livestock planning in Mozambique.

Shortage of dry-season grazing is an important constraint to improved cattle production, although the major constraint is thought to be the limited distribution of dry-season water sources. The provision of water by the use of small dams, greater use of strategic family fodder banks, and improvement in the cultivation of crops and use of crop residues, are seen as ways of ameliorating dry-season feeding problems.

A model of potential pasture productivity is presently being developed by Reddy and Timberlake (1985), based on models developed in Australia and on productivity data from Zimbabwe. The model uses potential evapotranspiration, annual rainfall and soil-moisture holding capacity to give the potential productivity of natural pastures with no tree or bush cover. The annual variations in production are also being calculated for a range of sites. The order of the results (see Table 3) seems to be reasonable, but no experimental data are available to support any conclusions. In addition, attempts are being made to link geological and soil-survey data, particularly regarding soil fertility and calcium levels, to pasture quality and species composition Again few supporting experimental data are available but it is hoped that this work will help in formulating guidelines for more rational pasture utilization.

Table 3. Potential pasture primary-productivity estimates for four locations in Mozambique on different unfertilized soil types at various probability levels

Location	Mean Annual rainfall (mm)	Potential evaporation (mm/year)	% probability[a]	Total dry-matter production (tonnes/ha/year)[b]	
				100 mm AWC	200 mm AWC
Pafuri	357	2,024	75	0.72	0.73
			50	1.06	1.09
			25	1.42	1.47
Catuane	577	1,622	75	1.92	2.02
			50	2.51	2.77
			25	2.91	3.40
Tete	627	1,911	75	1.90	2.01
			50	2.34	2.55
			25	2.68	3.02
Ilha de Mocambique	814	1,536	75	2.95	3.49
			50	3.04	3.91
			25	3.04	4.17

Source: Adapted from Reddy and Timberlake 1985.

[a]. Percentage of total years at which value can be expected.

[b]. Potential total dry matter production of natural grassland assuming no bush cover, negligible slope, and soil fertility not limiting.

[c]. 100 mm available water capacity soils represent sandy soils and 200 mm AWC soils represent clay soils.

Improved pastures and forages

There exists much potential in Mozambique for the cultivation and use of forage crops as the country has adequate rainfall and good potential for irrigation in many of the larger river valleys.

Traditional farmers do not normally feed their cattle or goats, relying on natural pastures or what the animals can find for themselves. With the increased use of animal draught power in certain areas, and the gradual intensification of production by some of the subsistence farmers, much effort will have to be put into determining suitable forage species and practices, and the productivity levels possible.

Forages grown under irrigation or dry land are commonly used for dairy cattle on State farms. The major species used for green feed is elephant grass (Pennisetum purpureum) and, more locally, lucerne, siratro, Cenchrus ciliaris and Leucaena (Timberlake and Dionisio 1984). No surveys have been made of smallholder usage but elephant grass is grown widely and successfully in moister locations. Leucaena leucocephala has shown promise in some areas (Ludemann 1984) and could prove well suited to traditional farmers' requirements and abilities, particularly for goat production.

One crop occasionally grown by smallholders for its edible seed is Dolichos lablab (= Lablab purpureus). This grows very well on better drained fertile soils in southern Mozambique with 600-800 mm rainfall, and remains green through the dry season. It would seem to have good potential as a dual-purpose crop being already well known and accepted. Sweet-potato leaves are often used as animal feed, and Amaranthus retroflexus is used as pig feed as well as a vegetable in some areas (Basto 1984).

Investigations are being carried out on urea treatment of rice straw (de Vries, personal communication). The technique is promising as large amounts of rice are grown by smallholders in parts of the Limpopo Valley and the straw is presently unutilized. In this area animal traction is extensively used and there is an increasing shortage of feed for the oxen. Large amounts of molasses are also available not too far away and it has been suggested that some of this could be sold to ox-owners for supplementary feeding, particularly at the times of the year when ploughing is in progress.

Some work has been carried out in recent years (Morgado 1985; Caulton and Wetlhii 1984; Pavesi 1985) into the identification of various native plants of value in the feeding of rabbits, ducks and chickens. Some of more widespread occurrence and use are shown in Table 4.

This work is continuing and it is hoped to obtain better data on their nutritive values, productivity and distribution in view of the potential and increasing raising of rabbits and ducks by smallholders. One result of this study is that, except on a very small scale, smallholders will have to devote some of their energies to the cultivation of suitable forages if they wish to raise larger numbers of these types of animals.

The areas of Mozambique climatically suited to the establishment of improved pastures under relatively low inputs and management (that is, those areas with a higher and more reliable rainfall) do not generally have a tradition of ruminant livestock raising. There is not thought to be much potential in the short and medium term for the use of any type of improved pasture in the smallholder sector.

Crop by-products and crop residues

Mozambique is a country with good agricultural potential and a range of crops can be grown. Many crops such as sugar, coconuts, cotton, maize, rice and sunflower are grown on a commercial scale and their byproducts can be used for animal feeds. Estimated or recorded quantities of these crops are shown in Table 5. Those used for animal feeds in the commercial sector at present are molasses, copra cake, cotton-seed cake and sunflower seed cake. Rice and maize bran are also used locally, but not sugarcane tops. The major problem with these byproducts is distribution as most of the large-scale agricultural production is in the centre and north of the country while the animal populations are in the south, which is less suited to crop production. Present levels of commercialized crop production are quite low and supplies are not always reliable. With all of these crops, except sunflower, the majority is produced by the State sector or by the larger private farms. Crop by-products are primarily used in the manufacture of feedstuffs for State livestock enterprises. Ration production in 1983 was running at 28,500 tonnes, of which 17,700 tonnes was for pigs.

Table 4. Some local plants as forage for small livestock species

Species	Goats	Pigs	Rabbits	Chickens	Ducks
Amaranthus deflexus	x	x	x	x	x
Psilotrichum boivinianum			x	x	
Commelina benghalensis		x			x
Bidens pilosa			x	x	x
Parthenium hysterophorus	x	x		x	
Sonchus cleraceus			x	x	x
Tridax procumbrens			x		
Ipomoea plebia		x	x	x	
Merremia tuberosa		x	x	x	x
Cassia petersiana			x		
Crotalaria monteiroi	x		x	x	

Glycine wightii	x	x	x	x	x
Leucaena leucocephala	x	x	x	x	x
Stylosanthes mucronata	x	x	x	x	x
Boerhavia erecta		x	x		
Giesekia africana		x	x		
Oxygonum delagoense		x	x		
Portulaca cleracea		x			x
Richardia brasiliensis			x	x	x
Solanum panduraeforme	x		x		
Lantana camera			x		
Priva cordifolia			x		
Ficus elasticus			x		
Morus alba			x		
Ipomoea equatica		x			
Eichornia crassipes		x			

Source: Caulton and Wetlhii 1984, and others

Presently small farmers do not make much use of crop by-products as the distance from the processing plants can be large, and little village-level processing takes place. Efforts are being made, particularly with chickens, to encourage use of rations in the cooperative sector using locally available products. Work has been carried out on the use of by-products (Wetlhii 1985), principally maize bran, for chicken and duck feed formulation in an attempt to reduce the imported component in feed formulations. The use of maize husks for feeding goats, and rice and maize bran for chickens and pigs, is often observed.

Few data exist on the importance or amounts of crop residues, but general observation shows that many fields are heavily grazed in the dry season or when fallow. It would seem that crop residues are an important source of cattle feed in the mixed-farming systems in southern Mozambique and in Angonia.

The areas where the major traditional-sector crops are grown are shown in Figure 2. In the cattle raising areas the main grain crops are maize, sorghum, and locally, rice. Groundnuts, pigeon pea (Cajanus cajan), and cowpea (Vigna unguiculata), are grown on lighter soils and common bean (Phaseolus vulgaris) on heavier soils, along with small areas of Lablab purpureus, mung bean (Vigna mungo) and chickpea (Cicer arietinum) (Heemskerk, personal communication). On lighter soils cassava is extensively grown, sometimes for sale by smallholder producers to commercial pig farms. Other crops are cotton, cashew, coconut, banana, sugarcane, pearl millet, finger millet, sweet potato and sesame. Fruits such as guava, pawpaw and mango are often used for pig feed.

Present strategies and constraints

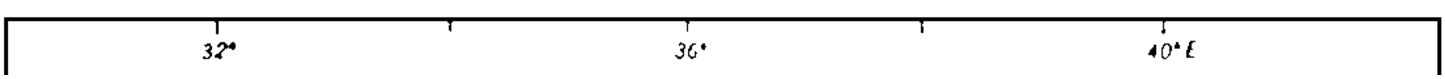
The most important limiting factor in commercial livestock production is shortage of trained manpower for management. In recent years attention has been increasingly directed toward support of smallholder production and lower-capital inputs.

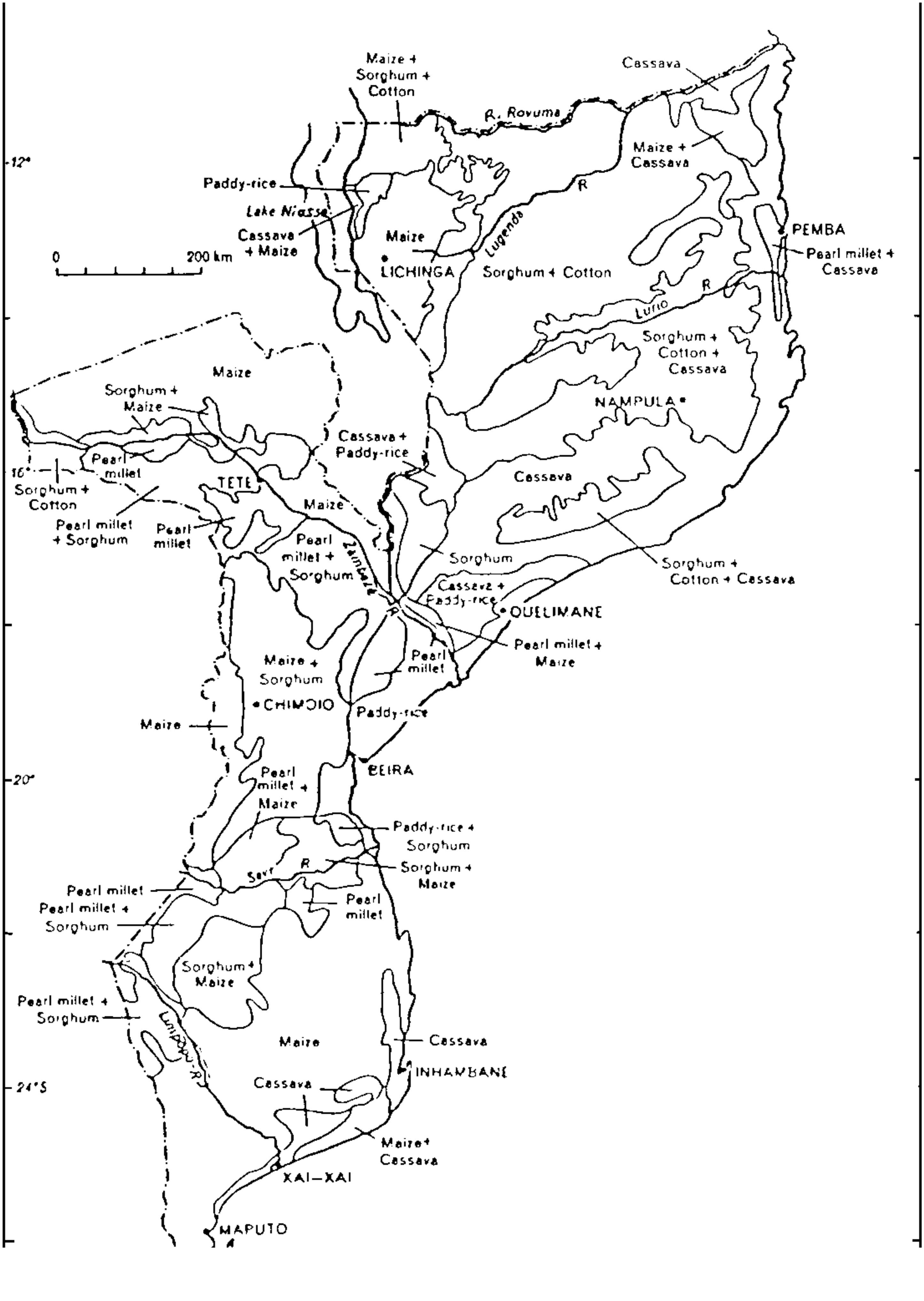
The feed resources used by smallholders for livestock production at present are predominantly natural pastures for cattle, sheep and goats. Even the few small farmers who possess genetically improved stock suitable for milk production do not practice supplementary feeding. Pigs are raised predominantly on what they find for themselves or on locally collected plant materials and scraps, while chickens mostly forage for themselves. Ducks and rabbits are fed locally-collected plant materials which are not usually systematically cultivated.

In the commercial sector a certain amount of deferred grazing is practiced on beef ranches and hay is sometimes made. Commercial dairy herds are raised on natural pastures with a certain proportion of silage, which is grown on the farm, freshly-cut feeds (in particular elephant grass), and some rations. Pig production, which is mostly in the State sector, is based on the use of rations, either mixed inside the country using what byproducts are available (copra, cotton-seed cake, bran), or imported premixed. Some rabbit-breeding enterprises grow lucerne or siratro under irrigation.

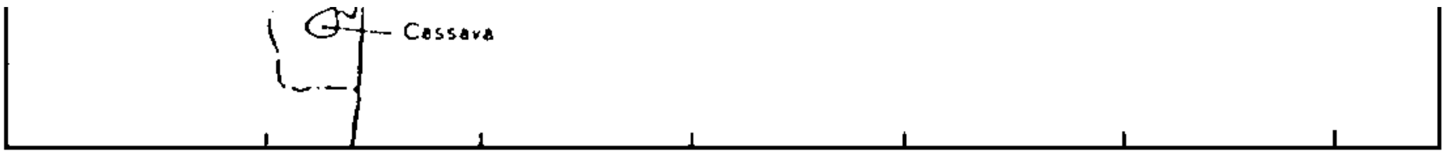
Present Government strategy regarding the use of feed resources is still in the process of formulation. The increasing use of natural pastures and other locally available feed resources is being encouraged. In the smallholder sector, particularly around the urban areas, the raising of small livestock species is being encouraged as much as possible using feeds that can be collected locally.

Fig 2. - Spatial distribution of traditional crop zones - Mozambique





Maize + Sorghum + Cotton
Cassava
R. Rovuma
Maize + Cassava
12°
Paddy-rice
Lake Niassa
Cassava + Maize
Maize
LICHINGA
Lugenda
R
PEMBA
Pearl millet + Cassava
0
200 km
Sorghum + Cotton
Lurio
R
Sorghum + Cotton + Cassava
Maize
Sorghum + Maize
NAMPULA
Cassava + Paddy-rice
Pearl millet
16°
Sorghum + Cotton
TETE
Cassava
Maize
Pearl millet + Sorghum
Pearl millet
Pearl millet + Sorghum
Zambeze
Sorghum
Sorghum + Cotton + Cassava
Cassava + Paddy-rice
QUELIMANE
R
Pearl millet + Maize
Maize + Sorghum
Pearl millet
CHIMOIO
Paddy-rice
Maize
BEIRA
20°
Pearl millet + Maize
Paddy-rice + Sorghum
Save
R
Sorghum + Maize
Pearl millet
Pearl millet + Sorghum
Pearl millet
Sorghum + Maize
Pearl millet + Sorghum
Limpopo
R
Maize
Cassava
INHAMBANE
24°S
Cassava
Maize + Cassava
XAI-XAI
MAPUTO



by S.J. REDDY

Crop	Condition (area %)
Paddy-rice	> 0
Maize	^{3} 35*
Sorghum + Cotton	^{3} 35**
Pearl millet	> 0
Cassava	^{3} 20

* South of 20°S latitude the maize area also includes beans and groundnuts
** In the sorghum + cotton zone, cotton is grown only in the north-western regions
Source: CARVALHO, M. (1969)
FAO/UNDP (MOZ/81/015)

Within the smallholder sector, particularly regarding cattle, it seems that a major constraint is marketing not feed availability. But the availability of dry-season feed is a limiting factor to increased production. This limitation could be overcome, most importantly (a) by better distribution of water sources, and also (b) by deferred grazing, which implies a degree of fencing or more rigid herding practices, (c) by control of wild fires, and (d) by the use of hay, silage or small areas of improved forages. Point (d), however, requires a certain input of energy and mechanization which limits its suitability at present. Small areas of improved forage under low-cost irrigation on suitable soils, possibly associated with small dam spillovers, show much potential in certain areas if inputs can be kept low. However, conflicts with the growing of human foods will arise. The relatively high carrying capacities and smaller herd sizes than found in some surrounding countries mean cattle are kept closer to the village and often under reasonable control, and so controlled regular access to supplementary feed is perhaps easier.

Constraints in smallholder pig, chicken, duck and rabbit production primarily revolve around quantity of feed, followed by quality. The increasing use of small areas of cultivated forages, especially indigenous ones not requiring imported seed, is the only way to overcome this.

Tsetse are a major limiting factor on livestock distribution but can also produce productivity substantially in some localized areas. The presence of the Amblyomma tick which destroys quarters of the udder can be a serious limitation to milk production and increase calf mortality. Otherwise health problems are less important than those associated with poor feeding.

Research priorities

Not much research has been carried out in Mozambique on pastures and animal feeds. Perhaps our biggest gap is in knowledge and understanding of the predominantly mixed farming systems in which so much of our livestock production takes place. In view of the low effective numbers of livestock of all types in the country, their present distribution, and the relatively rich and varied agricultural resources available, the following are thought to be the major areas for applied investigation in the next few years:

1. Inventory of existing farming systems involving livestock, including determination of herd size, grazing patterns, feeds utilized, distribution and use of water, strategies for overcoming dry-season feed shortages, importance of draught power, and use of crop residues;

2. Inventory of productivity and quality of natural pastures;

3. Productivity levels and quality of crop residues and crop by-products and ways of utilizing them better urea-treated straw, etc.;

4. Determination of appropriate methods of grazing control allowing for reduction in or control of bush encroachment;

5. Determination of intermediate farming systems for goats, pigs, chickens, ducks and rabbits.

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Session I: Inventory of animal feed resources

Rapporteur's Report: (N.A. Urio)

Summarized under:

A. The main feed resources.

B. The limitations/constraints on utilization and improving productivity of feed resources.

C. What has been done on utilization and improving productivity of feed resources.

D. What could be done to improve further the utilization and productivity of the feed resources.

The Main Feed Resources

1. Natural grasslands/permanent pastures.
2. Planted/established pastures/forage crops.
3. Crop residues.
4. Agro-industrial byproducts.
5. Others.

Note: Except for a few countries, it was generally observed that there was a lack of qualitative as well as quantitative data on each of the above outlined feed resources.

1. Natural Grasslands

The main pastures species include: Themeda, Hyparrhenia Brachiaria, Heteropogon, Aristida, Eragrostis, shrubs, trees, and indigenous legumes.

Constraints

The main constraints identified under this feed resource are:

(i) Seasonal and low productivity of natural grasslands, including conspicuous absence of legume species.

(ii) Lack of proper management, including serious overgrazing.

(iii) The inherent communal land-tenure systems which hamper efforts to improve management of the grasslands.

(iv) The inability to effectively carry out destocking.

What has been done:

(i) There has been some change in some countries (e.g. Kenya) on the land-tenure system from communal to individual ownership, which tends to facilitate proper management.

(ii) There has been some controlled grazing through fencing of grazing areas (e.g. Botswana and Zimbabwe), although the shortage of fencing materials is a major constraint.

(iii) There has been a limited introduction of legume species in grazing lands (e.g. in Swaziland in the past, and now in Zimbabwe).

(iv) There has been some efforts in providing more watering points in grazing lands.

What could be done:

(i) More realistic and effective approach to the problem of overstocking.

(ii) Improvement on management aspects of grasslands, including grazing management, introduction of more productive pasture species including legumes spp., and provision of more watering points.

2. Established Pastures

It was generally observed that broadly, these currently play a limited feed resource, and are specifically more important in intensively cultivated areas and in high population density areas. The main pasture species under this feed resource include Napier grass, Guatamala grass, Setaria, Rhodes grass and limited amount of legume species such as Alfalfa, Stylosanthes, Desmodiums, Siratro and Trifoliums.

Constraints:

(i) The productivity of the established pastures has not been fully exploited in terms of proper agronomical practices including use of proper varieties for each ecological zone, or the inclusion of legume species into the pasture leys.

(ii) Lack of pasture seed especially legume seeds.

(iii) Lack of technology among smallholder farmers, on establishment of pastures.

What has been done:

(i) There has been considerable use of three pasture species viz Napier grass, Setaria spp, and Guatamale grass among smallholder farmers.

(ii) There has been some improvement on agronomical practices e.g. spacing and manure application with considerable increase in yield of such spp. as Napier grass (e.g. in Kenya).

(iv) There has been some characterization of forage crops for different ecological zones e.g. in Ethiopia and Burundi.

(v) There has been some introduction of fodder trees like leucaena and others.

What could be done:

(i) There is a need to devise a production system that will ensure a continuous supply of forage throughout the year either by increasing yield and productivity of the forage crops through better agronomical practices, and or inclusion of suitable legume species in the pasture leys.

(ii) There is a need to devise suitable technology of forage conservation for the smallholder farmer.

(iii) Production of pasture seeds for both promising grasses and legumes.

3. Crop Residues

This feed resource include mainly crop left overs after havest i.e. stovers and straws and include such materials as maize stover, sorghum stover, millet stovers, rice straw and various forms of pulses straws/haulms.

Constraints:

(i) Generally observed that the crop residues are low in feeding value, and are particularly deficient in nitrogen.

(ii) The mode of harvest and transport limit their efficient utilization. They are generally bulky materials and the feeding practice either grazing in situ or stall feeding results into considerable losses especially of the leafy portions.

(iii) Some of the crop residues are produced in places far from user sites.

What has been done:

(i) Limited characterization and inventory of available quantities in terms of their nutritive value and quantities produced annually.

(ii) Crop residues have generally been accepted as an important feed resource and are incorporated into the various feeding systems.

(iii) There has been some improvement of the feeding value of the crop residues by supplementation with urea, molasses and oil seed cakes. Attempts to improve the nutritive value of crop residues through chemical treatments have not effectively taken off due to rise in the price of the chemicals as well as the unreliability on the supply of the chemicals.

What could be done:

(i) Proper inventories and characterization of the crop residues available in each country.

(ii) Improvement on utilization of the crop residues through supplementation for the limiting nutrients.

(iii) Improvement on methods of harvesting and handling of the residues to minimize wastages.

4. Agro-Industrial By-products

These broadly include sugarcane industrial by-products such as sugarcane tops, baggasse and molasses, cereal milling by-products, oilseed cakes and brewers waste.

(i) Lack of proper inventories and characterization of the byproducts.

(ii) Lack of proper and efficient distribution and market networks for the by-products from production sites to user sites.

(iii) Exportation of some by-products at the expense of local demands.

(iv) Wide variation on quality of by-products due to differences in processing methods.

What has been done:

(i) Wide use of the by-products in various feeding systems e.g. molasses urea by-products in Ethiopia, Kenya and Tanzania.

(ii) Inclusion of cereal by-products and oilseed cakes into various compounded livestock rations.

(iii) There has been attempts to improve the distribution networks for the by-products.

(iv) There has been some studies to characterize the nutritive values of a number of by-products.

What could be done:

Generally efforts could be directed towards the four constraints outlined above.

Fodder for high-potential areas in Kenya

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Abstract

Fodder crops that are or could be used in the high-potential areas of Kenya for purposes of maximizing animal production are identified and discussed in terms of their nutritive value and efficient utilization by animals. The DM productivity of most of the fodder crops was found to be about five times that produced by a common pasture species such as Rhodes grass (Chloris gayana). Data on in vivo digestibility, intake and performance of livestock when fed fodder are lacking, however, and information on chemical composition is scanty. It is suggested that feed resources be expanded to include crops other than the now well established Napier grass (Pennisetum purpureum) and that the defoliation practiced on maize be tried on other cereal crops. In a multi-disciplinary approach, it was recommended that research be directed towards evaluation of food crops which also double as fodder, and to multipurpose trees and shrubs, for the benefit of farmers in the high-potential areas.

Introduction

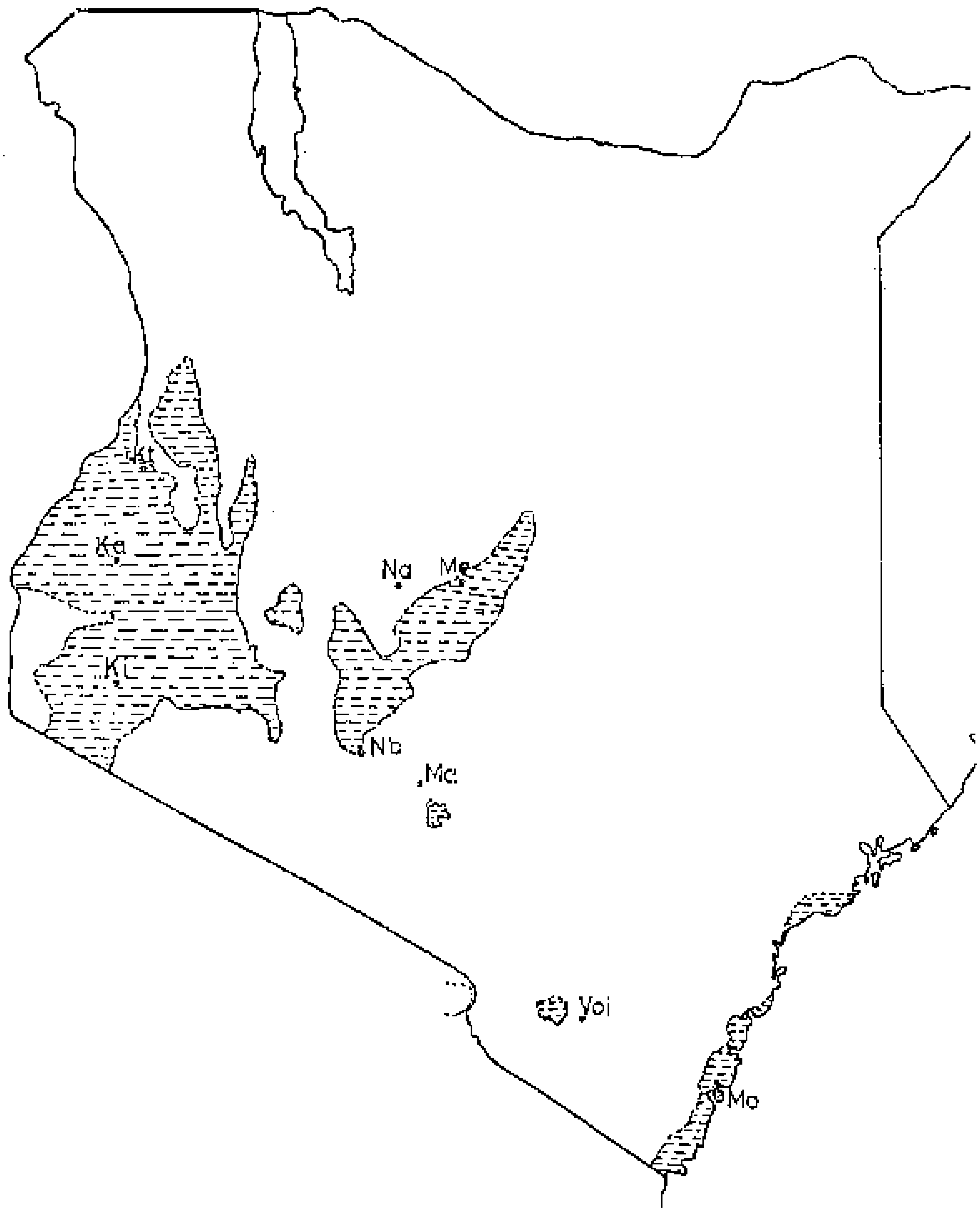
The high-potential areas of Kenya comprise about 15% of the total area of the country. They lie between 1,800 and 3,000 m above sea level and on average receive at least 1,200 mm of rainfall per annum spread in a bimodal pattern (Figure 1). Kikuyu grass (Pennisetum clandestinum) and star grass (Cynodon dactylon) predominate in the natural grass cover. Agricultural activity is intense in holdings that constitute about 55% of the smallholder areas of Kenya (Stotz 1979). Mixed farming is common on farms that average less than 4 hectares. The major crop enterprises include coffee, tea, maize, pyrethrum and horticultural crops. Dairying is important to the extent that about 82% of all the grade dairy cattle in Kenya are kept in the high-potential areas. In addition, there is a sizeable amount of sheep farming.

Increasing population pressure, coupled with a bias towards cash and food-crop production, has seriously limited the amount of land under grazing in these areas. This has led to the development of intensive systems of livestock production which include:

(a) Grazing animals by day and stalling or enclosing them at night to be fed fodder crops and farm by-products in a system known as semi-zero grazing;

(b) Feeding animals entirely on fodder crops and crop residues in stalls or enclosed areas in a cut-and-carry system or zero-grazing.

Figure 1. DISTRIBUTION OF THE HIGH POTENTIAL AREAS. (1200-2000 mm rain p.a.) OF KENYA



<u>Key</u>

Kt - Kitale
Ka - Kakamega
Na - Nanyuki
Me - Meru
Nb - Nairobi

Ma - Machakos
Mo - Mombasa

Fodder, therefore, is that forage that is fed to animals in confinement. It is the intention of this presentation to examine those fodder crops that are or could be used in the high-potential areas for the purpose of maximizing animal production.

Types of fodder

In the classification given in Table 1, an attempt has been made to distinguish between crops that are grown primarily for fodder and those whose contribution to fodder is secondary. Accordingly, we have the following main classes:

Table 1. Productivity and nutritive value of fodder for the high-potential areas of Kenya

	Productivity (tonnes DM ha^{-1} y^{-1})	Crude protein (g kg^{-1} DM)	Crude fibre	Ca	P	(MJ kg^{-1} DM)
Pure fodder cross						
Napier grass	12.6[a]	128	354	3.6	1.8	6.7
Bana grass Sudan grass	9.0[a]	127	394	5.2	4.2	-
Tree legumes						
Leucaena leucocephala	-	260	233	-	-	-
Sesbania sp.	-	280	172	-	-	-
Gliricidia sp.	-	260	-	-	-	-
Other fodder crops						
Green maize	20-26	180	580	-	-	-
Forage sorghum	-	78	161	0.5	3.4	10.4
Pigeon peas	15-18	200	262	8.7	8.2	-
Cassava tops	10-30	270	240	2.6	1.8	-
Banana leaves	-	160	200	5.8	1.8	9.6
Sugarcane tops	-	47	303	-	1.5	6.8
Sweet-potato vines	14-16	234	169	14.2	3.3	8.9

[a] Per havest

Pure Fodder Crops

The Ministry of Agriculture recognized the highly productive nature of Napier grass (Pennisetum purpureum) and launched a scheme for its popularization (Chema 1984). Napier grass has now become the key fodder crop among smallholders practicing stall feeding. It is intercropped with coffee and grown in all areas unsuitable for grazing and/or production of food and cash crops, including road sides and river banks. The other fodder crops have received less attention, but some, such as Sudan grass (Sorghum sudanense), have shown potential under similar production conditions. Available-data in Kenya suggest an annual increase of area under fodder of about 17.0% (MLD 1978).

Multipurpose Trees/Shrubs

The multipurpose trees and shrubs identified so far are the legume trees. The practice has been to use them as hedgerows dividing cultivated fields, to cultivate them as shade trees and windbreaks around homesteads, and to grow them specifically to provide firewood.

Recently, however, farmers have become aware of the high fodder-producing potential of tree legumes and have been particularly keen on feeding Leucaena leucocephala leaves and pods to sheep and dairy goats (Russo 1984).

Other Fodder Crops

The crops in this category are grown primarily for human-food production, but their ability to produce forage in the form of leaves and pods is considerable. Sorghum and maize may be harvested before ear formation and fed as such or after ear formation and conserved by ensiling, except that in smallholder farms scarcity of resources does not allow for conservation even in periods of plenty. Pigeon peas and cassava plants have the added advantage of being drought-resistant. Sweet-potato vines are already widely fed, while banana leaves and pseudostems alleviated the severe shortage of feed in the last drought period of 1984.

Nutritive value

The nutritive value of feed for livestock is determined by its content of dry matter, crude protein and crude fibre, digestibility of organic matter and the voluntary intake of ME and the other nutrients (Abate et al 1984). For milking animals, the concentration of calcium and phosphorus is also important (Underwood 1979).

Table 1 gives some of these data for some of the fodder crops listed earlier. It shows that the dry-matter productivity of most of the fodder craps is about five times that of a common pasture species such as Rhodes grass (Chloris gayana). Except for sugarcane tops and forage sorghum, the crude-protein content is well above the 7% level known to limit the intake of tropical forage (Milford and Minson 1966). The concentration of macro-elements seems sufficient to support lactation if the fodder is appropriately supplemented with minerals.

There is hardly any information on in vivo digestibility, intake and performance of livestock when fed fodder. There is, therefore, a great need to investigate these parameters to provide more data.

Non-conventional sources of fodder

The non-conventional methods of obtaining fodder have been developed as a result of efforts to integrate crop and animal production with benefits to both. The methods that have been tried or seen to be practical by farmers in the high-potential areas are mainly with maize varieties of the 500 and 600 series. The methods of interest include topping, thinning and defoliation.

Topping involves cutting off the top of the maize plant above the ear. It is known to be practiced by some farmers in the Central Province of Kenya but definitive scientific data are lacking-. There are suggestions that maize plants should be topped at 3.5-4.5 months of growth but the effect of the material so harvested on animal production is not known. It has, however, been reported that topping reduces grain yield by 15%, a figure which is biologically, socially and economically substantial (Russo 1984).

Thinning is reduction of a high population of maize plants per unit area. The recommended plant population for the 500 and 600 hybrids is about 44,500 per ha. Farmers who practice thinning achieve higher plant densities either by closer spacing or by planting more seeds than the usual two per hole. When plants are knee high, or between 4 and 6 weeks old, the excess plants are removed and fed to animals. The dry-matter content of thinned maize plants is low

(10–12%) and this could lead to digestive problems or scouring. Moreover, a farmer would thin only once, and therefore would have to face the problem of storing a bulky material with a high moisture content.

To defoliate is to deprive a plant of leaves prematurely. With maize, our experience has been that systematic picking of one leaf per plant once a week produced between 1.0 and 1.2 tonnes of dry matter per ha in a season. The best times to start plucking the leaves varies from 90 to 120 days post-emergence depending on location, but generally can be said to be about 30 days after silking. Since a large proportion of maize in Kenya is grown in the high-potential areas, defoliation is an attractive method of increasing animal resources. The cost of labour involved in collecting the material is also minimal. In one hour an individual can collect about 7.0 kg dry matter which can feed six mature sheep in a day.

The quality parameters of fresh maize leaves are given in Table 2. The data show that maize leaves posses nutritional characteristics that can support ruminant animal production better than the commonest fodder crop in the high-potential areas (Table 3).

Table 2. Average quality of defoliated maize leaves

Parameter	Mean (%)
Crude protein	12.6
Acid detergent fibre	43.0
Acid detergent lignin	7.4
Dry-matter digestibility	56.8

Table 3. Performance of sheep and cattle when fed fresh maize leaves or Napier grass

	Sheep		Cattle
	Fresh maize leaves	Napier grass	Fresh maize leaves
Initial weight (kg)	20.2	21.0	68.3
Final weight (kg)	29.8	24.9	87.2
DMI, gd	890.0	690.0	2,660.0
ADG, g	136.0	48.0	336.0
FCE	6.5	14.0	7.9

Defoliation has not been widely adopted by farmers in the high-potential areas, probably because there are certain problems associated with it. These are:

(a) Defoliation causes loss in grain yield. By some estimates, up to 25% of the yield may be lost if defoliation is not properly done. Thus the time to start defoliating and frequency of defoliation need precise definition by location and variety in order to minimize grain loss.

(b) There seems to be a relationship between defoliation and increased lodging. The factors contributing to this have not been quantified but appear to be a combination of poor root development, stem elongation, poor stem lignification and force exerted on the plant during defoliation. However, research at the Department of Animal Production, University of Nairobi seems to support these physical factors as being connected with lodging.

(c) Like everything that depends on rain for its growth, fresh maize leaves are available only during the growing season when grazing is also plentiful. Methods of preserving excess material, therefore, need to be developed. In the Department of Animal Production, the following methods of conservation have been tried on a pilot basis: sun drying, shed drying, and blanching coupled with sun drying. The first two methods would be appropriate for the smallholder in the high-potential areas. Blanching has an energy requirement and would be expensive.

Factors limiting increased use of fodder crops

Excepting Napier grass, the use of fodder in the high-potential areas of Kenya has not been widely practiced. A number of constraints can be invoked to explain this.

Population Pressure

In the smallholdings, a high population density of 8-10 persons per 12 ha implies that the demand for food far outweighs the desire of farmers to meet the feed requirements of their stock. The situation is aggravated by sub-division of land into ever smaller plots which means the space that could be used for growing fodder is progressively diminishing. We foresee even smaller holdings due to the high population growth rate, quoted at 4% per annum (Republic of Kenya 1981); and a shifting of the small-scale farmer's attention-towards growing dual-purpose food crops and multipurpose trees and shrubs, leaving pure fodders to the large-scale farmers.

Research Information

The volume of past research on the agronomic aspects of high-potential-area fodders is small. But more important, the limited information available is not being disseminated to the farmer quickly enough and in a form that he can immediately utilize. Research needs to identify the type of material to plant in accordance with the climatic and soil properties and the fertilization practices of a given locality. Equally, optimum harvesting time needs investigating so that harvesting is done when dry matter and the nutritive value of the forage are at their optimum. The dry-matter producing capacity of materials planted on the small-scale farms should be quantified. Factors such as cutting height, frequency of cutting and methods of feeding require studying as they affect the acceptability and efficiency with which the fodders can be utilized. Appropriate intermediate technology needs to be developed for the small-scale farmer to enable him to process his fodder and ensure maximum intake or to allow him to conserve it for dry-season use. The results of such research should then be communicated to the array of agricultural extension workers in the field.

Labour

Labour on a mixed farm in the high-potential areas would be required to cut and carry forage, manage the animals and ensure an adequate water supply, among other requirements. The demand for labour is particularly intense in the zero-grazing system during planting and weeding of fodder, which also coincides with the peak labour requirements for other crops.

The labour constraint to the use of fodder is very much tied to the farm size. Studies undertaken in Kenya suggest that zero-grazing was justifiable only where the returns to increased output of surplus family labour were greater than the would-be income from off-farm employment. This phenomenon obtained in the small farms but capital inputs were frequently lacking. For larger holdings, zero-grazing was less attractive because labour resources were in short supply (Stotz 1979).

Management Problems

In many cases forage yields from planted fodder crops are low because repeated harvesting depletes the soil of nutrients which are then not replenished. Farmers should, therefore, be educated on the value of fertilizer application for increasing crop production and be advised to practice it either using chemical fertilizers, or more appropriately, manure which would also improve the texture of the soil.

Conclusion

In addressing ourselves to problems of fodder production in the high-potential areas of Kenya, we have taken note of the positive contribution of Napier grass. Its dry-matter productivity is phenomenal. But there are gaps to be filled in terms of agronomic practices that would go a long way towards ensuring even higher practices that would go a long way towards ensuring even higher productivity and more efficient utilization by animals. We have also been careful to point out that availability of land may not favour the growing of pure fodder crops especially if the present annual population growth rate of 4% is maintained. We are suggesting, therefore, a fresh look at potential fodder-producing crops and an aggressive research commitment to their evaluation. This is in line with Government policy as spelled out in sessional Paper No. 4 of 1981 on national food policy which urges an intensification of land utilization for food and livestock production so that energy and protein in excess of the national average per caput nutritional requirement may be produced. In particular, we mentioned food crops which also double as fodder, and multipurpose trees and shrubs. There is also need to popularize the defoliation, topping and thinning practices that have been applied on maize and to extend them to other cereal crops. Such an approach would, we believe, benefit farmers in the high-potential areas of Kenya and beyond in the wider context of agricultural development in Africa.

