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Alley farming in the humid zone

Trends in sub-Saharan Africa's livestock industries

The trypanolerant livestock network

Cultivation using single oxen in Ethiopia

The *ILCA Bulletin* is a quarterly publication of the International Livestock Centre for Africa. It provides an up-to-date account of aspects of the Centre's work. Contributions to the Bulletin are invited from other livestock researchers in Africa whose work is closely associated with that of ILCA. The *ILCA Bulletin* is distributed to 1500 researchers, policy makers, donors and extension agents throughout sub-Saharan Africa and elsewhere in the world.

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Preface

The four articles appearing in this issue of the *ILCA Bulletin* reflect the varied nature of ILCA's research in sub-Saharan Africa. Reports on research projects in the humid zone of West Africa and in the Ethiopian highlands highlight the complementarity between livestock and food crop production in the continent. The other two articles reflect ILCA's regional approach to research, one being an analysis of recent trends in the livestock industries of the region, and the other a description of the West and central African network for trypanotolerant livestock which is coordinated by ILCA.

The first article reports on the alley fanning techniques currently being studied by ILCA's Humid Zone Programme based at Ibadan, Nigeria. The basic technique of alley cropping was initially developed by the International Institute of Tropical Agriculture (IITA). ILCA's team in Ibadan is evaluating different alley farming techniques and their benefits to both small ruminant and food crop production. While the Programme is continuing to look for further improvements to alley farming, for example by identifying *Gliricidia* germplasm which gives high yields in the more arid environments, the Federal Livestock Department of the Ministry of Agriculture in Nigeria is already starting a pilot development scheme during 1984 in which 60 alley farms are being planted on farmers' land.

The second article summarises the results of a study made by ILCA's Livestock Policy Unit at headquarters. The study focused on the trends in sub-Saharan Africa's livestock industries over the periods 1963 to 1970 and 1970 to 1980. Regional trends in West, central, East and southern Africa are compared with those for sub-Saharan Africa as a whole using statistical data from FAO Production and Trade Yearbooks. By considering changes in livestock populations, livestock production and external trade in livestock and their products the study brings to light the probable reasons for the poor performance of livestock production in sub-Saharan Africa.

The third article describes the activities of the trypanotolerant livestock network which ILCA coordinates in cooperation with national research organisations, other international bodies and a number of donor agencies. The ILCA group responsible for this work is the Livestock Productivity and Trypanotolerance Group based in Nairobi, Kenya. The Group works closely with the International Laboratory for Research on Animal Diseases (ILRAD), also based in Nairobi, and a network of research, training and communication is being established to cover nine countries in West and central Africa where the tsetse-borne disease trypanosomiasis is most prevalent. The network provides a means of coordinating data collection throughout the West and central African regions, and provides a framework for assessing the viability of trypanotolerant livestock in tsetse-infested areas.

The fourth article summarises the research to date on the use of single oxen for crop cultivation in the highlands of Ethiopia. This work by ILCA's Highlands Programme is another example of how ILCA's research on livestock can have direct benefits for food crop production in sub-Saharan Africa. ILCA's team has developed a technique of land cultivation using a single ox and a modified yoke, harness and *maresha* plough. The use of single oxen in place of the traditional pairs means that many more farmers in the highlands can become self-sufficient in land preparation, leading to more timely cultivation and more efficient food crop production. The technique is low-cost, and if adopted by large numbers of farmers then the number of oxen needed to support food crop production will be greatly reduced and the feed resources available for each working animal will be increased.

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Alley farming in the humid zone: Linking crop and livestock production*

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** The original version of this paper was presented under the title 'Small ruminant feed production in a farming systems context' at the Workshop on Small Ruminant Production Systems in the Humid Zone of West Africa, cosponsored by IL CA and the Federal Livestock Department of the Ministry of Agriculture, Nigeria, 22 to 26 January 1984, Ibadan, Nigeria. The paper will appear in the proceedings of the workshop.*

Summary

THIS PAPER *gives the background to small ruminant production in the humid zone of West Africa and describes the alley farming techniques which are being evaluated by ILCA's team based in Ibadan. The importance of crops in the zone is emphasised, to the extent that any improvement in livestock production should also show a positive effect on crop production. Alley farming employs the fast-growing leguminous trees Leucaena leucocephala and Gliricidia sepium which can provide both high-quality fodder for small ruminants and nitrogen-rich mulch for crop production. Crops are grown in alleys between rows of these leguminous trees.*

The cut-and-carry feeding of browse to small ruminants is expected to be one of the major benefits of alley farming. Alley farming also offers the possibility of allowing sheep to graze the fallow and the leguminous trees during periodic fallow years. A partial budget analysis of the two systems shows that short-term fallow grazing is competitive with continuous cropping.

During 1984, in a pilot development scheme of the Nigerian Federal Livestock Department, 60 participating farmers will plant 0.33 ha mixed browse alley farms and will start an animal health programme recommended by ILCA. ILCA's team will provide the browse seed, administer the health package and train the Ministry personnel in the principles and practices of alley farming.

Introduction

Ruminant livestock production in the humid zone of West Africa is limited by the disease trypanosomiasis. The most prevalent domestic ruminant species in the region are indigenous dwarf sheep and goats tolerant to trypanosomiasis. Of the 11 million of these animals in the zone as a whole, 8 million are found in the humid zone of Nigeria (ILCA, 1979).

In southwest Nigeria agriculture is dominated by the production of arable food and tree crops, including maize *(Zea mays* L.), yam *(Dioscorea* spp*.),* cassava *(Manihot esculenta),* cocoa *(Theobroma cacao)* and oil palm *(Elaeis guineensis).* Sheep and goats are kept by many rural households, but they are poorly integrated into the agricultural production system (Matthewman, 1980). The vast majority of small ruminants in this part of Nigeria are kept in free-roaming village flocks and are given only limited management or capital inputs. The average flock size is in the range of 2 to 5 animals per owner, with goats being more common than sheep. Feeding of household scraps is common, but the nutritional impact of this practice

is low. Few animals receive veterinary care, and mortalities within the first 3 months after birth are high.

Peste des petits ruminants (PPR) is perhaps the most important cause of early mortality, particularly among goats. Preliminary results from village trials show that PPR can be effectively and economically controlled by TCRV (Mack, 1982).

The work of the Humid Zone Programme

ILCA's Humid Zone Programme, based at Ibadan, Nigeria, aims to improve the productivity of indigenous breeds of sheep and goats in the zone. After disease, nutrition is probably the next most important factor limiting productivity. While it is difficult to demonstrate a seasonal feed shortage under present management conditions, there are compelling reasons why the feed situation deserves attention. PPR control is expected to reduce mortalities substantially, and thus should result in increased animal numbers and a greater demand for feed. Larger animal populations combined with the need to control animal movement around villages, gardens and farms are likely to result in some form of animal confinement. Total confinement of sheep and goats is already common in some parts of eastern Nigeria, and this necessitates cut-and-carry feeding and an easily accessible feed supply.

Because of the importance of crops in this zone, improvements in small ruminant production must also show a positive effect on crop production. For this reason ILCA's team is evaluating ways of linking crop and small ruminant production through the use of fast-growing leguminous trees such as *Leucaena leucocephala* and *Gliricidia sepium.* The foliage of these trees can be used both as high-quality fodder and as mineral-rich mulch for crop production.

Alley farming

Background

Kang et al (1981) described an alley cropping system developed by the Farming Systems Programme of the International Institute of Tropical Agriculture (IITA). In this system crops are grown in alleys 4 m wide between rows of densely planted trees which are pruned three to five times during each growing season. Trees managed in this way can produce 4 to 8 t of mulch DM/ ha, yielding over 100 kg N/ha/year for crop production. Alley cropping thus appears to be an attractive alternative to the traditional bush fallow system in that it can help to maintain soil fertility.

Small ruminant production can benefit from alley cropping through cut-and-carry feeding of the tree foliage, or, at a higher management level, by grazing both the natural fallow regrowth and the trees during periodic fallow years. Cut-and-carry browse feeding is applicable to both sheep and goats, while the grazing system is limited to sheep because goats damage the bark of the trees. ILCA's team is therefore investigating ways in which small ruminant and food crop production can be linked in an alley farming system.

When properly managed, the fast-growing leguminous trees *L. leucocephala* and *G. sepium* can together provide fodder throughout the year. Unlike grasses and some herbaceous legumes, browse trees show relatively little decline in nutritional quality during the dry season.

Cut-and-carry browse feeding

The cut-and-carry system of feeding a portion of the tree foliage to small ruminants is highly flexible and can be used with both free-roaming and confined animals. Depending on the availability and quality of other dodder resources, a range of browse feeding strategies can be developed. For example, browse may be fed as a protein supplement or as a sole feed. Browse can be fed on a year-round basis or solely during the dry season. Feeding browse to limited classes of animals, such as growing weaners or lactating dams, may be desirable in some circumstances.

Management

In order to give sufficient benefit to the crop and to ensure that nutrients are returned to the soil, the results of crop yield studies indicate that approximately 75% of the available tree foliage should be applied to the soil as mulch. An annual tree foliage yield of 4 t DM/ha would then give 1 t DM/ ha for feed. This amount would be sufficient to support approximately 14 adult animals/ha when used as a year-round supplement (25% of daily feed intake), or 4 animals/ha when used as a sole feed.

The management of browse trees within the alley farming context must take into account the requirements of the crop for nutrients and light, as well as the seasonality of demand for fodder. Year-round browse feeding, for example, will require a tree management strategy different from simple dry season supplementation. One aspect of ILCA's current research focuses on this relationship between tree management and feed requirements.

Supplementation trials

In two long-term browse supplementation trials, West African Dwarf sheep and goats are being fed varying amounts of a mixed-browse supplement together with an *ad libitum* basal diet. The objective of these trials is to determine the effect of browse supplementation on long-term dam productivity and short-term weaner growth. The basal diet consists of *Panicum maximum* of reasonable quality (fresh chopped, green, primarily vegetative growth). The diet is meant to mimic a diet of reasonable, but seasonally variable, quality which might be consumed by free-roaming animals in the humid zone.

Over a 14-week period a mixed *Leucaena/Gliricidia* browse supplement fed at approximately 200 g DM/doe/day increased the total intake of goats by 30% (Table 1). Fed at this level, browse constituted nearly 35% of the total dry matter intake. Browse supplementation of 200 and 400 g DM/ewe/day increased the total dry matter intake of sheep by 6% and 18% respectively. At 200 g DM/day, browse constituted 22% of dry matter intake, while with the ration of 400 g DM/day it accounted for 43% of the total intake.

Table 1. *The effect of controlled browse supplementation on daily dry matter intake by sheep and goats.*

Treatment		Total DM intake as % of basal diet only
Sheep	Basal diet only	100
	Basal + 200 g browse DM/ewe/day	106
	Basal + 400 g browse DM/ewe/day	118
Goats	Basal diet only	100
	Basal + 200 g browse DM/doe/day	130

Over a period of approximately 2 years the reproductive performance of dams and the survival and growth of offspring will be monitored. These trials will help determine the biological and economic values of browse supplementation to small ruminants in the context of alley farming.

Grazed fallow in integrated alley farming

Cut-and-carry browse feeding represents a highly flexible and relatively simple feeding strategy which can be implemented with a minimum of capital or management inputs. The grazed fallow approach with sheep will be somewhat more demanding in terms of management skills, but it represents a higher degree of integration of crop and livestock production activities since animal manure is returned to the soil.

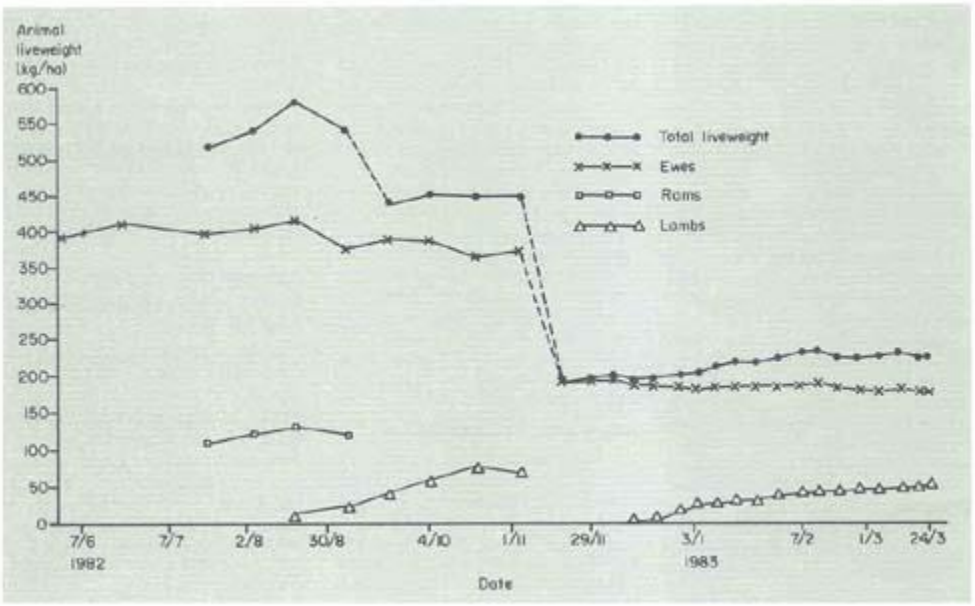
ILCA believes it may initially be easier to graze natural fallow vegetation in combination with browse trees than to establish and manage introduced pasture species for a short fallow grazing period. Future research may show that there are advantages in sowing high-producing grasses or herbaceous legumes for the proposed 2- or 3-year grazing periods between 3- to 5-year periods of alley cropping.

Paddock trials

In the preliminary evaluation of the grazed fallow system, two 0.25 ha paddocks containing natural fallow regrowth and the leguminous browse trees *Leucaena* and *Gliricidia* planted in rows 4 m apart were grazed by sheep for 10 months from June 1982 to May 1983. Ground vegetation, browse and animal performance were monitored in order to estimate appropriate stocking rates for such alley grazing systems and to identify potential problems and limitations of the system.

The components of animal liveweight supported per hectare during the grazing period are presented in Figure 1. From 1 June to 15 November, with a stocking rate of 16 ewes/ha, the paddocks supported an average of 472 kg liveweight/ha. Between 15 November and 31 March, with a stocking rate of 8 ewes/ha, they supported an average of 218 kg liveweight/ha.

Figure 1. *Components of animal liveweight supported by alley grazing over a 10-month grazing period, Ibadan, Nigeria, 1982–83.*



With the reduced stocking rate the animals were given a daily *Leucaena* supplement; each day two to three trees were bent and tied so that the upper foliage became available for consumption. This method of supplementation provided between 100 and 200 g DM/ewe/day and approximately 20 to 40 g CP/ewe/day. It would appear that the original stocking rate could have been maintained if supplementation had been started somewhat earlier.

During the rainy season the natural fallow vegetation provided an ample supply of good-quality herbage to support the stocking rate of 16 ewes/ha (Table 2). Standing dead plant material probably provided an important source of roughage during the dry season. *Leucaena* became an increasingly important component of the diet as the dry season progressed. Indeed, the success of this type of alley grazing system is dependent on the accumulation of browse during the wet season to supplement the diminishing ground vegetation in the dry season.

Table 2. *Monthly rainfall and feed components on offer during a 10-month grazing period, Ibadan, Nigeria, 1982–83.*

Month	Rainfall[a](mm)	Green grass (kg DM/ha)	Other green plants (kg DM/ha)	Dead plants (kg DM/ha)	*Leucaena* (kg DM/ha)	*Gliricidia* (kg DM/ha)	Total DM on offer (kg/ha)
J (1982)	1.6	–	–	–	–	–	–
F	44.6	–	_	–	–	–	–
M	92.7	–	–	–	–	–	–
A	87.9	–	–	–	–	–	–

M	124.4	–	–	–	–	–	–
J	166.7	566.7	1147.3	550.1	694.4	104.0	3062.5
J	136.9	1264.5	1869.0	460.1	968.7	111.7	4673.9
A	75.6	1441.8	2178.8	714.6	1086.1	129.2	5550.5
S	66.1	758.7	1574.7	929.8	727.5	92.5	4083.2
0	102.2	754.4	1642.3	851.0	1089.7	0.0	4337.4
N	8.9	507.8	1974.0	984.8	845.3	0.0	4311.9
D	0.0	115.9	681.8	1553.0	585.1	0.0	2935.8
J (1983)	0.0	0.0	0.0	1379.3	488.7	0.0	1868.0
F	3.9	0.0	0.0	1417.4	259.3	0.0	1676.7
M	3.2	0.0	0.0	1003.0	210.8	0.0	1213.8

[a] Rainfall data courtesy of T.L. Lawson, Farming Systems Programme, IITA.

Leucaena and *Gliricidia*

The height and flexibility of the *Leucaena* trees played an important role in restricting animal access during the wet season. At the end of the grazing period the *Leucaena* trees were as tall as 7 m. While the trees with thinner trunks (1 to 3 cm in diameter) were still being successfully browsed by the sheep, larger trees were no longer accessible. The method of controlled supplementation by bending trees daily worked satisfactorily and required a minimum of labour. After all foliage was consumed the trees were released and allowed to recover out of the reach of the animals.

Future alley farming systems could be based on a combination of tree species. Including several browse species may be advantageous in terms of diversity of diet, particularly if mimosine toxicity from*Leucaena* occurs. However, no adverse effects from *Leucaena* were observed during the course of this trial.

Gliricidia trees suffered heavy damage from the grazing animals, and the disappointing performance of these trees appeared to be due to the stake establishment method. Traditionally *Gliricidia* has been used for living fence posts and plantation shade, and for these uses stake establishment has obvious advantages. However, observations in Ibadan show that the root systems of trees established from stakes are shallow, less extensive, and have fewer and smaller tap roots than trees established from seed. It is unlikely that sheep would be able to

uproot seed-established *Gliricidia*trees, and certainly no problem of uprooting was seen with the seed-established *Leucaena.* It is believed that the deeper rooting system of sown *Gliricidia* plants will improve their dry season growth and retention of foliage, and their adaptability to more arid environments.

The branch damage that occurred during browsing also was related to the stake establishment method. Stake-grown trees tend to sprout and branch from the top of the stake, and it was these branches which were fund to be damaged. *Gliricidia* grown from seed can be managed to branch closer to ground level, and may be less susceptible to damage.

Budget analysis

A partial budget analysis of this alley grazing system comparing short-term fallow grazing with continuous cropping is presented in Table 3. At a stocking rate of 12 ewes/ha it would appear that a short-term grazed fallow period would be economically competitive with more traditional cropping activities. The grazed fallow period might also be advantageous with regard to improved soil fertility and crop yields. The effects of short-term grazed fallows on subsequent crop yields are currently being investigated in two major alley farming trials.

Table 3. *Partial budget analysis of alley grazing (incl. fallow) with sheep compared with continuous maize-cassava intercropping.*

System	US$/ha				
	Gross returns		Variable costs		Net returns
Alley grazing (12 ewes/ha)[a]	Weaners (16)	768	Labour	288	
	Adults (3)	288	Salt lick	29	
			Drugs	20	
	Total	1056		337	719
Maize-cassava In alleys[b]	Maize	985	Labour	808	
	Cassava	728	Seed/stakes	32	
			Fertilizer	128	
	Total	1713	Total	968	745

[a] Sale of weaners at 15 kg, adults at 30 kg at US$ 3.20/kg liveweight. Labour includes provision of water, checking of animals and tree management at 0.5 hr/day at US$ 1.00/hr. Cost of initial stock not included, but provision made for replacements. Assumes fertility rate of 1.3 lambs/ewe/year, and mortalities of 12,7 and 5% in the age groups 0–4 months, 4–12 months and adults respectively. Budget covers 18 months.