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Research on animal feed resources: Medium-potential areas of Kenya

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Abstract

The research studies carried out on animal-feed resources at the Katumani Research Station have shown that the problem of continuity of feed supply should be addressed by designing an integrated feeding system that includes the improvement of natural pastures, the production of pasture grasses and fodder crops and the increased use of crop residues in combination with legume fodders such as Leucaena, if adequate nutrition for livestock is to be ensured.

Introduction

The semi-arid regions of Kenya account for about 60% (342,000 km²) of the country's surface area. Although extensive, they are not homogenous. The areas cover a wide range of physical features, including flat lands and gently rolling or steep and rugged hills and valleys. Elevations range from 700 m to 1800 m. Slopes can be as much as 30%, making large areas prone to erosion. The majority of soil types are relatively shallow, and range from well drained reddish soils to loamy and stony sands with a limited capacity for storing water.

The rainfall is noted for being low in most years and for its erratic occurrence. The annual rainfall pattern is monomodal in certain areas (west of the Rift Valley) and bimodal in other areas (east of the Rift Valley). For 5-7 months of the year the climate over most of these areas is mild or hot resulting in high evapotranspiration. Areas with less than 500 mm of rainfall are considered to be too dry for rain-fed cultivated pasture with the current available technology.

Research work in pasture and animal production at the National Dryland Farming Research Station, Katumani, is aimed at finding ways of increasing feed resources in smallholder agricultural systems of dryland areas and developing technologies and management systems that will improve animal productivity and profitability.

Natural pasture grazing

Under the present livestock-raising system practiced by small-scale farmer, almost all the feed supply for livestock in the semi-arid areas comes from herbage on non-arable natural grazing lands or fallowed crop lands. A fixed rate of stocking is generally practiced by farmers as they do not have the option of decreasing stock numbers during the dry season or increasing them during the growing season. This situation almost always results in high grazing pressures leading to soil erosion and land degradation. Many areas become bare and others have been ingressed by scrub bush and unpalatable species which diminish the effective grazing area.

The experimental work carried out on these pastures included assessments of:

(a) Their productivity and nutritive value;
(b) The appropriate grazing pressure to be employed; and
(c) The contribution that these pastures can make to the year-round feeding system.

Vegetation

The vegetation of semi-arid areas is generally described as savannah, being almost treeless in some areas and with a scattering of trees in other areas (Rattray 1960). Although rainfall, temperature, soil conditions and topography are the main factors that determined the original distribution of vegetation in semi-arid areas, the tree/grass complex that is observed today is largely a direct expression of different degrees of man's disturbance to which the vegetation has been subjected in the recent past; i.e. fire, grazing, tillage, fuelwood extraction, and other activities. Large areas are covered by dense deciduous thicket and bush surrounded by areas that have degenerated under overgrazing. Natural swards found under thick thorny bushes where livestock have not been able to get at them contain an abundance of good grazing species.

Table 1 shows the distribution of grasses in combination with herbaceous plants, shurbs and trees as well as information on the percentage of plant species collected from bush and where grazing pressure has been controlled. The collected herbage was separated into major species of grasses and broad/leafed weeds. Trees and shrubs were only identified in the field and the most prominent species were Acacia spp. Combretum spp. Commiphora africana and Indigophera sp. It can be seen from the table that a wealth of very good grass and browse species grow in these environments when given the opportunity. Some of the grasses are of very high quality during the growing season and would be comparable to good-quality fodder crops. Even during the dry season when the grasses are extremely scarce, livestock browse to a considerable extent on the shrubs and herbs which are still succulent and high in nutritive value.

Dry-matter Production of Natural Pastures

Estimates of forage biomass were obtained from 3 m² enclosure cages which were moved to new sites every 20 days throughout the year. All plant material within the cage was harvested and weighed in the field. In order to overcome bias four cages were used at a time and they were placed at random on each cutting date. Samples of the vegetation harvested were oven dried at 65°C for 48 hours and the percentage composition and biomass data are given on an oven-dried basis that allows comparisons to be made irrespective of the moisture content of various species.

The biomass and percentage dry matter and rainfall during each cutting period are given in Table 2. The table shows that the natural pastures grow very fast with the onset of the rains and by the end of the rains the grasses have flowered and set seed. In eight weeks, most grasses will have completed their reproductive cycle and dormant and have set seed until the next season. The dry-matter accumulation at each cutting, shown in Table 2, shows marked seasonal variation which is closely related to precipitation. The total annual dry-matter yield of 2,335 kg per hectare, extrapolated from the clipping measurements, represents reasonably high dry-matter production. It must be pointed out, however, that this production level was from well managed grassland on an experimental station which is an indication only of what can potentially be achieved in a semi-arid environment. Dry-matter yields of open grasslands under farm or communal-grazing conditions are 25–50% lower than the yields obtained from clipping studies.

Plant factors affecting nutritive value of natural herbage

This fast growth and development of the pasture grasses is normally accompanied by rapid deposition of fibrous components making them less digestible by ruminants. Table 3 gives the chemical composition and in vitro dry-matter digestibilities of the natural grassland vegetation on various cutting dates. The values are averages for three years, including two good ones and one bad. The detergent system of partitioning forage dry-matter into cell wall and cell contents (Van Soest 1978), as well as the proximate-analysis method were employed. The in vitro dry matter disappearance system employed was the modified Tilley and Terry (1963) method using the cellulose enzyme in the second stage of the analysis.

It can be seen from the table that the time when the natural vegetation has a high nutritional value is limited to short period of rapid growth which last no more than two months. A rapid increase in crude-protein (of 7.47-10.11%) is observed in response to the first rains during November and December. From then onwards the drop is rapid (6.99% in January and 5.46% in February). The crude-protein content responded similarly to the second rains, with rising values in March (10.53%, April 10.9% and May 10.1%). The crude-protein content goes down to 4.40 to 5.12% during the dry months of August and October.

Figures, 1, 2, 3 and 4 show the relationships between date of cutting and the composition of various plant parts in the natural pasture herbage. The corresponding analysis of variances are shown in Table 4.

Table 1. Species composition of natural herbage and percentage occurrence of each species at different cutting dates

Species	CUTTING DATES										
	21/11/84	**5/12/84**	**7/1/85**	**5/2/85**	**5/3/85**	**4/4/85**	**6/5/85**	**20/5/85**	**5/7/85**	**5/8/85**	**5/9/85**
GRASSES											
1. Themeda triandra	49.69	50.75	15.5	-	16.49	13.41	31.59	14.48	22.23	32.01	34.09
2. Sporobolus fimbriatus	6.32	-	-	-	6.72	8.14	0,37	-	-	-	-
3. Cenchrus ciliaris	15.72	6.41	-	5.47	4.38	-	0.64	2.08	1.82	2.22	2.66
4. Digitaria milanjiana	9.21	20.97	3.3	40.41	0.92	-	3.89	-	-	-	-
5. Digitaria abyssinica	0.33	1.92	-	-	1.80	16.03	2.25	0.70	8.45	-	3.45
6. Eragrostis superba	-	0.86	0.8	-	-	4.21	1.18	-	-	-	1.73
7. Eragrostis cilianensis	-	-	-	-	-	-	1.08	5.11	-	-	-
8. Eustachyus paspaloides	0.94	1.02	-	-	-	-	-	-	-	-	-
9. Aristida adcensionia	0.56	1.25	3.2	-	1.23	-	-	-	-	-	-
10. Aristida kenyensis	-	-	-	3.86	22.69	44.78	36.84	32.17	43.51	61.79	58.05
11. Panicum maximum	-	-	8.9	9.60	-	-	4.17	-	-	-	-
12. Cynodon spp.	-	1.22	-	14.24	-	-	-	0.61	-	-	-
13. Bothriachloa insculpta	-	0.71	-	5.63	-	-	-	-	-	-	-
14. Heteropogon contortus	-	-	3.1	19.99	-	9.61	6.51	9.58	6.48	1.64	-
BROAD-LEAFED WEEDS											
1. Solanum incanum	-	-	1.3	-	3.53	3.09	-	8.92	-	-	-
2. Polygala sphenoptera	-	-	2.2	-	15.13	-	0.80	1.04	2.91	-	-
3. Umbelliferae	3.18	3.12	-	-	-	-	-	-	-	-	-
4. Papilionaceae	-	10.08	2.2	-	4.03	-	-	6.40	-	-	-
5. Commelina sp.	0.35	-	16.1	5.76	-	5.69	0.93	0.67	1.81	-	-
INDETERMINABLE SPECIMEN	13.68	3.38	30.5	-	23.0	-	6.51	18.0	13.0	2.0	-

Figure 1. Relationship between date of cutting and crude protein (%) content natural pasture herbage (1980-1983) Katumani

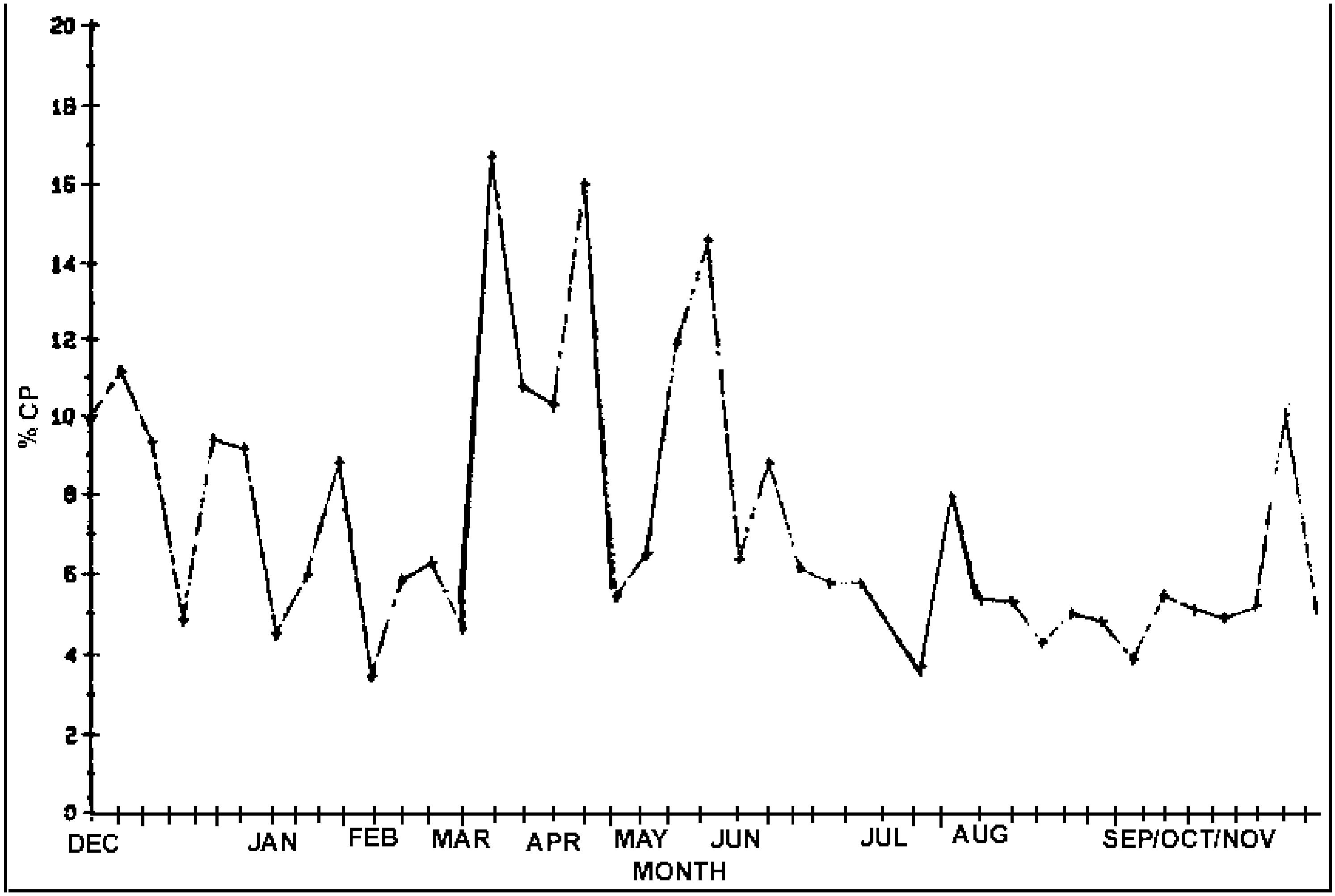

Figure 2. Relationship between date of cutting and acid detergent fibre (%) natural pasture herbage (1980-1983) Katumani

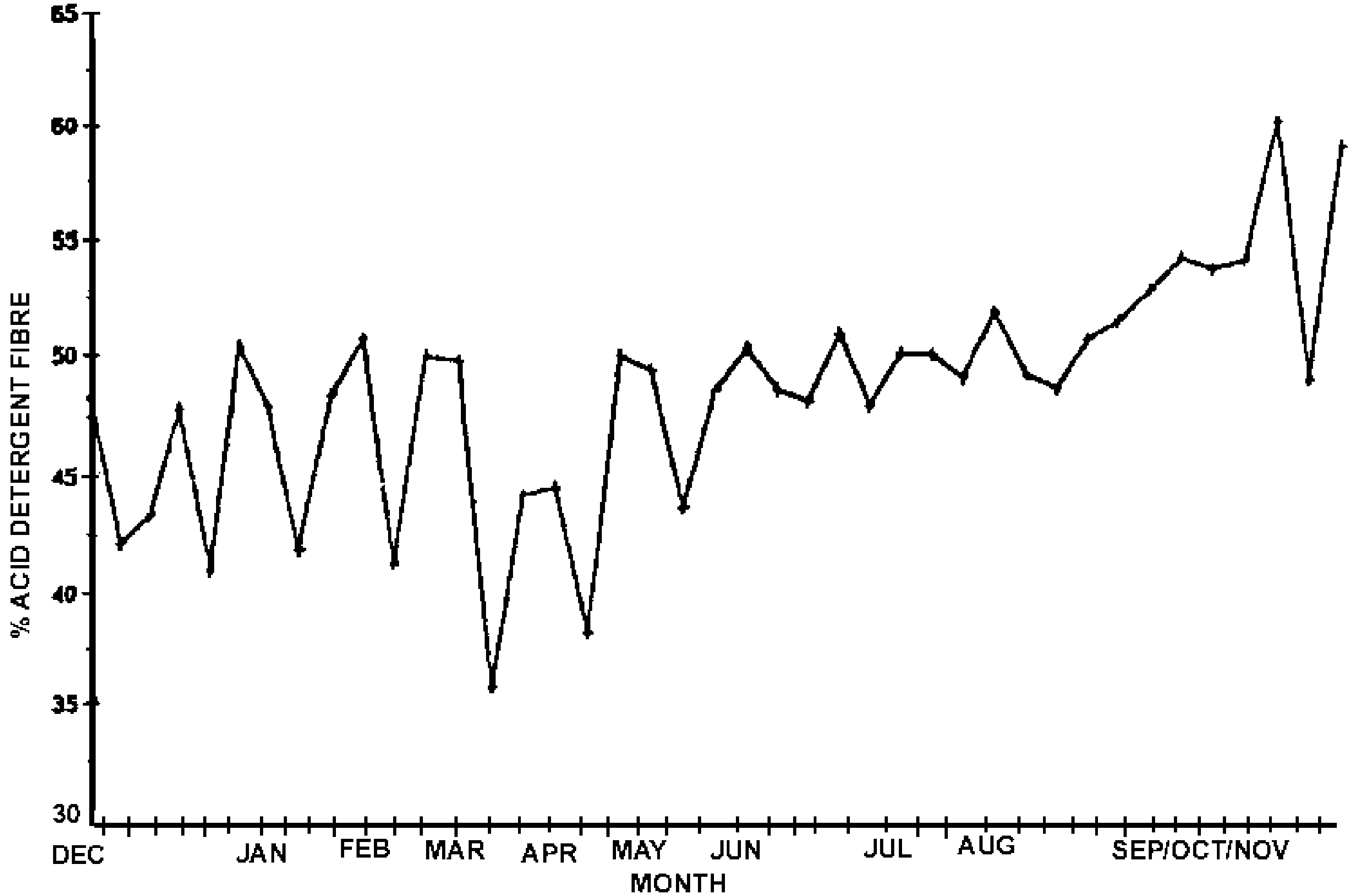

Figure 3. Relationship between date of cutting and lignin (%) content natural pasture herbage (1980-1983) Katumani

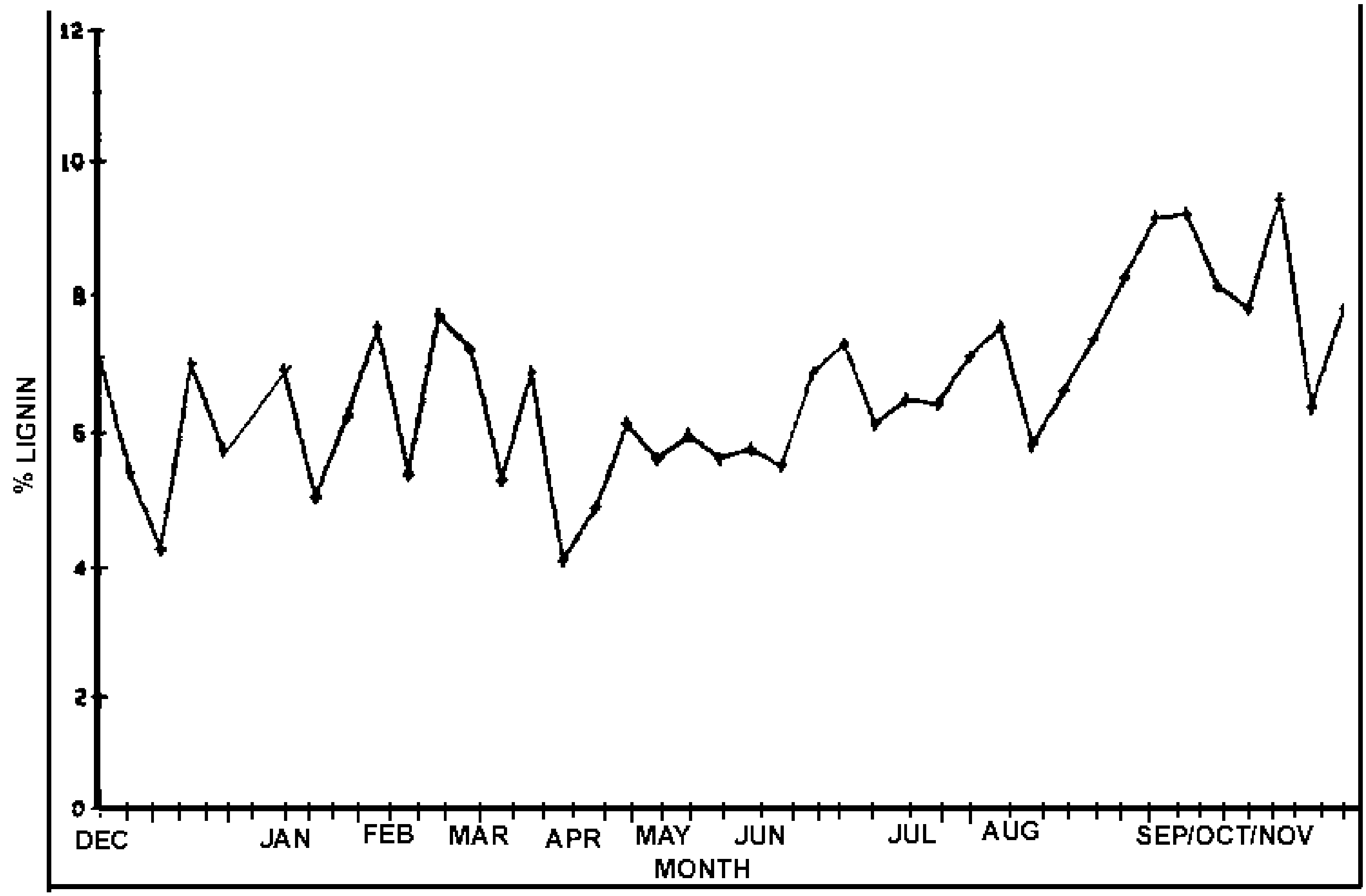

Figure 4. Relationship between date of cutting and in-vitro dry matter digestibility (%) natural pasture herbage (1980-1983) Katumani

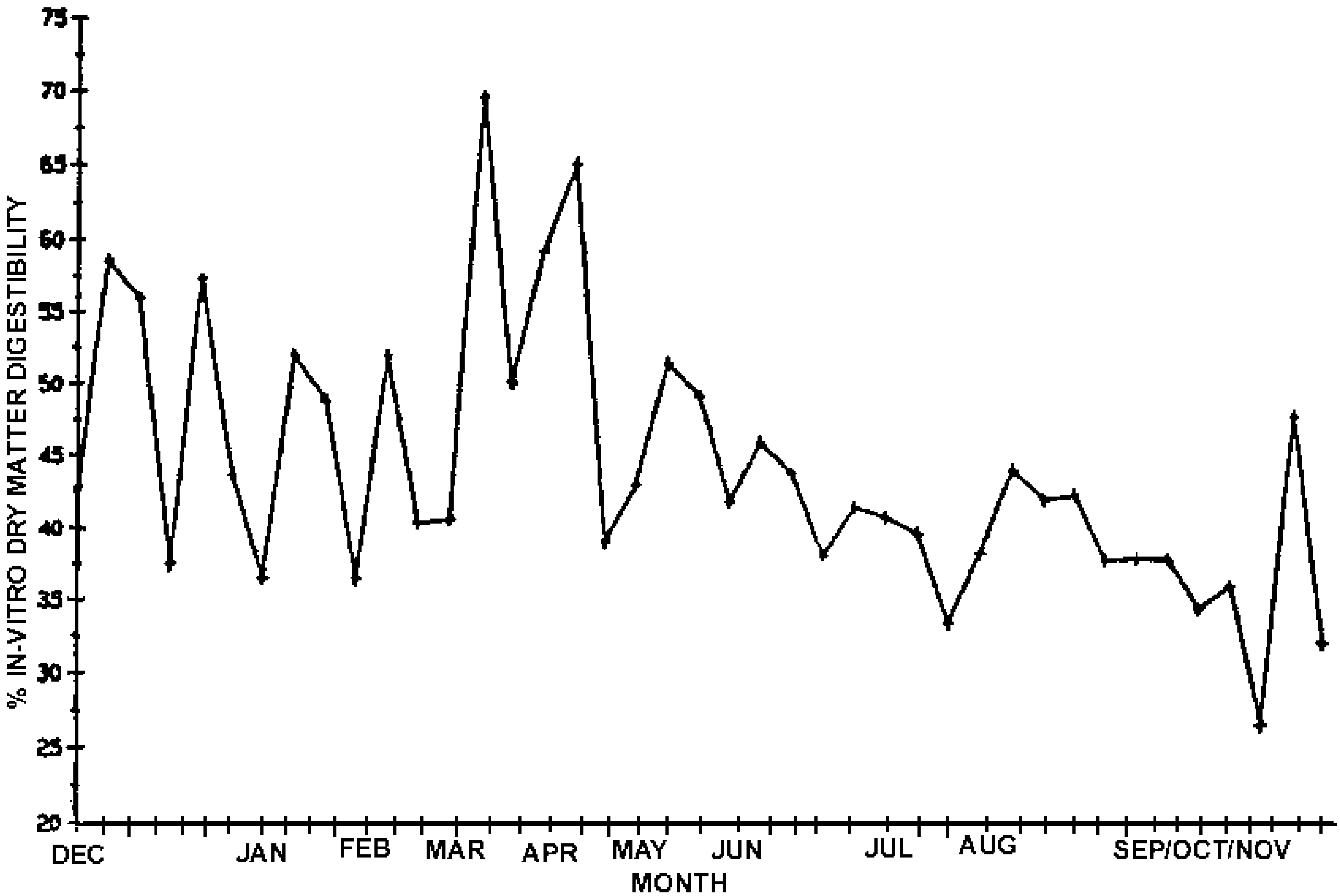

Table 2. Monthly rainfall, dry-matter production (kg/ha) and percentage dry matter of the herbage from natural grazing lands

Months	Rainfall (mm)	Dry-matter production (kg/ha)	DM %
November	154	292	40
December	80	318	40
January	56	191	35
February	43	134	63
March	73	191	58
April	115	109	45
Nay	64	298	48
June	11	287	59
July	4	156	59
August	4	188	70
September	7	171	73
TOTAL	611	2,335	

Table 3. Chemical composition and in vitro dry-matter digestibility of natural pasture herbage at various cutting dates

Date of cutting	CHEMICAL COMPOSITION						In vitro matter Digestibility	
	% ASH	% CP	% NDF	% ADF	% ADL	% CELL	% HEM	% CELL
9/12	9.06	10.11	71.12	44.53	5.61	34.64	26.79	52.44
31/12	8.13	7.77	73.29	46.34	6.38	34.56	26.95	46.16

22/1	7.86	6.39	74.01	46.01	6.30	35.86	28.01	45.80
13/2	7.25	5.46	75.64	47.26	6.87	36.16	28.38	42.97
7/3	9.38	10.58	68.16	42.67	6.25	32.31	24.99	55.22
29/3	10.05	10.48	66.22	44.13	6.86	34.02	22.09	50.18
20/4	9.81	10.90	70.01	44.15	5.04	32.95	25.86	54.57
12/5	8.67	10.90	71.53	47.08	5.73	37.59	24.45	48.00
3/6	7.64	6.99	73.28	48.88	6.04	39.06	24.40	42.96
25/6	7.05	5.59	73.04	49.30	6.70	38.81	23.54	40.00
17/7	7.02	5.68	75.32	49.60	6.60	39.61	25.72	38.19
8/8	8.59	4.82	72.28	49.76	6.64	38.16	22.52	41.70
31/8	9.49	4.40	78.17	51.54	8.22	38.52	26.63	39.66
21/9	7.47	5.12	78.19	53.84	8.63	41.27	24.35	36.48
13/10	7.65	4.88	73.52	57.04	8.58	39.83	16.49	31.73
3/11	9.19	7.47	74.57	53.85	7.07	38.93	22.19	40.30

The crude-protein composition showed the greatest change per unit of time. It ranged from 4.40 (August) to 10.90 (April and December). The proportion of cell wall, as determined by neutral detergent fibre (NDF) did not show significant changes with time (Table 4). It ranged from 66.22% (March) to 78.19% (August). As this fraction includes the hemicellulose, cellulose and lignin, it is the fundamental characteristic of the plant as it is the first stable product of photosynthesis and must remain so throughout the life of the plant. The acid detergent fibre (ADF) portion of the plants shows highly significant changes with dates of cutting (Table 4). The ADF fraction, as determined by the acid detergent solution, recovers cellulose as well as lignin in the plant.

Table 4. Analysis of variance data of plant characteristics and cutting dates

Source of variation	CP			NDF			ADF			ADL			CELL			HEMCELL			IVDMS		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F	df	MS	F	df	MS	F	df	MS	F
Between dates	9	22.25	2.80 (a)	9	28.00	98 NS	9	56.26	3.91 (b)	9	3.38	3.48 (a)	9	26.62	2.80 (b)	9	21.23	87 NS	9	155.54	2.55 (a)
Within dates	30	7.96		31	28.45		31	14.40		30			30	9.52		31	24.49		31	60.12	
Total	39			40			40			39			39			40			40		

(a) = ($P<0.05$)
(b) = ($P<0.01$)
NS = Not significant

The percentage ADF in the natural pasture ranged from 42.67 (March) to 57.04 (October). The proportion of lignin also, showed highly significant changes with dates of cutting (Figure 3). ADF and lignin were more consistently associated in the plant than were other components. Percentage lignin ranged from 5.04 (April) to 8.58 (October), while percentage cellulose ranged from 32.31 (March) to 41.27 (September), also showing significant variability with cutting dates.

These changes in herbage quality with time are functions of the maturation process as well as of environmental factors. Deinum (1976) and van Soest (1978) have shown that lignification is strongly influenced by environmental temperature. High temperatures decreased water-soluble carbohydrates and increased fibre content causing decreased digestibility. Light, on the other hand, increased water-soluble carbohydrates and decreased fibre content causing increasing digestibility. In the semi-arid bimodal rainfall areas such as Katumani, the natural pastures have two periods of morphological development during the year.

The Relationship Between Chemical Composition and Digestibility

To understand the nutritional worth of the natural pasture herbage, it is necessary to know the quantitative relationships of the various plant components. In Table 5, Correlation coefficients between these constituents are presented. The quantitative relationship between the structural components shows that the components are not uniformly controlled by lignification. As expected, all the fibre fraction, i.e. NDF, ADF, lignin and cellulose (except hemicellulose) show significantly high negative relationships with digestibility. Among the fibres, however, cellulose had a more negative (r = -0.86*) relationship than lignin (r = -0.78[a]). Lignin was also more closely related to cellulose than hemicellulose and had a greater effect on its digestibility. The lignin-cellulose ratio is the critical factor which determines the rate curve of cell-wall fermentation.

Table 5. Simple correlation coefficients observed between various plant dry-matter components of natural pasture herbage

	CP	NDF	ADF	ADL	CELL	HEMCELL	IVDMS
CP	1.00						
NDF	0.48	1.00					
ADF	0.68	0.53	1.00				
ADL	0.58	0.50	0.77	1.00			
CELL	0.68	0.65	0.87	0.58	1.00		
HEMCELL	0.19	0.51	0.44	0.21	0.21	1.00	
IVDMS	0.80	0.57	0.91	0.78	0.86	0.31	1.00

Regression equations that show the relationship between in vitro dry-matter digestibility and various plant parts are presented in Table 6. The equations show the regression of in vitro digestibilities on the percentage of various plants parts.

Table 6. Relationships between in vitro dry-matter digestibility and various plants parts

Plant parts (predictors)	Regression equation	Sdr	Sds	r	r²
Crude protein	Y = 28.67+2.17X	5.54	0.26	-0.80**	0.64
NDF	Y = 115.64-0.97X	7.69	0.23	-0.54**	0.32
ADF	Y = 125.42-1.68X	3.93	0.13	-0.9**	0.82
ADL	Y = 82.67 = 5.76X	5.83	0.76	-0.78**	0.61

Sdr = Standard deviation from regression
Sds = Standard deviation from the slope
a = P < 0.05
b = P < 0.01
NS = Not significant
Y = in vitro dry-matter disappearance (%)
X = plant parts in dry-matter (%)

The mean chemical composition values of the natural pasture herbage cut at various stages of growth show that the quantity of ADF in the herbage did not appear to be associated with digestibility.

The main factor that influenced the digestibility was ADF, as indicated by the regression equations in Table 6. The relationships are significantly negative for all fibre components (P= < 0.01).

While the ADF fraction, which consists of the lignin and cellulose components in close association, most positively affected digestibility, the most amount of protein in the forage was also a factor. It could also be used as a better predictor of digestibility of the natural pasture herbage than some of the fibre fractions (Table 6).

It has been found that the herbage consumed by the grazing animal may have a composition diverging widely from that of the total herbage available (van Soest 1978). A comparison was made between the nutritional value of hand-plucked samples and samples collected by the grazing animals from the same pasture. Table 7 shows the percentage of protein in the dry matter of the two samples.

The herbage consumed by the grazing cows contained more crude protein than the herbage clipping from the same source. When the grass was immature, during the months of April and May, there appeared to be little selection by the grazing animal. But as the plant matured, during the months of June and July, the difference in composition between the selected the clipped herbage became greater. Clipping herbage, therefore, did not provide definite quantitative values of the nutrients available to the grazing animal.

Table 7. Percent crude protein dry matter of sample collected from two oesophageal-fistulated cows

compared to percentage protein in dry matter of clipping herbage from natural grazing land (1985)

	Dates of sampling						
	16/4	30/4	11/5	3/6	25/6	5/7	16/7
	%	%	%	%	%	%	%
Fistula sample	13.50	12.69	13.13	11.80	9.38	11.94	6.56
Clipping sample	10.90	10.48	10.90	6.99	5.59	5.68	4.82

Livestock Responses to Natural Pasture Grazing with no Supplementary Feeding

Table 8 shows mean liveweight responses of steers, goats and sheep at two different stocking rates. Pronounced seasonal variations were observed in liveweight changes of all three species. Over the whole grazing cycle, however, no significant differences were observed between animals grazing at the rate of 0.54 LU/ha* and those grazing at the rate of 0.35 LU/ha. Compensatory gains during the wet season offset the losses made during the dry season. Sustained liveweight gains of between 160 and 180 g per day for steers and 35-40 g per day for sheep were achieved during a year's cycle. During the wet season, however, rates of gain were as high as 90 g for sheep and goats and 250 g for steers, clearly showing the possibility of intensive short-season utilization of natural pastures.

Grazing management had very little influence on weight changes. There were no significant differences in rates of gain between continuous and rotation grazing during any seasons of the year or over the whole year.

Planted pastures

Pasture research for medium- and low-potential areas has been going on for many years. However, it has not received adequate attention compared to pasture research in high-potential areas, and thus development of relevant technology for farmers in these areas has lagged behind.

Grasses for Planted Pastures

Bogdan (1965) described cultivated varieties of tropical and subtropical herbage plants in Kenya issued by the then Grassland Research Station, Kitale since 1953. The species that were recommended for dryland farming areas included Chloris gayana (Kunth), (Mpwapwa, Mbarara and Rongai), Panicum coloratum L. (coloured Guinea grass). Panicum maximum Jacq (Guinea grass, varieties Makueni and Mackinnon Road). Other species which had been tested included Cenchrus ciliaris, Brachiaria brizantha, Themeda triandra and Cynodon dactylon.

Table 8. Weight changes of steers, goats and sheep when grazing natural pastures at two stocking rates (1981/82)

	Steers		Goats		Sheep	
Number of days	323		323		323	
Stocking rates[a]	0.54	0.35	0.54	0.35	0.54	0.35
Number of animals	14	10	28	20	28	20
Initial average wt (kg)	246	260	30	29	31	32
Final average wt (kg)	308	312	38	42	42	42
Average daily gain (g)	189	161	25	36	30	32
	Summary of Analysis of Variance					
Source	**d.f.**	**MSS (F)**	**d.f.**	**MSS (F)**	**d.f.**	**MSS (F)**
Treatments	1	4,882 (NS)	1	1,509 (NS)	1	9 (NS)
Fields	1	51	1	1,509 (NS)	1	30 (NS)
Treatment x fields	1	7, 375 (NS)	1	240 (NS)	1	239 (NS)

Error	20	5,857	44	140	44	231
S E	20.5	24.2	2.2	2.6	2.5	3.5

a) In LU per hectare.
NS = Difference not significant
* One Livestock Unit (LU) represents 250 kg liveweight.

Many ley grass species were evaluated at the Katumani Research Station between 1957 and 1984. Studies comparing various planted grass species and cultivars showed that Panicum maximum (Makueni) and Cenchrus ciliaris (Biloela) were the two species with widest adaptability in dryland areas. The Makueni variety of Panicum was found to be the most vigorous tufted perennial. P. maximum (Makinnon Road) established from splits at a spacing of 2.4 m x 0.5 m and managed for dry-season utilization yielded a total of 4.5 tons DM per hectare. In trials to evaluate planted pastures through the grazing animal several varieties of Cenchrus ciliaris (Biloela, Mbalambala, P6012, P6010, Kongwa 531 and K5148), Chloris gayana (Mpwapwa); Panicum maximum (Makueni); and Cynodon dactylon and Cynodon plectostachysis were evaluated by liveweight increases of Dorper lambs at Katumani. The best performance was from P. maximum (Makueni) with lambs averaging 230 g per day (Department of Agriculture, Kenya 1964).

Establishment of ley grasses without fertilizers has been one of the major problems in the marginal potential areas due to unreliable rainfall. Unavailability of good quality seeds has also been a bottleneck. Weed competition was the most important factor affecting establishment. A study of the persistency of the ley grasses shows that production drops markedly after two or three seasons (12 to 18 months). Attempts to incorporate certain grasses such as Rhodes grass in mixtures with more persistent species were not successful.

Table 9 shows the dry-matter yields in pasture-grass ecotype trials during the long rains of 1983 (March/May) and the short rains of 1984 (November/December). The long rains of 1983 were much below average and the short rains of 1984 were much above average.

Table 9 shows that wide variations exist in dry-matter yields between the various ecotypes and these variations are not only due to species differences but also to variation in rainfall, establishment difficulties, weeds and persistency. Those that had a high dry-matter yield during a bad year did not respond well when rainfall was favourable due to their inability to compete with weeds.

Table 9. Dry-matter yield of 12 selected pasture grass ecotypes at Katumani Research Station

Ecotypes	1983 long rains (good season)		1984 short rains	
	DM production (mean t/ha)	Rank	DM production (mean t/ha)	Rank
P. maximum				
K7317/21	4.06	1	2.72	7
K583/87	4.03	2	0.36	11
K585	3.61	3	0.27	12
K6016	3.58	4	4.67	3
K6541/45	3.50	5	2.83	5
K8168/72	3.42	6	0.86	9
P. coloratum K5389	3.33	7	2.82	6
P. maximum (Makueni)	3.28	8	4.90	2
P. maximum K6462	3.17	9	5.11	1
Brachiaria brizantha	3.10	10	1.10	8
P. coloratum 52430	2.89	11	0.39	10
Cenchrus ciliaris	2.64	12	4.06	4

Although suitable pasture species can be identified through vigorous introduction and selection, the overall place of such grasses for ley farming in these dryland environments is becoming questionable. This is because of the difficulty of establishing and maintaining such pastures under an inadequate rainfall regime since, in the main, they have to be established from seed. The use of fertilizers for establishing these pastures is not economically feasible. Furthermore, the place of these pastures in small-farm systems is not clear in view of the type of livestock-raising system presently being practiced.

Legumes for Planted Pastures

Although pasture research in Kenya has been carried out for many years, our knowledge on forage legumes, particularly in the medium-potential areas, has lagged behind compared with that on pasture grasses. Grass-based pastures are usually very productive during the first two years, but yields drop markedly during subsequent seasons. Nitrogenous fertilizers could sustain yields and prolong the life of the pasture if applied at strategic times. Nitrogen fertilizer is, however, too expensive for farmers of the medium-potential areas.

The answer to these problems is the introduction of legume species to be grown in association with the grasses. A number of pasture legumes have been introduced and are being tested. Among these are Stylosanthes scabra, Macroptilium atropurpureum (siratro) and Leucaena leucocephala. These are still being examined both for use in grass/legume mixture leys or for improving pasture grazing schemes. Much testing for drought tolerance and herbage yield will be needed.

It has been suggested that productive legumes are absent from pastures in some parts of Kenya either because they have not been introduced or because they have not been maintained for various reasons including:

a) inadequate supply of nutrients and possibly trace elements;

b) failure to tolerate heavy grazing,

c) drought stress;

d) ineffective nodulation,

e) insufficient quantity of germinable seed of annual species at the start of the growing season; and

f) availability and cost of seed.

It is therefore suggested that serious research gaps exist in the area of pasture legumes for marginal- and low-potential areas and particularly the improvement of indigenous legume species such as Neonotonia wightii and Trifolium semipilosum glabrescens. Development of legumes which could be used to provide ground cover on arable land and high quality livestock feeds during the dry season should be given high priority.

Fodder Crops

Planted fodder crops, both annual and perennials, are becoming very important animal feed resources in the medium-potential areas, mainly because of their apparent dry-matter-yield superiority. The most important species are elephant grass or Napier grass (Pennisetum purpureum), and Guinea grass (Panicum maximum). Napier grass has received more research attention than most other potential fodder crops and has become very popular with farmers in all areas. Two varieties of Napier grass, i.e. French Cameroon and Bana, and one hybrid (Pennisetum purpureum x Pennisetum typhoides), known as Bajra, have been studied the most.

The Napier cv Bana variety is leafier and shorter than the other two. The Napier cv Cameroon variety has a distinct spreading habit while the hybrid Bajra grows tall and has more stalk. Bajra Napier outyields both the Bana and French Cameroon varieties and seems also to be more drought resistant than the other two as it grows and stays green-long into the dry season. There is, however, the disadvantage that it becomes quite stemmy and looses its quality very rapidly after flowering.

In cutting management and defoliation studies, the dry-matter yields attained from the three varieties, over a number of seasons that included those below and above average rainfalls, were as follows: Bana 3.25 tons per hectare, Bajra 4.43 tons per hectare and French Cameroon 3.75 tons per hectare per season. When rainfall was average, two 4-weekly cuts and one 6-weekly cut were possible from the three fodder grasses during each of the two growing seasons, i.e. from the three fodder grasses during each of the whole growing seasons, i.e. November/January and March/May. The amount produced from any of these grasses would be more than enough for the average smallholder. However, the farmer obviously needs a continuous supply of fodder and would not be able to utilize excess supplies over a short period of time, which would necessitate either the development of a conservation system (hay or silage) or the integration of fodder feeding within an intermitent system of utilization i.e. using fodder in the wet season and conserving other grasses for later grazing, or growing two plots, one for the wet season and one for the dry season with some fodder from the latter spinning off into-the wet-season system.

Screening studies of a number of Panicum maximum fodder ecotypes have also been carried out at the

Katumani Research Station. Nine promising ecotypes have been pre-selected and screening tests are still continuing. Table 10 gives the dry-matter yield as compared to that for Bajra Napier.

The reason underlying the decrease of yield in the long rains 1983 is the low rainfall received. The best ecotypes in both seasons responded better to more moisture availability. It is also seen from the table that some of the ecotypes compared very favourably with Bajra Napier in both good and bad years. An added advantage of those that compare well with Bajra was that they had a higher leaf-to-stem ratio and stayed even longer into the dry season. Those ecotypes of Panicums are therefore rapidly increasing in importance as fodder crops for small farmer systems.

Table 10. Dry-matter yields of Panicum maximum ecotypes as compared to the yield of Bajra Napier (t/ha)

Ecotypes	1982/83 short rains Good season	1983 long rains[a] Bad season
	DM production (t/ha)	DM production (t/ha)
P. maximum K52-129	4.62	1.79
P. maximum K8168/72	4.05	1.59
P. maximum K5383	3.29	1.51
P. maximum K74.2367	3.23	1.51
P. maximum K5918	3.13	1.61
P. maximum K1231	3.09	1.11
P. maximum K5083	1.91	1.07
P. maximum K5239/43	1.87	1.04
P. maximum K1234	1.59	0.71
Bajra Napier	5.43	2.57

SE Treatment mean = 0.279
CD at 5% = 0.81
CD at 1% = 1.09
a) The 1983 long rains were almost a complete failure.

Intensive animal production utilizing these fodder crops in an integrated feeding system is a possibility, although it can be a delicate undertaking in semi-arid situations because the farmer gives priority to growing food crops. Forage crops can only become part of the cropping system after improvements in food crop husbandry have resulted in two- or three-fold yields. Secondly, the impact of cultivated fodder crops on profitability depends upon the net income margin between the animal product and food-crop production.

Studies have been carried out at the Katumani Station to measure the amount of milk produced when fodder was fed as the sole source of feed made available to lactating dairy cows. Table 11 shows the milk production and dry-matter intakes of cross-bred lactating cows fed on Bana grass ad libitum as compared to milk production from similar cows supplemented with Bana grass plus dairy meal.

Table 11. Milk production from cross-bred dairy cows supplemented with Bana Napier grass fed ad libitum compared with cows supplemented with Bana Napier grass fed ad libitum plus dairy meal (16% protein commercial feed)

	Treatments		
	Bana grass alone	Bana grass + dairy meal	SE
Number of cows	18	18	
Number of days	143	143	
Average number of days after calving	163	177	
Average daily milk per day (kg)	6.56	9.75	1.32 (P<0.05)
Total milk yield/animal for period	938	1,395	
Average DM intake per animal per day (kg) as fed			
Bana	48.0	47.0	
Dairy meal	0	1.85	

Significant differences were observed between the treatments, as expected, in view of the wide differences in the feeding systems. However, the main goals were to see the magnitude of the difference and to determine the level of milk production that could be supported by the Bana grass alone. The table shows that Bana grass fed ad libitum level can support up to 6.56 litres of milk per day without recourse to concentrate feeding. The group on Bana grass plus dairy meal gave 30% more milk per day than those fed Bana grass alone. To increase the milk output from an average of 6.5 kg to an average of 9.75 kg per day, an additional intake of 1.85 kg of dairy meal was required. The expected increase from 1.85 kg concentrated feed was 4.6 kg of milk. The responses in this study showed that this method is not an economically attractive proposition. Such studies reinforce the role of fodder crops in small-scale dairy systems.

Crop residues

Cropping is now being practiced on substantial portions of the semiarid dryland areas and it is anticipated that more areas of the region will be put under crops in coming decades. In Kenya, most of the dryland areas are found in the Coast, Eastern and Rift Valley Provinces. Here the principal food crops with residues that are suitable for animal feeding are maize, sorghum, millet, beans, cow peas, pigeon peas, cassava and sweet potatoes. Maize is the most abundant, followed by sorghum, beans and pigeon peas.

At present, crop residues have a variety of uses including animal feeding, fuel, mulch, bedding and for returning organic matter to the soil. However, the utilization of crop residues for animal feeding is likely to be greatly increased in the future since:

1) crop production is increasing, following increases in acreages as well as yield, and

2) acreages of grazing lands and lands under fallow are being reduced making it necessary for animals to depend more and more on crop residues for part of their nutrition.

Table 12 shows total land areas under the three main cereal crops and yields and crop residues produced in the three provinces. The total quantity of residue available is then estimated by assuming a 1:1 grain to stover ratio. It can be seen from the table that a substantial amount of residue is produced seasonally from just these three crops. If we assume that one ton of maize stover produces 7,560 MJ of gross energy (Morgan Rees et al, 1977), the contribution that these feedstuffs can make to the feed budget is substantial.

Table 12. Land area (ha) under maize, sorghum and millet and amounts (tons) of the crops and crop residue produced in Coast, Eastern and Rift Valley Provinces (1982)

Province	Crops grown	Area (ha)	Crop yields (kg/ha)	Residue (tons)
Coast	Maize	51,570	831	42,855
	Sorghum	520	615	320
	Millet	160	375	60
Eastern	Maize	357,510	1,274	455,467
	Sorghum	34,300	528	18,110
	Millet	33,380	401	13,385
Rift Valley	Maize	153,220	1,191	182,485
	Sorghum	380	1,042	396
	Millet	2,750	495	1,361
TOTAL				714,439

Source: Ministry of Livestock Development 1983 Annual Report

At present, crop residues are the second most important feed resource available to livestock in the dryland areas of Kenya. While they are generally used after each harvest season, these residues may be the only source of feed for a large number of livestock for a period of one or two months at the end of the long dry season when natural grazing is drastically reduced. Some farmers collect and store these residues especially maize and sorghum stovers, while the bulk is left for the animals to graze in situ after the-harvest, thus losing a considerable amount from trampling wastage. Because of the difficulties of collection, transportation and storage, only a small part of the thousands of tons of crop residues available are used as feed, and when they are used, the efficiency of utilization is very low. These crop residues vary widely in nutritive value. The variations are due to differences in proportions of plant components such as the ratio of leaf-to-stem, genotypic differences and to environmental conditions of growth. Being deficient in several nutrients (protein, energy and minerals) and containing a number of factors that limit optimum utilization, these feed sources are of little value when fed as they are. The development by plant breeders of stiff-stalked and insect- and disease-resistant varieties of maize and sorghum may also result in varieties with high lignin content and low digestibility.

Improvement of the nutritive value of these feedstuffs can be achieved through:

a) treatment methods that increase the availability of nutrients, and
b) supplementation methods that correct nutrient imbalances.

It has been established by numerous research workers (Jackson 1978; Kategile et al 1981; Mwakatundu and Owen 1974) that processing of poor quality roughages by physical and chemical means can considerably increase the availability of nutrients in field-crop residues. In his review, Jackson (1978) reported that 10-20% increments in digestibility and more than 100% increments in voluntary intake can he achieved by processing. Physical treatments such as chopping do not increase digestibility but have the advantage of reducing wastage by reducing selection by the animal. They also increase the amount consumed. Treatment with alkali saponifies the linkages between lignin and fibrous fractions (cellulose ad hemicellulose). The lignin content is not reduced but digestibility is increased substantially.

Sodium hydroxide is the most fully investigated and widespread chemical applied to poor quality roughages. Its application, especially for small-scale operation, is usually discounted because it is expensive and difficult to handle. Of the alkalis tested, ammonia generated from urea is preferred because it provides both the alkali effect and a source of nitrogen for microbial fermentation. Supplementation aimed at alleviating nutrient deficiencies is another method of improving the utilization of low quality roughages. It is recognized that conventional energy and protein feeds such as grains and oil-seed cakes are not only unavailable but are also too expensive for the small-scale farmer. It is therefore necessary to consider cheaper, preferably home-grown supplements, e.g. fodder shrubs such as Leucaena leucocephala, pigeon pea stover, Sesbania, cassava leaves, sweet-potato leaves and vines.

Thinnings and stripping from crop fields are of little significance as supplements to poor quality roughages, for two reasons. Firstly, they are always available during the green season when plenty of green forage is available and little or no crop residue is being fed. Secondly, the crop fields (maize and sorghum) are thinned during the first weeding and at this time the thinnings amount to too little quantitatively. The farmer cannot afford to delay thinning in order to get bigger plants as this would lead to severe plant competition.

A number of palatable browse trees and shrubs exist in the region, e.g. Acacia spp., but they can only be grazed in situ. Small ruminants, especially goats, make better use of these feed sources than cattle. The growing of forage legumes such as Leucaena leucocephala, or the proper use of leguminous crop residues such as pigeon-pea leaves and stems and cassava leaves, seems to be a practical alternative to the problem of supplementing poor quality roughages.

A series of experiments have been conducted at the Katumani Research Station to:

a) determine the effect of alkali treatment of stovers;

b) determine the effects of supplementing stovers with protein sources; and

c) to evaluate the effect on weight changes in livestock fed with crop residues whose quality has been improved through various treatments and supplements.

Animal Responses to Treated and Supplemented Crop Residues

Table 13 shows the responses of sheep and goats to supplementation of treated and untreated stover with either Leucaena or pigeon-pea leaves and stems added to the diet. The trials were conducted during the dry season and the animals were grazed all day and supplemented with the diet in the evening.

It can be seen from Table 13 that the feeding of urea-treated stover improved weight gains in sheep and goats. In an earlier experiment, the feeding of untreated stover during the dry season only resulted in a daily gain of 19 g, while animals on grazing alone mostly lost weight during the dry season. It was not possible during this experiment to make an economic assessment of the value of the incremental weight gains from the feeding of treated stover when either Leucaena or pigeon-pea stovers were added to the diet as the animals were not immediately sold on the open market. But considering the fact that most animals lose weight during the dry season even the weight gains made with the Leucaena and pigeon-pea supplements were quite considerable.

Table 13. Responses of sheep and goats when supplemented with urea-treated and untreated maize stover and with either Leucaena leucocephala or pigeon-pea leaves and stems added to the diet

	Untreated stover + Leucaena[a]	Treated[b] stover + Leucaena	Untreated stover + Pigeon pea[c]	Treated stover + Pigeon pea
Number of animals (half sheep, half goats)	28	28	16	16
Number of days (trial)	90	90	110	110
Initial average weight (kg)	25.0	26.0	18.0	19.0
Final average weight (kg)	31.0	34.0	24.0	29.0
Average daily gain (g)	67	90	55	91.0
Average DM intake (g)	250	300	220	279

[a] = Leucaena leucocephala was fed as green chop and mixed with the stover at 20% of the dry-matter offered.

[b] = Treatment of stover was by 5% urea solution added to the chopped stover and the material kept in an airtight bin for 20 days before feeding.

[c] = Pigeon-pea residue (after grain harvest) was fed as green chop and mixed with the chopped stover at 50% of the dry-matter offered.

Summary

The primary source of feed in the semi-arid dryland farming systems is natural pasture. Improvement in the management and utilization of this important feed resource should thus be an essential point of departure for the development of a more productive livestock feeding system.

Total animal dry-matter production yield of the natural pasture (2,335 kg DM) was reasonably high when properly utilized. The high dry-matter yields are undoubtedly a function of the bimodal rainfall pattern that is common in the semi-arid regions of Kenya and this has a favourable effect on forage growth-cycle. Marked seasonal variations are observed in dry-matter yields, and the rates of growth were highest in May and December which corresponded with the times of highest rainfall. Trends in nutritive value, especially crude protein, followed the same pattern.

Mean liveweight gains from steers, sheep and goats showed pronounced seasonal variations. Compensatory gains during the green season compensate for the losses made during the dry season and sustained liveweight gains of 160-180 g per day per steer and 35-40 g per day per sheep and/or goat over a year's cycle.

Forage grasses and fodder crops offer the best possibilities for improving livestock products per animal and per land unit. A number of suitable pasture grasses, legumes and fodder crops have been identified. Among these are many Panicum species, Cenchrus ciliaris, Cynodon dactylon, varies varieties of Napier grass (Bana, Bajra, French Cameroon cultivars), the fodder Panicum ecotypes, Macroptilium atropurpureum, Stylosanthes scabra and Leucaena leucocephala.

Trials conducted to determine the amount of milk produced when fodder (Bana) was the only source of feed available to the grazing cow resulted in average yields of 6.56 kg of milk per day.

A series of trials to evaluate the results of various physical and chemical treatments and supplementation of stovers showed that the nutritive value of crop residues can be considerably improved. The method that showed the greatest potential for application seems to be that of supplementing these feedstuffs with home-grown proteinaceous feedstuffs such as Leucaena leucocephala or pigeon-pea leaves and stemps.

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Research on feed resources for small ruminants on smallholder farms in Western Kenya

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Abstract

The paper discusses the history of land-ownership patterns and agro-ecological zonation which have provided the basis for the complex smallholder farming sector in Kenya. Evidence is presented for the availability and costs of feeds being major constraints to improvement in levels of production, both per animal and nationally, for all livestock classes. Specific detailed consideration is given to the feeding of dairy cattle on the prevailing small, mixed farms, due to the national policy of expansion of local milk production to raise the level of human nutrition in general, and school children in particular. The difficulties associated with the high densities of population of both people and livestock, low feed availability and competition for resources with arable enterprises are among the constraints discussed in relation to possible feeding systems. The second half of the paper contains details of the latest available data on on-farm availability and possible future options and trends for ruminant feed supply on the small farm in Kenya. Fodders and pastures, on-farm and industrial by-products, bought-in roughages and concentrates are discussed in turn.

The relevance of the recent Kenya experience to future trends in smallholder livestock production systems in other countries of sub-Saharan is emphasized.

Introduction

Small-scale farmers in Kenya own between 1 and 4 ha of land (Jaetzold and Schmidt 1982). The land use is divided among food and cash crops and livestock. The livestock on these farms may include cattle, sheep, goats, donkeys and poultry. The main sources of feeds for small-scale farmers are:

1. Communal grazing land;
2. Fallow land on farms;
3. Feeds from food-feed crops; and

4. Crop residues (Onim et al 1984).

Due to very high population densities, up to 900 people/km² in some areas (such as western Kenya), sub-division of farms has substantially reduced pasture and fallow lands to the extent that cattle populations in those areas are diminishing rapidly (Russo et al 1983). Lack of adequate grazing land has led to intensive management methods such as tethering and zero-grazing. This situation has also led to more farmers reverting to small ruminants instead of cattle because smallstock require less forage and are therefore more adapted to the scarce and erratic feed supplies on small-scale farms.

Several methods have been developed to improve feed supplies on small-scale farms. These include estimating feed values of common plant species consumed by goats (Otieno et al 1984), total feed production capabilities of pastures and small-scale farms (Onim, Hart, Russo, Otieno and Fitzhugh 1984), potential of intercropping food with feed crops to increase livestock feeds (Onim, Hart, Otieno and Fitzhugh 1984) and the potential of food-feed crops (Onim et al 1984).

This paper reports results of experiments and surveys on the potential of simplified hay baling, roadside and fallow-land pastures, sugarcane tops and sesbania (Sesbania sesban var. nubian) as sources of livestock feeds under intensive management in small-scale farms.

Materials and methods

Productivity and Pasture Quality of Roadside and Fallow Lands

In order to estimate forage productivity and quality of roadside and fallow lands in western Kenya, forage sampling and analyses were done. A quadrat measuring 80 x 80 cm was randomly thrown on to representative parts of the pasture. The enclosed vegetation was clipped and weighed fresh. Later oven-dry weights were recorded. Sub-Locations, Locations, Districts and altitudes of the sites where the samples were collected were recorded. This survey was conducted from Kapsabet town at an altitude of 2,000 m to Asembo Bay on Lake Victoria at 1,190 m. A similar procedure was used to sample farms in three research areas once a month for 12 months.

Other feed resources on the farms were also estimated. These included crop residues, fence and hedgerow cut-and-carry, and crop thinnings and leaf strippings. The samples were analysed for neutral detergent fibre (NDF), acid-detergent fibre (ADF), acid-detergent lignin (ADL), hemicelluloses (HC), and crude protein (CP).

Goats have also been observed while grazing or tethered in the same pastures and the plants that they ate were recorded. Plant parts that they consumed were clipped and analysed for CP.

Simplified Hay Baling for Small-Scale Farmers

The extra feed produced from the new feed interventions and during the rainy season is often grazed down as soon as supplies begin to become scarce. It is important, therefore, that farmers find a suitable preservation method that could help them to carry over the surplus feeds to the periods with deficits. Since attempts to devise successful silage-making techniques for small-scale farmers in western Kenya have not been successful at Maseno, a hay-baling experiment was initiated.

Several high-yielding forage legume and grass species that are grown by the SR-CRSP respondent farmers in western Kenya were used. These included Sesbania (Sesbania sesban var. nubian), pigeon pea (Cajanus cajan), leucaena (Leucaena leucocephala), bana grass which is a cultivar from a cross between Pennisetum purpureum and P. typhoides, Sudan grass (Sorghum sudanense) and mixed grasses from fallow land and pastures. The mixed grasses mainly comprised star grass (Cynodon dactylon), couch grass (Digitaria scalarum), congo signal (Brachiaria ruziziensis), Rhodes grass (Chloris gayana) and a few minor forage legumes such as Glycine spp. and Desmodium spp.

Except for Sesbania and leucaena the other forages were cut in the morning from around 8.00 a.m. and allowed to dry in the field. Sesbania and leucaena were cut and the branches were placed on polythene sheets onto which drying leaflets dropped. The average air temperatures in the sun were taken at 10.00 a.m., 12 noon and 2.00 p.m. Fresh sub-sample weights of each forage were determined as soon as it was cut, and thereafter every 2 hours for 10 hours. Wooden baling box measuring 85 cm x 55 cm and 45 cm deep was used for making bales. These dimensions were chosen in order to make a well pressed bale that weighs 20 kg. This is the average weight of a commercial grass-hay bale. Sisal twine strings were placed lengthwise and crosswise in the baling box. The number of strings placed varied according to the nature of the hay to be baled. The short-straw grasses, for example, needed more lines of twine than long-straw types. The hay was placed over the strings in the baling box until it was full. The hay was then compressed by one man jumping on it. With the help of an assistant, the strings were tightly tied. The finished bale was then pulled out and stored in a bale barn for six months.

Crude protein (CP) of fresh forages in this experiment were estimated. CP values were again estimated six months later.

Supplementation with Energy and Protein Sources

In western Kenya, farmers supplement the forages that the livestock consume in pastures and under tethering with cut-and-carry and purchased forages. Experiments with various legume fodders have been conducted.

Experiments with Legume Fodders as Supplements

Intercropping pigeon pea (Cajanus cajan) and Sesbania (Sesbania sesban var. nubian) with maize (Zea mays) was tried in four sites, Kaimosi, Hamisi, Maseno and Siaya, in 1983 and 1984. DM yields and CP contents of these forages were estimated. Leucaena (Leucaena leucocephala) and gliricidia (Gliricidia sepium) were planted in pure stands at Maseno Research Station and the same parameters were estimated.

Purchased Fodders as Supplements

Zero-grazing is a common practice in densely populated areas of Central, Nyanza and Western Provinces. When farmers are short of planted fodder they often purchase from the open market. A survey was therefore conducted around Maseno to determine which fodders were sold and at what prices.

Market fodders were purchased and weighed before the plant parts that could be consumed by sheep and goats were separated and reweighed. These were then dried in an oven before DM was recorded. Quality analyses for the market samples will be done later.

Results and discussion

Productivity and Pasture Quality of Roadside and Fallow Lands

Feed production figures for a 1.5 ha farm in Masumbi, Siaya District taking into account communal grazing, fallow land, crop residues and hedgerow cut-and-carry forages are presented in Figure 1.

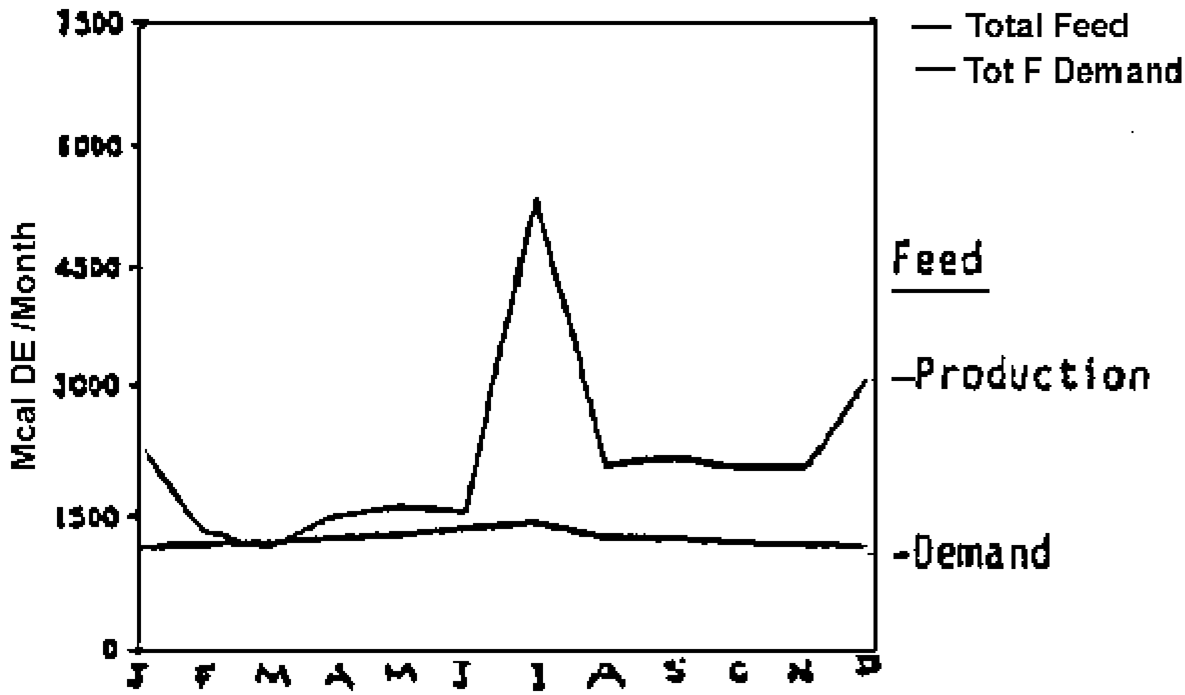
The demand line represents feed requirements of the livestock of an average household (e.g. three cows with calves, four sheep and three goats). The production line represents digestible-energy (DE) fluctuations through the year. These results show that feed deficits occur from January to May. Surpluses are realized during the rainy season from May to December.

The dominant plant species that the goats consumed in roadside and fallow-land pastures are given in Table 1.

Table 1. Crude-protein content of promising feeds consumed by goats in western Kenya

Forage/feed	CP %
Grasses	
Sorghum sudanense	14.1
Brachiaria brizantha	16.2
Digitaria scalarum	13.2
Cynodon dactylon	21.7
Mean	16.3
Common weeds	
Bidens pilosa	21.0
Lantana camera	24.1
Galinsoga sp.	14.4
Amaranthus sp.	32.5
Commelina sp.	26.3
Argemone mexicana	18.3
Leonotis mollisim	25.2
Tagetes minuta	26.8
Mean	23.6

Figure 1. An average year-round feed production and demand on a 1.5 ha farm in Masumbi, Siaya, western Kenya



Source: Onim, Hart, Russo, Otieno and Fitzhugh (1984)

The grasses had a mean CP of 16.3%, with star grass showing a high value of 21.7%. Common weeds had an average CP level of 23.6%, with several individual species having very high levels. These included Amaranthus (32.5%), Tagetes minuta (26.8%), Leonotis mollisima (25.2%), Lantana camera (24.1%) and Bidens pilosa (21.0%). These protein values indicate that when livestock graze in these pastures and get enough DM to consume, they get adequate CP and DE.

The effect of altitude on fibre and CP content of roadside and fallow-land pastures in western Kenya is shown in Table 2. There were no altitudinal effects on NDF and ADF, but ADL increased by an average of 1% with every 20 m drop in altitude. This indicates that plant species in lower altitudes had a higher lignin content and hence were of poorer quality as forage. However, RC increased with altitude at the rate of 1% CP for every 60 m. These results indicate that lower areas in western Kenya have poorer pastures than higher ones. We have also shown that food-crop DM yields are five times greater at an altitude of 1,800 m compared to 1,200 m. Rainfall seems to be the main factor here.

Table 2. Effect of altitude on the mean fibre and CP content of roadside and fallow-land pastures in western Kenya

Sample size	District	Altitude (m) range	Fibre (%)				
			NDF	ADF	ADL	HE	CP
3	Nandi	1,865-1,965	67.3	24.3	4.6	42.7	16.0
1	Nandi	1,765-1,865	77.0	30.8	11.8	46.2	20.7
12	Kakamega	1,665-1,765	80.8	32.2	11.6	41.9	12.2
2	Kakamega	1,565-1,665	68.3	34.3	7.9	36.5	7.5
2	Kakamega	1,465-1,565	57.9	26.7	10.1	31.2	12.7
4	Siaya & Kisumu	1,365-1,465	63.8	33.4	12.0	30.4	10.3
1	Siaya & Kisumu	1,265-1,365	74.3	35.3	14.5	39.0	15.4
2	Siaya & Kisumu	1,165-1,265	75.3	37.3	12.6	38.3	10.0

The rate of moisture loss by the various grasses varied. The three legumes - leucaena, sesbania and pigeon pea - dried fastest. On average, these three lost moisture at the rate of 66% in the first four hours of drying compared to 46% for Sudan grass and mixed grasses. This difference was caused by differences in leaf sizes and structure. The legumes have compound leaves, while both sesbania and leucaena have compound bipinate leaves and pigeon pea has simple trifoliate leaves. The leaflets in both sesbania and leucaena are small and thin, while those in pigeon pea are larger and thicker. The stems and twigs of the legumes were not considered part of the hay being made. However, the legumes were not considered part of the hay being made. However, in the grasses, leaves and stems were dried as hay. Since stems were thicker than leaves, they slowed down drying in grasses. Slow drying was most marked in bana and Sudan grasses which had thick stems. It was interesting to note, however, that although Sudan grass did not have as thick stems as bana, it had the slowest drying rate.

Since the moisture content of hay should be around 15%, these results indicated that the three legumes should be dried for six hours, bana and mixed grasses for eight hours and Sudan grass for more than ten hours. These drying times will increase on days when sunshine is inadequate.

The CP values and percentage changes in CP of the fresh forages and six-month-old hays are presented in Table 3. These results show interesting differences between grasses and legumes. The CP of Sudan grass did not change from fresh to six-month-old hays. That of bana grass showed a slight increase (11.1%) and that of mixed grasses showed slight decrease (8.7%). The changes in the three legumes are, however, much larger. Leucaena showed a CP drop of 27.4% in six-month-old hay as compared to the fresh forage. Jones and Megarrity (1983) have reported that the poisonous protein mimosine constitutes between 3 and 5% dry weight of leucaena. This protein is believed to disintegrate upon drying, rendering dry leucaena less poisonous. It is possible that these changes may be associated with the observed reduction of CP in leucaena hay after six months of storage.

CP in both pigeon pea and sesbania increased by more than 30% fresh forage to six-month-old hay (Table 3).

Table 3. Crude-protein content of forages and their hays

Species	% CP in fresh forage	% CP in 6-month-old hay change	% CP + -
Sudan grass	13.8	13.4	-2.9
Bana grass	14.4	16.0	+11.1
Mixed grasses	10.3	9.4	-8.7
Leucaena	26.6	19.3	-27.4
Pigeon pea	28.2	36.7	+30.1
Sesbania	26.9	36.0	+33.8

This increase indicates that some changes occurred in the plant tissue as it dried or during storage that favoured increased synthesis of CP. Fungal growth could be a plausible explanation, but both hays dried fast and maintained a moisture content of only 4% throughout storage, thus minimizing this possibility. This observation requires further investigation, perhaps with the inclusion of other legumes. It would be beneficial to livestock not only to be fed the hays during the dry season but also to be able to utilize a better quality feed even than that used during the wet season.

Supplementation with Cut-and-Carry and Purchased Forages

Farmers in western Kenya do not only supplement their livestock with cut-and-carry forages from hedges and planted fodders, but also with forages purchased from the markets. Some of the weeds and planted forages that farmers use as cut-and-carry were presented in Table 1. The results show that if livestock consume adequate DM, then their protein requirements will also be supplied. It is interesting to note that farmers specifically select and cut forages that are liked by the livestock and these are usually those with high protein levels. An example of such a species is Leonotis mollisima.

Another interesting species is sesbania. Farmers in western Kenya save it when they are weeding their food crops. The leaves which are 26% CP, are consumed by goats, sheep and cattle and are also believed to have medicinal uses. Sesbania roots fix up to 600 kg N/ha/yr and the stems provide fuel wood estimated at 40-60 t/ha. Sesbania leaves make an excellent protein supplement for livestock.

The types of forage purchased from the markets near Maseno are presented in Table 4.

Table 4. Partitioning of DM of purchased forages into consumable and unconsumable portions of small ruminants

Date	Types of forage	Total DM (kg)	% DM of purchased sample			
			Cattle		Sheep and goats	
			Consumable	Unconsumable	Consumable	Unconsumable
17.10.85	Sugarcane tops	5.08	2.45	2.63	34.44	17.89
17.10.85	Sugarcane tops	4.10	1.82	2.28	27.96	17.26
17.10.85	Napier grass	1.49	0.92	0.57	30.58	14.19
6.11.85	Napier grass	2.45	1.97	0.49	16.97	10.63
17.10.85	Green maize stover	4.14	3.38	0.76	19.99	10.75
6.11.85	Green maize stover	4.05	2.86	1.19	24.46	15.85
6.11.85	Green maize stover	4.28	2.68	1.60	25.16	16.97
17.10.85	Mixed riverside grasses	1.57	1.57	-	22.35	-
24.10.85	Mixed riverside grasses	4.01	4.01	-	28.64	-
23.10.85	Mixed riverside grasses	4.16	4.16	-	33.31	-

For small ruminants, the consumable portion of the purchased green maize stover, Napier grass, and sugarcane tops constitutes approximately 50%. For cattle, the whole sample can be consumed if it is chopped up. All mixed riverside and roadside grasses can be consumed by both smallstock and cattle. DM in the leaves about twice that in the young stems of maize, Napier grass and sugarcane tops.

Prices that the farmers pay for DM/tonne of the purchased forages are presented in Table 5.

Mean prices for portions consumable by small ruminants of sugarcane tops, Napier grass, green maize stover and mixed grasses were Sh 2,394, 3,443, 1,599 and 2,270/tonne DM, respectively. Although few farmers purchase fodder from the market, those who do so pay very dearly for it. These prices make such fodder crops attractive to grow, although there is only a small market for them at the moment.

Since sugarcane is widely grown in western Kenya and the tops are not utilized for livestock feeding, we felt it would be useful to estimate feed values of 10 top commercial sugarcane varieties. The results, presented in Table 6, show that most of the varieties have a very high fibre content.

Table 5. Costs of purchased forages on DM basis

Type of forage	Sample DM (kg)	Price of sample (Sh)	Price/tonne (KSh)	
			Consumble[a]	All
Sugarcane tops	5.08	5.00	2,040.80	984.25
Sugarcane tops	4.10	5.00	2,747.25	1,219.50
Mean	5.50	5.00	2,394.00	1,101.90
Napier grass	1.49	4.00	4,347.80	2,684.60
Napier grass	2.45	5.00	2,538.10	2,040.80
Mean	1.97	4.50	3,442.95	2,462.70
Green maize stover	4.14	4.00	1,183.40	966.20
Green maize stover	4.05	5.00	1,748.25	1,234.60
Green maize stover	4.28	5.00	1,865.70	1,168.20
Mean	4.16	4.67	1,599.12	1,123.00
Mixed riverside grasses	1.57	3.00	1,910.80	1,910.80
Mixed riverside grasses	4.01	10.00	2,493.80	2,493.80
Mixed riverside grasses	4.16	10.00	2,403.85	2,403.85
Mean	3.25	7.67	2,269.50	2,269.50

[a] By sheep and goats

Table 6. In vitro digestibility, fibre and CP content of the top 10 commercial sugarcane varieties in western Kenya

Variety	Fibre (%)					
	NDF	ADF	ADL	HC	IVD (%)	CP (%)
EAK7076	70.0	40.5	11.1	29.5	49.3	7.4
CO421	75.5	41.1	5.5	34.1	42.6	7.4
EAK69-40	92.5	57.6	7.9	34.9	47.7	8.7
EAK71-183	75.8	37.4	8.9	38.3	45.5	8.0
EAK7079	74.8	37.8	5.4	36.9	41.7	8.7
CO421	78.3	46.9	9.0	26.4	54.8	7.0
CO617	74.6	43.9	7.0	30.7	42.0	9.3
EAK6941	73.1	37.5	3.7	35.7	38.9	6.7
EAK71-420	73.1	39.2	3.6	33.9	46.6	6.7
CO1148	74.5	43.8	6.5	30.7	36.4	6.0

Their IVD values are also very low, and variable. In this regard it would seem that varieties 00421, EAK7076 (49.3%) and EAK69-40 (47.7%) may have some potential as fodder. CP levels of 7.6% were fairly low. However, because of the abundance of cane tops in western Kenya, they can be supplemented with cheap energy sources such as molasses and protein-rich sesbania to constitute an excellent feed not only for small-scale farmers even for fattening and in feed-lots.

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Small-ruminant production: The present situation and possible interventions for improvement

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Introduction

In tropical Africa there are estimated to be about 104 million sheep and 125 million goats (Jahnke, 1982) kept predominantly within the small-farming sector. It is only in highland regions that sheep outnumber goats (Table 1). Throughout the continent there are many different breeds, ranging from small trypano-tolerant animals found in the humid zone of West Africa to long-legged, rangy animals found in most arid regions. Day length in the tropics has little variation, females breed throughout the year, and variations in birth patterns from month to month are related to the plane of nutrition at the time of conception.

Table 1. Ruminant livestock population by species and ecological in tropical Africa

Ecological zone	Cattle	Sheep	Goats	Livestock units
	(x 10^6)	(x 10^6)	(x 10^6)	(x 10^6)
Arid	31.5	37.1	48.3	41.7
Semi-arid	45.5	23.1	33.2	37.5
Sub-humid	32.8	14.2	20.3	26.4
Humid	8.8	8.2	11.6	8.1
Highland	29.0	21.4	11.9	23.6

Source: Jahnke, 1982.

Mortality rates are usually high (25–40% per annum), and young stock are particularly at risk in the first three months postpartum. Neonatal losses can be closely correlated with birth weight, which is in itself a reflection of maternal nutrition during the final two months of gestation. The disease pattern varies from area to area and season to season. At all times animals that are undernourished will be at high risk. Undernutrition also lengthens kidding interval and decreases kidding percentage and growth rates which, together with survival rate, are components of productivity index.

Productivity index = KP x 365/KI x S x BW

Where

KP = kidding percentage/100
KI = kidding interval (days)
S = survival rate to weaning expressed as a proportion
BW = body weight at weaning

Thus any strategy to improve productivity of small ruminants must look closely at nutrition.

Table 2. The effect of alley farming on the yield of maize (tons/ha in southern Nigeria)

	1983 1st season maize	1984 1st season maize	1985 2nd season maize	1985 1st season maize
Continuous cropping (control)	2.19	2.55	1.16	2.49
Continuous alley cropping	2.54	3.75	1.45	2.83
	(1.16)[a]	(1.47)	(1.25)	(1.14)
Alley grazing/cropping	-	-	-	3.88
				(1.56)
Alley cropping/grazing	2.56	3.43	1.27	-
	(1.16)	(1.35)	(1.09)	

[a] Values in parentheses indicate yield expressed as proportion of control yield.
Source: Atta-Krah, Sumberg and Reynolds (1985)

Table 3. The effects of supplementary Leucaena and Gliricidia, with ad-libitum Panicum maximum, on the productivity of West African Dwarf sheep (mean ± SE)

Browse g/day	0	400	800
Parturition interval (days)	262 ± 13.5	226 ± 8.4	241 ± 8.9
Little size	1.26 ± 0.087	1.19 ± 0.082	1.17 ± 0.078
Survival to 90 days	0.65	0.65	0.82
Birth weight (kg)	1.80 ± 0.069	1.52 ± 0.073	1.72 ± 0.067
Daily liveweight gain to 90 days (g)	64.4 ± 2.98	73.4 ± 4.98	83.8 ± 3.69
Productivity index[a]	8.67	10.15	13.46

[a] Productivity index = kg of lamb weaned/dam/year.
Source: Reynolds and Adeoye, 1985.

The Current Situation

On the African continent food production for human consumption lags behind population growth and increased areas show a food deficit. Ruminants have a distinct advantage over simple-stomached animals, being capable of converting organic material unsuitable for human consumption into products of high nutritional value, while at the same time providing excellent fertilizer from undigested residues. Furthermore, in extensive farming systems, small ruminants, particularly goats, are complementary to cattle. Goats have catholic tastes and consume many more plant species than cattle. By preference goats are browsers rather than grazers while cattle take the opposite role. Provided an area is not overstocked, and in many areas of Africa that condition is unlikely to be fulfilled, goats and cattle together ensure a carrying capacity higher than would be possible for either species on its own.

The myth of the destructive goat should have been finally demolished by Staples, Hornby and Hornby (1942) who described the comparative effects of goats and cattle on fenced plots of semi-arid wooded grassland in central Tanzania. After four years of the trial considerable modifications had been effected to the plots. Goats browsed all plants within reach, but did not browse any plant down to ground level, so that none were destroyed as a result. Little bark damage was caused to trees, and young trees large enough to produce branches out of reach of the goats continued to grow. Thus a good ground cover was maintained at a stocking rate of approximately 1.4 livestock units/ha/year. In contrast, cattle, at a slightly higher stocking rate, concentrated on the grasses and eventually produced open thicket with little ground cover. Carrying capacity was reduced and erosion accelerated. Environmental degradation was therefore more likely from cattle than from goats. It is realized, however, that when an area is overstocked with goats damage to vegetation will occur.

In areas of extensive farming where the soil is of low agricultural potential, animal productivity is also low. There is little competition for the land and extensive livestock systems are most appropriate to the conditions. In such areas, despite the fall in nutritional value of maturing grasses, small ruminants are frequently better nourished than cattle because of their preference for browse (Marais 1983 and Coetsee 1983, 1984). In east Africa many browse species start to produce new growth ahead of the onset of rains. This contributes to a rising plane of nutrition and is associated with a peak in conception rates (Walker 1980; Reynolds 1985). The flush of young grass that accompanies the early rains, although highly nutritious, does not result in the expected increase in production. A concurrent rise in levels of both internal and external parasites also occurs (Adeoye 1985).