[b] Maize yield of 2.5 t/ha, cassava yield of 3.5 t/ha as intercrop. Maize sold at US$ 448/t, cassava at US$ 208/t. Labour at US$ 1.00/hr includes 25 days for pruning tree rows. Budget covers 18 months.

Preliminary observations thus indicate that alley grazing using short-term fallows and fast-growing trees is a promising approach to the integration of crop and livestock production in the humid zone of West Africa. The main advantages of the system are the relatively low capital and management requirements.

Several areas need further study, particularly the tree management aspects in the transition from cropping to grazing and grazing to cropping. Factors affecting the species composition and productivity of natural fallows also need clarification. In this regard, the effects of different weed control strategies during cropping years on the composition and productivity of subsequent fallow vegetation are being studied.

Browse and alley farming in West Africa

Small ruminant production is a common minor farm enterprise throughout the humid zone of West Africa, and improved feeding will certainly be an important component of intensified and/or more efficient production systems. ILCA is currently investigating the management and use of intensive 'feed gardens' in eastern Nigeria where animal movement is commonly restricted, necessitating daily cut-and-carry feeding.

Alley farming is an innovative production technique which has sufficient promise to be tested under a variety of conditions throughout the region. *Leucaena* and *Gliricidia* are the browse species most widely tested in alley farming, and while other potentially useful species are under investigation, ILCA's work will continue to centre around these two versatile species. Through the collection and evaluation of new *Gliricidia* germplasm, ILCA's team hopes to identify types which are more productive than the present material and better adapted to more arid environments. This unique genetic resource will be evaluated under as wide a range of environmental and management conditions as possible.

ILCA's team is at present evaluating 16 village alley farms. The team is now set to play a central role in a new pilot development scheme of the Federal Livestock Department of Nigeria. During 1984, 60 participating farmers will plant 0.33 ha mixed-browse alley farms and will start a health programme including TCRV vaccination. ILCA's team will provide the browse seed, administer the health package, and train Ministry personnel in the principles and practices of alley farming.

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Trends in sub-Saharan Africa's livestock industries*

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Summary

THE ANNUAL *rates of growth in livestock numbers between 1963 and 1980 show that livestock populations increased at a slower rate than did human populations. During the same period, beef production in sub-Saharan Africa grew at 2% per annum while mutton and goat meat production grew at 3.4% per annum. Sheep and goats contributed 30% of the total meat production.*

There were very small increases in beef yield per productive animal, and very little change in yield per animal for sheep and goat meat. In West Africa there were significant increases in milk yields, while in southern Africa there were declines in yield.

Sixty per cent of the increase in beef output during the 1960s and 80% in the 1970s was due to increases in numbers, the remainder to increases in yield per animal. Almost 90% of the increase in sheep and goat meat output in the 1960s and 70% in the 1970s was due to increased numbers. Increases in numbers contributed almost all of the increase in cow's milk output in both decades for sub-Saharan Africa.

In 1970, 16 countries out of a sample of 32 countries in sub-Saharan Africa were net importers of livestock, meat, dairy and poultry products. This number increased to 21 countries in 1980.

The livestock output situation in sub-Saharan Africa is very serious. Not only has the rate of output growth declined over the last two decades, but also the percentage of output growth attributable to productivity has decreased. Overall gross imports of livestock and livestock products into sub-Saharan Africa have reached approximately US$ 1.5 billion a year, or about half as much again as the figure of all foreign aid to the livestock sector over the last 15 to 20 years.

An earlier finding that livestock output is positively correlated with crop output has important policy implications. It indicates that livestock improvement need not be considered as competitive with crop improvement. Policies and programmes need to pay more attention to the complementarity of crops and livestock.

Introduction

During the 1970s the performance of livestock production in sub-Saharan Africa was poor. Technological and technical constraints, shortages of trained manpower, and lack of well-conceived projects have all been indicated as major reasons for this low performance. Constraints arising from outbreaks of animal disease and poor nutrition also contribute to increased mortality and low productivity. Constraints imposed or measures introduced by

government policies are also being increasingly recognized as equally important in supporting or discouraging increased production in agriculture. These policies include such issues as pricing, internal marketing and external trade.

Livestock production is an important economic activity in many African countries. For sub-Saharan Africa as a whole, livestock's share of the agricultural GDP averaged over *15%* in 1981, with a range, among 31 countries for which data are available, of 2 to 86% (Jahnke, 1982).

The main purpose of this paper is to describe the situation in sub-Saharan Africa's livestock industries over the last two decades. In provides a review of the most important trends in Africa's livestock industries. The paper concentrates on what trends have occurred in meat and milk output from ruminant livestock (accounting for all milk and 80% of meat output) and in the external trade in these commodities. In the hope that it may also offer a somewhat different perspective on these trends, the paper has been based on a regional comparison of the situation in four subregions of sub-Saharan Africa. The main sources of statistical information are FAO Production and Trade Yearbooks[1].

1. National aggregate data from these sources in both livestock numbers and output are currently the best available. One must be aware that the degree of reliability of the calculations made regionally on this basis is a reflection of the original country data made available to FAO. Calculated yield figures which arise from a combination of livestock numbers and output data could be doubly liable to error where the base figures are of low reliability.

The second section of the paper considers the resource base (livestock population) and the changes that have taken place in it over the last 20 years. The third section looks at total and unit production and productivity trends for milk and meat using different measures. This section also includes an assessment of the factors affecting output. The fourth section tries to elucidate the trends that have emerged in the export/import trade in milk as well as in meat and live animals. The concluding section discusses the implications for livestock policy in sub-Saharan Africa.

Trends in livestock populations

Table 1 summarises the growth and distribution of livestock units in sub-Saharan Africa. The subregion of East Africa has the largest share of the total stock of animals; in fact this subregion's share (in total livestock units or LSU) increased from 51% in 1963 to 55% in 1980. Central Africa's share, although it increased during the same period, still remained small at 6–7% in 1980. The shares of both West Africa and southern Africa declined during the period.

Table 1. *Growth and regional distribution of livestock units in sub-Saharan Africa during the period 1963–80*[a].

Region (no. of countries)	No. of livestock units[b] (millions) 1980	Growth rate in livestock units (% p.a.)		% of total for sub-Saharan Africa	
		1963–1970	1970–1980	1963	1980
West Africa (16)	38	2.0	0.3	30	25
Central Africa (8)	9	4.7	2.7	4	6
East Africa (9)	80	3.6	1.4	51	55
Southern Africa (11)	20	1.2	1.5	15	14
Sub-Saharan Africa (44)	146	2.8	1.2	100	100

a. *Except where otherwise stated figures in this paper for the years 1963, 1970 and 1980 are multi-year averages; i.e.1963 = 1961–65;1970 = 1969–71,1980 = 1979–81.*
b. LSU conversion factors: cattle = 0.7; sheep and goats = 0.1; Camels = 1.4

Between 1963 and 1980 sub-Saharan Africa's total ruminant livestock population in terms of LSU increased at 1.9% per annum. The rate of growth between 1963 and 1970 was higher than the rate of growth between 1970 and 1980, reflecting the adverse effects of drought during the early 1970s on the major livestock-producing areas of the Sahel and parts of East Africa. Understandably West Africa, which includes the major part of the Sahel, showed the lowest growth rate among the subregions during the whole period. The highest growth rate was recorded by central Africa perhaps because of the small initial base of livestock numbers compared to other subregions. East Africa recorded an annual growth rate of over 2% over the 17year period.

Overall, the annual rates of growth in livestock numbers between 1963 and 1980 show that livestock populations increased at a slower rate than did human populations, the average annual growth rate of the latter being around 2.8%. In terms of individual species, only the sheep populations have grown at about the same, or at a higher, rate than that of the human population (except in southern Africa). The West and southern Africa subregions show consistently lower growth rates (except for goats in southern Africa) than the average for sub-Saharan Africa.

It is difficult to be precise about the causes of these trends. Increasing conflicts as well as drought and more frequent outbreaks of disease (due to a breakdown of control measures) must have contributed to the deceleration in the growth of livestock populations over the two decades. Poorer nutrition resulting in decreased fertility and increased mortality has been another contributory factor in many countries (ILCA, 1983). Drought seems to have been a major cause in West Africa.

Trends in livestock production

Total and per caput output of meat and milk

In 1980 sub-Saharan Africa produced about 4% of the world's beef and only slightly more than 1 % of the world production of cow's milk. Table 2 provides a summary for 1980 of the absolute

figures of sub-Saharan Africa's production of beef, mutton, goat meat and cow's milk together with the percentage contributions of each subregion. East Africa had the highest share of total livestock output and this corresponds to its high share of the total livestock population already indicated in Table 1. In comparison with its share in the human population East Africa had rather a high share in livestock output, indicating relatively high availability, per head of the human population, of livestock output from domestic sources. In contrast West and central Africa had a relatively low availability from domestic sources.

Table 2. *Regional distribution of livestock output and human population in sub-Saharan Africa, 1980.*

Region	Beef Output (%)	Sheep and goat meat output (%)	Cow's milk output (%)	Human Population (%)
West Africa	27	40	20	42
Central Africa	8	4	5	16
East Africa	43	50	64	29
Southern Africa	22	6	11	13
Sub-Saharan Africa				
Total	100	100	100	100
absolute values				
(million tonnes)	2.05	0.87	5.65	
(millions)				350

Detailed figures showing the trends in meat and milk production in sub-Saharan Africa over the two decades are shown in Table 3.