Forage availability during the dry season determines the overall carrying capacity of the land. On more fertile land the perceived needs of pastoralists and arable farmers compete. Throughout Africa, with increasing population pressure, former grazing areas are being used for arable farming and the true pastoralist is restricted to a decreasing area. Although it may appear contradictory, this can be to the advantage of the pastoralist. In a symbiotic relationship pastoralists can graze animals on crop residues in the dry season, and the settled farmer benefits from deposited manure. It has been demonstrated that this can result in an increase in overall carrying capacity because the crop residues can support more animals than natural pasture during the critical dry period. In areas of higher soil fertility and cropping intensity, local communities view wandering animals with disfavour, and may demand that livestock be penned or tethered. Most localities, however, have areas unsuitable for cropping that can be set aside for communal grazing; but overstocking will be a hazard. Traditionally, herding of livestock has been performed by children, but with the spread of primary education, and in some places compulsory school attendance, this source of free labour is decreasing and herdsmen must be employed. One response to these combined pressures is stall- or pen-feeding where animals are not allowed out.

A continuum of management systems can be found between nomadic pastoralism and stall feeding. Where do small ruminants fit into these systems? In most parts of Africa they are merely adjuncts to the farming systems, albeit important ones. Attention is paid to cattle while sheep and goats continue as they have done for generations. It is only under special situations in moderate- to high-rainfall areas, for example, where tsetse flies combined with government directives exclude cattle, that small ruminants assume a dominant role. Where such situations exist infrastructural development is invariably poor. Farmers have difficulty marketing their animals because roads and transport to centres of population, and hence consumers, is lacking. Prices paid by itinerant buyers to farmers are low, and profits accrue to middlemen rather than to the farmer. In some African countries the demand for goat meat is high enough to favour the development of the goat industry. At the other extreme, where demand for land is intense, there may be moves to exclude livestock completely.

Scope for Improvement

Small ruminants are raised under a low-cost system and farmers are less likely to buy feedstuffs or provide veterinary care for sheep and goats than for cattle. Interventions that call for expenditure are unlikely to be adopted widely, while those that are simple adaptations of existing systems could be more acceptable.

Productivity can be improved by two major routes, with a degree of interdependence. The first involves improved health care, which reduces the mortality rate. ILCA (1985) have shown that prophylatic health measures in south-west Nigeria allowed goat numbers to rise over a two-year period by 118% compared with a 24% increase in control villages. The possibility of overstocking must always be borne in mind. However attractive increasing flock size appears in the short term, it is a long-term recipe for disaster unless forage availability is also increased. Are more animals needed or could higher productivity be achieved through better nutrition and health care while reducing the total population? If a reduction in numbers is to accompany health and nutrition interventions, this necessitates increased offtake. Are existing marketing arrangements adequate?

The second major route is through improved feeding. The form taken by any nutritional intervention will depend upon the overall farming system employed and environmental conditions. Certain questions must be asked whatever the farming system. What can be found on the uncultivated land? What is available from crop residues? Is the farmer aware of the nutritional value of the potential feed resources? Will using that material as animal feed fit into the existing farming system? If not, what changes will be necessary?

It can be argued that extensive systems, implying little competition for the land from arable farmers because of low soil fertility and lack of water, are the most difficult to assist given the necessity of minimal cost interventions. The major feed resource in extensive systems is uncultivated browse and grasses. Goats, in particular, are capable of selecting the most nutritious plants, and parts of plants, obtaining a reasonably balanced diet throughout the year. It is rare to see extensively raised goats in poor condition unless carrying capacity is exceeded. Farmers may assist by lopping branches that would otherwise be outside the reach of livestock, and by providing water to animals overnight. This latter intervention will be particularly beneficial to lactating females since 86% of milk is water. Shortage of water will inhibit milk production. Bush improvement may be suitable for selected areas within cattle ranches, but is generally uneconomic for small-ruminant farmers. Communal agreement to reserve an area for dry-season feeding can be beneficial and has been successfully adopted in some areas. One such example is in West Mzimba, Malawi (Dzowela 1980) where the reserved area was improved with Stylosanthes guianansis cv. Cook.

A cost-effective approach for research workers is to check on mineral nutrition. Tissue and feed samples will show whether supplementation is necessary, if so, they can easily be incorporated into salt-licks. Use must be made of whatever crop residues are available. Crop residues left in the field will help to maintain soil structure through the provision of organic matter. Is it more beneficial to allow incorporation of residues into the soil or to return manure from livestock as a by-product of crop residue feeding? The value of feedstuff from a particular residue will be related to the overall feed situation. Where there is a shortage of forage, a residue of low nutritional value will assume a greater importance than when adequate feed is available. Under the latter conditions quality rather than quantity becomes the major factor.

As human population density rises, the importance of crop-residue feeding increases relative to uncultivated forage. Livestock can have free access to arable fields after harvest in addition to whatever natural forage is available. Animals grazing maize stover always waste part of the feed by knocking it over. Contamination with soil, urine and faeces occurs, and the resultant mixture is unpalatable. A bimodal rainfall patter limits access to first-season crop residues in situ because second-crop cultivation closely follows the first harvest. Access to fields after the second harvest is less restricted and labour is more readily available for collection and transport of residues to animal pens.

In many areas, maintenance of soil fertility depends upon the inclusion of fallow periods in the farming system. Regrowth during these periods can be available to animals. ILCA in West Africa have shown that alley farming, the use of leguminous trees such as Leucaena leucocephala and Gliricidia sepium in rows, with food crops between the rows, provides mulch and browse to the advantages of both crops (Atta-Krah, Sunberg and Reynolds 1985, Table 2), and livestock (Reynolds and Adeoye 1985, Table 3). This provides high-quality feed on a cut-and-carry basis for confined animals. Emphasis is placed on managing the trees to ensure maximum forage availability for the dry season. In addition, mulch helps to maintain soil fertility (Kang, Grimme and Lawson 1985) and reduces the need for a fallow period so that a higher proportion of available land can remain under cultivation.

The resultant crop residues are important feed resources during the dry season. The same question that was raised earlier, whether the farmer is aware of the value of crop residues, must be asked here. In addition, household and small-scale food-processing wastes, such as maize bran and cassava peels, may also be available. Maximum use must be made of them since as energy sources they complement high-protein browse. Less wastage of feed occurs in cut-and-carry systems but the labour requirement is naturally, high. In the Oume Province of the Republic of Benin, with confined animals on a cut-and-carry system, forage is deliberately spread on the floor so that much of it becomes unpalatable. Food residues, mixed with urine and feaces, are composted in situ and the resultant manure is highly valued. Animals are kept, therefore, to provide manure, with meat as the by-product of the system (Atta-Krah, personal communication). Does the labour requirement for a cut-and-carry system conflict with other farm activities? Who owns the animals, and who looks after them during the owner's absence? The farmer puts a low cost-value on his labour, but in any economic analysis labour time will be charged at the market rate. What is the return that the farmer can expect for his extra labour and is this economic system?

Where there is only a limited amount of supplements available, preferential feeding of these to animals in late pregnancy and lactation is advisable. This will ensure that animals under the greatest nutritional stress will benefit. In intensive systems the provision of extra rations prior to malting (steaming-up) has been demonstrated to increase litter size, particularly when breeding females are in poor-to-moderate body condition initially. With an extensive system and year-round breeding it would be difficult to implement steaming-up, but where confinement is practiced implementation is quite feasible.

It is possible to select for twin-bearing females to increase the overall kidding percentage of the flock, but unless adequate nutrition is provided this may simply result in a higher mortality rate. A close inverse relationship exists with birth-type classes between birthweight and mortality rate. Single offspring are heavier at birth than twins, which in turn are heavier than triplets. Neonatal deaths amongst offspring from multiple births is higher than for singles. Undernutrition of the dam during the final two months of gestation, when foetal growth is greatest, will adversely affect birthweight. Improvement of the genetic base must, therefore, be accompanied by good nutrition, otherwise the additional potential, gained at such cost during selection over a number of years, cannot be realized.

Selection for improved growth rates to weaning, in part at least, is selection for higher milk production from the dam. Milk yield will depend on both condition, nutrient intake, and number of offspring being suckled, as well as on genetic potential. When the crude-protein level in natural grasses is low and lignin levels are high, as happens after flowering in maturing plants, digestibility will fall. At this stage the provision of additional nitrogen, whether from browse or from urea, will increase rumen microbial growth rates and improve digestibility. This, in turn, will be matched by a higher food intake because of a faster rate of passage of food through the gastro-intestinal tract. Thus the nutrient intake of lactating females on poor-quality forage can be greatly improved by the provision of browse.

Milk production from small ruminants kept for meat has received little attention in Africa, and it may be useful to extrapolate from cattle data, differences in response to supplementary feeding during lactation have been noticed between beef and dairy breeds. Incremental increases in feed intake of dairy cows have most effect on total milk production during the early lactation period and decline thereafter (Broster, Broster and Smith 1969). Hart et al (1975), in a matched-pair trial with beef and dairy cows, showed that beef cows gained weight but produced little milk, while dairy cows on the same level of feeding lost weight but had a high milk yield. Supplementary feeding of small African ruminants and Zebu cows at any stage of lactation produces a response comparable to that observed in temperate beef cattle. Genetic selection for high milk production has increased the importance of early-lactation feeding, but in meat animals the timing of supplementation during lactation is less critical. Nevertheless, milk production is important, ensuring as it does a high pre-weaning growth rate. Zebu cows are sometimes expected to provide milk for human as well as for calf, often to the detriment of calf growth. Lambs and kids are less likely to be affected since human consumption of sheep and goat milk is less widespread.

Conclusion

Small-ruminant production by small farmers is at present a low-cost enterprise. Development agencies must take this fundamental point into account, and look first for modifications of the existing farming systems before proposing drastic changes. Low-cost intervention might include pro of water in pens, maximum use of residues from small-scale food processing, household wastes, crop residue utilization and the reservation of areas of the bush for dry-season use. The use of leguminous trees for browse should be considered.

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Feed resources for dairy farmers in Kilimanjaro, Tanzania

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Abstract

Smallholder dairy production has become an important agricultural activity in Kilimanjaro area in recent years. Land is very scarce in the region, particularly in the area immediately surrounding Mt. Kilimanjaro. Scarcity of feeds is one of the major constraints facing these smallholder dairy producers. The feed resources commonly used are grass cut and transported from the lowlands, established pastures, crop residues and agro-industrial by-products. Increased productivity of established pastures can be effected through improvement in agronomic practices, the inclusion of suitable legume species in pasture leys, and through better supply of pasture seeds. Utilization of crop residues can be improved through efficient handling and transportation, and supplementation for the most limiting nutrients. Organized markets and distribution networks for the agro-industrial byproducts will improve the availability of inputs and increase productivity.

Introduction

Kilimanjaro Region is one of the 20 administrative Regions that make up the United Republic of Tanzania. Most of the land in this Region lies at more than 800 m above sea level with Kibo peak, (the highest point in Africa) being 5,895 m. Because of the high altitude, the region has a mild climate with temperatures ranging from 17 to 34°C rainfall varies greatly from place to place. The humid, intensively cultivated highland area receives 1,000–1,500 mm annually, with the probability of at least 1,000 mm even in the driest years (Naveh and Anderson 1966). Agriculture is the main industry of the region, and since the 1930's the production of arabica coffee has played a major role in the economic development of the region. Other important crops include bananas, maize, beans, paddy, wheat and cotton. Coffee and bananas, are by far the most important crops, occupying about 55% of the cultivated land in the region as a whole and about 69% of the cultivated land around Mt. Kilimanjaro (Mlambiti, Edelsten and Colyer 1982).

Livestock raising is traditional, and despite the land problem, the region had 751,823 head of cattle, 192,810 goats, 99,211 sheep and 12,300 pigs in 1978 (Ministry of Agriculture 1978). Since the mid-1960's there has been an increasing tendency towards diversification away from coffee. This desire to diversify production has resulted from the threat of frequent outbreaks of coffee disease as well as the need to maximize the use of scarce land resource. As a result, dairy farming has developed-very rapidly in the past decade in Kilimanjaro area. In a recent survey conducted in one of the Districts (Urio and Mlay 1984) it was revealed that about 90% of the farmers raising cattle had replaced their indigenous Zebu cattle with higher-yielding crossbred animals.

Land is limiting, however, more than 60% of the farm holdings are less than 1 ha, and 80% are 2 ha or less (Table 1). As a result farmers have very few options for increasing fodder production, and scarcity of livestock feeds is one of the major constraints facing the smallholder dairy farmer.

Table 1. Proportions of holdings by farm-size group in Kilimanjaro Region

Farm size (ha)	Holdings in Moshi and Rombo Districts (%)	Holdings in Pare District (%)	Holdings in the Region
Under 1	65	82	72
1-2	22	11	18
2-3	8	4	6
3-4	2	1	2.0
4-5	2	1	2.0
5-10	1	0.5	0
10-20	0	0.5	0

Source: Mlambiti, Edelsten and Colyer. 1982

Feed Resources

For convenience the major livestock feed resources can be grouped into natural grasslands, established pastures, crop residues, agro-industrial byproducts, and others.

Natural Grasslands

As most of the smallholder dairy farmers in Kilimanjaro live in the densely populated highland areas, there are hardly any areas which can be reserved for herding cattle. All the cattle in the highland areas are stall-fed and feed has to be brought in from long distances. Nevertheless, the natural grasslands do play an indirect role in that grass is cut from the lowlands and transported to the mountain homesteads. The quality and quantity of such grass is typically affected by the seasonal variation in rangelands productivity. The grass is either carried on people's heads or, for those who can afford it, by hired pick-ups, tractors or trucks. This grass may contain such species as Cynodon, Digitaria, Echinochloa and indigenous strains of glycine. During the dry season, however, such grass may consist largely of mature Hyparrhenia and Themeda. Farmers may travel to the lowland areas and cut/harvest the grasses themselves, or they may purchase by the head-loads from hawkers.

Established Pastures

Kilimanjaro is one of the few areas in Tanzania where established pastures do play a significant role in livestock feeding. Three grass species are specifically grown for cutting and feeding livestock in Kilimanjaro. These are Setaria splendida, Pennisetum purpureum (elephant grass, Napier grass) and Tripsacum laxum (Guatemala grass). Nearly every small dairy farmer in Kilimanjaro has at least two of the above grass species in his pasture plots. Due to scarcity of land these grasses are grown mostly in rows and terraces between the coffee and banana plants, on farmstead boundaries and along road sides. The three grass species have become extremely popular in Kilimanjaro and there have been instances of farmers having up-rooted their coffee in order to give room for fodder crops. It is interesting to note that the widespread use of the above grass species has generally taken place largely through farmers' own efforts to supply fellow farmers with rooted cuttings for propagation free of charge. Despite the popularity there is still a tendency to neglect pasture and not to give it the degree of husbandry that is accorded to cash or food crops. Inputs such as fertilizers, proper spacing and irrigation could increase the yield and hence the productivity of these grass species several fold.

In addition to the above three grass species, a few farmers grow alfalfa and Rhodes grass but due to scarcity of land the acreage is very limited. Two commercial farms grow and sell bales of alfalfa and Rhodes grass hay, but their production is far outstripped by demand. The potential exists, however, for growing these fodder crops on a large scale and selling the bales to the smallholder dairy farmers who otherwise purchase low-quality grass.

A number of research projects in the northern part of Tanzania have had the specific objective of improving both the bulk and quality of the herbage on established pastures. Most of this work has concentrated on trying to find suitable legumes to include in mixtures with the three common grass species. Nevah and Anderson (1966, 1967) investigated the suitability of several legume/grass mixtures for the highland areas of Kilimanjaro and Arusha. They particularly singled out Desmodium uncinatum, which gave a dry-matter yield of more than 20,000 kg/ha, as well as two strains of Medicago sativa (Saladina lucerne and hairy Peruvian lucerne) as suitable legumes for inclusion in the pasture leys. Rapidity of germination, vigour, growth habit and seeding rate were factors considered of importance in addition to yield. In a later study at Lyamungu Research Station reported by Lugenja (1979) several Desmodium species were again identified as being suitable legumes for inclusion in the pasture leys (see Table 2).

Despite the apparent benefits of including legumes in pasture leys, farmers in Kilimanjaro continue to grow pure stands of the grasses mentioned. There is clearly a missing link between the research findings and their application at the farmers' level. Lack of seeds is one of the constraints to the adoption of legumes, but the farmers also have to be convinced of the actual benefits in terms of greater and higher-quality yields from the inclusion of legumes in the pasture plots taking into consideration the limited land resource.

Crop Residues

Two main crop residues are utilized as livestock feeds in Kilimanjaro. These are maize stover and bean haulms. Unlike other areas in the country where these crop residues are produced in the vicinity of livestock dwellings, in Kilimanjaro the crop residues have to be transported from the lowland areas to the highland homesteads. Transport is the main factor limiting the quantities utilized per year.

Table 2. Dry-matter yields of grass/legume mixtures for a five-year period at Lyamungu Coffee Research Station

Grass/legume mixture	Annual yield (tonnes DM/ha)				
	1972	1973	1974	1975	1976
Guatemala/Neonotonia wightii	26.3	17.8	13.5	13.3	16.2
Guatemala/Desmodium uncinatum	26.6	20.8	12.7	16.9	14.5
Guatemala/Desmodium intortum	39.7	20.6	13.7	12.8	12.7
Guatemala/Pueraria phaseoloides	26.3	12.2	13.7	11.0	12.0
Setaria/Neonotonia wightii	32.2	15.7	10.3	8.0	12.8
Setaria/Desmodium uncinatum	27.3	15.0	9.2	10.3	13.1
Setaria/Desmodium intortum	30.6	21.0	10.3	9.2	18.5
Setaria/Pueraria phaseoloides	23.7	14.2	9.4	10.6	13.6

Source: Lugenja 1979.

Current research work going on in Hai District has indicated that baling of these crop residues is beneficial and economical as it reduces bulk and greatly facilitates transport and storage. Use of hand operated hay binders has been proposed as a possible and probably more appropriate technology for smallholder dairy farmers.

Bean-haulm chaff is a product which appears to have promising potential, particularly if mixed with molasses. Appreciable amounts of this product are produced in West Kilimanjaro area, but again transport limits utilization.

Large quantities of barley and wheat straw are also produced in the West Kilimanjaro area, but due to the distance to the user sites, these are simply burnt.

Where transport is not a limiting factor, farmers make use of all the crop residues produced on their farms, and occasionally this may be supplemented by purchases from other farmers. All the crop residues are fed without any form of chemical treatments. Although considerable work has been done in Tanzania and elsewhere on upgrading the nutritive value of crop residues by means of chemical, these have become prohibitively expensive and their supply extremely erratic. For the time being the most appropriate way of improving the feed values of these crop residues is to supplement them with these nutrients known to be most limiting.

Agro-Industrial By-Products

These can be divided into two main categories: the milling by-products of cereals and the by-products of oilseed industries. The milling by-products commonly used in Kilimanjaro are maize bran, wheat pollard, wheat bran and rice polishings. The supply of these is, however, directly related to the production of the respective cereals. Since the production of cereals for human food is generally inadequate, the production of the cereal by-products for animal feeding is also in short supply. The limited amounts produced are available to the farmers sporadically and at high prices. When utilized for feeding these by-products are fed straight without mixing them with other ingredients and are generally fed only to lactating cows during milking times.

Although appreciable quantities of oilseed cake and particularly cotton-seed cake, are produced in Tanzania, very limited amounts are utilized by smallholder farms. Most oilseed cakes are produced in places distant from Kilimanjaro, and this leads to thigh transport costs. As with the cereal by-products, only limited amounts of oilseed cakes (mostly cotton-seed cake) are utilized by dairy farmers in Kilimanjaro.

Molasses, which is produced by a sugar-cane processing plant about 20 km south of Moshi town, has been used extensively for feeding livestock in Kilimanjaro area rather than elsewhere in the country. Until recently, however, use of this product was limited to well-to-do farmers, particularly those with transport. A distribution network has now been established for this product through the FAO/UNDP Dairy Development Project for Arusha and Kilimanjaro areas. Through this project, a small plant for mixing urea and molasses has been constructed at the sugar factory which produces molasses with 3% urea.

Collection centres have been constructed in selected villages where 10,000 litres of molasses can be stored and from which farmers can then purchase their requirements. Tanker loads are regularly delivered to these centres on request from the farmers. Plans have also been worked out to develop the molasses/urea-receiving centres into distribution centres for other inputs such as cereal by-products and oil cakes.

Other Feedstuffs

Traditionally banana pseudostems, banana leaves and banana peelings are perhaps the most important feed resource for livestock keepers in Kilimanjaro area. As is evident from Table 3, bananas play an important role not only as a staple food for the local people, but also as a reliable and important feed resource. Their low nutritive value notwithstanding, banana pseudostems and/or banana leaves are always mixed with other forage and the chopped pseudostems aid in moistening dry roughages such as maize stover, and thereby apparently increasing feed intake. Occasionally "Magadi" salt is sprinkled on the copped pseudostems and banana peelings to increase intake. Farmers do realise the low feeding value of banana pseudostems, but, on the other hand, they regard this as a reliable feed resource that is readily available whenever supplies of other forages becomes short.

Brewers waste is obtained from the Arusha and Moshi breweries, but the supply of this product is far outstripped by demand. Only a few farmers, particularly those with transport and 'contacts', are able to use this product for feeding their dairy cattle.

Table 3. Land-use categories in Kilimanjaro Region

Crop	Moshi District		Pare District		Region	
	hax 1,000	%	hax 1,000	%	hax 1,000	%
Coffee/banana	124.4	68.5	10.8	16.6	135.3	54.7
Maize	21.3	11.7	14.3	21.8	35.6	14.4
Maize/beans	30.4	16.7	3.1	4.7	33.5	13.6
Paddy	1.4	1.8	16.9	23.9	18.3	7.4
Fallow	0	0	12.4	18.9	12.4	5.0
Bananas	3.5	1.9	2.8	4.3	6.3	2.5
Cotton	0.5	0.3	2.6	3.9	3.1	1.3
Cassava	0.1	0.1	2.5	3.9	2.6	1.1
Total	181.7	100.0	65.4	100.0	247.1	100.0

Source: Mlambiti, Edelsten and Colyer 1982.

Conclusion

Farmers in Kilimanjaro and Arusha areas have a keen interest in dairy farming, perhaps more than any other area in the country. Due to land scarcity, however, feed resources are very limited. The productivity of the established pastures could be increased by applying proper agronomical practices, including application of manure/fertilizer, irrigation, and the inclusion of suitable legume species. Improvement or better utilization of crop residues through handling and transportation, and supplementing for deficient nutrients, could greatly increase feed supply and productivity. Organized markets and distribution networks for molasses and other concentrate feeds will facilitate input supply to farmers and increase productivity.

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Maize stover improvement with legume forages

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Abstract

A simple technology which integrates maize grain production with improved forage/pasture legumes is being tested in Malawi using the on-farm-/adaptive and station research concepts. This work focuses on the enhancement and more efficient utilization of maize stover, a cheap and widely available small-scale livestock feed resource as a byproduct of the national maize grain production system. Results of this work which is currently undertaken are discussed.

Introduction

In Malawi, agricultural crop production has reached unprecedented levels in recent years (Appendix 1). More importantly, maize grain production between 1974 and 1984 rose from 65,470 to 296,292 tonnes, an increase of 353%. Maize is the most widely grown crop, occupying some 1.0 million hectares of a total 1.7 million hectares devoted to smallholder agricultural production (Dzowela and Johnson 1984). It is the major cereal grain used for human consumption along with other cereal grains, rice (9,771 tonnes), wheat (960 tonnes) and minor cereal grains such as sorghum and millet. Since cereal-grain production has surpassed local demand by the country's human population of 7.2 million, some surpluses, particularly of maize, are being exported.

Recent estimates put the cattle population at about 1 million with an annual growth rate of 5%. The majority of these cattle belong to smallholders, with only about 4% of the total herd being on commercial estates (Booker Agriculture International 1983). Smallholder ownership is generally at the level of a few head per family and only about 11% of all households own cattle. Associated with this ownership pattern, therefore, is the problem of management, and especially improvement of feed resources.

In spite of high national cereal grain production, the use of cereal grain for animal small feed in the smallholder situation, a practice commonly associated with commercialized livestock establishments, risks a corresponding diminution of grain resources available for direct human consumption. The importation of animal feedstuffs is a further drain on national foreign-exchange reserves. The most logical course of action is to improve the management of natural forage/fodder resources, and especially the efficient utilization of crop by-products. The recent increase in national maize production of 296,292 tonnes represents enormous amounts of maize stover (Appendix 2).

Cattle Production Systems in Malawi

There are two systems of smallholder cattle production. The first one is based on zero-grazing in which animals (dairy or beef) never leave the pen and fodder/crop residues are taken to them throughout the year. This system is common amongst dairy and stall-fattening beef farmers. It has resulted in increasing amounts of high quality meat and milk produced from low cost-diets and is based primarily upon crop residues. The system makes negligible demands on land and utilizes waste materials and crop by-products such as maize stover and groundnut haulms. It blends very well with arable cropping and helps to provide a sufficient cash income for the smallholder. It also helps the rural farm economy and spreads the concept that cattle ownership can be profitable. Furthermore, the value of the dung from stall-fed cattle as a manure for crop production, particularly in view of the cost of organic fertilizers.

The other system is one of summer grazing and winter stall-feeding and grazing. It is less labour-intensive than exclusive stall-feeding. However, under this system, feed resources are so limited during the dry (winter) season that animal liveweight gains and milk production are curtailed. The situation is aggravated by bush fires which can wipe out all feed resources in the vicinity of farmsteads.

Improved Pasture Technology

Improved pasture technology in Malawi has been an extension effort throughout the dairy development areas. All smallholder dairy farmers are encouraged to establish Rhodes grass, Napier grass, buffelgrass or staff grass pastures occasionally with a forage legume such as Stylosanthes spp., Desmodium spp. or Leucaena leucocephala. Adoption of this technology is good for as long as the farmers are repaying the loan for the cost of the dairy cows and milking equipment. After this period, however, adoption is comparatively slow. The reasons advanced for this low adoption are:

(a) The high cost of seed and other planting materials. For example, Rhodes grass seed costs MK 6.50 per kg and one would require some MK 45 for seed just to establish one hectare of pure Rhodes grass sward.

(b) The high cost of fertilizer required to sustain sufficient forage production with annual applications of inorganic N-fertilizer. At current Agricultural Development and Marketing Corporation prices, inorganic N-fertilizer costs MK 1.67, MK 1.50 and MK 2.05 per kg N as ammonium sulphate (21% N), calcium ammonium nitrate (26% N) and 20:20:0 compound fertilizer (20% N), respectively.

Integrated Maize/Fodder Production

An increasing demand for dairy and meat products has prompted efforts to integrate maize production with fodder production. Maize stovers with groundnut tops are an important feed resource during the dry season on which the smallholder steer-fattening and dairy schemes depend (Mtukuso, Gray and Pervis 1983; Addy and Thomas 1976; Mtimuni 1982; Balch 1977; Kategile 1982). Addy and Thomas (1976) recorded feed protein values of 5.43 and 8.35% for maize stover and groundnut tops respectively. National Research Council (1976) proximate-analyses values intended for beef cattle show that maize stover has a metabolizable energy (ME) content of 2.13 Mcal/kg DM, marginally above the 2 Mcal/kg DM threshold value for meeting maintenance requirements. Addy and Thomas (1977), however, reported an ME value of 1.09 Mcal/kg DM for maize stover.

Maize stover is low in nutritive value. As a consequence, there have been numerous attempts to enhance the availability of energy, mainly through chemical-treatment procedures (Kategile 1982; Said 1981; Kategile and Frederiksen 1979; Kiangi 1981; Kategile et al 1981; Edelsten and Lijongwa 1981). This chemical-based technology, although successful in appreciably enhancing availability of energy, may not be appropriate for the Malawi smallholder livestock producer who may not have adequate finance handling resources.

Following the technique of work of Thomas and Bennett (1975a; 1975b) and Thomas (1975) the undersowing maize with forage legumes has been advanced in Malawi under this system, there is no deleterious effect on productivity of the maize crop. If anything, it results in the production of a crop by-product (maize residue) with a high legume content which could be utilized with the maize stover. The common practice in Malawi is to graze the maize stover in situ after the ears have been removed. The presence of an improved pasture, such as a forage legume, provides extra dry matter and crude protein essential for animal production during the dry season. Where maize is a cash crop, the cost of pasture establishment is absorbed by the maize crop enterprise.

The present paper discusses some research avenues in forage-legume establishment and production in maize crops. The primary objective is to enhance the utilization of maize stover in Malawi.

Materials and methods

On-farm Pasture Improvement Study

These pasture-improvement systems were tested in conjunction with the Adaptive or On-farm Research Team in the Kasungu Agricultural Development Division in which the target group was smallholder dairy farmers who wanted to improve their pasture resources as a pre-fallow operation following a maize crop. The pasture systems were:

(a) A pure Rhodes grass cv. Boma pasture undersown in a maize crop after the first weeding in January;

(b) A mixed Rhodes grass-Desmodium uncinatum pasture undersown in maize after the first weeding in January;

(c) A mixed Rhodes grass-Centrosema pubescens pasture, also undersown in maize after the first weeding.

The legumes were drilled on top of the maize ridges which were spaced 90 cm apart. The legume seed rate was 2.5 kg/ha, a rate of 5 kg/ha. The maize varieties used were either NSCM41, MH whereas the Rhodes grass was broadcast along the ridge furrows at 12 or local, all depending on individual farmers' choice. The maize was planted following standard cultural practices with respect to plant population and fertilization. Quantification of components of maize yield (stover and grain) was done in early May, but that of the forages was done early in June.

Main-station Maize Undersowing Study

Three blocks of a maize crop MH 12 were grown following standard cultural recommendations. Forage legumes, (Macrotyloma axillare, Neonotonia wightii and Centrosema pubescens) were undersown in the maize crops immediately after the first weeding when the maize was about 30 cm high. The legumes were drilled along the maize ridges. To encourage legume establishment and growth, maize leaves below the cob were stripped from the maize at the anthesis/pollination stage of growth onwards. One leaf was removed each week. Work conducted at Muguga in Kenya (Abate, personal communication), shows that removal of maize leaves below the cob contributes an important animal feed resource for the small-scale livestock producer without appreciably affecting grain yields. The physiology of the maize plant is such that only the leaves above the cob contribute effectively to grain-filling after anthesis and pollination.

Within the three forage-legume undersowing treatments, seven leaf-stripping treatments were superimposed and these were replicated three times. Components of yield (maize grain and stover) and forage dry-matter (stripped maize leaf and forage legumes) were measured. A chemical analysis of forage samples was done for crude protein values.

Results and discussion

In the on-farm study, the amount of forage produced was very small. This was largely due to it being an establishment year because of the smothering effect of the maize crop on the undersown forage. Yield differences in maize grain and stover between the three pasture systems were not significant. Discounting the maize-grain and stover yields which the farmers could have realized from a pure maize stand, the differences in the extra amounts of forage from these systems were considerable. Assuming that a mature 450 kg dairy cow consumes 3% of its own body weight in dry matter per day (i.e. 13.5 kg DM/day) then the pure Rhodes grass sward was capable of providing 92 extra days of feed. The Rhodes grass-Desmodium sward on the other hand, provided 66 days and the Rhodes grass-Centrosema sward 144 days.

Table 1. Yield components of the pasture undersowing systems

Pasture system	Maize grain yield (kg/ha)	Maize stover yield (kg/ha)	Forage yield (DM) (kg/ha)
Maize-pure Rhodes grass	6,100	4,403	1,240
Maize - Rhodes grass + Desmodium	5,479	4,605	887[a]
Maize - Rhodes grass + Centrosema	5,770	4,503	1,950[b]

[a] Of the total forage DM produced only 9% was contributed by the legume component.
[b] Of the total forage DM produced only 7% was contributed by the legume component.

Indications from other studies (Dzowela 1985) are that grass-legume swards have much higher crude-protein values than pure grass swards. Even so, the advantages of a mixed sward over a pure maize-stover feed resource are great in terms of crude-protein values (Table 2). Although the differences between the maize stover samples from the different pasture systems were not significant, the fact that the maize - pure Rhodes grass system not only provided extra feeding days but also an extra feed resource of higher protein value than a pure stover feed made this a very worthwhile intervention. There was an even better forage by-product from the maize-Rhodes grass-legume systems. This is further supported by work from ILCA (Table 3). The higher protein values of the pasture system in which a forage legume was included would certainly result in much better fodder utilization and better animal performance than those from a system in which maize stover was the only feed resource available.

Table 2. Crude protein values (% of DM) of forage components

Pasture system	Maize stover	Rhodes grass (hay)	Legume forage (hay)

Maize-pure Rhodes grass sward	3.75	6.80	-
Maize - Rhodes grass + Desmodium sward	4.69	7.50	8.80
Maize - Rhodes grass + Centrosema sward	4.12	7.65	9.69

In the maize undersowing study conducted on the maize station, the significant differences in maize grain yields between the three different forage legume systems were probably incidental (Table 4). A heavy storm affected maize on the station and lodged most of the maize in the Neonotonia and Centrosema-based blocks. This was because of their location far away from the Gmelina aborrea tree wind-breaks. This was most obvious in the form of poorly filled maize grains from these two systems. Although the more intense maize stripping treatments (5 to 7) resulted in lower grain yield, these reductions were not statistically, significant.

There were no differences in maize stover yields resulting from the forage-legume and maize-stripping treatments (Table 5). As expected, the amount of stripped maize leaf forage increased with the intensity of stripping from 1 to all 7 leaves below the cob (Table 6). However, the actual forage-legume treatments had no appreciable effect on the amount of maize leaf yield. There were differences between forage-legume treatments in dry-matter production (Table 7). Because of its very slow establishment Neonotonia wightii produced the least forage dry-matter. Contrary to expectations, the maize-stripping treatments did not appear to have any effect on forage-legume dry-matter production. It would appear that this maize stripping effect was nullified by the storm that lodged most of the maize. Light relationships in the maize crop canopy were not affected by the stripping of leaves because of the lodging which took place.

Table 3. Grain and fodder yields of sorghum when sown with forage legumes

Crop mixture	Grain yield	Crop residue	Legume DM (kg/ha)	Total fodder	Total CP
Sorghum alone	1,296	4,467 (2.7)[a]	-	4,467	126
Sorghum + S. hamata	313	1,685	2,278 (11.4)	4,463	363
Sorghum + S. guianensis Cook	388	1,555	2,063 (12.8)	3,618	326
Sorghum + C. pascuorum	1,019	2,981	1,296 (14.2)	3,407	241
Sorghum + Alicecarpus vaginalis	1,092	2,519	926 (10.8)	3,445	168
Sorghum + M. lathyroides	1,297	2,761	1,481 (16.5)	4,222	316

[a] Figures in parentheses are % CP of fodder crop
Source: ILCA Report, 1984

Table 4. Yields from undersowing trials: maize grain (kg/ha)

Pasture system	Maize leaf stripping intensity							
	1	2	3	4	5	6	7	Means
Macrotyloma axillare	5,466	6,750	7,890	7,614	7,435	7,080	5,792	6,861
Neonotonia wightii	6,548	6,920	6,428	6,775	5,352	5,812	5,291	6,161
Centrosema pubescens	6,212	4,845	4,962	5,557	4,415	5,088	5,074	5,164
Means	6,075	6,171	6,427	6,647	5,734	5,993	5,386	

S.E. of legume means ± 226**
S.E. of stripping treatment means ± 335 NS

S.E. of legumed x stripping means ± 597 NS

Table 5. Yields from undersowing trails: maize stover (kg/ha)

Pasture system	Maize leaf stripping intensity							
	1	2	3	4	5	6	7	Means
Macrotyloma axillare	4,717	3,649	4,418	3,938	4,506	4,309	4,094	4,233
Neonotonia wightii	3,782	3,936	4,450	4,185	3,449	3,560	3,902	3,895
Centrosema pubescens	4,804	4,419	3,282	3,412	3,612	4,382	3,277	3,884
Means	4,434	4,002	4,050	3,845	3,790	4,150	3,758	

S.E. of legume means ± 203 NS**
S.E. of stripping treatment means ± 310 NS
S.E. of legumed x stripping means ± 597 NS

Table 6. Yields from undersowing trails: maize leaf (DM kg/ha)

Pasture system	Maize leaf stripping intensity							
	1	2	3	4	5	6	7	Means
Macrotyloma axillare	86	235	442	687	1,077	1,470	1,788	187
Neonotonia wightii	126	279	500	751	1,075	1,420	1,712	838
Centrosema pubescens	128	289	491	726	1,169	1,578	1,877	894
Means	113	268	478	721	1,107	1,490	1,792	

S.E. of legume means ± 113 NS
S.E. of leaf stripping treatments means ± 162**
S.E. of legumed x stripping means ± 533 NS

Table 7. Yields from undersowing trails: forage legume (DM kg/ha)

Pasture system	Maize leaf stripping intensity							
	1	2	3	4	5	6	7	Means
Macrotyloma axillare	176	304	152	218	179	103	173	187
Neonotonia wightii	177	31	34	47	30	27	20	47
Centrosema pubescens	161	144	182	186	231	187	117	173
Means	158	160	123	150	146	106	104	

S.E. of legume means ± 17**
S.E. of leaf stripping treatment means ± 26 NS
S.E. of legumed x stripping means ± 45 NS

The stripped maize leaves had adequate amounts of crude protein from the first to the seventh leaf stripped (Figure 1). The protein values were well above 12%. While in the first four weeks the maize-Neonotonia system had the highest protein values, during the last three weeks the maize-Centrosema system ranked first in this respect. No adequate explanation could be advanced for this switch. The adequate amount of crude protein in these maize leaves does indicate their value as a feedstuff. Thus a byproduct from the maize crop, which is usually wasted, could provide an extra source of feed in smallholder livestock production enterprises.

Conclusion

The need to provide sufficient amounts of cereal grain for direct human consumption precludes the possibility of channeling these feed resources to livestock production in small-scale farming situations. It is logical, therefore, that efforts be made to improve the management of natural forage/fodder resources, and especially the efficient utilization of crop by-products. While attempts have been made to enhance the availability of nutrients in these feedstuffs through chemical treatment, there is still a dearth of technology for these small-scale livestock producers.

The Malawi experience of undersowing forage legumes in maize crops shows that there is a possibility of improving the quantity and quality of feed resources available to small-scale livestock producers during the dry season. This simple technology is cheap and makes few demands on labour and land as it involves an integration of arable crop, forage legume and livestock production. It is a good chance of improving the utilization of low-quality waste products such as maize stover. Research efforts in this area continue with a wide range of tropical forage-legume species.

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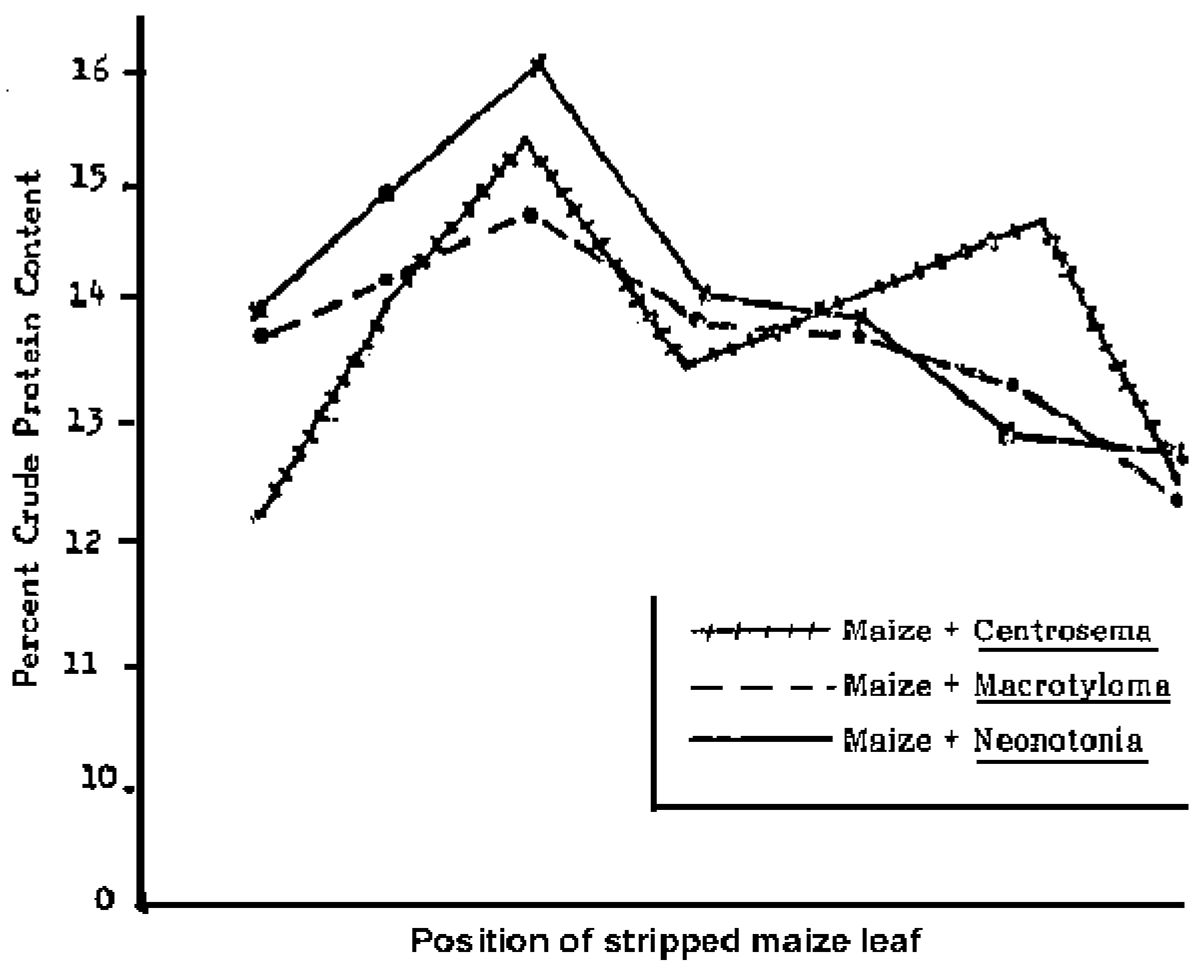
Figure 1. Crude protein values (% of DM) of stripped maize leaf from different positions below the cob



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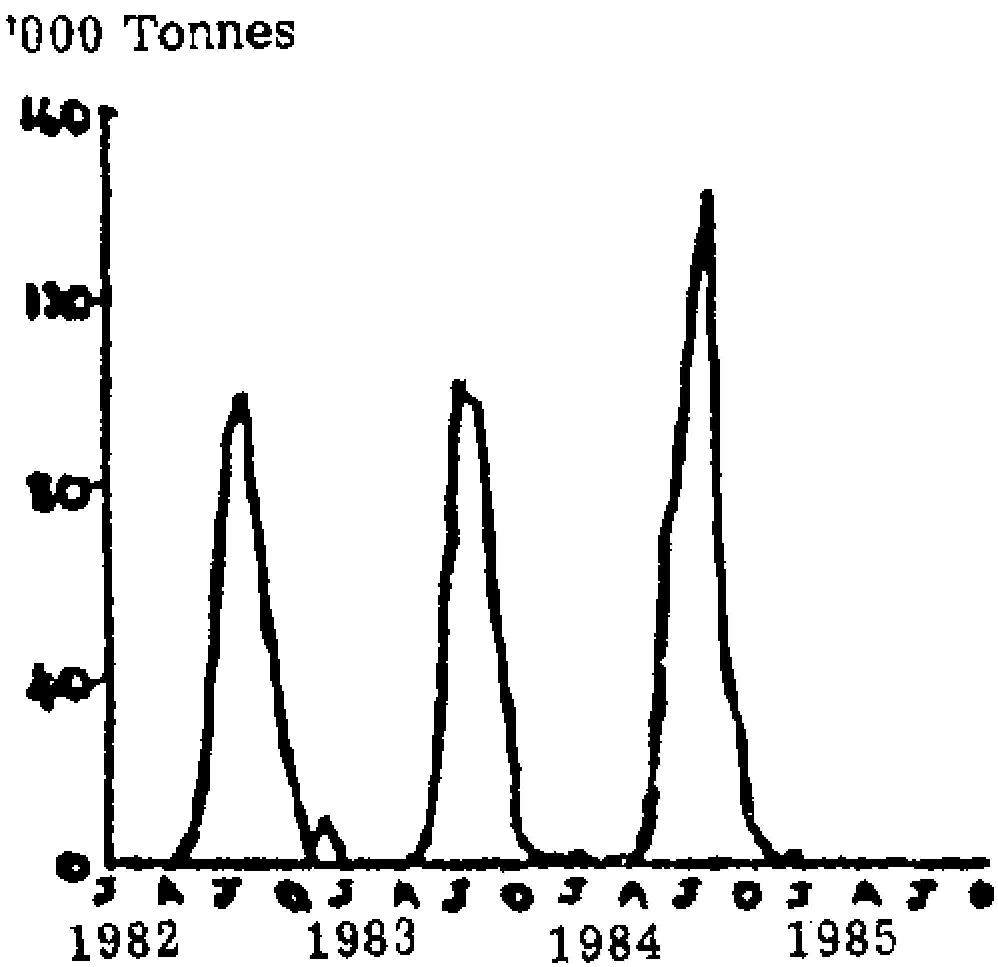
Appendix 1

Figure A1. Agricultural Development and Marketing Corporation Domestic purchases of agricultural crop produce



Source: National Statistical Office Monthly Statistical Bulletin, January 1985

Appendix 2

Table A1. Maize grain and stover production (tonnes)[a]

Period	Grain	Stover[b]
1974	65,470	65,470
1981	136,647	136,647
1982	246,062	246,062
1983	244,937	244,937
1984	296,292	296,292

Source: National Statistical Office, 1985, Zomba, Malawi.
[a] Represents only grain quantities
[b] Using a 1:1 grain to stover ratio.

Introduction of fodder crops in rural areas of Burundi

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Introduction

The problem of feeding livestock is particularly acute during the dry season. There are several alternative solutions, namely improving natural pastures (division into paddocks, rotation of grazing lands, control of fires, and mowing), use of agricultural pastures byproducts, and introduction of improved pastures. The traditional system does not include forage production and is wholly dependent on natural pastures of Eragrostis and Hyparrhenia. These natural pastures supply adequate feeds in the rainy seasons but are inadequate in the dry seasons. Research has been undertaken in Burundi to test improved pasture species.

To achieve this goal many grass species have been introduced in the various centres and research stations of the Institute of Agricultural Research (ISABU - IAR). Among those tested, the most promising are Tripsacum laxum, Pennisetum purpureum, Setaria splendida and Setaria sphacelata which gives a good yield of high feed value. Consequently these have been selected for introduction into the rural areas. However, the introduction of these forage crops in Kigozi and Mahwa areas is combined with the introduction of Sahiwal x Ankole heifers/cows. The use of improved cattle is important to ensure economic returns to investments in fodder production. The choice of the two areas is based on their proximity to the two research stations and it is therefore easy to visit and advise the farmers.

At the moment, this study will focus on the productivity of these fodder crops under intensive cultivation and on their impact on animal and food production.

Characteristics of the Recommended Grasses

Tripsacum laxum is recommended in the agricultural zones situated between the 750 m (at Lake Tanganyika level) and 1,700 m in altitude. It is planted up to 2,000 m, however, it is excellent for dry-season feeding as it does not become stemmy and has a good leaf-stem ratio.

Pennisetum purpureum grows at altitudes ranging from sea level up to 2,000 m receiving between 1,000 to 15,000 mm of rain on rich soils. It grows in areas where any crop can grow. Setaria splendida and S. sphacelata grows at high altitudes (1,700 to 2,400 m) while Setaria sphacelata grows at altitudes of 700-1,700 m. They require rainfall of more than 600 mm in some areas per year. At altitudes above 1700 m of Mugamba and Bututsi. Setaria grows where Tripsacum cannot thrive. Setaria is also used to control soil erosion when planted on contours.

Type of Usage

The four grasses are sub-grouped in accordance with their suitability for grazing. T. laxum and P. purpureum are used in a cut-and-carry system while Setaria sphacelata and S. splendida can be either grazed or cut and carried.

The Establishment of the Pastures

Soil Preparation

For the four grasses it is recommended to plough deeply to a depth of 3 cm irrespective of the type of implements. With hand cultivation it is advised to bury the organic matter under the soil. If tractors are available it is recommended to harrow. The application of manure at 40 tons per ha before planting has been found to be beneficial. Annual applications at 10-15 tons of manure per ha at the onset of the rains in October is also recommended.

Results

The production of green matter in intensive farming

The productivity rates (total green matter per hectare from two harvests per year) presented in the graphs below were obtained with a large input of artificial fertilizers and organic manure.

Forage Production

Generally, elephant grass produces more green fodder in a four-year cycle than Guatemala grass (170 and 130 t/ha in Mugamba, 150 and 120 t/ha in Bututsi, 240 and 185 t/ha in the Eastern Savannas as well as 180 and 130 t/ha in Imbo and Lower Ruzizi, respectively). Estimates of dry-matter yield can be made based on dry-matter content of the fresh material.

Table 1. Production of T. laxum, P. purpureum and S. splendida in the three regions according to the different cutting intervals (green matter/ha)

Cutting interval (months)	T. laxum		P. purpureum			S. splendida	
	Mugamba	But.	Moso	Mugamba	But.	Moso	Mugamba
2	-	-	116.7	-	-	186.7	-
3	131.5	111.3	-	167.3	137.3	-	121.4
4	142.7	124.2	169.0	187.3	128.7	272.0	111.7
6	172.2	155.6	219.0	194.0	156.7	268.1	115.3

Setaria splendida produced similar amounts of green matter to that of the T. laxum in four years at high altitudes (140 t/ha in Mugamba and 120 t/ha in Bututsi). In all the regions of Burundi the distribution of the annual harvests shows that the production of T. laxum is similar during the first four years of farming. The production of T. purpureum, on the contrary, decreased drastically in the course of the four-year period in Imbo and Bututsi region. In the same ecological zones, Setaria splendida yielded constantly for the first three first years followed by a sharp drop in the fourth year.

In conclusion we can say that the most productive grass for cutting is P. purpureum, but its decreasing production of forage with time makes it imperative to re-plant at shorter intervals in order to increase its productivity. This constraint does not apply to T. laxum.

With regard to the two species of Setaria, they can be grown for cutting for the three years and thereafter, their good resistance to grazing makes them adaptable to grazing management.

Leaf-stem Ratio

The leaf-stem-ratio was calculated for the plants at the ideal harvest stage - plants aged two to three months for Setaria and four months for T. laxum and the P. purpureum.

The ratios were 9.6 for the T. laxum, 0.5 for elephant grass, 2.25 for S. splendida and 2.50 for S. sphacelata. We note straight away the extremely high ratio of the Guatemala grass and the very low ratio for P. purpureum. The ratio for the two Setaria is similar with an intermediate value. Based on this we can assume that T. laxum is of good quality followed by Setaria.

The Food Value

Chemical analyses have been carried out on the grasses harvested at high altitude (Bututsi). Cutting was done every 2-3 months, four months or six months (Table 2). Dry-matter content varied between 22 and 29%. There is little difference between regions. However, the T. laxum seems to have slightly higher rates of dry matter than the other two grasses. T. laxum has a higher protein content and a higher energy value than the elephant grass, but the reverse is the case for cellulose content and mineral elements (Ca, P, Na and Mg). The changes in the content of mineral and organic substances are similar in the two fodder crops for cutting. There is, however, a reduction in the amounts of protein K, Ca and P, as well as an increase in the cellulose content, when the cutting is done frequently. It appears then that the mowing should be done every three to four months in order to maintain a high forage value of the harvested grass.

With regard to the graminaceae for mowing and for pasture the highest protein content is observed in frequent cuttings and the highest rate of cellulose is also observed when the cutting is done at the time of flowering. This suggests that these two grasses must be harvested before they flower in order to ensure that they are of high food value.

Table 2. Dry-matter content of grasses at various stations (%)

Cutting interval (months)	**T. laxum**			**P. purpureum**			**S. splendida**
	Bututsi	**Mug.**	**Moso**	**Bututsi**	**Mug.**	**Moso**	**Mugamba**
2 or 3	26.0	29.1	27.4	22.5	26.2	24.5	24.5
4	27.5	27.8	28.4	22.7	27.4	27.2	26.9
6	28.6	27.3	29.1	26.4	27.3	27.6	22.4

Studies on chemical composition have been made at Bututsi. The results are shown in Table 3. Seasonal variations are most significant in protein contents of elephant grass. Mineral contents are generally low with the exception of potassium.

Table 3. Changes in average organic matter content (% of dry matter) and mineral elements (Mg/kg of dry matter) during the dry rain seasons

Elements		**Tripsacum laxum**		**Pennisetum purpureum**	
		Rainy season	**Dry season**	**Rainy season**	**Dry season**
Cellulose		33.2	34.4	37.2	37.0
Crude protein		13.0	9.3	10.3	2.2
	Ca	2.340	2.206	2.700	2.971
	P	1.698	1.680	1.854	2.038
	K	20.281	16.413	19.237	17.847

	Na	112	92	102	280
	Mg	1.379	1.667	1.365	1.509

The evolution of the contents of the various elements between the dry and rainy season is similar for the two species: an increase in cellulose and Mg, a decrease in proteins and K, and little change in the concentration of Ca and P. The differences already noted for the two grasses with regard to average annual content are reflected in the seasonal rates. It can also be noted that whatever the season, T. laxum has less cellulose than P. purpureum.

Changes in the dry matter were marked between the two seasons (Table 4) as was to be expected.

The analysis of the general production levels obtained by the different cutting systems (Table 1) reveals the superiority of cuttings practiced more than twice a year: the four-monthly system being in between while cuttings carried out every two or three years turn out to be the least productive. A three monthly cutting rhythm is best for S. splendida.

A comparison of these results with those of the chemical analysis shows that a four-monthly cutting rhythm is the system which guarantees satisfactory production of high quality mowing grass, while for Setaria, the three-monthly rhythm gives the best results.

Table 4. Changes in percentage dry matter

	Tripsacum laxum		**Pennisetum purpureum**		**S. splendida**	
	Dry season	**Rainy season**	**Dry season**	**Rainy season**	**Dry season**	**Rainy season**
Mugamba	30.9	24.9	30.1	22.7	27.8	20.5
Bututsi	29.6	25.1	26.5	20.9	-	-
Moso	28.9	26.8	26.7	24.7	-	-

Ensiling

The only preservation method which is practiced in Burundi is ensilage. The usual loss in green matter is in the region of 25 to 30%. However, prior drying of the grass, which reduces the water content by 10%, limits the loss in weight to 15%.

The extension of forage crops in the rural areas

The extension of fodder crops is done in the same way as the extension of other plants through the regional development projects and societies as well as through the new research project by ISABU (Institute of Agricultural Research - Burundi). The objective is to transfer modern agro-pastoral techniques to the rural areas. ISABU produces the planting material and crossbred Sahiwal heifers for introduction into the rural areas. Farmers are advised to plant the grasses in accordance with the research findings, but it is obvious that farmers do not have all the required inputs, in particular adequate manure. Fields of the forages are lower than on station. In the future it is planned to introduce a legume such as Desmodium intortum in the system.

Conclusion

The poor quality of Burundi soils and the ever-worsening deterioration of the pastures calls for an intensification of fodder crop cultivation. However, even if the intensification of forage crop cultivation remains the basic component of the improvement of animal feeding, certain constraints hinder such vital action, especially:

1. The arable area being quite small, the area allocated to fodder crops will be reduced in favour of food crops.

2. These fodder crops need manure, but priority in the use of manure will go to the food crops before anything else.

3. Extension methods are not yet sufficiently developed to sensitize peasants to the advantages of fodder crops, and this accounts for the persistence of transhumance.

The project undertaken by ISABU with the aim of changing the present extensive method of livestock production in the rural areas into a semi-intensive one through the introduction of fodder crops and improved cattle may result in the improvement of the environment, more livestock productivity, and better nutrition of the rural population.

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Research experience of reinforcing veld with legumes in Zimbabwe*

*This paper is based on a presentation to the Grassland Society of Zimbabwe Symposium on Forage Legumes in Zimbabwe, 26 September 1985.

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Abstract

Better management of veld (rangeland) has led to an improvement of veld condition which has led to sustained economic production of beef off veld, although overall production has not increased dramatically. Research in Zimbabwe has shown that reinforcing veld with legumes can increase body-mass gains per hectare by over 60% compared to natural veld. The forage legumes with potential under Zimbabwean conditions are listed, and investigations into planting procedures and nutritional requirements for their successful establishment are outlined. Required management practices for veld reinforced with legumes have been shown not to differ significantly from those for natural veld. The applicability of veld reinforcement with legumes by small-scale livestock producers in Zimbabwe is discussed.

Introduction

For a number of decades there has been an increasing need to improve the production of veld in Zimbabwe. Much research into better methods of veld management continues to take place. Whilst this has led to a better understanding of the veld, the results in real terms have been for an improvement in veld condition which has led to sustained economic production of beef off veld. However, overall production has not increased dramatically. Applications of fertilizer to the veld have certainly improved production, but at tremendous cost. At the same time, the poor performance of cattle which over-winter in the highveld persists if they are not fed expensive protein-rich supplements at this time. Thus, interest in reinforcing veld with legumes grew, particularly as it had been shown in other parts of the world that native grassland reinforced with legumes resulted in marked improvements in the performance of individual animals and in overall carrying capacity. This paper sets out to review some of the research on veld reinforcement with legumes that has been carried out in Zimbabwe.

Plant Screening and Introduction

In the early 1960s, from 124 legume introductions a short-list was drawn up of a number of species which showed promise of being adapted to conditions in the high-rainfall sandveld of Zimbabwe, including Desmodium intortum (greenleaf desmodium) Lotononis bainesii (Beit lotonosis), Stylosanthes fruticosa, S. guianensis, and Trifolium semipilosum (Kenya white clover) (Barnes 1966). These species were further evaluated in disced sandveld plots and only Stylosanthes guianensis established and persisted well (Clatworthy and Thomas 1972). Further introductions and screening of legumes took place, and by 1973 almost 300 additional legume strains had been grown at the Grasslands Research Station in Marondera (Clatworthy 1975). It was found to be important that the screening procedure be carried out under grazing conditions (Clatworthy 1980), and this is now done routinely (Clatworthy 1985).

The legumes which have promise under Zimbabwean conditions are given in Table 1. This list is not exhaustive and not all the legumes do well in reinforced veld.

Table 1. Legume With Promise under Zimbabwean Conditions

Cajanus cajan	Pigeon pea
Cassia rotundifolia	Roundleafed cassia
Desmodium discolor	Horse marmalade
D. intortum	Greenleaf Desmodium
D. uncinatum	Silverleaf desmodium
Leucaena leucocephala	Leucaena
Lotononis bainesii	Beit lotononis
Macroptilium atropurpureum	Siratro
Macrotyloma axillare	Archer
Neonotonia wightii	Cooper glycine
Stylosanthes guianensis var. guianensis	Graham stylo
S. guianensis var. intermedia	Oxley fine-stem stylo
S. hamata	Verano stylo
S. humilis	Townsville stylo
S. Scabra	Shrubby stylo
Trifolium semipilosum	Kenya white clover

Establishment and Nutrition

It has been shown that for successful establishment to occur it is necessary to disturb the soil surface and to set back grass growth (Clatworthy and Thomas 1972). Subsequently, the achievement of successful establishment of legumes in veld has been investigated.

With the small-seeded legumes Desmodium intortum (greenleaf desmodium), D. uncinatum (silverleaf desmodium), Macroptilium atropurpureum (siratro), Neonotonia wightii (Cooper glycine), Stylosanthes guianensis var. intermedia (Oxley fine-stem stylo) and Trifolium semipilosum (Kenya white clover), the ideal depth of planting was found to be between 5 and 10 mm; below 10 mm there is a marked fall-off of emergence. Under conditions of water-stress, covering the soil surface with a mulch increases emergence, but has the opposite effect if the soil is moist (Grant 1975). Burning-off of top hamper before discing the strips also improves emergence, possibly because there is greater soil-surface disturbance. Rolling with a Cambridge roller or with a tractor wheel after seeding, and where the seed is covered either with a flat roller (if Cambridge roller is used before seeding) or-by lightly brushing or raking, has also been shown to be advantageous (Grant 1976).

Desmodium discolor (horse marmalade), a woody legume, can be established in veld after burning in disced strips (Boultwood 1964). In further investigations, cultivation was found to be more important than burning for good establishment of this species.

Many pasture legumes have hard seeds and scarification needs to be carried out by use of hot water, dry heat, mechanical means of treatment with concentrated sulphuric acid (Grant and Clatworthy 1978; Grant 1979). Some legumes are specific in their Rhizobium requirements and need to be inoculated, in particular Beit lotononis, Kenya white clover and Oxley fine-stem stylo, and greenlead desmodium and silverlead desmodium on sandy soils.

Some confusing responses to the application of fertilizer have been obtained. With increasing applications of single superphosphate (SSP), there have been increases of herbage yields on both sandy and clay soils with Cooper glycine, Oxley stylo, silverlead desmodium and siratro. However, with Oxley stylo there have been marked decreases in yield by the second year when high levels of SSP have been applied (Anon. 1973; Grant and Tanner 1984a). Thus, although with silverlead desmodium and siratro 100 kg SSP/ha can be used, with Oxley stylo it may be advisable to use no more than 50 kg SSP/ha. Since the possible cause for this response may be an inherent low level of zinc in the soil or that the zinc is bound up in non-available from by the phosphate (Grant 1985), this problem could also be overcome by keeping the applications of phosphate to 100 kg SSP/ha and applying a zinc compound or trace-element cocktail. This would ensure that the full potential response to applications of phosphate is realized.

Legumes appear to have a more critical need for trace elements than grasses and if there is a known deficiency a mineral cocktail should be applied. The use of these mixtures is most beneficial when legumes are used to reinforce sandveld vleis (Penny Grant, Soil Productivity Research Laboratory, Marondera, personal communication).

Dolomitic limestone has also been shown to enhance establishment and herbage yields (Grant and Tanner 1984b) and should be applied at approximately twice the rate at which SSP is applied. Single superphosphate contains magnesium, both of which are important in the process of nitrogen fixation.

Management

There has been little research into whether legume-reinforced veld would require different management from unimproved veld. In one trial, Oxley stylo was shown to thrive under conditions of frequent and short defoliation (Mufandaedza 1976 a, b). Three cutting frequencies (2, 4 and 8 weeks) and three harvesting heights (4 cm, and progressively increasing to 10 cm and 12 cm above ground level) were used. Total yields of dry matter, crude protein and digestible dry matter in the herbage increased as the interval between harvests increased (Table 2). Height of cutting had relatively little effect on the yields of herbage, although close cutting tended to reduce the amount of crown and root yields.

Table 2. Yields (G/POT) of Dry Matter (DM), Crude Protein (CP) and Digestible Dry Matter (DDM) of Stylosanthes Guianensis var. Intermedia (Oxley fine-stem stylo) grown in pots and Harvested at 2, 4 or 8 Week Intervals

		Harvest interval (weeks)		
		2	4	8
DM				
	- leaf	8.8	13.4	16.2

	- stem	5.6	7.1	18.5
	- total	14.4	20.5	43.7
CP		3.6	4.8	6.8
DDM		10.6	14.3	21.0

Source: Mufandaedza 1976b.

In a later trial Hyparrhenia filipendula tufts were planted into plots (Mufandaedza 1978). One-third of the area was left as a pure grass stand, one-third was oversown with siratro and the remaining third with Oxley stylo. Different intervals (2, 4, 8 and 16 weeks) and heights (4 and 12 cm) of cutting were used over a four-year period. Reinforcing with the legume increased the dry-matter yields. In addition, not only were the total yields of crude protein and digestible dry matter contents of the grass increased by up to 130% (Table 3), but also the crude protein and digestible dry-matter contents of the grass were increased by up to 40%. Thus, clearly, it is mainly the legume which is providing the additional protein. Increasing the interval and height of cutting increased the yields of siratro, but with Oxley stylo this was not so, and in fact, with the longest interval (16 weeks), yields were decreased. Overall, the responses to cutting treatments were similar, which showed that all three species can be grown together.

In a trial in which Oxley stylo under Hyparrhenia veld was bulked-up for winter use by resting from January to April, the legume was shaded out as the Hyparrhenia grew too fast for the legume during this period (Clatworthy, undated). Thus, if stylo is grown with tall grasses, the rest period should not be too long as the stylo is intolerant of shading. If long rest periods are necessary, then it would be better to use siratro as it is able to twine up the grass. However, siratro does not yield well under frequent close grazing and will not persist, and under these conditions stylo gives better yields.

In a grazing trial with steers grazing Oxley stylo-reinforced veld, it was observed that at the start of the season, grasses (in particular Hyparrhenia filipendula) constituted the major portion of the diet. By mid-February, legumes (in particular Oxley stylo) were the major constituent and this increased as the dry season was approached (Mufandaedza 1976c, 1977) (Figure 1). Later work on a grass-legume pasture showed that cattle were able to select their diet very effectively in terms of crude protein and digestible dry-matter content, keeping both these reasonably constant throughout the growing season, although they did progressively decline (Mufandaedza 1981) (Table 4).

Table 3. Effects of frequency of harvesting and addition of the legumes Stylosanthes guianensis var. Intermedia (Oxley stylo) or Macroptilium atropurpureum (Siratro) to plots of Hyparrhenia filipendula on dry matter (DM), crude protein (CP) and digestible dry matter (DDM) total yields (kg/ha). Crude protein and digestible dry matter contents as percentage of dry matter in brackets

	Frequency of harvesting (weeks)			
	2	**4**	**8**	**16**
Grass alone	2,450	3,300	4,000	5,040
Grass + stylo	3,800	4,720	5,440	7,940
Grass + siratro	3,110	4,080	5,160	7,510
CP				
Grass alone	260 (10.6)	290 (8.8)	210(5.3)	160 (3.2)
Grass + stylo	660 (17.4)	740 (15.7)	660 (12.1)	440 (5.5)
Grass + siratro	410 (13.2)	460 (11.3)	430 (8.3)	510 (6.8)
DDM				

Grass alone	1,460 (59.6)	1,900 (57.6)	2,080 (52.0)	2,170 (43.1)
Grass + stylo	2,420 (63.7)	2,910 (61.7)	3,050 (56.1)	3,400 (42.8)
Grass + siratro	1,710 (55.0)	2,270 (55.6)	2,660 (51.6)	3,350 (44.6)

Source: Mufandaedza 1978

Table 4. Changes in crude protein (CP) and dry-matter digestibility (DMD) of available grass-legume pasture and the diet selected by cattle during the growing season

	Sampling period	Sample		Difference
		Pasture	Diet	
CP (%)	19/12 - 21/1	16.6	15.1	-1.5
	22/2 - 22/3	11.9	14.4	+2.5
	28/4 - 8/6	10.5	12.8	+2.3
DMD (%)	19/12 - 25/1	58.7	54.5	-4.2
	22/2 - 22/3	53.8	63.5	+9.7
	28/4 - 8/6	46.0	56.5	+10.5

Source: Mufandaedza 1981

Bearing these points in mind, it would appear that the main value of the legume in reinforced veld lies in its contribution to the animals' diet in the late growing and early dry seasons. Thus, a farmer should aim to ensure a high proportion of legume during these periods. Management should favour high nutrient yields of the grasses in the early part of the growing season, and in the latter part high yields of legume. This can be achieved through rotational grazing without excessive defoliation using a rest of four to five weeks between grazings in the early to mid-growing season and a rest of from six to eight weeks in the latter part (Mufandaedza 1976b). This procedure also allows some sort of late-season rest for the grasses which helps to ensure their vigour.

While cutting trials are useful in helping to understand how the legumes grow, ultimately the legumes should be tested in a full production trial. One system which has been recommended for producing finished beef steers is to buy weaners in May or June, carry them on veld with a protein supplement during the dry season, and then on heavily fertilized star grass (Cynodon nlemfluensis) pastures during summer, and finally pen-finishing them on a high-energy diet between June and August. With rapidly rising costs of winter protein supplements and nitrogenous fertilizers, the use of legumes would be a decided advantage.

In a trial to test this system at Henderson Research Station, Mazowe, Hyparrhenia veld was reinforced with different amounts of silverleaf desmodium (zero, one-third, two-thirds and whole area) for use by steers during winter (Clatworthy 1984). Two stocking rates were used, one 50% greater than the other. Stocking rate had no effect on amount of herbage on offer at the start of the grazing each year. However, the addition of the silverleaf desmodium significantly increased herbage yields above those of the veld alone, particularly in the later years (Table 5). There were also obvious changes in species composition in the reinforced plots which lodged badly, became moribund and led to invasion of the reinforced plots by weeds. By contrast, the control plots remained dominated by lower-growing Hyparrhenia filipendula and Sporobolus pyramidalis. By the end of the trial there were larger weed yields in the reinforced plots. Although the silverleaf desmodium grew well, it was not ideally suited to a system of winter grazing only as it formed a tangled mass which was largely trodden underfoot and wasted by the cattle. Also, frost caused the legume to shed its leaves so that only bare stems were left. Grazing during the growing season may have prevented some of the lodging that occurred.

A fire in 1982 did not damage the silverleaf desmodium unduly, and it seemed to rejuvenate the Hyparrhenia spp. so that periodic burning could be beneficial. Observations with Oxley stylo in veld which has been burnt have indicated that it will withstand fire.

From the little knowledge that we have, it is generally recommended that veld reinforced with legume (in particular Oxley stylo) be managed the same way as unimproved veld, that is, by rotational grazing with a grazing period of not more than two weeks and a rest period of at least five weeks (Clatworthy 1985).

There has been little research on the management of reinforced veld in communal grazing areas, although screening trials in Masvingo Province have shown that round-leafed cassia (Cassia rotundifolia), Townsville stylo (Stylosanthes humilis) and Oxley stylo can be established and will spread under these conditions (Clatworthy, Maclaurin and Avila 1985).

Figure 1. The selection of grasses and legumes by steers at different times of year (after Mufandaedza 1976c, 1977)

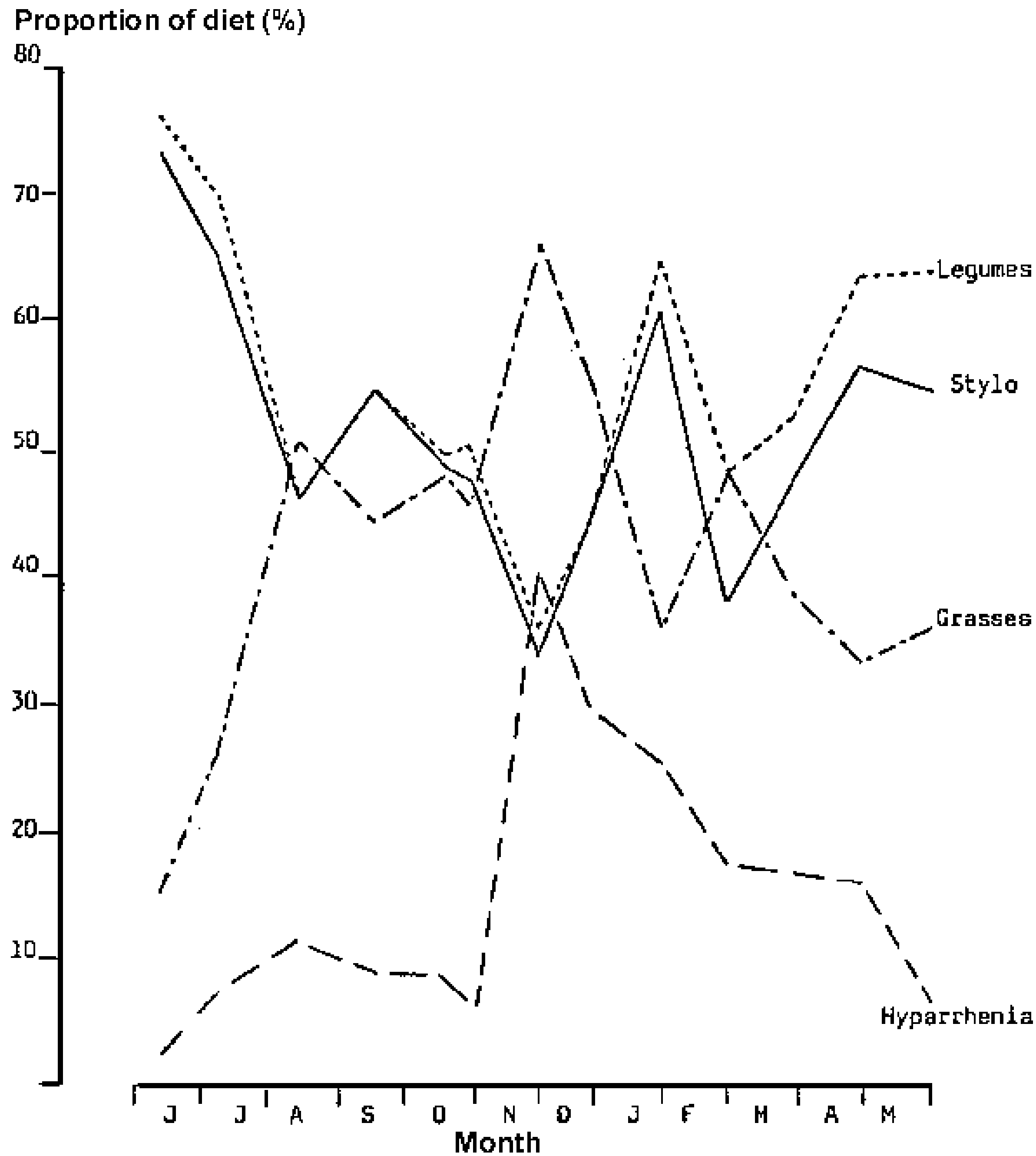


Table 5. Amounts of total Desmodium uncinatum (Silverleaf desmodium) herbage (kg DM/ha) on offer at the start of grazing each year on reinforced Hyparrhenia veld seeded with different proportions of legumes

Proportion of legume		Year				
		1978	1979	1980	1981	1982
0						
	Silverleaf	-	-	-	-	-
	Total	4,720	3,260	3,010	2,920	1,890
1/3						
	Silverleaf	140	580	1,180	1,280	960
	Total	4,780	3,240	4,130	4,810	2,730
2/3						

	Silverleaf	480	1,170	2,080	1,270	1,060
	Total	5,480	3,660	4,530	4,350	2,760
All						
	Silverleaf	1,140	1,780	2,110	1,380	1,120
	Total	5,590	3,980	4,690	5,010	2,640

Source: Clatworthy 1984

Productivity of reinforced veld

The first major trial to determine the effect of legume reinforcement of veld was carried out at the Grasslands Research Station. Stylo was sown in a 12-ha block of reverted veld whilst another 12 ha was used as a control. For a number of years, weaner steers bought in June were run on these plots for 12 months and then removed for pen-fattening. A four-paddock rotational grazing procedure was used (Clatworthy and Holland 1979). Steers on veld lost, on average, 20 kg body mass over the dry season whilst those on reinforced veld maintained their body mass. Animal performance between November and February was similar for both treatments. However, between February and June, steers on reinforced veld gained 20 kg more than the control group (Figure 2). Thus, there was a 40 kg greater gain by animals on reinforced veld than those on veld only. As the stocking rate was 20% greater on the reinforced veld, this represents a 61% increase in terms of body-mass gains per hectare (Table 6).

As a follow-on to this trial, the whole area was seeded to Oxley stylo and stocked with weaner steers at four different stocking rates. A four-paddock rotational grazing procedure was used. In order to assess the feasibility of finishing steers off on reinforced veld they were partially destocked at the end of their first year so that similar stocking rates were maintained over the two years. The trial has run for five years now (Maclaurin, Clatworthy and Muyotcha 1985). Seven Hereford steers were used for the first two years, nine Afrikaner steers for the next two, and over the last years, (1984/85) eleven communal-farming-area-type steers and heifers. The steers all lost body-mass during the dry season, especially those at the heaviest stocking rate. During the wet season all groups gained well, although the heaviest stocked group gained significantly less. There was little difference between the performance of the animals at the three lightest stocking rates which consistently gave well-finished steers with excellent carcasses fleshing indices. The steers at the heaviest stocking rate did not perform so well. A short summary of the results is given in Table 7. Stocking rate had a significant effect on animal performance.

Table 6. Live-mass gains of steers on reverted veld and on similar veld reinforced with Stylosanthes guianensis var. intermedia (Oxley stylo) over 12 months without winter protein supplement

	Gains/steer (kg)		Gains/ha (kg)	
	No stylo	With stylo	No stylo	With stylo
1973-74	123	152	107	135
1974-75	115	165	103	191
1975-76	139	164	139	205

Source: Clatworthy and Holland 1979

Table 7. The effect of stocking rate on weaner steer performance when grown out over two years on reverted veld reinforced with Stylosanthes guianensis var. Intermedia

(Oxley fine-stem stylo)

	Treatment (ha)			
	8.4	**6.3**	**5.04**	**4.2**
1980-1982				
Initial no. head (1st year)	7 Hereford weaners			
Initial body-mass (kg)	205			
Gains/head (kg)	141	133	136	113
Gains/ha (kg)	118	148	189	189
No. head (2nd year)	4 Hereford yearlings			
Gains/head (kg)	151	171	150	130
Gains/ha (kg)	72	109	126	124
Mean gain/head (2 years)	146	152	148	122
Mean gain/ha (2 years)	95	128	158	156
CDM (kg)	264	272	255	236
1982-1984				
Initial no. head (3rd year)	9 Afrikaner weaners			
Initial body-mass (kg)	212			
Gains/head (kg)	151	142	123	115
Gains/ha (kg)	162	203	220	246
No. head (4th year)	5 Afrikaner yearlings			
Gains/head (kg)	152	157	161	136
Gains/ha (kg)	90	124	160	162
Mean gain/head (2 years)	152	150	142	126
Mean gain/ha (2 years)	126	164	190	204
CDM (kg)	264	256	250	231

Source: Maclaurin, Clatworthy and Muyotcha, 1985

At Makaholi Experiment Station, Masvingo, veld reinforced with either siratro or Oxley stylo has been compared with natural veld. Although there have been some soil-nutrient problems in the legume establishment, steers on reinforced veld gained more than those on unimproved veld (Kelly and Tiffin 1984). Gains were not as good as at the Grasslands Research Station, but considering the marginal rainfall, this does show that even under these circumstances there are benefits to be gained from veld reinforcement.

In the trial at Henderson Research Station, where steers were given access to silverleaf desmodium-reinforced veld during winter, they lost body-mass, although not as quickly as in the case of the steers on veld alone. There were no consistent differences-due to stocking rate. The main differences were due to whether the veld had been reinforced with legume or not (Clatworthy 1984) (Figure 3).

Most of the trials involving reinforced veld have been on reverted veld using steers. At the Grasslands Research Station, a breeding herd and their progeny on reinforced veld are being compared with other systems of beef production (Grasslands Research Station 1985). This is the first major trial of reinforcing virgin veld with legumes. Unfortunately, there was poor establishment of the Oxley stylo, possibly due to soil-fertility problems. In addition, due to a lack of appreciation that stocking rates Figure 3 should be reduced by up to a third in the establishment year in proportion to the loss of veld grazing in the disced strips, the early results for reinforced veld in this trial have not been conclusive (Table 8).