Table 3. *Production of meat (indigenous animals only)[a] and cow's milk in sub-Saharan Africa, 1963–80.*

Region	Type of meat or milk	Production of meat and cow's milk								
		1963		1970		1980		Growth rates (% p. a.)		
		'000 t	% share in SSA[b]	'000t	% share in SSA	'000 t	% share in SSA	1963–70	1970–80	1963–80
West Africa	Beef	372	26	477	27	544	27	3.6	1.3	2.3
	Mutton and goat meat	194	39	292	40	344	40	6.0	1.6	3.4
	Cow's milk	784	18	951	19	1118	20	2.8	1.6	2.1
Central Africa	Beef	80	6	112	6	164	8	4.9	3.9	4.3
	Mutton and goat meat	23	5	28	4	38	4	2.9	3.1	3.0
	Cow's milk	261	6	242	5	284	5	–1.1	1.6	0.5
East Africa	Beef	587	42	749	43	887	43	3.5	1.7	2.5
	Mutton and goat meat	239	48	356	49	434	50	5.9	2.0	3.6

	Cow's milk	2787	63	3186	64	3624	64	1.9	1.3	1.6
Southern Africa	Beef	364	26	420	24	451	22	2.1	0.7	1.3
	Mutton and goat meat	39	8	8	7	55	6	3.0	1.4	2.0
	Cow's milk	606	13	584	12	626	11	–0.4	0.7	0.6
Sub-Saharan Africa	Beef	1403	100	1758	100	2046	100	3.3	1.5	2.2
	Mutton and goat meat	495	100	724	100	871	100	5.6	1.9	3.4
	Cow's milk	4438	100	4963	100	5652	100	1.6	1.3	1.4

[a] Production figures relating to indigenous animals include the meat equivalent of exported live animals and exclude the meat equivalent of imported live animals.
[b] SSA = sub-Saharan Africa.
Sources: FAO Production Yearbooks, 1975 and 1981

Overall one can see that between 1963 and 1980 beef production for sub-Saharan Africa as a whole grew at slightly over 2% per annum while mutton and goat meat production grew at 3.4% per annum. Sheep and goats, however, contributed no more than 30% of the total meat production. In the 1970s production of ruminants' meat (all types) grew only at 1.6% while population growth in sub-Saharan Africa was close to 3% (ILCA, 1983).

Subregional trends

Although the general trend of declining growth rates is very evident for the three major livestock-producing regions, southern Africa recorded the lowest growth rates in meat production during the whole period –1.3% for beef and 2.0% for mutton and goat meat. This reduced the subregion's share in total production. West Africa seems to have fared considerably better and maintained its share of the total production (for both types of meat) at almost the same level throughout the period. East Africa's share has not only continued to be the largest but has grown slightly during the period. Central Africa's share, although small in absolute terms, increased between 1963 and 1980 mainly at the expense of southern Africa.

The rate of growth of beef production per caput during 1963–70 was positive for sub-Saharan Africa as a whole as well as for all the subregions with the possible exception of southern Africa. The rate of growth of mutton and goat meat output per caput was positive for all subregions over the same period. The situation changed dramatically during the 1970s with per caput growth rates for both types of meat becoming negative for sub-Saharan Africa as a whole and for all the subregions except central Africa.

Data on sub-Saharan Africa's production of milk of all kinds in the 1960s are thought to be very unreliable (ILCA, 1983), and to some extent this also applies to data for cow's milk. Thus although data are provided for the 1963–70 period (Table 3), discussions of trend will focus mainly on the 1970–80 period. Overall, cow's milk production in sub-Saharan Africa increased from about 5.0 million to 5.7 million t during the past decade, registering an annual growth rate of only 1.3%. The annual growth rate of sub-Saharan Africa's milk output in the 1970s was much below the estimated rate of population growth, resulting in a negative per caput change in production much higher than that for meat.

The decline in growth rates in output between the 1960s and 1970s already seen in the case of meat also occurred with milk although the decline was proportionately less and was less uniform between regions. There was some tendency for the share of West Africa in total cow's milk production to rise and that of southern Africa to fall but the shift was very small. With the possible exception of West Africa in the 1960s per caput production of cow's milk fell for all subregions in both decades.

Factors affecting meat and milk output

Table 3 shows that total output of meat and milk combined has increased. In considering the factors affecting this increase, we can study two aspects. The first would be to see if, and how much of, this increase in output can be attributed to the mere *extension* rather than to *intensification* of existing livestock systems. One can do this by calculating, from available national data, the proportion of total output increases due simply to increases in livestock numbers and the proportion due to increases in yield per animal. The second aspect would be whether one can identify the factors affecting the rate and direction of the changes which took place between periods and subregions. This is more difficult to examine because of the limited availability of precise data to test the validity of causal relations between output increases and the factors which bring these about.

Yield per animal

There are two ways of calculating yield per animal. One is to express yield per directly productive animal, i.e. to divide the total quantity produced by the number of animals from which the product is directly derived. In the case of meat, this would be the number of slaughtered animals, while for milk it would be the number of cows constituting the milking herd. The other way is to express yield per animal over the whole herd, i.e. to divide the total quantity produced by all the animals in the herd. For instance in the case of milk this would mean all animals including bulls, oxen and calves.

If flocks/herds produced only one product, i.e. milk or meat, and if technology and management were unchanging so that calving, mortality and other technical coefficients remained constant, the two ways of expressing yield would amount to the same thing, the yield expressed in terms of directly productive animals being a constant multiple of the yield expressed per animal in the whole herd. Since herds are multi-purpose (e.g. they produce milk, meat and draught power) and technical coefficients change over time, changes occur in herd structures such that yields expressed in the two different ways may actually change in different directions at the same time.

Table 4 shows the changes in yield per animal, expressed in the two different ways, over the last two decades. The yields are presented as index numbers; and in each case the yield in 1963 is taken as 100 so that only the figures for 1970 and 1980 appear in the table.

Table 4. *Changes in yield per animal in sub-Saharan Africa, 1963–1980.*

Region	Class of animals on which yield based[a]	Relative yield per animal (1963= 100)					
		Beef		Sheep and goat meat		Cow's milk	
		1970	1980	1970	1980	1970	1980
West Africa	productive	101	102	114	117	106	109

	total herd	114	131	123	126	108	128
Central Africa	productive	109	110	107	107	130	131
	total herd	99	111	100	104	66	59
East Africa	productive	104	103	94	97	96	101
	Total herd	108	109	93	99	97	94
Southern Africa	productive	101	99	94	95	103	96
	Total herd	109	99	87	98	91	82
Sub-Saharan Africa	productive	102	102	103	106	99	102
	Total herd	109	112	104	110	97	98

[a] For explanation see text.
Source: Calculations based on data in FAO Production Yearbooks.

For beef the general picture presented is of very modest, if any, increases in yield per productive animal, i.e. almost no increases in carcass weight. However, there is some evidence of higher beef offtakes from cattle herds as a whole. This is most obvious in West Africa where there was a fairly steady rise over both decades in the productivity (in respect of beef) of the cattle herd.

For sheep and goat meat in sub-Saharan Africa as a whole there was little change in yield whichever way it is expressed. In East and southern Africa yields seem to have declined, while in West Africa there was an increase in the 1960s but not much consistent change in the 1970s. In central Africa the two ways of expressing yield give contradictory results.

For cow's milk the overall picture is confusing. For sub-Saharan Africa as a whole there was very little change in milk yields in either decade. In West Africa both decades saw yield increases while in southern Africa there was some decline. In East and central Africa the two methods of estimating yield give contradictory results, to an extent that is difficult to explain in any plausible manner.

Attribution of changes

The results of calculations attributing increases in total output to extension of numbers and intensification of herd productivity are shown in Table 5.

Table 5. *The relative contributions of increases in herd numbers and herd productivity to changes in total livestock output in sub-Saharan Africa, 1963–80.*

Region	Cause	Relative contribution[a] to change in total livestock output (%)					
		Beef		Sheep and goat meat		Cow's milk	
		1963–70	1970–80	1963–70	1970–80	1963–70	1970–80
West Africa	numbers	44.9	–9.2	44.5	81.7	59.5	–7.4
	productivity	55.1	109.2	55.5	18.3	40.5	107.4
Central Africa	numbers	102.3	65.6	101.8	85.5	562[b]	175.4
	productivity	–2.3	34.4	–1.8	14.5	–662[c]	–75.4
East Africa	numbers	64.6	94.1	122.3	64.4	27.91	211.4
	productivity	35.4	5.9	–22.3	35.6	72.09	–311.4[c]
Southern Africa	numbers	39.4	247.7	181.0	6.6	168.8[b]	254.2[b]
	productivity	60.6	–147.7	–81.0	93.4	–268.8[c]	–154.2
Sub-Saharan Africa	numbers	60.6	80.2	87.1	69.3	129.6	94.6
	productivity	39.4	19.8	12.9	30.7	–29.6	5.4

[a] The formulae used to calculate these are:
Change due to productivity: $N_2 (Y_2 – Y_1)$
Change due to numbers: $Y_1 (N_2 – N_1)$
where N_1 , N_2 = livestock numbers in years 1, 2

Y_1, Y_2 = yield per animal in years 1, 2 and is equal to
$\frac{Q_1}{N_1}, \frac{Q_2}{N_2}$ respectively, where Q_1, Q_2 = quantity of output in years 1, 2.
b. This high percentage is due to the very small value of the denominator, the change in total output.
c. Output actually declined in the period so the attribution of change adds up to –100%.
Source: Calculations based on data in FAO Production Yearbooks.

Beef

In the case of beef 60% of the increase in output in sub-Saharan Africa as a whole during the 1960s was due to increases in numbers and 40% to increases in yield per animal. The proportion of the total increase due to numbers was highest in central Africa where it accounted for all of the increased output, and lowest in southern Africa where it accounted for only 40%. During the 1970s more than 80% of the total increase in output over sub-Saharan Africa as a whole was due to increased numbers and less than 20% to increased yield. Only in West Africa, where cattle numbers actually fell in the decade, was it significantly less than two thirds of the increased output due to increased numbers.