Table 8. Calving rate (%) and weaning mass (kg) of cows and calves run under different beef production systems at Grasslands Research Station

	Veld alone	Veld + legume	Veld + protein supplement
Calving rate			
1980	91.5	88.1	88.1
1981	71.4	64.4	84.5
1982	58.2	59.6	79.3
1983	69.0	64.9	87.7
1984	85.2	86.8	87.3
Mean	75.1	72.8	85.4
Weaning mass			
1981	165.3	167.8	174.9
1982	168.7	171.7	193.2
1983	185.0	195.7	210.9
1984	198.5	207.0	230.0
Mean	179.3	185.5	202.2

Source: Grassland Research Station 1985

Figure 2. Body mass changes of steers grazing legume reinforced or unimproved reverted veld 1975/76 (Clatworthy and Holland 1979)

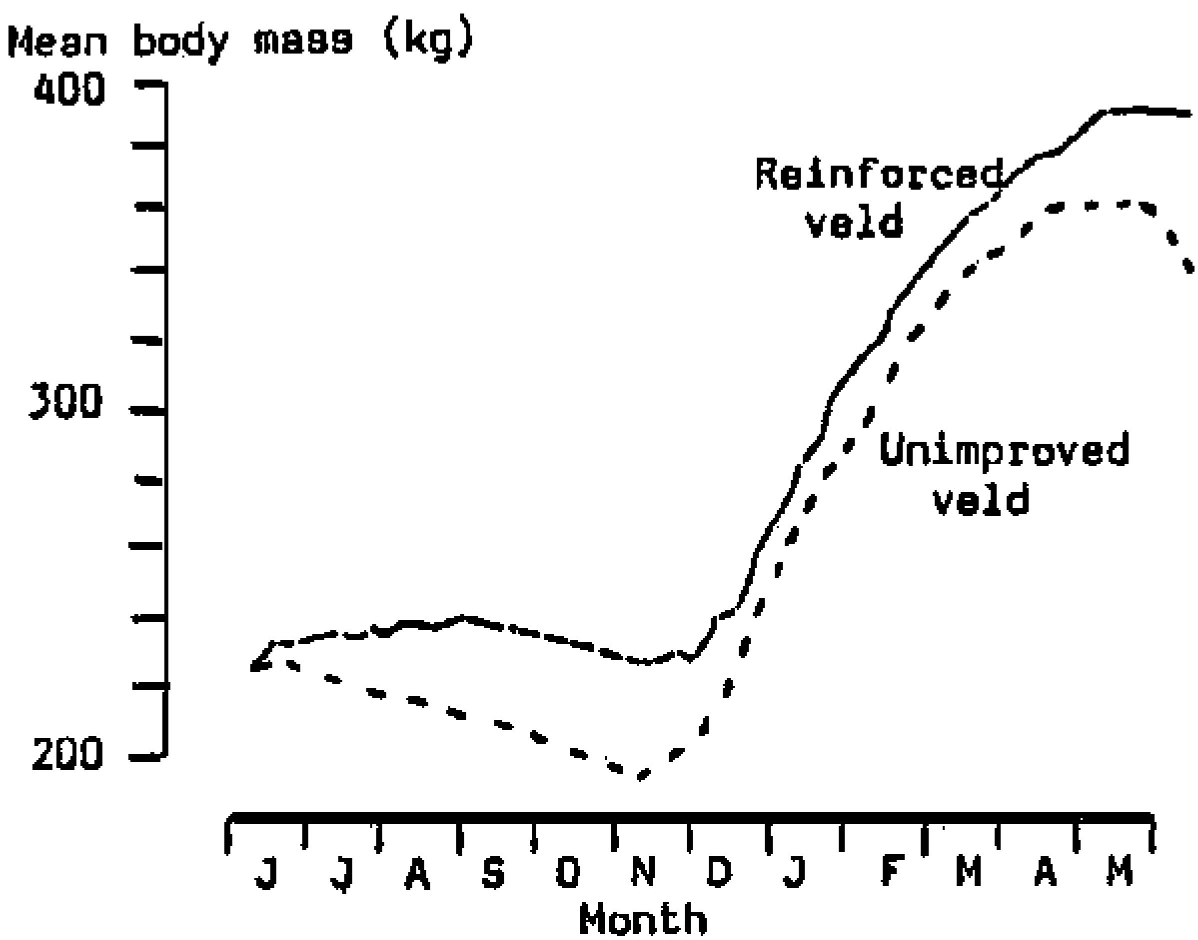
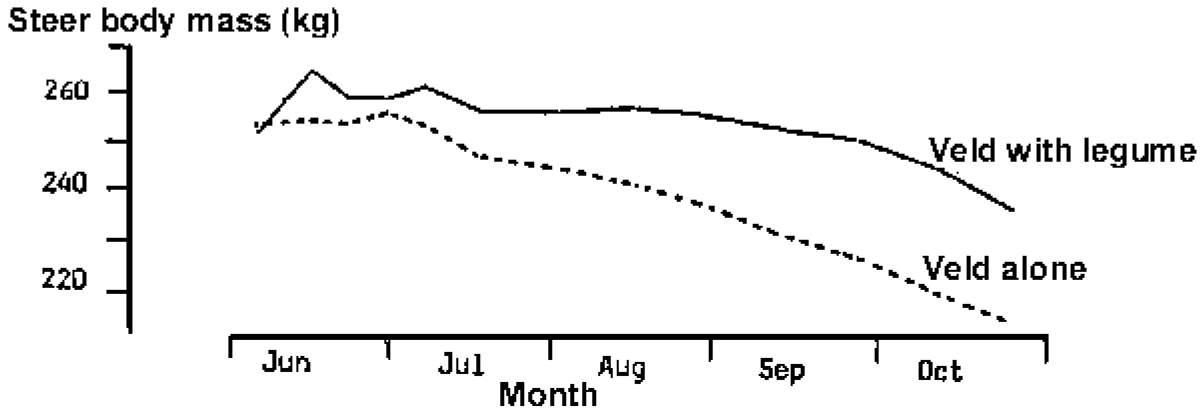


Figure 3. Body mass changes of weaners on veld alone or silverleaf desmodium-reinforced veld during the dry season (Clatworthy 1984)



Discussion and conclusions

Research experience with legume-reinforced veld has shown that it can be a successful means of improving the productivity of veld. In terms of individual animal performance, body-mass gains of up to 40 kg above those on unimproved veld have been achieved using 20% higher stocking rates. This has resulted in over 60% increases in livestock production per hectare over veld alone. These improvements are important because they allow a beef farmer to grow out his weaners and steers faster and so get them into pens for fattening more quickly. In addition, the dairy farmer is able to grow out his replacement heifers either faster or by using less supplementary feeding.

Whilst there may be fairly substantial improvements in terms of animal production, to a large extent these are made possible only if management standards of the reinforced veld are high. Careful attention needs to be paid to stocking rates and the way in which the veld is grazed and rested. Unless the establishment of the legumes is successful, the improvements are not likely to occur.

Small-scale livestock producers in Zimbabwe generally make use of communal grazing areas. There is little or no control of stocking rates and grazing tends to occur where the herdsman feel there is most forage for their livestock. No form of grazing management is practiced. Many of the communal grazing areas are severely degraded and of poor fertility. Before successful reinforcement of these areas with legumes can occur, it will be necessary to improve grazing management in order to restore the condition of the veld. For continued high production of the legume-reinforced veld, good management would be necessary. The only way that veld could be successfully reinforced and used in the communal grazing areas, therefore, would be if the farmers who have communal tenure in these areas were to be able to group themselves together and apply suitable grazing management. Due to the low fertility of much of the degraded veld, some fertilizer inputs would be necessary during reinforcement, but these costs could be shared equitably amongst all the farmers using the grazing area. Seed of suitable legumes could be made readily available for quite large areas of communal veld grazing to be reinforced.

The advantages of reinforcing veld in the communal grazing areas are numerous. The quality and quantity of the grazing would be enhanced and this would improve the performance and condition of the animals. However, unless stocking rates are controlled these benefits will not be realized. In many areas it is unlikely that stocking rates will be controlled as there is a critical shortage of draught power and farmers would not willingly maintain this situation. Thus, it does not appear that there would be much success with legume reinforcement of communal grazing areas. In these areas the main emphasis should be on improving veld management in the first instance.

Whilst attempting to reinforce communal grazing areas may be a doubtful starter, there is no reason why the larger areas of reverted cultivated land that often exist in the cropping areas should not be reinforced with legumes. Groups of farmers could "pool" their reverted veld and allow access to these areas for selected animals, for example their draught oxen, cows in milk or steers that they wish to fatten for slaughter. They could share the costs of fencing, which would be necessary to protect their crops, and of fertilizers and seed. These groups of farmers would be small and so consensus with regard to management could be reached more easily.

There are areas which require further research work. There is a need for a broader selection of legumes for use in reinforcing veld, particularly in the drier areas both in the large-scale and small-scale communal farming areas. The legumes need to be screened under grazing, particularly in the communal farming areas. There is a need for trials to be carried out under the conditions found in communal farming areas so that an accurate evaluation of benefits can be made and thereafter used for planning purposes. The nutrient requirements (especially micro-nutrients) of the legumes in reinforced veld, and in particular virgin veld, need to be determined for the different soil types found in Zimbabwe.

With the present state of knowledge of reinforced veld, it should be possible for farmers to successfully reinforce their veld and make use of its greater productivity. It has been shown to be an economically justifiable method of improving veld provided there is successful establishment of the legumes and attention is paid to management. For the small-scale livestock producer this would most likely be in reverted veld in the cropping areas rather than in the communal grazing areas.

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Farmer circumstances in Ethiopia and the improvement of animal feed resources

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Abstract

The productivity of both crop and animal agriculture in Ethiopia is stagnant. Major increases in both crop and animal production are a prerequisite to the nation achieving food self-sufficiency. Livestock play a vital and catalytic role on Ethiopia's smallholder farms. Oxen, for example, are the main source of agricultural power.

Different farming systems have evolved in Ethiopia over many generations, but many of them will be unable to sustain adequately the increased human and livestock populations certain to exist in the coming years. The middle altitudes of the country are the areas most likely to be required to absorb the bulk of the increased population.

In the future, livestock will depend increasingly upon crop byproducts as their feed source. Pasture areas are decreasing as cropped areas expand. Subsistence-oriented smallholders have limited means with which to boost production and will be unlikely to adopt new feeding systems requiring substantial cash outlays. Furthermore, they will not invest their resources in increasing fodder production if it is at the cost of reducing the output of subsistence food crops.

Researchers must seek innovative ways of boosting livestock production, and recognize that the ultimate beneficiary of the research is the farmer through the links between livestock and crop production. Benefits occurring to the livestock enterprise will carry forward to crop production.

Different technical means exist to boost fodder production on farms and to raise the effective feeding value of crop by-products. However, not all these technologies are well suited to the resource endowments and objectives of smallholders. If gains in fodder production require substantial investments, or the returns on investment are only via a multi-stage production process, they will not be likely to be adopted by farmers. Some strategies to increase fodder production were examined and found wanting in this regard.

The most promising research thrust which addresses the problems of both crop and livestock

production concerns crop-legume interactions. This study area deserves priority allocation of research resources. Successful research on this complex of issues, i.e. research producing adoptable results, will require use of the farming-systems approach to research and a commitment to multidisciplinary during its execution.

Introduction

Agriculture in Ethiopia is dominated by smallholder farms where over 90% of the country's grain is produced. Smallholder farmers cultivate an average of less than 1 ha and the 7 million farm families in Ethiopia cultivate perhaps 6 million ha each year. Although agriculture is organized in a socialist framework, collective farming accounts for less than 5% of the total area cultivated. The bulk of agricultural output is produced by individual farmers who have "farming rights" over the land they till (Gryseels et al 1984). With few exceptions, crop irrigation is not practiced, and under these dryland conditions farmers produce a surplus above subsistence needs equivalent to approximately 10% of total production on each farm.

In adverse years, grain production shortfalls are ordinarily made up by the sale of livestock and surplus grain that farmers may have been able to accumulate from previous years. However, as the Ethiopian tragedy of 1984 and 1985 revealed, even such actions can be pitifully inadequate. Hunger, destitution and death can easily occur in the subsistence farming areas.

Integrated crop and livestock production is an ancient tradition in Ethiopia. However, changes are taking place in the production systems in many parts of the country which are challenging the ability of subsistence farmers to sustain the integration which was easily achieved by past generations when there was much less pressure on land resources. The more important changes occurring include progressively declining average farm sizes in response to rising rural populations, encroachment of cropping land onto erstwhile grazing areas and onto less fertile and more easily erodable lands, and expansion of degraded lands which can no longer support either annual crops or pastures.

These factors are combining to increase the relative dependence of farmers' livestock upon cereal-crop residues and stubble. Unless supplemented, these products are seldom adequate for livestock maintenance and even less so for milk production or as finishing rations. Also, using current technologies, farmers in the coming years will have smaller quantities of crop residues available per farm and be less able to augment these cereal products by pasture grazing or hay. The areas under pasture are being reduced and average stocking rates are increasing.

Existing and future agricultural production systems in Ethiopia will require draught power for cultivation. Livestock will also continue to be farmers' principal buffer in times of crop failure, as well as a vital source of cash for the purchase of farm inputs and consumption goods.

The challenge to forage researchers will be to reduce this emerging competition between crop and livestock production and enable new, more productive and stable farming systems to develop. Improvements in animal-feed production from declining land areas are urgently and will be a critical means of addressing this problem.

This paper highlights issues concerned with research on the improvement of animal feed resources for the livestock of Ethiopian smallholders. Farmers' circumstances directly influence the acceptance and adoption of new technologies and are stressed here as necessary and desirable influences on forage-related research if the research is to produce relevant results.

The following section of the paper gives an overview of important smallholder feeding systems in Ethiopia with special reference to the farmers' objectives in managing these systems. The problems confronting farmers in achieving these objectives are emphasized. The penultimate section relates research needs to farmers' forage-production problems and opportunities. Finally, this is followed by a summary and conclusions.

An overview of smallholder feeding systems in Ethiopia

The General Production Environment and Livestock Management Systems

Mixed crop-livestock farming in Ethiopia is dominantly on farms located above 1,500 m above sea level and with annual rainfall in excess of 700 mm. Crops are grown at altitudes up to about 3,300 m. Some highland areas have a bimodal rainfall pattern. Most crops are sown in the main rains, which fall between June and October over most of the country. The short rains from February to May are unreliable and only in some areas can farmers crop routinely in that secondly season. Nationally, some 5% of the grain crop is produced in the short rains.

The complex physical environment and ecology of the Ethiopia highlands has resulted in the evolution of distinct agricultural production systems in different parts of the country. Some 85%, or 35 million of the 43 million people in the country, are resident in the highlands. A similar percentage of the country's estimated 30 million cattle, 25 million sheep and 20 million goats are kept by smallholder mixed farmers. Farmers in these systems also practice different animal-feeding and management strategies, reflecting differences in crops grown, in the relative importance and productivity of crops and pastures, in the proximity of the cropping areas to pastoral areas (meaning access to replacement stock and especially draught oxen) and differences in the intensity of-land use by farmers and their livestock.

Domestic livestock in the central highlands are grazed communally on fallow and permanent pasture lands for the duration of the cropping season and on crop lands after harvest. Livestock of indigenous breeds are seldom fed, with this practice being restricted to the few thousands of crossbred dairy cows owned by smallholders. Selected classes of livestock, especially draught oxen and lactating cows, receive supplements to grazing when they are housed at night. Production levels are low. Cows of indigenous breeds, for example, calve about every two years on average and produce some 300 litres of milk per lactation over and above that consumed by the suckling calf.

The Objectives of Livestock Keeping

The primary purpose of cattle keeping in most of the highlands is to produce oxen. The low rates of reproduction and milk production of indigenous cows, both of which are directly influenced by nutrition levels throughout the cows' production cycles, result in low overall levels of conversion efficiency of feedstuffs into draught power. Draught power is the primary product of cattle enterprises. At present farmers keep up to ten cattle to produce and maintain the pair of oxen conventionally used for cultivation.

Oxen are only used for some 60 pair days of work each year. Thus the feed demands of this subsystem (oxen plus cows and followers) in relation to the direct contribution of oxen to production are burdensome and favour changes in management to reduce aggregate feed demands per unit of draught power and the draught-power needs to crop production. The single-ox cultivation system developed by ILCA is one way of reducing the feed demands of the draught animals on farms with up to 1.5 ha under cultivation (Gryseels et al 1984). Using one ox rather than a pair can effectively have the total feed requirements of the cattle kept to provide-draught power.

Cattle manure provides an important fraction of domestic fuel needs in areas with limited fuel-wood supplies. Manure sales make significant contributions to cash incomes. Meat and milk are relatively less important products of cattle enterprises. In some farming systems, such as in western Shoa Province, selected fields are intensively manured by livestock penned overnight in the fields. However, little of the animal manure produced in the country is used intentionally as fertilizer for crop production.

According to location, farmers keep sheep and/or goats as producers of cash and meat. The high rates of flock growth, relative to cattle herds, and the different grazing behaviour of small ruminants make them appropriate complements to cattle through most of the Ethiopian highlands. Small ruminants are the best stock to be sold in times of crop failure They seldom receive special feeds and ordinarily are grazed together with cattle. Special-purpose fattening of smallstock is not practiced by Ethiopian smallholders.

Livestock are also a major source of cash income. In large parts of the highlands, trade in livestock and the sale of livestock and livestock products provide up to 80% of farm cash income in a normal year (Gryseels and Getachew 1985). In summary, livestock produce a range of intermediate and final products in the traditional farming systems of Ethiopia. Regional differences exist in the relative importance of these products, but in all cases the presence of livestock on smallholders' farms enables them to be more productive and stable over time than would be the case in their absence (Rodriguez and Anderson 1985).

Some Problems of Existing Smallholder Feeding Systems

Seasonality of Fodder Production

A production problem common to most Ethiopian livestock feeding systems is the seasonality in animal feeds supplies. Some parts of the country have dry seasons of up to 200 days each year. Such areas farmers must harvest and store fodder for dry-season use when feed supplies in the fields are extremely limited. Communal grazing of crop and pasture lands after harvest is the norm, so individual farmers cannot calculate with certainty the contribution of such grazing to their needs. Farmers usually stack all cereal straws near the homestead after threshing, selling only that portion needed to provide for basic household needs.

Effective short rains in a particular year can result in pasture growth enabling farmers to sell surplus straw. As noted previously, farmers have competing demands on their labour during the cropping season and "ideal" conservation practices for hay, especially, are not often used. The development and adoption of labour-saving technologies for crop production could release labour for fodder conservation, in turn improving livestock production.

The low frequencies with which cows calve oblige farmers to maximize annual conception rates by not limiting breeding to any time of the year. The resultant spread of calving over the year means that farmers have difficulties in matching feed supplies and feed demands. Farmers maximize their use of communal grazing lands (for which there are no cash payments due) and then utilize stored feeds for their stock on a priority basis. Oxen have first call on conserved feed, followed by lactating cows and the classes of cattle and smallstock if supplies are adequate. Informal surveys by ILCA in the Debre Birhan area of Ethiopia (about 2,800 m above sea level) suggest that farmers trade in smallstock (sheep in that area) both to increase cash incomes and to balance feed demands with available feed supplies.

Fodder Quality

The second major problem in smallholder feeding systems in Ethiopia is that the quality of most harvested and conserved feedstuffs is such that when fed alone it is often unable to provide even for the maintenance needs of livestock. Thus, on an annual basis, livestock must make sufficient liveweight grains during the flush period of the year to be able to offset losses occurring during the following dry season. The regular cycle of liveweight gain and loss each year is the principal cause of the low annual average conversion efficiencies of fodder into meat, milk and draught power.

In commercially-oriented mixed farming systems farmers could if it were profitable, negate this cyclical pattern by feeding of purchased supplements. Such a strategy is rarely possible in Ethiopia at present and is limited to the few farmers with easy access to major urban centres. The majority of dairy and fattening operations are in such situations. (Some 75% of all smallholders are more than one day's return walk from even an all-weather road.) Alternative means of overcoming the annual cycle of gain and loss will have to be developed for these farmers.

Land Tenure

Some aspects of the social context of crop and livestock production in Ethiopia have been noted. All land is the collective property of the Ethiopian people and individuals have user rights only over the land they till each year. While, in principle, an individual farmer can be assigned new plots each year, in practice this does not happen. However, it does foster discernible reluctance in farmers to invest in the maintenance and improvement of any plots of land they use. Also the current system whereby crop land becomes available for communal grazing after harvest encourages farmers to leave crop lands bare of cover after harvest. This predisposes such fields to erosion and has negative long-term impacts on soil fertility and structure.

Also, the individual's fragmented holdings require farmers to haul crop by-products to the homestead for safe keeping. From there they are given to their stock as required. The labour costs of this operation are substantial. Although the traditional method of threshing by trampling using cattle and equines (horses and donkeys) is relatively inefficient from the point of view of grain extraction, it does favour livestock production through the relatively higher grain and husk fraction remaining than would occur if the grain where threshed by mechanical means.

Examples of feeding systems

Shoa Province

Farmers in the central Ethiopian highlands in Shoa Province, have a tradition of hay-making from permanent (usually valley-bottom) pastures. The hay is usually cut well after its protein content has peaked, and the protein percentage in harvested hays on a dry-matter basis seldom exceeds 5%. If harvested at the "right" time, the protein content on a dry-matter basis can exceed 11%. However, at the "right" time for hay making, farmers favour using their scarce labour for weeding of cereal and pulse crops. Subsistence food crops have the highest priority for farmers' time. Furthermore, as most of the hay is used as a feed supplement for oxen, farmers report that they maximize dry-matter yields per hectare by harvesting later in the season, although they are aware that the feeding value of hay made at that time is reduced. Hay making is relatively more important in the higher altitude areas (say above 2,500 m) than in lower altitude areas. The latter tend to be more intensively cultivated and have less pasture land available per farmer.

Frost is a major crop hazard toward the end of the main growing season in the higher altitudes and farmers there attempt to avoid frost damage to crops by sowing on land away from the more frost-prone valley bottoms. Even in the long term it is unlikely that main-season crop production will be important in these high-altitude valley bottoms. Routine cropping on them would require development of frost-tolerant, short-duration cereal and pulse varieties. Maturation periods as short as 90 days under relatively low temperature and radiation conditions will be required. Crop-breeding research in Ethiopia will be less problematic and have greater impact on national production if targeted on the needs of the less rigorous agricultural environments in the middle altitudes of the highlands.

Crop production in the higher and cooler mixed-farming systems will continue to be risky and farmers are likely to become increasingly dependent upon livestock production as human populations increase. However, without significant improvement in overall soil fertility (perhaps largely rectifiable by rock phosphate application), the quality of feedstuffs available to stock will not be increased. In turn this places upper bounds on the per-unit productivity of livestock. Gains in productivity per head will then only be possible if strategic supplements are provided and these will not be likely to be produced within these systems. Also, the prospects of identifying a productive legume shrub for the higher altitude areas are remote (S. Jutzi, personal communication).

Under traditional management regimes both crops and pasture are more produced for livestock. Leguminous plants are not cultivated specifically to provide supplements for the cereal-straw-based diets. These straws are now complemented only to a limited extent by pasture grazing and hay. Purchased feed supplements are used routinely by an insignificant percentage of farmers and fallow land is a diminishing proportion of the land used regularly for cropping. In the Debre Zeit area, for example, the proportion of cultivable land under fallow in any year is less than 5% (Gryseels and Anderson 1983).

Hararghe Province

In other parts of Ethiopia, such as the highlands of Hararghe Province in the south-east of the country, limited areas of permanent grazing are available and livestock depend more than in the central highlands upon thinnings from annual crops during the growing season and crop stover and stubble during the dry season. The proportion of arable land left fallow is minimal. Substantial areas of land on more than 50% slopes are cultivated, reflecting the severe shortage of arable land, even though net returns from crops on such land are at best, marginal. Sorghum and maize are the dominant annual crops. Perennial crops, including coffee, provide a substantial proportion of the cash income of farmers in the area.

All cattle and most small ruminants are tethered in the field during the day and hand fed selected crop parts according to the season. As elsewhere throughout Ethiopia, all animals are penned at night, usually at the owner's homestead. The Hararghe highlands are close to extensive rangeland areas and the working oxen in Hararghe Province come mainly from the rangelands. Typically smallholders purchase oxen from the rangelands (through traders), use them as draught animals for some years and then fatten them prior to sale. The oxen are fattened successfully on farm products alone. The regional success of this strategy is reflected in the price premium offered to fatstock from Hararghe Province on the Addis Ababa market, the most important domestic meat market in the country. The relatively close proximity of the Province's smallholders to pastoralists in the rangelands areas enables Hararghe farmers to keep relatively more efficient herds and flocks (in terms of rates of conversion of animal feed into draught power and other livestock products) than is the case in the central highlands. More than half the cattle kept by Hararghe farmers are working oxen. The interregional links between cattle breeders and smallholders who have different production objectives are advantageous to both groups.

Implications for research

The Approach

Cost-effective agricultural research requires that researchers undertake research only on those problems for which results are expected a priori to have an impact on production. A substantial body of theory and experience under the rubric of the "farming systems approach to research" (FSR) has been developed in the last decade. The philosophy guiding this approach is that adequate knowledge of farmers' production circumstances is a prerequisite to the efficient design and execution of agricultural research. The FSR approach offers relevant guidelines for research on animal feeding systems and forage research.

As argued earlier in this paper, improvements in animal-feed resources in the Ethiopian highlands, both in total and on an individual-animal basis, necessitate substantial changes to traditional practice. Ethiopian agricultural systems are under stress and simple incremental changes to existing systems will be an inadequate means of producing the major increases in production which are necessary.

Subsistence-oriented smallholders, such as those which dominate Ethiopian agriculture, will not adopt technologies which increase the production risks associated with their staple crops. In regard to staple food crops, the annual rates of return on marginal investments to increase crop yields need to be as high as 40% before farmers will adopt them on a large scale. Forage crops as pure stands produce intermediate products and only have their value expressed when they are used by animals. It is arguable, therefore, that the annual rates of return on investments in such fodder crops in subsistence-oriented systems with shortages of arable land must exceed 40% as this will also have to account for the opportunity cost of not producing staple crops which are ordinarily the main users of arable land. Together, the opportunity cost of not producing staples, and the production of intermediate products, only militate against the prospect of widespread use of special-purpose fodder crops by subsistence farmers.

The urgency of solving the feed-supply problem for both people and their animals means that other methods of raising the quality and quantity of feed on offer to livestock must be sought. Several avenues are possible. These are outlined below. The first concerns the strategic use of agro-industrial by-products to raise the effective feeding value of farm produced fodders. The second concerns strategies to increase farm production of animal feeds. The last strategy considered relates to exploitation of the synergistic link between legumes and cereal crops.

Agro-Industrial By-Products

Agro-industrial by-products are in short supply in most African countries. Ethiopia has only limited supplies of various oilseed cakes and molasses which, even when efficiently used, cannot boost production for more than a small proportion of the ruminant livestock in the country.- Research is in progress to identify where these resources would be best used. This will most likely be by enterprises producing meat and milk and will be unlikely to be used by smallholders in support of draught oxen feeding. The general shortages of cash and credit in Ethiopian smallholder systems make it improbable that farmers will purchase such inputs to enhance the working capacity of their draught oxen.

Difficulties of access to markets for farm inputs and products will also limit the use of agro-industrial by-products by farmers in remote situations. Thus, while research on the best utilization of these products is important, at this stage in Ethiopia's agricultural development it has lower priority than the two other avenues of fodder development outlined below.

Intensified Crops and Pasture Production

Crop yields are low in Ethiopia. Nationally, average cereal yields are substantially less than 1 t/ha for most crops. Grain and straw yields of most crops are positively correlated, and increases in grain yields through the use of new crop varieties and fertilizers can be expected to increase the yields of crop by-products. However, significant increases in grain yields at the national level will take many years to achieve. Even at this time the yield gaps between crops on research stations and the same crops on farmers' fields are indicative of the major research effort needed to have farmers adopt even currently available technologies. However, there are potentially conflicting changes to crop production as regards the impact on animal feed supplies and at present it is not possible to predict which changes will dominate. For example, if farmers adopt dwarf cereal varieties in order to increase grain yields they may reduce the quantity of byproducts produced per hectare. Alternatively, if they change from a wheat to a sorghum-based cropping system they would ordinarily increase the byproducts available to their stock.

Concerning pastures, as all permanent pasture areas in Ethiopia have at least some element of communal tenure related to their use, it is improbable that they will be a target for development by individual farmers. If profitable productivity gains are demonstrable, then the proper avenue for investment would be by the Peasants Association which has group control over the use of pasture lands within their boundary. Research on technical and socio-economic issues related to permanent pasture development is not well advanced.

Fallow lands are relatively more important in the higher altitudes of the highlands where the soil-fertility levels are such that fallowing for several years (sometimes up to 15 years) is necessary to support low-input cereal and pulse cropping for three or so years. In these cases farmers will not invest directly in fallow land improvement. Here the principal means of improving pasture yields will be through fertilization of the cereal crops in the cereal-pulse-fallow rotation. In this way farmers will receive the benefits of the purchased inputs directly through the increase in cereal and pulse-grain yield and indirectly through the carry-over of nutrients to the fallow pasture phase. Research on ways and means of improving fallow lands alone without reference to the crops in the rotation has low priority.

The Cereal-Legume Link

Legume crops are an important element in most Ethiopian smallholder farming systems. Only in those systems which are semi-commercial, as in Hararghe Province, do some farmers eliminate legumes from their cropping patterns. Nationally legume production is almost exclusively of grain legumes. Pulses are an integral part of the diet of most Ethiopians. In addition to contributing to soil nitrogen and producing a break in cereal-dominated crop rotations, legume crap by-products contribute modestly to livestock production. Vicia faba, for example, is not fed to livestock except in combination with cereal straws. Ordinarily farmers favour cereal production over legume-grain production because of the higher prices received for the former.

Forage legumes are grown as single-stand crops by an insignificant number of smallholders. The conditions of subsistence production do not favour using crop land for fodder crops instead of grain crops. Fodder crops produce only an intermediate product which must then be transformed into a saleable commodity such as meat or milk for the farmer to receive the benefits of his cash outlay and investment of labour and land. The risks perceived by farmers to be attendant upon this multi-stage process are sufficient to limit its adoption by farmers even though it can be a profitable activity (Gryseels and Anderson 1983). Regular and successful participation by Ethiopian farmers in the market economy is a precondition for the widespread adoption of special-purpose fodder crop production.

Given these considerations, can the well-established benefits which legumes confer upon cereal crops be tapped to advantage by subsistence farmers and incorporated into their farming system?

While a definitive answer to this question must await the results of research now in progress by several agencies in Ethiopia, the evidence to date is that innovative approaches to using legumes will enable smallholders to increase food-crop production (and the quantity of crop by-products) and simultaneously produce significant quantities of high-protein leguminous materials. Intercropping, serial and relay cropping of cereals with legumes are only a few of several ways of including legumes in systems without diverting land from subsistence food crop production. Research at ILCA initiated in 1985 has shown how legume shrubs, in rows at 5 m spacings between rows, can produce up to 2 t/DM/ha/year of 20% crude protein content (at 1,850 m above sea level) without significant reduction in yields of the cereals grown between the rows. This quantity of leguminous material is adequate on a per-hectare basis as a strategic feed supplement to convert a below-maintenance straw diet into one allowing a crossbred cow to produce 58 litres of milk per day.

Such results are indicative of the substantial potential of legumes to boost and stabilize food-grain and fodder production in Ethiopia. Research on ways and means of profitably integrating fodder legumes into Ethiopian farming systems is a high priority. They are especially relevant as they require modest cash inputs in addition to those used to boost crop production and are adoptable equally by farmers in areas of easy and difficult market access. Also, given the degradation of agricultural land which-is now occurring in Ethiopia, such legume technologies will play a central role in ensuring the long-term ability of Ethiopia to be self-sufficient in food needs. Effective research on the crop-legume complex will require multidisciplinary research with an FSR perspective.

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Economics of intercropping maize with forage crops in small-scale farming systems in western Kenya

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Abstract

Maize (Zea mays) Hybrid 512, was intercropped with Sudan grass (Sorghum sudanense), pigeon pea (Cajanus cajan) cultivar "Kioko", and sesbania (Sesbania sesban van mubian) in split plot designs at Maseno and the Small Ruminant Collaborative Research Support Programme (SR-CRSP) cluster areas in Kaimosi and Masumbi during the short-rains season of 1983. The main plots were fertilizer treatments (NPK 20–20–0) at the rate of 40 kg per ha of N, P_2O_5 and the sub-plots were crops and their intercropping combinations. Standard agronomic practice was applied in planting maize and maize-intercrop plots. Sampling for dry matter (DM) yield estimates was done whenever any forage was ready as various forages were ready for feeding at different times in the various treatments and environments. DM yields from each forage crop in one site were accumulated until the last sampling was done. Maize grain and stover DM yields were also estimated when the crop matured at various sites.

A partial budgeting model was applied for economics evaluation of the biological data. Incremental benefits and incremental costs for each crop treatment at each site were calculated. The resultant benefit: cost ratio (BCR was derived as a ratio of net incremental benefits to incremental costs and was used as the choice criterion for ranking the various maize-forage intercrops).

Results indicate that intercropping maize with forages with or without fertilizer application generated greater economic returns than pure-stand maize in Kaimosi Cluster, and with fertilizer application in Masumbi Cluster. There was no economic advantage over pure-stand maize at Maseno Research Station, and in Masumbi Cluster without fertilizer application. In Kaimosi Cluster, maize intercropped with leguminous forages yielded greater returns than maize intercropped with Sudan grass when fertilizer was applied, but the converse results

were the case without fertilizer application. For Masumbi Cluster, maize-Sesbania followed by maize-Sudan grass were the most promising intercrops only when fertilizer was applied, otherwise pure-stand maize was economically superior to the maize intercrops without fertilizer application. Overall, fertilizer application was economically more profitable than non-fertilizer application at all the sites for both pure-stand maize and maize intercrops. It is concluded from the results of this one season trial that while intercropping maize with forage crops yields greater economic returns than pure-stand maize in some areas, it may lead to economic loss in other areas depending upon soil fertility and rainfall conditions.

Introduction

Shortage of livestock feed, particularly during dry seasons, is one of the major constraints to increasing livestock production in small-scale farming systems in western Kenya. The Feed Resources Project of the Small Ruminant Collaborative Research Support Programme (SR-CRSP), has conducted various station and on-farm trials on alternative forage producing interventions for relaxing this constraint. Trial interventions have involved intercropping the staple food crop, maize, with leguminous or grass forages with or without fertilizer application.

The objectives of this paper is threefold:

1. To quantify the economic costs and benefits of intercropping maize with selected forage crops;
2. To assess the economic impact of applying fertilizer to maize both in pure stand and intercropped with forage crops;
3. To identify the economically most promising maize-forage intercrops for the SR-CRSP Cluster areas in Kaimosi and Masumbi and for the Maseno Research Station environment.

Two main hypotheses are tested: that intercropping maize with forages yields less economic returns than maize grown in pure stand, and that applying fertilizer to maize in pure stand or intercropped with forage crops yields greater economic returns than non-fertilized pure-stand or forage-intercropped maize.

Materials and methods

Biological Trials

During the short-rain season of 1983, maize (Zea mays) Hybrid 512, was intercropped with Sudan grass (Sorghum sudanense), pigeon pea, (Cajanus cajan) cultivar "Kioko", and sesbania (Sesbania sesban var. nubian) in split plot designs at Maseno and in cluster areas. The main plots were fertilizer treatments (NPK 20-20-0) at the rate of 40 kg per ha of N, P_2O_5 and the sub-plots were crops and their intercropping combinations.

Maize was-planted at the standard spacing of 90 cm between rows and 30 cm between plants in the row. Pigeon pea and Sesbania were then planted between these rows but only 45 cm from the maize rows and with inter-row spacing of 30 cm. Sudan grass was drilled between maize rows at the same inter-row spacing as the other forage crops. Fertilizer was applied only once at planting time.

Maize, pigeon pea and Sesbania were thinned to single plants per hill at the second weeding. The thinnings were oven-dried at 80 for 24 hours. Because various forages were ready for feeding at different times in the various treatments and environments, sampling for dry matter (DM) yield estimates was done whenever any forage was ready. DM yields from each forage crop in one site were accumulated until the last sampling was done at the end of the second rainy season in February 1984. Dry matter maize grain and stover yields were also estimated when the crop matured at the various sites between the middle and end of February 1984.

Dry maize grain and DM forage yields obtained per hectare are summarized in Table 1. There was a complete crop failure for maize grain yield in Masumbi Cluster due to a severe drought. However, DM stover yields for maize and forage crops were measured.

Table 1. Dry maize grain and dry-matter forage yields from station and on-farm trials at Maseno Station and in Kaimosi and Masumbi Clusters, Western Kenya, short-rain season, 1983

Intercrop	Without fertilizer		With Fertilizer		Intercrop (Mean)	
	Dry grain	Forage dry matter	Dry grain	Forage dry matter	Dry grain	Forage dry matter
	Maseno Station					
Maize-pure stand	2.49	40.20	2.47	48.10	2.48	44.15
Maize-Sudan grass	1.38	28.00	1.87	38.90	1.63	33.45
Maize-Sesbania	1.64	28.50	1.75	39.40	1.70	33.95
Maize-Pigeon peas	1.67	26.60	2.32	40.60	2.00	33.60
Fertilizer treatment mean	1.80	30.83	2.10	41.75	1.95	36.29
	Kaimosi Cluster					
Maize-pure stand	1.66	10.10	2.03	23.10	1.85	16.60
Maize-Sudan grass	0.72	17.20	2.78	34.10	1.75	25.65
Maize-Sesbania	2.47	17.50	1.58	30.20	2.03	23.85
Maize-Pigeon pea	2.34	21.70	3.33	23.50	2.84	22.60
Fertilizer treatment Mean	1.80	16.63	2.43	27.73	2.12	22.18
	Masumbi Cluster					
Maize-pure stand	0	4.80	0	10.00	0	7.40
Maize-Sudan grass	0	2.90	0	13.80	0	8.35
Maize-Sesbania	0	4.50	0	13.80	0	9.15
Maize-Pigeon pea	0	4.00	0	11.30	0	7.65
Fertilizer treatment Mean	0	4.05	0	12.23	0	8.14

[a] There was no maize grain yield due to a severe drought
Source: Onim, et al, 1984

Economic Analysis

A partial budgeting model was applied for economic evaluation of the biological data in Table 1 (Mukhebi and Onim, 1985). Maize grain yields were valued at farm-gate prices. Forage DM yields were converted into SR-CRSP dual-purpose goat products (liveweight and milk) using the Kenya Dual Purpose Goat Model (Ruvuna and Blackburn 1984). The animal products were then valued at farm-gate prices (Mukhebi and Onim 1985).

Incremental benefit and incremental cost for each crop treatment at each site were calculated. The resultant benefit cost ratio (BCR) was derived as the ratio of net incremental benefit to incremental cost. It is the absolute marginal rate of return (or loss, if negative) to incremental cost. BCR is the choice criterion for ranking the alternative maize-intercrops against respective control practices. A positive BCR implies that a particular crop treatment is economically superior (yields positive marginal return) to the control treatment or practice, and vice versa. The higher the positive BCR, the more economically superior the crop treatment vis-a-vis the control treatment. The converse is also true.

BCRs were computed in two ways. First, pure stand maize was taken as the control practice against which incremental benefits and costs for intercrops were measured, both with and without fertilizer application. This was to determine the effect of intercropping maize with forages with or without fertilizer application. Second, maize and maize intercrops without fertilizer application were regarded as the control practice against which the same crop treatments, but with fertilizer application, were compared. This was to assess the effect of fertilizer application to maize in pure stand or intercropped with forages.

Results and discussion

Intercropping Maize with Forages

Benefit cost ratios from intercropping maize with various forage crops with or without fertilizer application at the various sites are shown in Table 2. The ratios are summarized from partial budgeting results presented in Appendix 1, Table A1 for Maseno Station, Table A2 for Kaimosi Cluster and Table A3 for Masumbi Cluster.