Sheep and goat meat

In the case of sheep and goat meat in sub-Saharan Africa as a whole nearly 90% of the increase in output in the 1960s and 70% in the 1970s was due to increased numbers. West Africa in the 1960s and Southern Africa in the 1970s are the only subregions where a substantial proportion of the increased output came from increased yield.

Cow's milk

For cow's milk the situation is very mixed. In sub-Saharan Africa as a whole increases in numbers contributed almost all of the increase in output in both decades. In West Africa improvements in yield contributed 40% of the increase in output during the 1960s and all of it during 1970s. In East Africa yield improvements contributed nearly three quarters of the increase in output in the 1960s but their effect was negative in 1970s. In southern Africa increases in numbers were not enough to match the decline in yield in the 1960s, so that total output fell, whereas in the 1970s although yields continued to fall the effect was more than compensated by the increase in numbers.

The nature of the calculations lying behind the figures presented in Table 5 is such that where output itself does not alter very much between two periods of time quite small changes in yield or herd numbers can have very large effects on the proportionate attribution of change to different causes. Nevertheless, in spite of these drawbacks, the figures in Table 5 represent the best estimates we can at present make of the relative contribution of herd numbers and yield to changes in output. Too much weight, however, should not be placed on the specific figures of the estimates.

Causal factors

Tables 3 to 5 demonstrate that the rate, and occasionally the direction, of changes altered from time to time and from subregion to subregion. This could be due to either random chances or specific factors.

Some countries in sub-Saharan Africa have performed appreciably better than others in increasing the supply of domestic livestock products. In an attempt to explain this, a desk study was carried out at ILCA in mid-1983 to see whether it was possible to identify causal factors by using national-level data and simple correlation techniques. The results were reported in McClintock (1983) and in 1LCA (1984). The study involved analysis of output changes between 1965 and 1980.

The results showed only two strong and significant correlations: that between increased output of livestock products (except cow's milk) and growth in the livestock population, and that between increased livestock output and increased cereal output. The first corroborates what has been shown in Table 5. The second, although the correlation does not tell us much about the direction of causation, has important implications for policy, a point to which we will return later.

External trade in livestock and livestock products

Some overall indicators

The preceding sections give an extremely gloomy picture of the trend in Africa's livestock industries over the past two decades. Sub-Saharan Africa has shown declining growth rates in livestock output in the face of a fast-growing human population and even faster rates of urbanization as well as, in some cases, a rising per caput income. This has almost certainly resulted in lower levels of human nutrition which has serious implications for food policy issues in the region. A more readily quantifiable consequence, evident from available data, is the growing volume and value of imports of livestock products into sub-Saharan Africa.

ILCA (1983) analysed 1970 and 1980 data on net external trade in livestock, meat, dairy and poultry products for about 32 countries. In 1970, 16 of these countries were net importers; the number increased to 21 countries in 1980. These five additional net importers in 1980 included Ethiopia and Kenya, countries with large livestock populations.

Table 6 shows sub-Saharan Africa's net external trade in 1980 in meat, milk and live animals in absolute values and as a ratio to the region's total value of exports of agricultural (including fishery and forestry) products. For sub-Saharan Africa as a whole the ratio of net livestock imports (livestock products and live animals) to agricultural exports was 5%, ranging from a net export ratio of 4% in East Africa to a net import ratio of 10% in West Africa. For all regions except central Africa there were net exports in respect of live animals matched, on the other side, by net imports in respect of livestock products (meat and milk) in all subregions except southern Africa. For livestock products alone (i.e. excluding live animals) net imports for sub-Saharan Africa as a whole were about US$ 700 million, or 7% of the value of agricultural exports. The comparable ratio for Asia is 11% and for all developing countries 4%.

Table 6. *Net trade in 1980[a] in meat, milk and live animals as a percentage of the value of total agricultural exports, sub-Saharan Africa.*

Subregion (no. of countries)	1 Exports of agricultural products [b] ($1000)	2 Net imports of milk[c] ($1000)	3 Net imports of meat[d] ($1000)	4 Net imports of live[e]animals[f] ($1000)	5 Net livestock related imports (2+3+4)[f] ($1000)	Column 5 as % of Column 1[f]
West Africa (16)	4 731 020	389 890	148 019	–42 905	495 004	10
Central Africa (8)	1 564 700	68 253	56 866	20 478	145 597	9
East Africa (9)	2 453 660	56 899	4 618	–161 855	–100 338	–4
Southern Africa (11)	2 026 720	60 119	–60 860	–47 083	–47 824	–2
Sub-Saharan Africa (44)	10 776 100	575 161	148 643	–231 365	492 439	5

a 1980 = average of 1979–81 at current prices.
b Total agricultural products in this case include agricultural, fishery and forestry products.
c. Milk = fresh, dry, condensed.
d Meat = fresh, chilled, frozen.

e Live animals = cattle, sheep, goats, camels.
f Negative numbers indicate net export surpluses.

Source: FAO Trade Yearbook, *1981.*

External trade in live animas

Table 7 provides information .on the gross exports and imports of live cattle, sheep and goats for sub-Saharan Africa as a whole.

Table 7. *External trade in live animals in sub-Saharan Africa[a], 1963–80.*

Type of animals	Year	External trade in live animals (number of head)	
		Exports	Imports
Bovine cattle (head)	1963[b]	394 420	226 780
	1970[c]	998 255	883 882
	1980[d]	1 284 736	824 394
Sheep, lambs and goats (head)	1963	1 487 567	171 220
	1970	3 875 049	2 253 573
	1980	3 800 266	1 247 602

[a] Figures for sub-Saharan Africa were calculated from figures for Africa minus Mediterranean countries and the Republic of South Africa.
[b] 1963 = average of 1961 to 1965. `
[c] 1970 = average of 1969 to 1971.
[d] 1980 = average of 1979 to 1981.
Sources: FAO Trade Yearbooks 1963, 1965, 1967, 1973 and 1981.

Subregional trade

In West and to some degree in central Africa trade in live animals, particularly cattle, takes place between individual countries within the subregions. For instance, exports from the countries of the Sudano-Sahelian zone (Mauritania, Mali, Upper Volta, Niger, Chad and Sudan) go to their respective coastal neighbours in West and central Africa (Shapiro, 1979; ILCA, 1979; Holtzman, 1982). Nigeria and Ivory Coast are the major importers. Exports from Mauritania, Mali, Upper Volta and Niger approximately equal the imports of Nigeria and Ivory Coast (e.g. in 1980 these two countries imported 580 000 head while exports from the four exporting countries were 550 000 head).

The second identifiable pattern is that of the surplus countries in East Africa exporting to the Middle East. Almost 70% of sub-Saharan Africa's export trade in bovine cattle and more than 85% in sheep and goats originate from four East African countries—Ethiopia, Kenya, Somalia and Sudan. About 60% of the live animals exported from these markets are sheep and goats (AOAD/FAO, 1979). In both cases official transit trade and illicit trade in live animals are important features of exports going to the Middle East.

Intra-subregional trade in live cattle in West and central Africa faces increasing competition from cheaper priced beef imports from Europe and Latin America. Live sheep exports from East Africa to the Middle East face similar competition from Australian and Indian exports despite the advantages of short distance (lower freight costs) and consumer preference by the importing countries. Although recovering now, exports from surplus producers in the West African subregion have been affected by the Sahel drought in the early 1970s. In East Africa all surplus exporters, with the exception of Somalia (Reusse, 1982), failed to exploit a relatively ‘captive' market. In the short-term the prospects for capturing the whole potential offered by these large and lucrative markets does not look as bright as one could expect.

External trade in meat and milk

Sub-Saharan Africa experienced a fundamental reversal in its net trade position for meat from having a virtual balance in 1963, a slight export surplus in 1970 (almost 15 000 t) to becoming a net importer of almost 60 000 t in 1980. This meant that in 1980 sub-Saharan Africa spent almost US$ 150 million more for meat imports than it earned from its meat exports.

Subregional trade

The development in the position of the subregions differs markedly from that of sub-Saharan Africa as a whole. During the two decades considered central Africa remained a net importer throughout, with Gabon and Zaire accounting for 50% of the subregion's value of net imports of meat in 1980. Of the eight countries in the subregion only the Central African Republic and Cameroon reversed their position from net importers in 1963 to net exporters in 1980.

At the other extreme, southern Africa remained a net exporter, five of the nine countries for which data are available being net exporters in 1980. Botswana, Zimbabwe and Madagascar have always been the major net exporters, while Reunion and Mauritius have become the two major net importers of the subregion. Southern Africa owes its success, particularly in recent years, partly to the preferential quota arrangements accorded by the EEC to the four meat exporters of the subregion—Botswana, Zimbabwe, Madagascar and Swaziland. The prices received by these countries for beef exports to the EEC are far above world prices (von Massow, 1983).

West Africa's position in meat trade fluctuated between a net importer in 1963 to a net exporter in 1970 and the largest net importer subregion in 1980. The shift in the subregion's position between 1970 and 1980 must be mainly accounted for by the inflow of oil revenues to Nigeria which accelerated in the mid-1970s, and by the reduced supply of live animals from the Sahelian countries as a result of the drought which forced importers such as Nigeria and Ivory Coast to look for other sources of meat supply. In 1980 the subregion's value of net meat imports almost equalled that of the sub-Saharan Africa.

In East Africa meat exports from Kenya and Ethiopia, which accounted for almost the total net export figures of the subregion in 1963 and 1970, gradually declined to make the subregion as a whole a net importer. Despite this unsatisfactory performance, East Africa remained in a relatively better position vis-à-vis the other two net importer subregions in 1980 (0.01 kg/ caput/year as against about 0.45 kg/caput/ year for each of West and central Africa).

For milk, the picture is even more gloomy. Net import values for sub-Saharan Africa as a whole rose from US$ 39 million in 1963 and US$ 81 million in 1970 to US$ 575 million in 1980 (all in

current prices)—representing an increase of more than 600% over the past decade. Even if one takes into account that about one third of this rise in the value of net imports is attributable to price increases, this still represents an increase greater than 400% in the volume of net imports.

West Africa accounted for the largest increase in the value of net imports of milk: its share of sub-Saharan Africa's total rose from 54% in 1963 to 68% in 1980. Nigeria and Ivory Coast accounted for about 82% of the subregion's value of total net imports of milk in 1980. In the same year, the other three subregions more or less equally shared the remaining 32% of the total for sub-Saharan Africa.

There is no success story to tell in any of the subregions about a favourable net external trade position in milk and milk products. Despite the relative advantage that its high-potential areas possess in increasing domestic milk output, even East Africa failed to do better than central and southern Africa.

Factors affecting external trade in livestock products

Natural factors

Natural factors, such as the drought in West Africa, have affected intra-regional as well as extra-regional trade. They have influenced livestock supply and have led to subsequent rises in imports or declines in exports. In West Africa the oil boom in Nigeria has substantially contributed to the enormous increase in the subregion's high import bill in the 1970s.

These factors can only provide a partial explanation for the overall situation in sub-Saharan Africa, and there are some subregions which have not been affected at all, or only to a smaller extent, by these factors. There have been other factors, perhaps with a longer-lasting effect, which have contributed to the situation.

Internal and external prices

The internal prices for meat and milk and their ratios with respective world market prices determine the extent of external trade in the products. In the last decade domestic prices for food commodities in general were set at relatively low levels in many sub-Saharan African countries. Producers therefore had too little incentive to meet the food demand of a fast-growing population with increasing income at its disposal. At the same time world market prices, in particular for milk and beef in most years, were also at depressed levels, to a great extent due to the protectionist policies of the EEC and other developed countries (Tangermann and Krostitz, 1982). Thus the growing gap between production and demand of livestock products in sub-Saharan African countries could be filled by imports at relatively favourable prices. Additionally, food aid in the form of milk powder and butter oil as well as commercial imports were available for many countries. Both these categories of imports must have had adverse effects on domestic production, thus generating increased demand for imports.

Besides these basic interactions between domestic and international supply, demand and prices, there are other factors which can be described at this stage only qualitatively. For example, the southern African surplus beef exports were stimulated to some extent by the EEC's preferential ACP[1] quota for Botswana and Madagascar.

[1] ACP = African, Caribbean and Pacific states

National policies

The last but rather important point to be made relates to national government policies. Apart from setting domestic prices at relatively low levels, governments have used various policy instruments and have thereby directly or indirectly influenced external trade. These instruments include direct interference in trade by way of import and/or export taxes, quantitative restrictions and exchange rate policies, as well as indirect influences that may result from marketing activities, various subsidies and other policy measures introduced at the domestic level. Although no detailed quantitative assessment of the impacts of these factors is yet available, one has to bear in mind that these factors can substantially alter the basic effects of the price mechanism and therefore require much more attention than has been given to date.

Conclusions

The livestock output situation in sub-Saharan Africa is clearly very serious. The situation is doubly alarming in that not only has the rate of output growth declined over the last two decades, but also the percentage of output growth attributable to productivity (i.e. yield growth) has decreased.

The performance in the subregions provides no better basis for optimism. In terms of production per caput it is only central Africa which seems to have improved its production performance vis-à-vis population growth in the 1970s. This is the only region showing a positive growth rate in meat output per caput. However, this subregion had in 1980 only 6% of the livestock population and contributed 8% of the beef output, 4% of the sheep/goat meat output and 4% of the milk output of sub-Saharan Africa as a whole. The subregion's performance may have been influenced by the few countries such as Cameroon that have done relatively well and dominate the livestock production scene. On the other hand, one must also recall that central Africa is the most heavily tsetse-infested subregion of sub-Saharan Africa and that the potential for increased livestock production does theoretically exist.

The situation in external trade in livestock products has become alarming, particularly for milk. Overall gross imports of livestock and livestock products into sub-Saharan Africa have reached approximately US$ 1.5 billion per annum—about half as much again as the figure of all foreign aid to the livestock sector over the last 15 to 20 years.

Table 5 and the results of the correlation analysis in McClintock (1983) show that in all cases of livestock output in the 1970s, increased livestock numbers contributed most of the change in total output. With the area of unused tsetse-free land decreasing due to overall population pressure, this suggests that there is a need for a shift towards finding the appropriate technologies and policies to increase yield per animal.

Perhaps the most important finding from the correlation analysis is the one showing that livestock output is positively correlated with crop output. This appears to allay fears that livestock and crops are competing with each other for scarce resources of land, labour and capital. It also appears to support the view of complementarity between crops and livestock: crop residues feed livestock, livestock cultivate and fertilize fields and provide cash to purchase cropping inputs such as fertilizers and seeds. It has important policy implications in that it indicates that livestock improvement need not be considered as competitive with crop

improvement, and that policies and programmes should pay more serious attention to the complementarity between livestock and crops in the struggle against the food crisis in Africa.

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The trypanotolerant livestock network in West and central Africa*

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Summary

THIS PAPER *describes the background to the problem of trypanosomiasis in Africa. The exploitation of trypanotolerant breeds of cattle such as the N'Dama and the West African Shorthorn is presented as one of the most important approaches to the use of tsetse-infested areas of Africa. ILCA is coordinating a network of trypanotolerant livestock situations throughout West and central Africa in cooperation with national research organisations, other international bodies and a number of donor agencies. The sites used cover a range of trypanotolerant and trypanosusceptible livestock breeds under different levels of risk and under different management regimes. The aims of the network activities are described and the parameters and techniques used in data collection are outlined. The paper concludes by summarising the current network activities in Zaire, Gabon, Nigeria, Ivory Coast, Togo, Benin, Congo, Gambia and Senegal.*

Background

The exploitation of genetic resistance to infectious diseases is being given increasing attention in developing countries, where conventional disease control measures are often not effective, do not exist, or cannot be implemented because of lack of finance or trained manpower. However, in animal breeding programmes disease resistance can be only one of many aspects of production that have to be considered. In the vast majority of selection programmes practical breeders usually select on overall viability, which is one of the least clearly defined characters in livestock breeding work. A major problem in making progress from such selection decisions is that the heritability of overall viability is generally low, mainly because of the large environmental variance component. In contrast the heritability of well-defined resistance to specific diseases, or of traits correlated to disease resistance, is likely to be higher than that of overall viability. Controlled challenge conditions would also be expected to increase heritability by reducing environmental variation.

Trypanosomiasis is found over about 10 million km^2, or roughly over one third of Africa. The disease occurs in nearly every country between the deserts of southern Africa and the Sahara. Approximately 7 million km^2 of this area is tropical savanna which could support an estimated 125 million additional cattle without environmental stress. Traditionally many African livestock producers used to bring their herds and flocks into tsetse infested areas in search of grazing during the dry season when there were few tsetse flies, and moved quickly back to drier, disease-free areas when the rains began. As populations increased and grazing land was used

for farming, this type of herding system became less practical, resulting in high grazing pressures in the drier, disease-free areas.

Trypanotolerant breeds

Bos taurus types

The exploitation of trypanotolerant breeds of cattle such as the N'Dama and West African Shorthorn is one of the most important approaches to the utilisation of tsetse-infested areas in Africa. The ILCA/ FAO/UNEP report on trypanotolerant livestock in West and central Africa (ILCA, 1979) emphasised the importance of trypanotolerance by indicating that West African taurine breeds are at least as productive as other indigenous African breeds in areas of low or medium trypanosomiasis risk. In areas of high trypanosomiasis risk, comparative data are not available because only trypanotolerant breeds can exist there. The report illustrated the major effects of different levels of trypanosomiasis risk for which only rather subjective measurements had been available in the past; and the effect of management and nutrition as indicated by ranch or village production systems. Major interactions exist between breed type, the level of trypanosomiasis risk and other physiological, disease, nutritional and management factors.

Many small-scale experiments carried out in West Africa indicate similar dramatic differences between N'Dama and Zebu cattle in susceptibility to natural infection when judged by mortality levels and associated prevalence, and level and duration of parasitaemia and anaemia. Similarly, evidence is available on the effects of level of challenge on subsequent anaemia. Using animals that had never before been exposed to trypanosomes, it has been confirmed that N'Dama cattle are significantly more resistant than Zebu to experimental challenge with infected tsetse caught in the wild (Stephen, 1966; Roberts and Gray, 1973), to natural field exposure (Toure et al, 1978; Murray et al, 1981), and to trypanosomes inoculated by syringe (Murray et al, 1979; Saror et al, 1981). The resistance of the West African Shorthorn appears to be intermediate between that of the N'Dama and the Zebu (Roberts and Gray, 1973).

Further evidence that trypanotolerance has a genetic basis and is not due only to acquired resistance to local trypanosome populations has been provided by the successful establishment of cattle from West Africa in distant tsetse-infested areas of West and central Africa. Examples are the introduction of Lagune cattle in 1904 and N'Dama cattle in 1920 into Zaire, and more recently that of N'Dama into the Central African Republic, Gabon and Congo (ILCA, 1979).

On the basis of this knowledge, N'Dama heifers and bulls are now being imported by several countries in West and central Africa to form the nucleus of livestock development programmes in tsetse-infested areas.

Bos indicus types

There are now several reports from Kenya and Upper Volta that differences *in* resistance to trypanosomiasis have been found in certain *Bos indicus* types. However, as the animals in these studies had all previously been exposed to trypanosomiasis, it is not possible to assess the relative contribution of innate and acquired resistance. While critical comparative studies on the differences in susceptibility and productivity remain to be carried out, the degree of genetic resistance in *B. indicus* types is probably significantly less than in the recognized trypanotolerant breeds.