Figures in Table 2 demonstrate clearly that there were no incremental economic benefits generated by intercropping maize with Sudan grass, Sesbania or pigeon pea with or without fertilizer application at Maseno station. BCR is negative unit for each maize intercrop indicating zero incremental benefits. This implies that pure-stand maize is the economically superior practice for the site whether fertilizer application is undertaken or not. This result is apparent from the biological data in Table 1 which show that for Maseno station both grain and dry-matter yields for each maize intercrop were less than those of pure-stand maize.

Table 2. Economics of intercropping maize with forage crops with and without fertilizer application in station and on-farm trials at Maseno Station, Kaimosi and Masumbi Clusters, Western Kenya, short rains season, 1983

Intercrop	Benefit: Cost ratios		
	Without Fertilizer	With Fertilizer	Intercrop Mean
Maize-pure stand	**Control**		
	Maseno Station		
Maize-Sudan grass	-1.0	-1.0	-1.0
Maize-Sesbania	-1.0	-1.0	-1.0
Maize-Pigeon peas	-1.0	-1.0	-1.0
	Kaimosi Cluster		
Maize-Sudan grass	0.1	5.3	2.7
Maize-Sesbania	11.9	1.0	6.5
Maize-Pigeon pea	16.2	3.0	9.6
	Masumbi Cluster		
Maize-Sudan grass	-1.0	0.3	-0.4
Maize-Sesbania	-1.0	1.2	0.1
Maize-Pigeon pea	-1.0	-0.3	-0.7

For Kaimosi Cluster Table 2 shows that without fertilizer application the maize-pigeon pea intercrop yields the highest BCR of 16.2, followed by the Maize-Sesbania intercrop with a BCR of 11.9. The maize-Sudan grass has the lowest BCR of 0.1. On the other hand, with fertilizer application, the maize-Sudan grass intercrop yields the greatest BCR of 5.3, followed by the maize-pigeon pea intercrop with a BCR of 3.0, and lastly by the maize-Sesbania mixture with a BCR of 1.0. Each intercrop with or without fertilizer is economically superior to the pure-stand maize control as indicated by positive BCRs.

Results for Kaimosi Cluster also show that when fertilizer is not applied, maize-legume (pigeon peas and Sesbania) intercrops generate significantly greater marginal returns (higher BCRs) than the maize-grass (Sudan grass) intercrop. The explanation for this is that when fertilizer is not applied, maize benefits from the nitrogen fixation by the legumes, while it competes with a grass intercrop for available nitrogen in the soil. On the other hand, when fertilizer is applied, the maize-grass intercrop generates higher marginal returns than the maize-legume intercrop. In this case, the yield response to fertilizer application is greater for the maize-grass intercrop which does not fix any nitrogen than for the maize-legume intercrops which fix some nitrogen of their own.

Table A1. Partial budget analysis of intercropping maize with forage crops with and without fertilizer application, Maseno, short rains season, 1983

Intercrop	**Without fertilizer**			**With Fertilizer**		
	Incremental[a]					
	Benefit	**Cost**	**Marginal Benefit (+) (Ksh/ha)**	**Benefit cost (-)**	**Cost**	**Marginal Benefit (+) cost (-)**
Maize-pure stand	**Control**					
Maize-Sudan grass	0	6,878	-6,878	0	7,007	-7,007
			(-1.0)[b]			(-1.0)[b]
Maize-Sesbania	0	8,111	-8,111	0	6,588	-6,588
			(-1.0)			(-1.0)
Maize-Pigeon pea	0	9,950	-8,950	0	4,640	-4,640
			(-1.0)			(-1.0)
Maize-Benefit cost	0	7,980	-7,980	0	6,078	6,078
			(-1.0)		(-1.0)	

[a]. Incremental benefit (gain) or cost (loss) as compared to pure-stand maize used as control practice.

[b]. Figures in parentheses are benefit: cost ratios (BCR) computed as a ratio of marginal net benefit (+) or cost (-) to incremental cost: BCR is an absolute marginal rate of return on incremental cost. When multiplied by 100 it yields a percentage return.

Intercrop mean BCRs for fertilizer and non-fertilizer treatments are 9.6, 6.5 and 2.7 for maize-pigeon pea, maize-Sesbania and maize-Sudan grass respectively.

For Masumbi Cluster all the three intercrops are inferior to the pre-stand maize control without fertilizer application, as shown by negative unit BCRs. With fertilizer application, maize-Sesbania and maize-Sudan grass yield positive BCRs of 1.2 and 0.3 respectively, while the maize-pigeon pea intercrop yields a negative BCR of -0.3. Only the maize-Sesbania intercrop has a positive intercrop mean of 0.1 for fertilizer and non-fertilizer treatments.

Table A2. Partial budget analysis of intercropping maize with forage crops with and without fertilizer application, Kaimosi Cluster, short rains season, 1983

	Without Fertilizer			With Fertilizer		
	Incremental[a]					
	Benefit	Cost	Marginal benefit (-) cost (-) (Ksh/ha)	Benefit	Cost	Marginal benefit (+) cost (-)
Maize-pure stand	**Control**					
Maize-Sudan grass	3,433	3,138	+295[b]	7,109	1,129	+5,980
			(0.1)			(5.3)
Maize-Sesbania	5,521	428	+5,093	3,433	1,741	+1,692
			(11.9)			(1.0)
Maize-Pigeon peas	7,215	420	+6,795	2,644	658	+1,986
			(16.2)			(3.0)
Mean benefit or cost	5,390	1,329	+4,061	4,395	1,176	3,219
			(3.1)			(2.7)

[a]. Incremental benefit (gain) or cost (loss) as compared to pure-stand maize used as control practice.

[b]. Figures in parentheses are benefit: cost ratios (BCR) computed as a ratio of marginal net benefit (+) or cost (-) to incremental cost. BCR is an absolute marginal rate of return on incremental cost. When multiplied by 100 it yields a percentage return.

Fertilizer Application to Maize and Maize-Forage Intercrops

BCRs from applying fertilizer to maize and maize-forage intercrops are reported in Table 3. These ratios are summarized from partial budgeting results presented in Appendix Table A4 for Maseno Station, Table A5 for Kaimosi Cluster and Table A6 for Masumbi Cluster.

Table A3. Partial budget analysis of intercropping maize with forage crops with and without fertilizer application, Masumbi Cluster, short rains season, 1983

	Without Fertilizer			With Fertilizer		
	Incremental[a]					
	Benefit	Cost	Marginal benefit (-) cost (-) (Ksh/ha)	Benefit	Cost	Marginal benefit (+) cost (-)
Maize-pure stand	**Control**					
Maize-Sudan grass	0	1,612	-1,612	1,440	1,129	+311
			(-1.0)[b]			(0.28)

Maize-Sesbania	0	542	-542	1,440	665	+775
			(-1.0)			(1.16)
Maize-Pigeon pea	0	722	-722	493	658	-165
			(-1.0)			(-0.25)
Mean benefit cost	0	959	-958	1,124	917	+307
			(-1.0)			(0.38)

[a]. Incremental benefit (gain) or cost (loss) as compared to pure-stand maize used as a control practice.

[b]. Figures in parentheses are benefit: cost ratios (BCR) computed as a ratio of marginal net benefit (+) or cost (-) to incremental cost. BCR is an absolute marginal rate of return on incremental costs. When multiplied by 100 it yields a percentage return.

Table 3. Economics of fertilizer application to maize intercropped with forage crops at Maseno Station, Kaimosi and Masumbi Clusters, Western Kenya, short rains season, 1983

Intercrop	Benefit: Cost ratios of fertilizer application over non-application of fertilizer			
	Maseno Station	Kaimosi Cluster	Masumbi Cluster	Inter-Crop Mean
Maize-pure stand	12.4	29.2	7.3	16.3
Maize-Sudan grass	26.1	54.1	16.4	32.2
Maize-Sesbania	22.3	1.6	13.8	12.6
Maize-Pigeon peas	12.7	12.7	10.6	12.0

Table A4. Partial budget analysis of fertilizer application to maize intercropped with forage crops, Maseno station, short rains season, 1983

Intercropped	With Fertilizer		
	Incremental[a] benefit	Incremental[a] cost	Marginal net benefit (+) cost(-)
Maize-pure stand	3,816	285	+3,531
			(12.4)[b]
Maize-Sudan grass	6,436	238	+6,198
			(26.1)
Maize-Sesbania	5,528	238	+5,290
			(22.3)
Maize-Pigeon pea	3,247	238	+3,010
			(12.7)
Mean benefit cost	4,757	250	+4,507
			(18.0)

[a]. Incremental benefit (gain) or cost (loss) as compared to the same intercrop without fertilizer application.

[b]. Figures in parentheses are benefit: cost ratios (BCR) computed as a ratio of marginal net benefit (+) or cost (-) to incremental cost. BCR is an absolute marginal rate of return on incremental cost. When multiplied by 100 it yields a percentage return.

It is quite clear from Table 3 that fertilizer application is economically superior to non-fertilizer application at all sites (Maseno, Kaimosi and Masumbi) and for both pure-stand maize and all the maize-forage intercrops. BCRs are all positive and considerably greater than zero for all treatments. For Maseno Station trials, maize-Sudan grass and maize-Sesbania intercrops generate the highest BCRs of 26.1 and 22.3 respectively. For Kaimosi trials, the highest BCRs are recorded from maize-Sudan grass (54.1) and pure-Sesbania with a BCR of 13.8. Overall, the BCRs in Table 3 again demonstrate that the maize-Sudan intercrop generates greater economic response (BCR = 32.2) than maize-legume intercrops (BCR of 12.6 and 12.0 for maize-Sesbania and maize-pigeon pea respectively).

While the results in Table 2 address the first hypothesis, namely that intercropping maize with forage crops yields less economic returns than maize grown in pure stand, the results in Table 3 address the second hypothesis that applying, fertilizer to maize in pure stand or intercropped with forage crops yields greater economic returns than non-fertilized pure stand or forage-intercropped maize. The first hypothesis appears to be acceptable for Kaimosi Cluster, unacceptable for Maseno Station and inconclusive for Masumbi Cluster. This implies that, while intercropping maize with forages is an economically superior practice in some areas, it may lead to economic loss in other areas depending upon soil fertility and climatic conditions of the areas in question. The second hypothesis appears to hold for all sites and for all crop regimes (pure or intercrops), i.e. it is economically beneficial to apply fertilizer whether maize is grown in pure stand or intercropped with forages.

Table A5. Partial budget analysis of fertilizer application to maize intercropped with forage crops, Kaimosi Cluster, short rains season, 1983

	With fertilizer		
	Incremental[a]	Incremental[a] cost (Ksh/ha)	Marginal net benefit (+) cost (-)
Maize-pure stand	7,173	238	+6,935
			(29.2)[b]
Maize-Sudan grass	13,096	238	+12,858
			(54.1)
Maize-Sesbania	6,137	2,365	+3,772
			(1.6)
Maize-pigeon pea	3,247	238	+3,009
			(12.7)
Mean-benefit or cost	7,413	769	+6,644
			(8.6)

[a]. Incremental benefit (gain) or cost (loss) as compared to the same crop intercrop

without fertilizer application.

[b]. Figures in parentheses are benefit: cost ratios (BCR) computed as a ratio of marginal net benefit (+) or cost (-) to incremental cost. BCR is an absolute marginal rate of return on incremental cost. When multiplied by 100 it yields a percentage return.

Conclusions

It should be noted that the above results are based upon biological data from one season only, namely short rains 1983. Nevertheless, several conclusions may be drawn from the results. First, intercropping maize with forage crops with or without fertilizer application has no economic advantage over pure-stand maize at Maseno Station, and in Masumbi Cluster without fertilizer application. Second, intrecropping maize with forage crops yields greater economic returns than pure-stand maize, with or without fertilizer application in Kaimosi Cluster, and with fertilizer application in Masumbi Cluster except for the maize-pigeon pea intercrop. Third, for Kaimosi Cluster, maize intercropped with leguminous forages yields higher economic returns than maize intercropped with Sudan grass when fertilizer is not applied. In this case, the maize-pigeon pea and maize-Sesbania intercrops, in that order, are economically the most promising intercrops for Kaimosi Cluster. Fourth, for Kaimosi cluster, maize-Sudan grass intercrop generates greater economic returns than maize-legume intercrop when fertilizer is applied. In this case, maize-Sudan grass and maize-pigeon pea intercrops, in that order, are economically the most promising intercrops. Fifth, for Masumbi Cluster, maize-Sesbania followed by maize-Sudan grass are the most promising intercrops only when fertilizer is applied. When fertilizer is not applied, pure-stand maize is economically superior to the maize-forage intercrops. Sixth, fertilizer application was economically more profitable than non-fertilizer application at all sites for both pure-stand maize and maize intercrops. Seventh, and lastly, while intercropping maize with forage crops yields greater economic returns than pure-stand maize in some areas, it may lead to economic loss in other areas depending upon soil fertility and climatic conditions of the areas in question.

Table A6. Partial budget analysis of fertilizer application to maize intercropped with forage crops, Masumbi Cluster, short rains season, 1983

	With Fertilizer		
	Incremental[a] benefit	**Incremental[a] cost (ksh/ha)**	**Marginal net benefit (+) cost (-)**
Maize-pure stand	1,971	238	+1,733
			(7.3)[b]
Maize-Sudan grass	4,130	238	+3,892
			(16.4)
Maize-Sesbania	3,523	238	+3,285
			(13.8)
Maize-pigeon pea	2,766	238	+2,528
			(10.6)
Mean benefit or cost	3,097	238	+2,859
			(12.0)

a

. Incremental benefit (gain) or cost (loss) as compared to the same intercrop without fertilizer application.

[b]. Figures in parentheses are benefit: cost ratios (BCR) computed as a ratio of marginal net benefit (+) or cost (-) to incremental cost. BCR is an absolute marginal rate of return on incremental cost. When multiplied by 100 it yields a percentage return.

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The economics of smallholder dairy production in Hai District, Tanzania

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Abstract

This paper presents a cost-returns analysis of smallholder dairy production in Hai District, Tanzania. The use of gross-margins analysis to assess the economic impact of proposed technologies is demonstrated. The data used were obtained during a 1984 household survey of 150 randomly selected farmers keeping dairy cattle.

The results indicate that dairy production is economically attractive for smallholder farmers in both the short run and long run. The high internal rate of return (over 50%), while suggesting an overestimation of enterprise costs, explains the high demand for dairy cattle by smallholder farmers despite the present critical shortage of feedstuffs.

The comparison of gross margins per cow and per man day with existing feeding technology, and an improved technology that incorporates the use of an urea-molasses mixture, shows that productivity can be improved with these inputs. While merely reorganizing resources is unlikely to raise farmers' income substantially, technologies that can make existing resources more productive do have this potential.

Introduction

Smallholder dairy production in Tanzania is concentrated in the highland areas of Kilimanjaro, Arusha and Mbeya. The increased demand for fresh milk in urban centres in recent years has resulted in an expansion of smallholder dairy production around these centres. Until recently, Government policy on dairy development focused mainly on large-scale State-owned farms. The new Tanzania livestock policy gives due emphasis to the development of the smallholder sector through increased supply of upgraded cattle, animal feeds and other production inputs, including extension services (Ministry of Livestock Development 1983).

The emphasis on smallholder dairy production in Tanzania calls for increased efforts towards the development of locally tested technology that will increase productivity given farmers' present resources. Available information about peasant farmers indicates that they are good decision makers, given their experience and resources, and that a mere reallocation of their resources will not appreciably increase incomes (Stevens 1977). Assuming that smallholder farmers allocate their resources to maximize profit or expected utility of profit, subject to satisfying their subsistence needs, new technologies will only have a chance of success if they effect an improvement in standard of living. There is, therefore, a need to understand the economics of current smallholder production systems and the potential impact of proposed new technologies before making definite recommendations.

This paper reports on the results of a study of the economies of smallholder dairy production in Hai District. The work is part of an ongoing project on smallholder dairy feeding systems whose main objective is to design innovations that will increase productivity. The data used in this paper are based on a household survey conducted in February/March 1984 on a randomly selected sample of 150 households keeping dairy cattle.

Farming Systems in Hai District

Land use in the District is based on kinship structures which are basically patrilineal as far as patterns of land ownership and inheritance are concerned. Farmers own farms in two distinct zones: the highlands, where they live in permanent homesteads, and the lowland zone.

The highland zone has relatively more rainfall and the cropping pattern is coffee with bananas. The lowland zone is cropped with maize and beans. The survey conducted in 1984 indicated that the median farm size in the highland zone is 1.01 hectares, while in the lowland zone it is 1.2 hectares. The average distances from the homestead to the lowland farms is 18 km (Urio and Mlay 1984). These statistics suggest that land in the District is a critical constraint and that agricultural production can only be increased through intensive land-use measures.

Crop Production

In the highland zone, coffee intercropped with bananas are the main crops. Vegetables are also growing in this zone. Maize and beans are the main crops in the lowland zone, either as pure stands or intercropped. Tractor utilization during land preparation is a common practice in the lowland zone. While coffee is the main cash crop in the District, production has been falling in recent years due to the high incidence of coffee berry disease. Falling production coupled with declining real producer prices have resulted in a growing tendency towards diversification.

Livestock Production

Livestock production is an integral part of the farming system in the District. Land scarcity has contributed significantly to the high degree of dependence between the crop and livestock sub-systems. Stall feeding is the rule, and crop by-products are extensively used as feed, while the manure from the livestock is, in turn, used on the banana/coffee plots to maintain soil fertility.

According to the 1978 national census, cattle are the most numerous livestock in the District, followed by sheep, goats and pigs, as shown in Table 1.

Table 1. Numbers of domestic animals in Hai District, 1975

Type	Number	Average per household
Cattle	132,000	4.0
Sheep	28,200	0.9
Goats	9,000	0.3

Source: Adapted from M.E. Mlambiti et al 1982.

The rapidly increasing demand for milk as reflected in the parallel market price of Sh. 20 per litre compared with the official price of Sh. 10 per litre coupled with declining income from coffee has seen a rapid growth in commercial milk production by smallholder farmers in the District. The relatively unproductive local Zebu is being replaced by improved breeds.

Land constraints and the scarcity of commercial feeds pose special problems for livestock feeding. The main sources of feed are crop byproducts (mainly banana leaves and pseudostems), maize stover and bean straw. Some farmers have also established pasture leys (Pennisetum purpureum, Tripsacum laxum and Setaria spp.) along farm boundaries, footpaths, and on any patches of land unsuitable for crop production, the use of commercial feeds is limited and erratic, and reflects availability rather than ignorance on the part of farmers. On the basis of the survey conducted in 1984, only 58% of sampled farmers used commercial feeds and all indicated that the levels used were below the recommended rates (Urio and Mlay 1984).

Analytical Procedures

Three main analytical procedures are used. These are gross-margin analysis, production-function analysis and returns to investment. Important measures of technical and economic efficiency of resource utilization can be derived from these three analyses.

Gross-Margin Analysis

Gross margins are widely used in farm planning. They can be used to prepare partial budgets for minor changes in the farm programme, or to prepare completed budgets for major changes in farm programmes (Styrrock 1971). Gross-margin analysis involves determining all variable costs and revenue associated with an enterprise. The difference between revenue and total variable costs is the gross margin for the enterprise, and, in essence, this is the return to capital, management and risk.

Several efficiency measures can be calculated from the general analysis and compared with standards to identify areas of potential improvement. Such efficiency measures include gross margin per unit of the enterprise, gross margin per unit of a scarce resource, and gross margin per unit of an investment. In addition, the potential effects of introducing a new technology on the above efficiency measures can be assessed before resources are committed to production.

Production Function Analysis

A production function shows the technical relationship between inputs and output. The general form of the relationship is presented in equation 1.

$Y = f(X_1, X_2 \ldots X_n)$ .... (1)

where X_1, to X_n are the production inputs and Y is output.

While several function forms have been used to study the productivity of agricultural inputs, the Cobb-Douglas production function is the most commonly used (Welsch 1965). It has the following form:

$Y = A \text{ II } Xi_i \, B_i$ .... (2)

where B_i (i = 1, 2..., n) are the partial elasticities of production.

Each measures the degree of responsiveness of output when the corresponding input is changed by 1%. The magnitudes of these coefficients can be used to assess the productivity of the inputs.

The data required for the analysis are cross-sectional, collected across households. Detailed records on outputs and levels of use of the identified inputs are necessary. With appropriate logarithmic transformation and assumptions, estimates of the elasticities can be obtained by the least-squares method. This approach is not used in this paper due to lack of suitable data.

Return to Investment

The returns-to-investment method allows direct comparison with alternative enterprises. This method is particularly useful in cases where loans are to be sought for establishing or expanding an enterprise. The measure proposed here is the internal rate of return whose formula is as follows:

$$\sum_{j=1}^{n} \frac{1}{(1+i)^{n}} F_n = 0 \quad \text{......... (3)}$$

where

n = number of years for which the internal rate of return is relevant

F_n = Net cash flow for year n, and

i = an internally calculated rates of interest that makes the discounted present value of the flow of costs equal to the discounted present value of the flow of returns at a point in time.

The observed returns to investment can be used to explain the observed returns to investment can be used to explain the observed investment behaviour by the farmers.

Results and Discussion

Gross Margins

Table 2 presents results of gross margin analysis based on current production organization in the District. The prices used are those that prevailed in the market when the survey was conducted.

Table 2. Gross margins for a smallholder dairy farmer in Hai District

Animal numbers and performance	
Average herd size excluding calves	4
Average number of calves	1
Average number of cows in milk	2
Average milk yield per cow per day (litres)	7.4
Average lactation length in months	10
Revenue (TSh)	
Milk (2,220 x 2) litres @ Sh. 10	44,400[a]
Variable costs (TSh)	
Concentrates	1,755.00[b]
Mineral supplements	824.20
Purchase and transport of crop residues	988.50
Maintenance of cattle shed	750.00
Veterinary expenses	320.00

Total variable costs[c]	4,637.70
Gross margin (revenue-costs) (TSh)	39,762.30
Gross margin per cow (TSh)	9,940.58
Labour in man days per year[c]	220.00
Gross margin per man day (TSh)	180.74

[a] The revenue on milk sales assume that all milk is sold.

[b] Accurate data on concentrate feeding rates were not available.

[c] Only family labour is used, and the figure of 55 man days per cow per year is adapted from Mlambiti 1983.

One of the innovations currently being tested in the District is the use of a molasses-urea mixture. Apart from improving the intake of maize stover, it is intended to improve feed quality by providing nitrogen. Since data are still being collected, the results presented below are based on created data to illustrate the use of gross margins in assessing the potential economic impact of a new technology. It is assumed that 13 man days will be required to collect the molasses-urea mixture from the selling centres and that the feeding rate is 2 kg per animal per day. The milk yield is assumed to increase by 10% when all other factors are maintained at their present levels.

Table 3. Gross margin analysis incorporating molasses-urea mixture

Revenue	
Milk sales (2,442 x 2) litres @ Sh. 10	48,840.00
Variable costs (TSh)	
Original cost (Table 2) in TSh	4,637,70
Molasses urea (2 kg x 4 x 365) kg @ 0.60 (TSh)	1,460.00
Total variable costs	6,097.70
Gross margin (revenue costs)	42,742.20
Original labour in man days	220
Additional labour in man days	13
Total labour in man days	233
Gross margin per cow in TSh	10,685.50
Gross margin per man day in TSh	183.44

The results in Table 2 indicate that, in the short run, smallholder dairy production under the existing production system is economically viable. The enterprise covers all the variables in costs and has a large positive return to capital, management and risk. The long-run viability of the enterprise is dependent on it being able to cover all production costs. The gross margin per cow and per man day can only be assessed in the presence of other figures for comparison.

The cash-flow results indicate that, with the exception of the first year, the net benefits from the dairy enterprise are positive. The apparently high positive net benefits suggest that costs have been underestimated, in particular the cost of feeds. The exclusion of costs of family labour have also contributed to the under estimation of costs. In computing the internal rate of return, a figure of over 50% was obtained, again suggesting that enterprise costs have been underestimated. However, the high demand for dairy heifers, as reflected by the high parallel market price of Sh. 15,000-18,000 compared with an official price of Sh. 6,000 per heifer, suggests that the enterprise has high returns to investment.

Table 4. Cash-flow analysis of a typical smallholder dairy enterprise in Hai District (TSh)

OUTFLOW	YEAR									
	1	2	3	4	5	6	7	8	9	10
Capital expenditure										
Heifers	45,000.00	0	0	0	0	0	0	0	0	0
Construction of shed	25,000.00	0	0	0	0	0	0	0	0	0
Subtotal	70,000.00	0	0	0	0	0	0	0	0	0
Operating expenses										
Maintenance of shed	0	350.00	450.00	550.00	650.00	750.00	750.00	150.00	750.00	750.00
Concentrates	1,755.00	1,755.00								
Crop residues	988.50	988.50	988.50	988.50	988.50	988.50	1,755.00	1,755.00	1,755.03	1,755.00
Veterinary costs	320.00	320.00	320.00	320.00	320.00	320.00	988.50	988.50	988.50	988.50
Mineral supplements	824.00	824.00	824.00	824.00	824.00	824.00	320.00	320.00	320.00	320.00
Subtotal	3,887.50	4,237.50	4,437.50	4,437.50	4,537.50	4,637.50	824.00	824.00	824.00	824.00
Total outflows	73,887.50	4,237.50	4,437.50	4,437.50	4,537.50	4,637.50	4,637.50	4,637.50	4,637.50	4,637.50
INFLOW										
Sales of milk	0	3,120.00	35,400.00	40,200.00	44,400.00	44,400.00	44,400.00	40,200.00	35,400.00	31,200.00
Sales of calves	0	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00	0	0	0
Sales of culls	0	0	0	0	0	0	0	0	0	0
Total inflows	0	0	3,200.00	36,900.00	45,900.00	45,900.00	45,900.00	40,200.00	35,400.00	46,200.00
Net benefit	-73,887.50	28,462.50	32,562.50	37,262.50	41,362.50	41,262.55	41,262.50	35,562.50	30,762.50	41,567.50

Conclusions and recommendations

This paper has demonstrated the application of gross-margins analysis and internal rate of return to assessing the economics of smallholder dairy production in the Hai District. The results indicate that, both in the short and the long run, dairy production is a viable economic activity under smallholder conditions.

Work done by other researchers in the District has shown that a mere reallocation of resources through enterprise reorganization will not increase farmers' income appreciably (Mlambiti 1983; Msechu 1979). This suggests that an increase in farmers' incomes will come from improved technologies that will make the existing resources more productive. As indicated by the results on potential use of molasses-urea mixture, the gross margins per cow and per man day can be changed if livestock are made more productive.

It is recommended that researchers involved in developing or tasting technologies for use by smallholder farmers first obtain detailed base-line data on current farming practices and resource utilization and then use them to assess the economics of those enterprises without improved technologies. Alternative technologies should then be subjected to economic analysis and the results compared with those of the traditional practices. This will allow us to make more rational choices and technology recommendations, which are, therefore, more likely to be adopted by farmers.

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Strategies for farming systems research

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Abstract

FSR is not really a new practice. However, there are institutional bottlenecks in it. Interfacing research, extension and other support service institutions, usually separated by commodities or broad disciplines, to focus their attention on farmers is a major problem for implementing FSR. Nevertheless, FSR is receiving increased attention and the trend will continue because efforts to improve small-farmer production systems have made researchers recognize the strong linkages between farming activities and the environment, the household and community. Consequently, there is an obvious need to study, learn from and exploit those linkages to the benefit of the farm households.

The objectives of this paper are to present an overview of farming systems research (FSR), review key methodological guidelines and issues, and briefly describe the organization and operation of the FSR Unit in Zimbabwe.

Overview of FSR

Farming systems research is an approach for generating appropriate technologies for studying existing farming systems and involving the technology users - usually the small farmers in the planning and evaluation process. The approach is justified on the basis of three vital considerations. Firstly, the farmer and his family are rational in their decision-making. Given their available resource base, circumstances, opportunities and knowledge, they typically manage a combination of crops, animals, and other on-farm and off-farm activities to satisfy basic physical, financial and social needs. Secondly, the production systems of small farmers embody an integrated set of husbandry practices that have developed over centuries so that these systems are stable, complex and very sensitive to the ecological, biological and socio-economic environment. Thirdly, a farming system belongs to the goal-setting and purposeful category of systems and its direction is determined by the farmer and his family. The decision to introduce changes or adopt any innovation depends entirely on how the household assesses the relative advantages and disadvantages in terms of its own perceptions and priorities. Because of these considerations, FSR is an interdisciplinary, integrative, problem-oriented and farmer-centred approach.

The research experience on cropping systems in the developing countries has resulted in a progressive refinement of FSR concepts and methodologies (Harwood 1979; Byerlee et al 1980; Gilbert, Norman and Winch 1980; and Zandstra et al 1981). Similarly there are research experiences on livestock production (Li Pun and Zandstra 1982; Fine and Lattimoer 1982; CATIE 1983; Gryseels and Anderson 1983; Ruiz and Li Pun 1983) and mixed production systems (McDowell and Hilderbrand 1980; Fitzhugh et al 1982; Huxley and Wood) which have successfully applied FSR approaches and methodologies. State-of-the-art reviews have also been carried out at the request of donors (Dillon, Plucknet and Vallaeys 1978; Shaner, Philipp and Schmehl 1982; Simmonds 1984).

At first glance the review of the wide range of experiences tends to suggest a state of confusion in FSR.

There appear to be differences in terminologies, approaches and methods and these are sometimes intentionally exaggerated by FSR proponents for personal or institutional reasons. Upon careful analysis, however, these differences can be explained on the basis of the following characteristics of research programmers the primary objective (system description and analysis, technology development or methodology development), the type of farming system/environment interaction under study (maize production in humid areas, lowland and upland rice production, savannah livestock production, agroforestry in semi-arid areas, etc.) and the composition/leadership of research teams (economic, agronomic, land-use planning, plant protection, or other bias). Furthermore, it is interesting to note that crop FSR generally tends to have its roots in the "Green Revolution" and studies of adoption patterns, livestock FSR in systems analysis and modelling, and agroforestry FSR in resource conservation and ecology. To a large extent these schools of though determine how the practitioners perceive and analyse a given farming system.

In spite of such varied experience and schools of thought, there is a consensus on FSR philosophy and strategy. To improve a farm system, it must be studied and understood. FSR is an interactive stepwise process that has three actors - the researchers, extension agents and farmers - in the conduct of the four basic phases:

1. Characterization involves an understanding of the structural and functional relationships of current farming systems in specific geographical areas and an identification of the endogenous and exogenous constraints to achieving farmers' goals;

2. Design of technological alternatives involves an x-ante evaluation and selection of strategic interventions, components, inputs and/or practices that results in a well defined and effective agenda for follow-up research with respect to farm monitoring, component experimentation and/or technology testing;

3. Testing involves evaluation, on farmers' fields and under partial or exclusive farmer management, of the assumptions, decisions and expected performance of the technological alternatives as designed in the previous phase;

4. Diffusion usually refers to the dissemination of tested innovations to credit and extension personnel or to small groups of farmers, usually through intensive assistance. Large-scale adoption ad impact on productivity is more difficult to achieve.

Although extension to farmers is an intrinsic activity of FSR, there is not much experience of this phase mainly because international centres consider it the responsibility of national programmers. However, national programmers are unable to effectively transfer such results due to their own resources constraints or lack of infrastructural support and incentives for farmers.

Methodological guidelines and issues

This section will highlight some of the more critical research steps in FSR. More emphasis will be given to livestock FSR.

Analysis of the Farming Systems and its Sub-systems

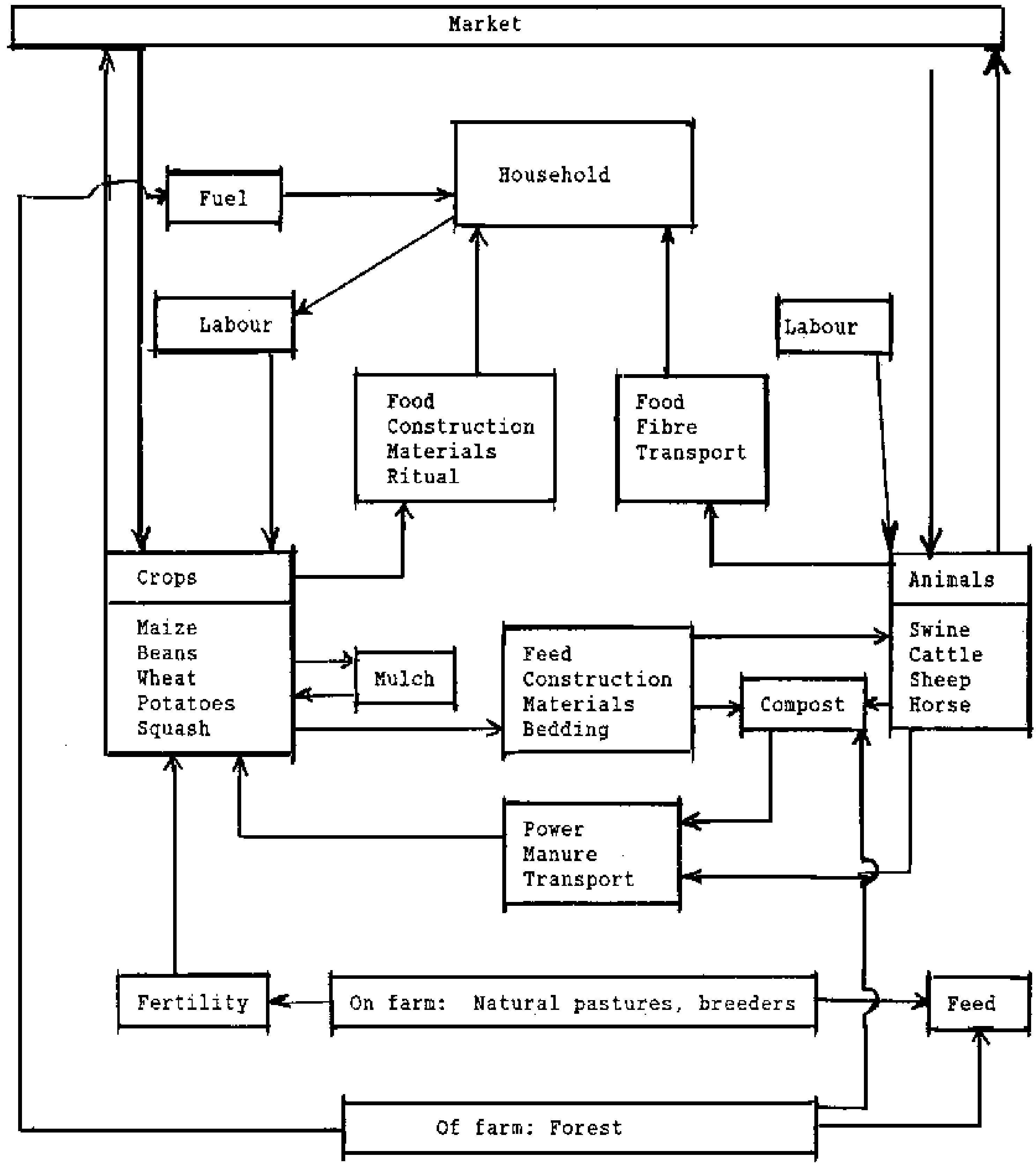
Understanding how a system works implies knowing the parts and how they relate to each other and to the environment (Dillon, Plucknet and Vallaeys 1978; Roundtree 1977; Van Dyne and Abramsky 1975). From a pragmatic viewpoint, one begins with an identification of the components of the farming system as illustrated in Figure 1. An inventory of crops with the cropping components, species within the animal component, and other on- and off-farm activities, is used to illustrate the major interactions of these components with each other, with the household component and with the outside market. This diagram provides a global picture of the farming system which can be improved with a quantitative description of the components and their interactions. Such a semi-quantitative model is extremely useful to ensure that one does not unintentionally exclude important parts of the system, or to select, on a preliminary basis, specific parts for further analysis.

As a second step, one must understand how these parts are related to one another, with respect to space and time. To do so, one must know how the land is used and managed on different production enterprises during the course of the year. Cropping patterns are examples of this type of relationship and could likewise be extended to livestock production as follows:

(a) Maize/sorghum: intercropping of maize and sorghum;
(b) Sorghum-beans: cropping of beans after harvesting sorghum;
(c) Pasture/cattle/goats: pastures grazed by cattle and goats together;
(d) Maize-cattle: cattle grazed on maize field after harvest.

If present in a given farming system, these can be called sub-systems or agro-ecosystems (Hart 1981).

Figure 1. The identification of components and their interactions in a mixed farming



Source: McDowell and Hilderbrand 1980

As a third step, one must describe, quantify and interpret the input-output relationships, that is, the flows of energy, materials, information, and so forth. With respect to both inflows and outflows of a sub-system, one must ask and answer the following questions:

What?	Water, labour, seed, fertilizer, draught power and technical advise are examples.
Why?	The reasons for conducting certain activities could be social, economic, etc.
How much?	Quantitative and qualitative measures are essential to estimate their value or opportunity cost.
When?	This should be done at least on a monthly basis.
From where and to where?	Other on-farm sub-systems or storage deposits and off-farm sources or buyers/beneficiaries should be identified

Although there are different levels of specificity and detail to deal with these questions, it should be borne in mind that this analysis should provide the basis for:

(a) Understanding the specific roles of each crop or animal species in the farming system;

(b) Determining the types (direct or indirect and technical or administrative) and levels (low, high, etc.) of existing functional interactions among sub-systems; and

(c) Determining technical and economic performance, the positive and negative effects, and the advantages and disadvantages of each sub-system.

It may be decided to proceed with distinct levels of analysis for different sub-systems as a way of streamlining the analysis of the total farming system.

Identification of Constraints

Identifying constraints is a continuous process of discovering opportunities or potential for change - at the region/community, family, farm or subsystem level - that could improve the performance of the farming system. As knowledge of the structural properties of the system improves through the implementation of the various phases of farming systems research, constraints are progressively refined and redefined.

Although constraint identification is one of the main objectives of the characterization phase, it is very much a function of who does it. Is it the farmer or the researcher? If it is the researcher or a research team, then care must be taken to avoid disciplinary biases (Zandstra in Fitzhugh et al 1983). Even when interdisciplinary teams are used, differences occur because of:

1. The criteria of evaluation applied. Researchers generally use physical or economic productivity criteria within the short-term context (Perrin and Anderson 1976; Dillon and Hardaker 1980; Banta 1982), whereas farmers may consider these as means rather than ends for achieving family objectives, or as of secondary importance within a broader set of criteria and a longer term context;

2. The scope of analysis. Researchers focus on enterprises or, at best, on sub-systems and perceive their range of decision variables as being confined to the biological and technological aspects of the production systems. Farmers assess opportunities in terms of how they fit in with on-farm and off-farm conditions. Their perceptions of decisions or manipulable variables may differ substantially from the researchers.

3. The analytical methods used. The researchers use simple descriptive statistics, regression functions, analysis of variance, optimization and simulation models, basically quantitative approaches. The farmers use their experience, common sense and intuition, basically qualitative approaches. What assumptions concerning risk and uncertainty are made and how they can he considered in these two general approaches is certainly a major issue. Farmers tend to act conservatively because they are faced with unpredictable factors such as fluctuating weather conditions, disease and parasitic attacks, uncertain input availability and costs, and unstable product outlets and prices. Farmers do not assume favourable conditions as researchers do.

Thus the basic question to be addressed is what present conditions, when changed, would have the largest net effect in the quickest time on the relevant performance criteria. Answering this question requires symbiotic interaction among social and natural scientists and direct and continuous discussion with farmers.

Ex-Ante Analysis

The design phase is a process of identifying, fitting and screening technological innovations (components, inputs and/or management practices) into the traditional system, that should solve the farmers' problems. Design objectives pertain to particular levels of desired performance, income generation or welfare, defined in conjunction with farmers. For example, they-could be stated as maximizing yields per hectare, yield per dollar of cash input, yield per unit of moisture, gross income per hectare, family net income per labour day, or an index of living standard. In addition to these, the researchers may define other objectives, such as applying existing experimental results, designing transfer "packages", or setting priorities for the research organization. The definition of the type and levels of these objectives determines the intrinsic characteristics and expected performance of the interventions and the time required to complete the task.

Technologies to be considered in the modelling exercise can be procured from farmers, from the existing body of information from past research, or developed by conducting component research. Some farmers in the same geographical area or farmers from other areas have agricultural practices that overcame similar constraints and are worthy of consideration. Past independent research on specific components provides technologies that may be suitable. The need for component technology research, that is trials managed mainly by researchers following experimental station procedures, may arise due to a conspicuous lack of information, for example on the range productivity of natural species of grass, appropriate stocking rates and utilization potential of various crop by-products and residues.

Fitting technological innovations within the traditional system involves identifying conflicts with the endogenous and exogenous conditions of the system which are created by the requirements and impacts of the proposed technologies. The analysis has to be conducted in a series of progressive steps, summarized as follows:

1. The ecological and physical environment. Soil capabilities, rainfall patterns, temperature levels and their relationships are the basic determinants of technological design;

2. The socio-economic environment. Technologies are determined and do affect social customs, religious beliefs and values, age and sex occupational roles, forms of social or communal organizations, credit policies, input markets, product markets, etc.

3. The family goals and objectives. Although the definition of design objectives is based on these considerations, the introduction of a particular technology may interfere with other goals and objectives;

4. The sub-systems. Conflicts may be intensified or reduced with respect to the management of other sub-systems;

5. The farm resources. New technologies directly affect the use or replacement of locally existing resources, tools or techniques. They may be too difficult or complicated for the farmer to manage.

At each stage the number of technological options to achieve the design objectives would progressively diminish.

From the view point of the farmer, the ex-ante evaluation procedure of technological options includes a quantification of:

1. The magnitude of the real benefit in terms of the design objectives, that is, physical, economic or financial benefits;

2. The predictability of benefits (levels of risk), at least in terms of favourable, unfavourable and normal conditions;

3. The requirement of resources, particularly labour and cash costs;

4. The length of time required to implement recommended changes and to obtain acceptable levels of success.

From the viewpoint of research scientists the ex-ante evaluation usually includes one additional concern, transferability. These are questions related to the divisibility of the designed alternative (can the farmer apply a part of the "whole package"?), the scope of application (how widely can the designed alternative be applied?), and the expected impact on other key sectors of the society (who will be the beneficiaries or losers among leaders, input suppliers, product intermediaries and buyers, etc?). For this reason, it is important to define, from the beginning of the design phase, the endogenous and exogenous environment of the farming systems within which the technological alternative is being modelled. A precise description of the target farmers, decisions and assumptions made with respect to the key determinants of the expected performance of the interventions, vis-a-vis the traditional practices, results in a clear statement of what the proposed technological change is, what type of farmers and production system it is designed for and what conditions (ecological, physical and socio-economic) it is suitable for. These are the basic hypotheses to be evaluated in the testing phase, and which are particularly significant for extension purposes. Consequently extensionists can make an effective contribution in addressing these issues and understanding their broader implication.

It is common that for the same geographical area several target groups of farmers are identified because of particular endogenous and exogenous characteristics of the farming systems and that for the same target group several interventions are designed because of particular decisions and assumptions made in the ex-ante evaluation.

Types of on-farm research trials

The results of the design process set the stage for and define the terms of reference for the following activities:

(a) Further analysis of existing systems (complementary single-visit surveys, farm monitoring or case studies);

(b) Technology testing under farmer conditions and management (on-farm farmer-managed trials);

(c) Component technology development under farmer conditions but under the shared management researchers and farmers (on-farm researcher and farmer-managed trials);

(d) Component technology development under farmer conditions but under the exclusive management of researchers (on-farm research-managed trials);

(e) Component technology development on experimental stations (on-station researcher-managed trials); and it is conceivable to have

(f) Component technology development on experimental stations but under partial management of researchers (on-station researcher and farmer-managed trials).

Accordingly, there are three types of on-farm trials: researcher-managed (RM), researcher and farmer-managed (RFM) and farmer managed (FM). These are compared in terms of design and evaluation criteria based on the experience of cropping systems research (Table 1).

In RM trials, the farm is used as the experimental unit or laboratory, primarily to find out the characteristics of the area and its ecological/physical potential, to screen available or high-risk, technologies and to learn from farmers. In FM trials, on the other hand, testing is aimed at evaluating how the proposed technology fits into the farming systems, permits assessment of the impact on farmers' performance criteria, the easiness or difficulties of management and adoption potential, in addition to providing guidelines for needed infrastructural support and appropriate extension strategies. Field days with participating farmers in FM trials can be used as an effective method to obtain feedback on collective issues and priorities.

In RFM trials, research focuses on exploring alternative treatments with respect to the key determinants of the proposed technology in FM trials. For example, if the performance of the technology being tested is sensitive to the proposed level of fertilization, the researcher may design an experiment (with the proposed, the farmer's and optimal level) to be conducted on the same fields as the FM trials and with some prearranged degree of farmer involvement. Similarly, RM trials may be designed to identify key biological and physical determinants of technologies for FM trials under more controlled conditions.

Table 1. Comparison of on-farm cropping systems research trials in terms of design and evaluation criteria

Criteria	Researcher	Researcher and farmer	Farmer
Design:			
1	CR, RCB, RIB, SP	CR, RCB, RIB	CR, RIB, PT

	Field design			
	No treatment combinations	5-20	4-6	2-4
	No replications	4-5	2-4	1-2
	Plot size, M²	15-25	15-100	50-1000
	Precision (farms, land types)	within farm	across farm/farmer	across farmer
Characteristics for selection of site				
	Evaluation			
	Objective	Generation	Verification	Acceptance
	Level of performance	Higher	Intermediate	Lower
Variation of performance indicators				
	Loss of experiments	Moderate	High	Very high
	Loss of experiments	Moderate	High	Very high
	Risk consideration	Biological	Management	Economic

[1] Complete randomized (CR), randomized complete block (RCB), randomized incomplete block (RIB), split plot (SP) and paired treatments (PT).

Source: Adapted from Shaner, Philip and Schmehl p. 101, 1982.

A crucial aspect of evaluation concerns the analysis of risk. Risk refers to the expected levels of performance depending on the probability of occurrence of certain events and acts. There are risks associated with biological (climatic conditions, pest and disease attack, etc.), management (understanding by the farmer, sequencing of activities, compatibility with available resources, etc.), and economic factors (availability and prices of cash inputs, availability of markets and prices of products, opportunity cost of resources and services, etc.). These considerations have obvious implications for the different types of on-farm trials, particularly with respect to the level and variation of performance indicators and the loss of experiments. Thus in RM trials, biological risk is the major source of performance variability since the other factors are under control, whereas in FM trials farmers always tend to act more conservatively because they are confronted with the entire array of unpredictable factors. Consequently, it is critical to identify the specific circumstances and causes of variation and loss when it occurs.

Usually the three types of on-farm trials are conducted simultaneously in order to gain time. However, the decision to implement one or the other first depends on the relative stage of technological development and complexity of farming system in the particular area. If component technology research is at an advanced stage (or results can be extrapolated from ecologically analogous areas) and the farming systems comprise monocropping sub-systems with minimal interactions with animals or their farm enterprises, on-farm research could focus on FM trials. On the other hand, if component technology research is at a very early stage (which is usually the case in areas with multiple cropping systems and strong crop/animal interactions), FM trials may he premature and therefore extensive RM trials are necessary to achieve a better understanding of real farming systems constraints.

On-farm research trials with animal production systems are extremely difficult to implement particularly RM trials with traditional experimental designs. Experimentation requires many animals with comparable weight and sex characteristics. The required experimental period (a minimum of 4 months for feeding trials or 3 to 4 years for cattle grazing experiments) makes it almost impossible for farmers to agree to provide their animals and facilities. Even when negotiations with farmers are successful, the probability of losing experiments is extremely high because of the lack of appropriate facilities and conditions in traditional production systems. Because of the enormous cost of animal production research ($1,000-5000 per experiment in cattle production), the number of treatments and replications on FM and RFM trials has to he reduced. Unlike cropping systems research, the farmers cannot he asked to provide a small plot or part of their herd for experimentation. Thus statistical evaluation of RM trials usually leads to ambiguous results because of the inability of researchers to control non-treatment variables. System experimentation (livestock or whole-farm) may be more suitable for on-farm research but logical analysis and farmer assessment are more relevant evaluation methods. Here modelling is recommended as a helpful tool but it must he practically oriented to reflect how the farmers manage the system. Usually, in livestock system experimentation, it is the cost, troth investment and operational, which limits the type of interventions. This is a blessing in disguise since it is also a very important criterion from the farmers' perspective.

The FSR unit in Zimbabwe

Organization of the Unit

The specific objectives of the Farming System Research (FSR) Unit in the Department of Research and Specialist Services (DR & SS) are to study mixed crop and livestock production systems in the communal areas, to adapt, develop and test on-farm improved crop and livestock production technologies and systems; and to provide information for the formulation of agricultural development policies for the communal areas (FSR 1985).

The FSR staff consists of one agricultural economist (team leader), two livestock scientists, two agronomists, eight research assistants and four field hands under the overall co-ordination of the Deputy Director of DR & SS. The five-member core team, which is stationed at DR & SS Head Office in Harare, is technically responsible for designing or adapting research strategies, methodologies and programmes of work and for guiding, supporting and participating with the field teams in the implementation. One member of the Head Office team has also been assigned the task of co-ordinating technical and resource inputs for and monitoring the activities in each of the two selected communal areas.

A field team, consisting of a research technician, two agricultural assistants and two field hands, has been permanently assigned to each area. Their duties include selecting suitable research sites and farmers, conducting farming systems surveys and monitoring studies, and implementing research trials as well as continuous liaison with farmers to obtain feedback on proposed interventions and, as they develop competence, participating in the analysis and interpretation of research results.

The contribution of institute or station research scientists of DR & SS to the FSR Programme has been substantial in that they have provided reviews of past research on key topics or problem areas, have assisted in assessing farmer situations and identifying research opportunities in situ, have participated in designing research trials, and are planning to establish on-station trials which have been identified as priorities for component technology development. The close interaction between the FSR staff and staff scientists in the various DR & SS activities has resulted in a better understanding of FSR philosophy and strategies and in a mutually beneficial working relationship.

An interesting feature of the model is the active participation of the extension staff and organized communal groups in the research programme. Extension staff usually help with designing and carrying out diagnostic activities. Additionally, to cover a large number of households while saving on travelling time and costs, trial sites in each research area are clustered on the basis of extension workers and their farmer groups, given particular soil climatic and farmer characteristics. Extension staff participate in discussions on farmers' problems, research progress and research diagnosis, extension workers accept responsibility for establishing and monitoring farmer-managed trials and conducting pre-planting demonstrations for farmers before the start of the cropping season. An added dimension of extension participation in FRS is the contribution of the social science experts in planning and implementing household and community decision-making studies.

The international research centres, ILCA, CIMMYT and IDRC have a special role to play in terms of providing experienced scientists whose aim is to complement and build on FSR in the Department of Research and Specialist Services (DR & SS). They provide technical expertise in methodological approaches and subject matter-staff training and documentation services. The participation of all these organizations has been co-ordinated to focus almost exclusively on the felt needs and priorities of the FSR Programme.

Methodological steps

The FSR Unit carried out the following activities in 1984 which demonstrate the methodological steps followed in designing the 1984/85 programme:

1. Organization FSR;
2. Review past research;
3. Selection of areas;
4. Informal survey;
5. Screening interventions;
6. Formal surveys;
7. FSR meetings.

A summary of the specific objectives pursued and procedures employed in each activity follows.

Review of past research

This review covered a series of specific topics: national development policies and priorities, the role and ownership patterns of livestock, communal grazing practices and schemes, nutrition and supplementation, as well as health conditions and management, genetic potential of local breeds and crosses, and livestock marketing and markets. Although livestock production systems were particularly emphasized because of the general lack of information in this regard, information on crop productivity and constraints was reviewed, particularly the previous FSR work under the Agronomy Institute. For the FSR meeting in September, station researchers prepared three research review papers on topics of critical importance to the communal-area production systems: veld management, cattle manure utilization for crop production, and moisture harvesting and conservation techniques.

Area Selection and Description

Three major sets of area selection criteria were identified and used, namely: the ecological and physical conditions of communal areas in the country, the biological and economic potential for both crop and livestock production systems, and the managerial or logistic conditions for setting up a research base. From a total of four suggested areas, Chibi and Mangwende were selected, representing low- and high-potential areas, respectively.

Informal Survey

A one-week informal survey was conducted in each area. Crop and livestock research and extension specialists familiarized themselves with the areas and interviewed and discussed with a wide diversity of farmers to obtain a broad view of the existing farming systems. The specialists worked intensively in small inter-disciplinary teams and rotated on a daily basis to provide ample opportunity to discuss and analyse critical problems faced by the farmers from different personal (within discipline and disciplinary (across disciplines) perspectives). Their findings resulted in a tentative list of research proposals defining potential technological interventions within all the major components of the farming systems.

Screening/selection of Technological Interventions

To evaluate the technical and economic feasibility of specific interventions resulting from step 3 above, the FSR would be attempting to overcome and the target group of farmers likely to benefit from such interventions. They were classified into constraints at the levels of the household, crop component and livestock component. Within and across class, they were organized into a cause and effect hierarchy. For example, within the livestock component, poor digestibility of feeds results in insufficient consumption of feeds and this results in low animal weight gains. Another example, across components, is that inadequate quantity and quality of feeds causes low calving rates which causes small herd sizes which causes poor access to draught and low quantity of manure for crop production, and both results in low productivity of land, thereby resulting in the household problems of cash shortage, unstable cash hierarchical levels within the farming systems becomes the initial method of analysing technical options.

The previous exercise sets the stage for identifying the opportunities to intervene in the system, which constitutes the fundamental objective of this exercise. Firstly, the FSR Team attempted to describe on which constraints and in what manner (direct or indirect) each research intervention (if results were satisfactory and applied successfully) should be having an impact (positive or negative). Secondly, for each research intervention, the probable advantages (benefits for farmers) and disadvantages (conflicts) were identified. The team gave special attention to conflicts with existing on-farm (objectives of farmers, on- and off-farm enterprises, resources), community (tenure arrangements, organization) and exogenous conditions (markets for inputs and products, availability and prices of inputs) which would likely arise from effecting the proposed changes. Thus far, no quantification of these aspects had been done (see Table 2).

Formal Surveys

A special purpose survey of 76 farmers, approximately two-thirds of whom were well aware of the crop-trial programme, was conducted in Mangwende to assess crop production technologies that were tested for the area, namely tine and herbicide use for maize production.

Another survey was conducted to consult farmers on more appropriate technological interventions and important assumptions made for the analysis in step 4, and to determine to what extent their reactions are conditioned by selected farmer characteristics, available resources and productive activities. A five-page pre-tested questionnaire was used to interview 131 and 108 farmers in Chibi and Mangwende, respectively. The farmers were selected following a stratified (extension-worker areas, village within area, and households within village) and systematic (every unit) or random procedure which was considered appropriate for drawing a representative sample from the entire geographical area.

FSR meetings

A total of 36 Mangwende workers participated in a four-day meeting to evaluate the results of the crop production trials of the 1983/84 season and to plan a preliminary programme for the 1984/85 season It was proposed that maize, groundnut, soyabean, sunflower, sorghum, and finger millet trials be established in 66 sites in Mangwende and that extension workers be directly involved in roughly 50% of these trials.

A meeting with DR & SS researchers, AGRITEX officers, and other Zimbabwean and international organization researchers was held in Harare. The purpose of the meeting was to set out the on-farm research proposals, and to analyse them in detail to obtain feedback from the participants. Specific suggestions for improving proposed designs, the identification of other on-farm and on-station research, and relevant information from past research and/or other projects were being sought. During the deliberations the need to consider at all times farmer's priorities and conditions was emphasized.

Farmer Target Grouping and Policy Recommendations

At every step in the process described above, decisions and assumptions were being made on the basis of the actual on-farm, community and exogenous conditions or on the basis of possible changes that could be effected therein. It was essential to record them for two reasons. Firstly, such decisions and assumptions define the target group of farmers (e.g. farmers with and without draught cattle, farmers with and without fallow arable land) for whom each technical intervention is being designed and therefore with whom interventions should be tested. Results of the testing phase will further refine the definition of the target groups. Secondly, the set of "possible" changes which is assumed in the design phase and becomes necessary to promote adoption after successful testing, defines the basis for interphasing FSR with the political or policy setting entities. In other words, researchers can also be very precise as to what non-technical elements need to be asessed or changed (credit, markets, roads, etc.) to promote particular innovations among farmers. These should be formulated into policy recommendations for communal area development.

This particular model of FSR in DR & SS was negotiated and defined according to the peculiar circumstances prevailing in Zimbabwe, namely the strength and tradition of the agricultural research organization, the DR & SS commitment to FSR, the objective/commitment of the international centres and the present socio-economic and organizational conditions in the communal areas.

Table 2. Identification of possible positive and negative effects of introducing fodder legumes on arable land into the farming system

Affected resource or activity	Farmers with permanent cropping practice		Farmers with fallow practice (fallow = uncultivated arable land)	
	Positive	**Negative**	**Positive**	**Negative**
Labour	Less labour required for land preparation at establishment			Labour required for establishment
	No labour required for harvesting (grazing)			
Land use/soil	Nitrogen/root enrichment of soil		Unused land properly covered (reduced erosion danger) Nitrogen root enrichment of soils	
Draught power	Reduced draught power through			Draught power required

use/requirement	use of minimum tillage at establishment No draught power requirements in years 2+3			for land preparation in year of establishment
Crop production	More labour input available for crops (e.g. quicker planting, better weeding)	Reduced crop area	Higher yield of crop in year 1 after cultivation due to better soil fertility	Draught labour input available for crops in year of establishment
	Higher yield of crap in year 1 of recultivation (better soil fertility)			
Animal production	More supplementary protein feed available for cattle and other ruminants, donkeys (stronger animals, reduced mortality, increased conception rates, increased milk production)	Less crop residues	More supplementary protein feed for cattle and other ruminants donkeys	
Cash income/expenses	No cash requirements for seed (and fertilizer) in year 2+3	Less cash income from crop due to reduced crop area	More cash income from higher yields in year 1 of recultivation, or	Cash expenses for fertilizer and seed required
	More cash income from higher yields in year 1 or recultivation cc less cash requirement for fertilizer in year 1 of recultivation due to soil fertility		Less cash expenses in year 1 of recultivation for fertilizer due to better soil fertility	Additional cash expenses for draught power in year of establishment for farmers with no draught power
	No cash requirement for draught power in year 2+3 for farmers with no draught power Possibly cash income from better fed animals		Possibly more cash income better fed animals	
Food supply to family	More milk available due to better cow nutrition More meat from small ruminants available due to better animal nutrition	It is assumed that the reduced crop area will not affect the subsistence food supply	More milk available More meat from small ruminants available	
Community	More draught animals available due to increased herd sizes/reduced mortality	Increase of herd sizes/stocking rates, denudation of grazing land if off-take is not increased to the same extent	More draught animals available due to increased herd sizes/reduced mortality	Increase of herd sizes/stocking rates and increased denudation of grazing land it off-take is not increased to the same extent

Source: FSRU, Animal Report, 1984. Farming Systems Research Unit, Department of Research and Special Services, Ministry of Lands, Agriculture, and Rural Development, Harare.

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Rapportuer's report on session III - Socio-economics aspects

A.R. MacLaurin

In order for useful economic analyses to be done, it was necessary to closely identify and define the system within which the analyses is made. This meant that there was an urgent need for more and/or better co-operation between specialists in different disciplines. At times this can result in the formal setting up of farming systems research teams. However, this has often been strictly crop oriented although Zimbabwe and Ethiopia recognise the need to incorporate the animal component, particularly with respect to forage and/or livestock research. It was generally felt that data bases were weak and FSR teams can help to alleviate this and help define research priorities.

The way in which FSR can be conducted was outlined and clearly showed the need for close team and farmer-researcher interaction. Cognisance of the farmer-system interaction needs to be made. It was pointed out that small-scale farmers are by nature subsistence farmers and will not adopt strategies or interact if they are put at risk.

For innovations to be effective they should require low inputs, which do not upset the stable system, and produce improved increments. Innovations should not upset the system and should lead to sustained changes.

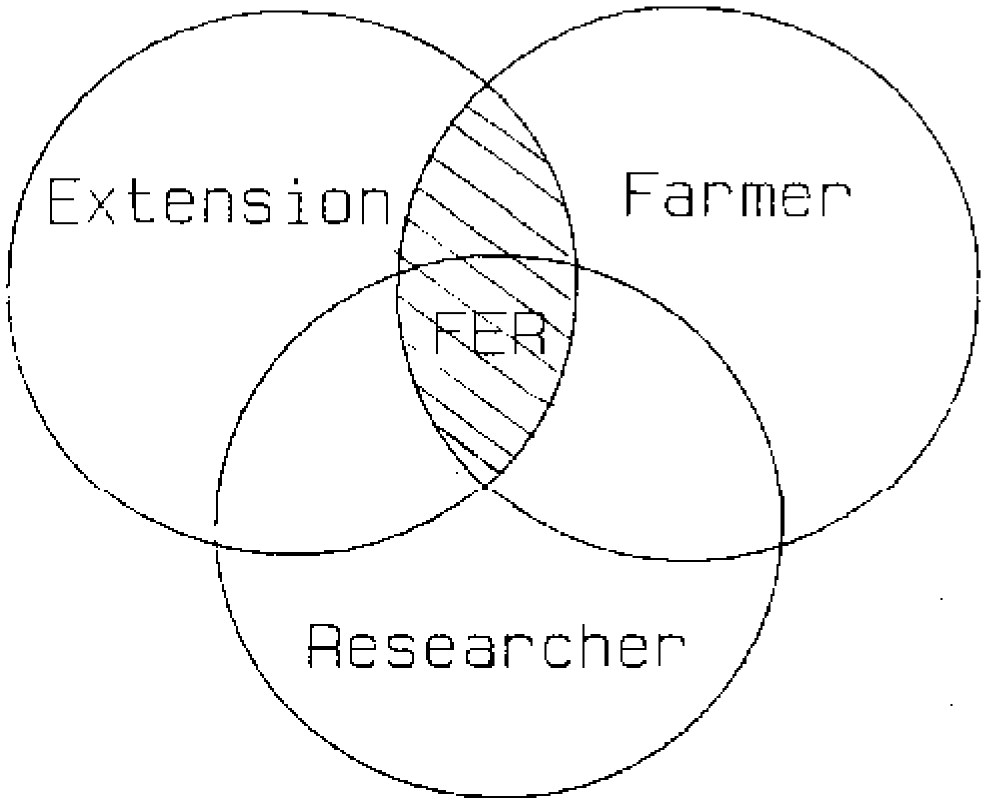
A number of different ways of performing economic analyses were illustrated and clearly showed the need to closely define the system and what assumptions need to be made. Biological and climatic limitations and levels must be defined. Caution was expressed over the use of surveys in defining parameters, particularly with regard to cash flows and labour use and requirements.

In many places, there are FSR teams working in isolation. These should be induced to co-operate both nationally and on an interdisciplinary basis. Where possible formalization of linkages should occur and possibly national approaches developed. However, it was felt that FSR teams should not become too institutionalized.

Where FSR-extension-researcher-farmer linkages are weak, care should be taken not to adopt downward approaches (such as "on a ladder") but have an equally interactive basis as illustrated:

Where FSR teams are testing new technologies on-farm, they should not be too cautious in trying their innovations, which should not only be applicable in the present: but also future contexts. It was generally felt that payment for use of farmer resources should not be done lest it set a precedent, but this would depend on individual cases.

Extension - Farmer - Researcher


Extension
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Researcher

Legumes in forage research programmes for small-scale livestock producers

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Abstract

The emphasis in research for small-scale livestock producers should be on fitting legumes into existing farming systems by means of-such techniques as intercropping, undersowing, hedges, alley-cropping, cut and carry and reserved grazing. Multipurpose legumes warrant particular attention. Genera of potential value for use in small farms, and which are available for testing from ILCA, are given together with information on the environments to which they are adapted.

Introduction

Forage research in the tropics has traditionally emphasized the oversowing of natural grasslands with legumes and the planting of grass-legume pastures. There are good reasons for these approaches. There are large areas of natural grassland in Africa where conditions are unsuitable for cropping and which support mainly livestock. Improved productivity on these lands would, in many countries, significantly increase the productivity of the national herd. However, vigorous and persistent legumes have yet to be identified which can significantly increase grassland productivity under the generally prevailing African conditions of low fertility, low rainfall, poor management and overstocking.

Mixed grass-legume pastures for more intensive, commercial farming conditions have also received considerable research attention. The legumes are grown in mixtures with grass because a pure legume sward will not persist being quickly invaded by weeds due to the increasing soil fertility under the legumes. Such mixed swards, once established, can maintain comparatively high levels of productivity with relatively small labour and fertilizer inputs.

There are factors, however, which indicate that grass-legume mixtures are not the best way of increasing livestock productivity for small-scale farmers. The farmer may not have sufficient land to use for longer term pasture and he may not be prepared to alienate land from cropping, even for a few years, despite the improvements that would occur in soil fertility. In addition, vigorous, stable species combinations which persist are difficult to identify and fairly careful grazing management is often necessary to prevent one component from dominating the pasture. Vigorous legumes are usually identified by researchers long before vigorous grass-legume combinations are identified and their management needs defined, and there is thus a gap of some years between the identification of a productive legume and its introduction. Frequently the final research stages are never accomplished and thus the legume is never introduced at all.

Thus the rapid introduction of legume forage to small farmers is unlikely to be accomplished by the oversowing of natural grasslands or by the establishment of grass-legume pastures.

Methods of legume introduction into farming systems

The small-scale farmers who are most likely to respond to the introduction of legumes as fodder are those who have restricted area for grazing and farming, are dependent on milk and milk products for food and cash and who also cut and carry fodder and have good markets for their animal products.

There are a number of ways in which legumes can be effectively introduced into small-scale farming stems. The effective method or methods will be dependent on the individual farmer, the farming system, the adapted legumes, and the germplasm screened. Some of the more important methods of introduction will be briefly described and some of the legumes identified by ILCA as being of potential value will be listed. Summaries of the promising genera, their environments of adaptation and their areas of usefulness are presented in Tables 1, 2 and 3.

Natural Legume Resources

Frequently there are natural leguminous resources available to the farmer and these can be further developed (Tables 1,2 and 3). In some environmental zones such resources have been critical elements in the farming systems. Natural Acacia woodlands, for example, are used as grazing lands in drier environments. The Acacia enhance grass growth in the wet season, and prolong its growth into the dry season. The Acacia leaves and pods provide significant amounts of high-quality dry-season fodder and thus animals are maintained in reasonable condition through the dry season. At Abernosa Ranch in the Rift Valley of Ethiopia, for example, cattle grazing Acacia woodlands have liveweight gains which are only slightly reduced during the seven month dry season. For male and female Boran cattle gains of 713 and 500 g/day in the wet season and 643 and 456 g/day in the dry season have been recorded (Daboba, personal communication).

There are traditional farming systems in the Sudano-Sahelian zone which utilize A. albida, tall trees which are leafless in the wet season. Farming is done directly under them and the crops are thus able to benefit from the improved soil conditions under the tree canopies.

In areas of higher rainfall and where A. albida is not common, the Acacia trees are thinned and the remaining scattered natural trees are cut back to the main trunk (pollarded) periodically to provide wood for fuel and construction and dry-season fodder.

These valuable resources are frequently destroyed by land clearing and for short-term gains for firewood or charcoal. Research and extension workers should encourage the maintenance and controlled utilization of existing stands, and their re-establishment where they have been destroyed. Research is badly needed to quantify their contribution to productivity.

Herbaceous legumes can also be an important natural legume resource. In the Wolayta region of Ethiopia, an area of high population density with little available grazing land, cut-and-carry feeding of cattle is commonly practiced. Native herbaceous legume (Zornia, Stylosanthes, Desmodium, Neonotonia, etc.) are collected by hand and fed to animals to increase milk yields and improve butter quality. In their search for adapted legume germplasm researchers should not neglect the possibility of enhancing the production of native species and genotypes, particularly those with which farmers are already familiar.

Traditional Legume Crops

In some communities leguminous crops are used as animal feed. It is a common practice for residues of pulse crops to be fed to animals in the dry season. In some cases the crop may be planted solely as animal feed, for example Vigna unguiculata (cowpea) in the Sudano-Sahelian zone of West African. Various species of Erythrina are commonly planted in the middle-altitude regions of Ethiopia for fencing, and/or dry-season fodder. This plant is apparently unpalatable in the wet season, but quite palatable in the dry season.

Researchers should look carefully at the methodologies which farmers have developed and look for ways of enhancing the use of these traditionally developed resources.

Small plots for cut-and-carry Feeding

Small plots of perennial legumes for cut-and-carry feeding of selected classes of stock are particularly appropriate for small-scale farmers. While these plots may have the disadvantage of requiring inputs such as weeding and fertilization, they permit the utilization of a large group of very productive plants which are not normally utilized for cut-and-carry feeding due to their high palatability or sensitivity to mechanical damage by trampling. Viney plants are particularly susceptible to damage by trampling and there are many vigorous and palatable species belonging to the genera Centrosema, Vigna, Phaseolus and Rhynchosia which have potential for cut and carry. In order to encourage rapid regrowth of viney plants, leaves can be stripped from the stems or a generous residual amount of stem can be left on cutting. Almost all leguminous forage genera have some potential for use as cut-and-carry, although the bulkier browse, shrub, sub-shrub and viney species are most useful.

Table 1. Perennial legume genera of forage potential for small-scale farming

Genus	Spmecies	Origin	Potential	Morphology	Rainfall	Altitude	USES								
							1	2	3	4	5	6	7	8	9
Alysicarpus	2	A	G	Herbs	Moderate-high	Medium-high		x		x					
Calopogonium	2	E	G	Vines	Moderate-high	Low		x	x				x		
Canavalia	2	E	E	Vines	Low-moderate	Low-medium							x	x	
Centrosema	7	E	F-E	Vines	Low-high	Low-medium		x		x			x		
Clitoria	1	A	G	Vines	Moderate	Low-medium				x			x		
Desmodium	6	E	F-E	Herbs/vines	Moderate-high	Low-medium		x	x	x		x	x		
Lablab	1	A	G	Herbs	Low-high	Low-medium							x	x	
Lotononis	1	A	E	Herbs	Moderate	Medium		x							
Lotus	3	A	G	Herbs	Moderate?	Medium-high?		x					x		
Macroptilium	3	E	G	Vines	Moderate	Low-medium		(x)		x			x		
Macrotyloma	1	A	E	Vines	Moderate	Medium		(x)	x	x			x		
Medicago	1	E	E	Herbs	Moderate-high	Low-medium		x		x			x		
Neonotonia	1	A	E	Vines	Moderate	Medium		(x)		x			x		

Rhynchosia	3	AE	G	Vines	Moderate	Medium				x			x		
Stylosanthes	8	AE	F-E	Herbs	(low) moderate	Low-medium	x	x	x	x			(x)		x
Trifolium	5	AE	E-G	Herbs	Moderate	Medium-high		x		x			x		
Teramnus	1	A	G?	Herbs	Moderate	Medium-high		(x)		(x)					
Vigna	3	E	G	Vines	Moderate-high	Low-medium				x			x		
Zornia	?	AE	F-G	Herbs	Low-high	Low-medium	x	x							x

Table 2. Annual legume genera with forage potential for small-scale farming

Genus	Species	Origin	Potential	Morphology	Rainfall	Altitude	USES								
							1	2	3	4	5	6	7	8	9
Alysicarpus	2	A	G	Herbs	Moderate	Medium-high	x						x		
Arachis	3	A	G?	Herbs	Moderate	Low-medium(?)	x						x		
Cassia	1	E	F	Herbs	Low	Low-medium							x	x	
Neonotonia	1	E	G	Herbs	Moderate	Low-medium	x						x		
Macrotyloma	1	A	F	Herbs	Low-moderate	Low-medium	x						x		
Phaseolus sp.	3	AE	F-E	Herbs/vines	Low-high	Low-high				x	x		x	x	
Pisum	1	AE	G	Vines	Moderate-high	High							x	x	
Stylosanthes	1	E	F	Herbs	Moderate-low	Low-medium		x							x
Tephrosia	2	A	F	Herbs	Moderate-high	Medium-high		x					x		
Trifolium	6	A	G-E	Herbs	Moderate-high	Medium-high	x	x					x		
Vicia	2	A	E	Vines	Moderate-high	(Medium) high	x	x		x			x		
Vigna	1	A	E	Vines	Low	low-medium	x						x	x	
Zornia	1	A	F	Herbs	Moderate	Medium		x		x					x

Table 3. Browse species with forage potential for small-scale farming

Genus	Species	Origin	Potential	Morphmology	Rainfall	Altitude	USES								
							1	2	3	4	5	6	7	8	9
Cajanus	1	AE	E	Shrub	Low-high	Low-medium	x	x	x				x	x	
Codariocalyx	1	E	E	Shrub	Moderate-high	Low-medium	x	x	x				x		
Desmanthus	1	E	G	Shrub	Low-high	Low-medium	x	x	x				x		x
Desmodium	3	E	G-E	Shrub	Moderate-high	Low-medium	x	x	x				x		
Erythrina	2	A	E	Tree	(Low)-high	(Low)-high	x	x	x				x		

Gliricidia	1	AE	E	Tree	Moderate-high	Low-medium	x	x	x				x		
Leucaena	9	E	E	Tree	Moderate-high	Low-(high)	x	x	x				x		
Medicago	1	E	F	Shrub	Low-moderate	Low-medium	x	x	x				x		
Prosopis	6	E	?	Shrub	Low	Low-medium?	x	x	x				x		
Sesbania	3	AE	E	Tree	Moderate-high	Low-medium	x	x	x				x		x

Key for Tables 1,2,3

Species: Number of species

Origin: A African, E Exotic

Potential: Fair, Good, Excellent, suspected

Rainfall: Low, <800; moderate 800-1,200, high >1,200 mm per annum

Altitude: Low <1,500; medium 1,500-2,000, high >2,000 (at 9 degrees)

Use:

1. pure sward grazed
2. grass-legume mixture grazed
3. reserve fodder
4. inter-crop
5. catch crop
6. under crop
7. cut and carry
8. food and fodder
9. on low potential land

Reserved grazing

Areas of pure or mixed grass-legume swards can be reserved for feeding selected productive classes of animals year-round or during the dry season. These protein or fodder banks are grazed for brief periods daily. The legumes are usually perennial and thus must be drought resistant and unaffected by trampling, although their palatability can be high as the grazing pressure can be controlled. Such areas would normally be larger than those reserved for cut and carry and fencing may be required, although labour inputs would be lower. Useful species and genera for reserved grazing include Pueraria phaseoloides, Stylosanthes, spp. Macroptilium atropurpureum and Zornia spp.

Undersowing in perennial cash crops

There may be opportunities for the sowing of a leguminous ground cover under perennial tree or shrub crops. In the Wolayta region of Ethiopia, for example, the weeds growing beneath coffee and ensete (false banana, a carbohydrate food crop) are cut and fed to livestock. Desmodium intortum has proved to be well adapted to growing under these crops, and is beginning to be planted by farmers for providing better quality fodder as well as providing nitrogen for the cash crop.

Intercropping in annual crops

Legumes can be sown between rows of annual crops. They can be sown at the same time as the crop if they do not compete too strongly with its growth. If they do compete, the farmer may be prepared to cut them back and feed them during the early growing season, or, alternatively, may plant the legume two to four weeks after the cash crop. Perennial and late-maturing annual legumes would then continue to grow after maturation of the main crop, producing additional fodder.

Perennials which can persist through the dry season are particularly useful as they will produce some growth in response to any showers during the dry season and this growth can be grazed as standing hay or used for cut-and-carry fodder. In the following growing season the farmer will have a number of options in the management of his perennial legume. These are to:

(i) cut back the legumes sufficiently severely or frequently to allow rapid establishment of the cash crop;

(ii) allow the legume to regrow and seed after the dry season to provide a permanent cut-and-carry or grazed plot;

(iii) remove the permanent legume stand after a period of years, or cut it back, and plant a regular crop to take advantage of the additional nutrients fixed by the legume.

ILCA has had success intercropping S. guianensis cv. Cook, Macrotyloma axillare and Lablab purpureus in Ethiopia and S. hamata cv. Verano in Nigeria near Kaduna. The annual vine Vigna unguiculata (cowpea) is widely and traditionally intercropped in the Sudan zone.

Catch crop

Legumes which have a short a short life-cycle may have a place as a crop in seasons with unrealiable rainfall, or when planted during or after the maturity of the main growing-season crops to take advantage of residual soil moisture and late rains.

Short-lived annuals adapted to dry conditions which could be useful as catch crops are Macrotyloma uniflorum and Phaseolus acutifolius.

Hedge plantings

Browse species may play an important role in small farms for they can provide natural fencing, fuel, construction material, food and fodder. They may be planted around fields and houses in rows or broadcast in pastures, or in rows in cropped land (alley farming) where the leaves can be used as a fertilizer or mulch, cut and carried as feed, and grazed in situ during fallow periods. Leucaena, Cajanus, Gliricidia, Sesbania and Erythrina are among the more widely planted species.

Low-potential areas

While small farmers will usually not have control of extensive areas of rough land or eroded, infertile areas, even small areas may provide significant additional fodder. Legumes are commonly good pioneer plants. The appropriate legume may be exotic or native and should have a weedy, hardy character. Townsville stylo (S. humilis) is a well known Australian example of an exotic which naturalized and spread on infertile and degraded soils which were unsuitable for cropping. In Ethiopia the native legume S. fruticosa is often the major component of vegetation on eroded areas in certain environmental zones.

Multipurpose crops

A forage plant is much more likely to be attractive to a farmer whose land area is limited if it has more than one use. As has already been mentioned, browse species commonly have multiple uses and there is also a broad range of herbaceous annual legumes whose seeds are used for human food while the stovers are used for fodder. The genus Phaselous contains many of these and within the species P. vulgaris there is a tremendous range of growth forms. P. vulgaris is of American origin and this species is traditionally intercropped with maize. The larger bushy or climbing forms not only produce more fodder, but also more seed. Other species of actual or potential value for Africa include cowpea (V. unguiculata), lablab, pigeon pea (Cajanus cajan), wing bean (Psophocarpus tetragonolobus) and groundnut (Arachis hypogea).

Availability of germplasm for research

ILCA is in the process of establishing a Forage Genetic Resources Section in the Forage Legume Agronomy Unit (FLAG). Currently there are about 8,000 accessions in the collection of African and exotic legume, grass and browse species which have been collected or acquired by the section. These include tropical, sub-tropical, Mediterranean and temperate germplasm. Considerable effort has been put into building a computerized database on passport and site-of-accession environmental data and some of these data are available to researchers in the ILCA Forage Germplasm Catalogue in order that they may ensure selection of germplasm which is appropriate for specific environments. Seeds are multiplied by the section for long-term storage and for provision to researchers.

Because of space considerations most experimental lines are only multiplied to a level of 3,000 seeds to cater for the needs of researchers. Thus only up to 30 seeds can be provided of these lines and researchers must multiply the seed themselves before being able to plant them in trials. Promising experimental and commercial lines are continuously multiplied in small plots and, depending on the quantity of seed available, usually 0.5 g of seed would be available on request, with larger quantities of up to 50 g being available for some commercial lines. These quantities are sufficient for simple screening trials.

The FLAG Unit also has many types of experimental designs available, particularly those for germplasm screening which will utilize minimal amounts of seed. Requests for seed and experimental designs should be forwarded to the Leader, FLAG, P.O. Box 5689, Addis Ababa.

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