Level of innate resistance

While there is evidence in cattle that the innate levels of resistance may be increased by exposure to trypanosomiasis, it must be emphasised that trypanotolerance is reduced under certain adverse conditions. In order to realize the full potential of trypanotolerant breeds, it is essential that the main factors affecting the stability of trypanotolerance be identified and the extent of their impact quantified. For example, it is known that as tsetse challenge increases the productivity of N'Dama cattle falls (ILCA, 1979) as a result of stunting, wasting, abortion and even death. Therefore, the ability to quantify tsetse-trypanosomiasis risk critically is required in order to determine at what level of risk the N'Dama ceases to be productive. Similarly, factors including the stress of overwork, pregnancy, parturition, lactation, suckling, poor nutrition and intercurrent disease have been identified as affecting the susceptibility of cattle to infection with trypanosomes. Such factors are reviewed by Murray et al (1982).

The network

A network of trypanotolerant livestock situations is therefore being built up throughout West and central Africa in cooperation with national research organisations and with the help of a number of donor agencies. Within this network ILCA is coordinating in-depth investigations at up to 10 sites. These sites cover a range of trypanotolerant and trypanosusceptible livestock breeds under different levels of tsetse-trypanosomiasis risk and different management regimes. Additional work in East Africa by ILRAD and ILCA has led to similar studies being developed on sites in four countries of this region. The technical training and supervision of the network's scientists is being provided jointly by ILCA, ILRAD and ICIPE. By defining the parameters to be measured and through well organised training and supervision it is hoped to standardise the technology being used throughout Africa in order that the results obtained in different study areas can be critically compared.

Objectives

The objectives of the network activities are to evaluate the productivity of different breeds of domestic ruminants living under different levels of tsetse-trypanosomiasis risk, under different management systems, and in different ecological zones. The results should allow a critical evaluation of genetic differences in susceptibility to trypanosomiasis between breeds throughout Africa. In addition they should permit critical evaluation of the role played by acquired resistance in field situations and allow between-breed comparisons of the rate at which such resistance develops.

Once these essential baseline data are established and meaningful productivity indices based on production, economic, health and tsetse data are computed, it should be possible:

1. to predict the productive capacity of different breeds of domestic ruminants living under different levels of tsetse-trypanosomiasis risk, leading to more efficient use of different breeds and, consequently, to increased livestock production; and
2. to evaluate the cost-effectiveness and impact of the introduction of current or new methods of control, e.g. the strategic use of chemotherapeutic or chemoprophylactic drugs, tsetse control, trypanotolerance, improvements in management and nutrition and, possibly, immunotherapy and genetic selection.

Parameters and techniques in data collection

A training manual (Murray et al, 1983) has been produced jointly with ILRAD and ICIPE, describing the parameters and techniques used in the collection of data on animal health, tsetse-trypanosomiasis risk and animal productivity in different areas, and indicating how relevant information is extracted, analysed and interpreted. The manual will be revised after 18 months to include additional experience gathered in field operations and during training sessions.

Animal health

The most reliable indication that a herd is affected by trypanosomiasis is the detection of parasites in the blood, commonly accompanied by anaemia. In field situations anaemia may arise from causes other than trypanosomiasis, and it is therefore necessary to identify any other anaemia-producing pathogens that may be present. Thus, this manual describes the basic techniques for estimating anaemia, detecting trypanosomes and diagnosing other anaemia-producing diseases.

Animal productivity

The important performance traits are reproductive performance, viability, growth and milk production. These are then amalgamated into suitable indices of overall animal productivity. To allow concurrent evaluation of animal productivity, health and the prevailing tsetse situations requires recording of all animal numbers, dates of parturition, birth, death, sale, movements in or out of herd etc., and sampling at appropriate intervals of body weights and milk production. Economic evaluations aim to provide useful information to development project planners and managers on production potentials and the cost-effectiveness of introduction of improved practices.

Tsetse situation

The collection of concurrent data on degrees of risk from tsetse infestations is essential for the appraisal of livestock production, and entails general surveys of the location of foci of infestation infringing on the study areas, and the monitoring of seasonal alterations in tsetse density distribution and infection rates.

Current network situation

Following staff training in Nairobi, work has commenced at sites in Zaire, Gabon, Nigeria, Ivory Coast and Togo. Further sites will include Benin, Congo, Gambia and Senegal. At some of the network's sites attempts are being made to improve the productivity of trypanotolerant breeds by the use of chemotherapeutic or chemoprophylactic drugs.

In **Zaire** implementation focuses on the N'Dama breed raised both on ranches and in metayage-village operations under various levels of trypanosomiasis risk. The field operations started in November 1982. Recording is operating at full scale in the ranches and will be operating in the *metayages* by the end of September 1983.

In **Gabon** the ranch of the Office Gabonais d'Amélioration et de Production de Viande at Okouma maintains N'Dama and Nguni cattle and their crosses under two levels of trypanosomiasis risk, with a range of trypanosomiasis control interventions. In October 1982 herds were organised, and data collection according to ILCA's protocol commenced.

In **Nigeria** ILCA's Humid Zone Programme in 1981 extended its existing production recording with small ruminants to collect matching data on trypanosomiasis risk and incidence. A veterinarian from ILCA's Nigeria team spent 4 weeks in Nairobi in April 1982 in specialised training while three other researchers were trained in February and March 1983. ILCA's Humid Zone Programme will monitor an importation of Gambian N'Dama cattle in cooperation with the Federal Livestock Department and the Western Livestock Company. Heifers from low, medium and high trypanosomiasis risk situations in Gambia are being maintained in low and medium risk ranching situations in Nigeria, with and without initial prophylaxis. Comparison is also being carried out with progeny (born in Nigeria) of previous importation.

In **Ivory Coast** work on sheep in the SODEPRA-Nord operations was extended with support from ILCA during 1981 to cover all the recording requirements in a village situation in the semihumid savanna around Korhogo. The work is being carried out in collaboration with SODEPRA (Ministry of Animal Production), the Veterinary Laboratory of Korhogo and an FAO project on tsetse control. A project document has also been presented to GTZ in Germany and to the Ministry of Animal Production in Ivory Coast, proposing the extension of the operations to a higher tsetse challenge area and to cover both sheep and cattle (Zebu, Baoule, N'Dama). Agreements have now been signed and the project became fully operational in January 1984.

Togo and GTZ proposed an extension of the activities of CREAT at Avetonou to carry out comprehensive work involving the station cattle and *metayage* operations. The latter have been enlarged to cover 300 N'Dama females in village herds around the station. ILCA will provide technical advice, training for local scientists and carry out the data analysis. The same recording scheme will be applied also to a continuing village cattle project working with Somba and Borgou cattle, which was funded by Togo and GTZ in the Centre Region. Two Togolese scientists have recently completed the training course in Nairobi, and field operations started in December 1983.

In **Benin** a package of six small livestock development projects has been proposed by FAO for funding by UNDP. Two of them concern the creation and development of a unit of veterinary and animal production research, having as an important goal the study of the trypanotolerant breeds and their potential. The first phase will last 3 years. The operations will focus on three farms: Samiondji (Lagunes), M'Betecoucou (Borgou) and Okpaha (Somba, Zebu), together with surrounding village herds. It has been agreed that ILCA will organise necessary training and provide technical supervision and data analysis. The project is currently delayed due to lack of funds.

In **Congo** contacts have been established with the Dihesse ranch where N'Dama cattle are raised under low and medium trypanosomiasis risk. Currently arrangements are under way to allow the analysis of production and health data collected on the breeding herds since 1975, through a 4-month fellowship to a Congolese scientist.

In **Gambia** a recent major development in the exploitation of N'Dama cattle is that the Government is establishing an N'Dama Centre which will cooperate with ILCA and ILRAD. The main objectives of this centre are first to provide channels for marketing and export of stock, and

second to undertake epidemiological studies to evaluate the productivity of N'Dama cattle exposed to different quantified levels of tsetse-trypanosomiasis risk.

Senegal has requested ILCA to organise and support similar research work on Djallonke sheep and N'Dama cattle in Casamance and Senegal Oriental which encompass different ecological zones and tsetse challenges. This proposal has been linked to the request submitted to EEC for funding of work in Gambia. The two research projects will therefore constitute an integrated operation and are expected to start in November 1984.

Initial data analysis

Data covering the initial 12 to 18 months of operations in Gabon, Ivory Coast, Nigeria and Zaire are currently being prepared for analysis. It is expected that preliminary interpretation of these analyses will lead to more precise protocols being devised in all situations.

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The use of single oxen for crop cultivation in Ethiopia

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Summary

ILCA's HIGHLANDS PROGRAMME *aims to find ways of improving the overall productivity of mixed smallholder farms in the highlands by increasing the technical and economic efficiency of livestock enterprises. Particular emphasis is given to enhancing the complementarity of the livestock and crop components. A substantial part of the work of the Programme focuses on topics related to animal traction, including studies of the use of oxen worked as singles rather than pairs.*

Ploughing in the Ethiopian highlands is traditionally done using paired oxen; but surveys showed that half of the smallholder farmers in the highlands owned either one or no oxen. During 1983 ILCA's team developed a yoke and harness and modified version of the local wooden plough, the ***maresha,*** *suitable for use by a single ox of local breed. On-station testing showed that an adequately fed ox could cultivate in a day 60 to 70% of the area ploughed by a pair.*

Field days were organised for local farmers from the Peasants' Associations around ILCA's research stations in the Ethiopian highlands. After the field days, farmers were invited to try the adaptation of the traditional method on their own farms at their own risk and expense. ILCA provided assistance in retraining oxen to work as singles, then closely monitored the use of single oxen on the test farmers' land through twice-weekly visits. By October 1983 more than 140 farmers had approached ILCA for assistance in ploughing with a single ox.

Subsequent crop yields on the test farms were similar for land cultivated with single or paired animals. The time taken for cultivation by single oxen was around 30% more than by oxen pairs.

Oxen worked as singles require more feed per head than paired oxen. Research is therefore planned to investigate whether a short duration forage legume can be sown during the early rains prior to the usual cereal or pulse crops in order to have high-quality feed available for draught oxen when it is most needed.

The widespread use of the single ox method of ploughing could dramatically reduce the number of oxen needed to support food crop production, thereby increasing the feed resources available for each working animal. The technique does not put subsistence crop yields at risk and requires only minimal investment—the new yoke and harness can be made cheaply from local materials, while the modifications to the ***maresha*** *can be done at home or by the village blacksmith.*

If uptake occurs on a large enough scale, the new technique will have far-reaching implications for the smallholder farmers of Ethiopia who are among the world's poorest people.

Introduction

Research approach

ILCA's Highlands Programme follows a farming systems approach to research. This integrated and problem-oriented approach stresses on-farm technology testing and appraisal, complemented by relevant station research on individual components in cases where greater experimental control is advantageous.

The Ethiopian highlands

To date, research in the Highlands Programme has focused on Ethiopia, a country accounting for almost half of the total African highland zone. Ethiopia also has the largest livestock population in sub-Saharan Africa with some 26 million head of cattle, 24 million sheep, 12 million goats, 7 million equines and 1 million camels. The great majority of the cattle, sheep and equines are found in the highland areas of the country.

Of the total area of Ethiopia (1.22 million km^2), half is made up by highlands above 1500 m in altitude. Some 80% of the total human population of about 38 million live in the highlands. Agricultural conditions vary widely throughout the country, according to topography, climate and soils. However, the highlands are generally temperate and comparatively favourable for both crop and livestock production.

Since the mid-1970s, rural development has been organised in a socialist framework. However, collective farming accounts for less than 5% of the total area cultivated. The bulk of agricultural output is still produced by individual subsistence smallholders who have 'farming rights' over the land they till[1].

1. In Ethiopia, land is not individually owned, but is allocated by the Peasants' Association (PA) of which each farmer is necessarily a member. The size of individual allocations, comprising several plots depends on family size, local population density and the policies of the local PA. Land distribution takes account of the different fertility levels of the soils within the land area of the PA. Each PA has on average 250 members and controls around 800 ha of land.

Farming in the central highlands

ILCA's field research in the Ethiopian highlands has concentrated on the central highlands where smallholder mixed farming is the dominant mode of production. Rainfall here averages between 600 and 1200 mm/year, of which about 70% falls in the main rainy season between July and September. Farm sizes range from 0.5 to 5 ha, and around 80% of all farm produce is used for subsistence consumption. About two thirds of the cultivated land is sown to cereals; most of the remainder is sown to pulses. The proportion of fallow land in different parts of the highlands is quite variable. In some areas almost no land is fallowed, while elsewhere fallow periods of up to 12 years following 3 crop years are common.

The major crops grown are teff, wheat, barley, maize, sorghum, horse beans, chickpeas and field peas. Grain yields average between 500 and 1000 kg/ha sown. Access to modern inputs is limited; for example fewer than 10% of farmers regularly use either chemical fertilizer or

improved seed. Most farmers own livestock and a typical farm inventory includes two oxen, a cow, a few sheep and a donkey. As most livestock manure is used as household fuel, only small amounts are returned to the fields.

Cattle are kept mainly as a source of draught power and for manure. Milk, meat and hides are less important byproducts. Livestock are privately owned, and as such are an important form of investment and financial security. Usually only oxen are used for cultivation. Productivity of all livestock is low, reflecting an under-exploited genetic resource and generally inadequate nutrition, particularly during the extended dry season of up to 7 months each year. For example, milk offtake from indigenous Zebu cows kept under traditional management rarely exceeds 400 kg for lactations of 7 months and calving intervals average 2 years. Sheep also are comparatively unproductive as, along with cattle, they are subject to heavy endoparasite burdens and to extended periods of nutritional stress.

Research in the highlands programme

Objectives

The basic objectives of the Programme's research are to find ways of improving the overall productivity of mixed smallholder farms by increasing the technical and economic efficiency of livestock enterprises. Particular emphasis is given to enhancing the complementarity of the livestock and crop components. Results and experiences of the research in Ethiopia will, in many cases, have direct relevance to other highland smallholder situations in sub-Saharan Africa.

Research locations

In addition to research undertaken at ILCA's headquarters in Addis Ababa, field work is carried out in two study areas where research stations have been established: around Debre Zeit, 50 km south of Addis Ababa at an altitude of 1800 m, and around Debre Berhan, 120 km northeast of Addis Ababa at an altitude of 2800 m. The area around Debre Zeit is intensively cultivated with virtually no arable land kept fallow. Teff *(Eragrostis teff)* is the principal cereal grown. Debre Berhan is representative of the higher altitude zone of the country. Frosts, hail and a shorter growing season, in addition to low soil fertility cause the area to be less productive than Debre Zeit. Most of the land cultivated around Debre Berhan is sown with barley.

Animal traction

The Programme has allocated a substantial part of its resources to studies on various topics related to animal traction. Work on the research stations includes the evaluation of different cultivation systems using oxen of local origin and crossbreds, the technical and economic efficiencies of using crossbred cows for both draught purposes and milk production, the use of oxen worked as singles rather than as pairs, and the working efficiency of oxen subject to nutritional stress. Different harnesses and yokes are also being developed.

This paper reports the experiences with on-farm trials to assess the use of oxen worked as singles rather than pairs.

Draught power and agricultural production

The primary contribution of cattle to agricultural production in the Ethiopian highlands is as a source of draught power. ILCA's surveys have shown that animal power[2] used for crop-related work averaged more than 1000 hr/farm/year. Most of this power was supplied by oxen, but other cattle were sometimes employed for threshing. Some 60 to 70% of the total animal power input was for seedbed preparation and planting, with approximately 350 hr/oxen pair used for these purposes.

2. Not including power supplied by donkeys, which are used mainly for transport of agricultural products.

Traditional methods

Throughout most of the Ethiopian highlands the land is tilled using a pair of oxen of one of the indigenous Zebu breeds[3] which pull the locally-made traditional cultivation tool, the maresha[4]. The power output of oxen pulling this plough is dependent on their body weight, nutrition and health status, the terrain and soil condition, depth of ploughing, working speed, pass number[5], the training of the animal and the skill of the handler. Depending on the soil type and the crop, the land is cultivated up to six times before planting.

3. An ox in working condition weighs approximately 250–300 kg.
4. The *maresha is* constructed by the farmer from wood and has a metal tip for penetration. This plough does not turn a furrow like the conventional mould board plough, but disturbs the soil to a depth of about 15 cm.
5. Ploughing using the *maresha is* done perpendicularly and diagonally across plots. Pass numbers refer to the number of cultivations done in the season.

Oxen are commonly worked for 4 to 9 hr/ day, depending mainly on the time available for soil preparation[6]. Traditionally, animals within the Debre Zeit area are worked throughout the day with few breaks. In contrast, farmers in the Debre Berhan areas normally give their oxen a rest period at mid-day during which animals are watered and fed.

6. Shorter working days are often associated with longer distances to watering places and with watering frequency which varies with season.

Ox ownership

A major constraint to crop cultivation in Ethiopia is the unequal distribution of oxen/household. Available data for the Debre Berhan area indicate that half the farmers owned two or more oxen, around 30% had one and 20% owned no oxen. In the Debre Zeit area relatively more farmers had two or more oxen, but around 25% of the smallholder had none or only one ox. These results from the two ILCA study areas are representative of the national situation as, according to one study (Ministry of Agriculture, 1980), around 29% of Ethiopian farmers have no oxen, 34% one, 29% two, and 8% three or more. Since oxen are traditionally paired for work, more than 60% of the farmers have to rent or borrow one or two animals for cultivation.

Cultivation strategies

A farmer owning fewer than two oxen has various ways of overcoming this problem of inadequate draught power. For farmers with one ox, the usual arrangement is a *mekanajo* agreement with another farmer also having one ox, whereby the two oxen are used on the partners' fields on alternate days. The drawback of this strategy is that often the ploughing season is so short that the draught capacity is insufficient to allow both farmers to plough at the optimal time. In many locations, especially where soils have a high clay fraction, cultivation can only start after the beginning of the rains because of the difficulty of tilling dry soil. Moreover, the changing of handlers of the pair of oxen and the pairing of different animals causes a substantial reduction in the tractive power developed. It is also often difficult to find a partner living close by.

Another widely used strategy called *minda* is for the farmer to rent one or two oxen in exchange for grain or human labour. Around Debre Zeit it has been observed that farmers with one ox rent another ox from farmers with surplus oxen, at an annual cost of 200 kg of grain or some 15% of total farm production. A farmer can also use an ox of another farmer in return for 1 day's field labour. If a farmer has no oxen, the common exchange system is to give 2 days of human labour for every day a pair of oxen is borrowed. Sometimes oxen will be rented on a cash basis, usually US$ 1.50/day for a pair, and US$ 2.50/day if a handler is included.

Ox number and cropping pattern

ILCA's surveys have revealed that the number of oxen owned by a farmer strongly influences the area cultivated and the cropping pattern. The cropping pattern is most strongly influenced if the draught power inputs for land preparation vary substantially among crops. This favours the selection of crops with lower power requirements (e.g. pulses instead of cereals) by farmers with less than two oxen. For the study area around Debre Zeit, for example, substantial differences were observed among ILCA's control group of outside farmers in the crop year. These are summarised in Table 1.

Table 1. *Impact of ox ownership on area cultivated and cropping pattern at Debre Zeit, 1980.*

No. of oxen owned by farmers	Average area cropped/farm (ha)	Percentage of area sown to cereals (%)	Percentage of area sown to pulses (%)
None	1.2	54	46
One	1.9	44	56
Two	2.7	67	33
Three or more	3.6	92	8

These results show an approximately liner relationship between the number of oxen owned and the area cultivated. The differences in cropping pattern reflect the need for more intensive land preparation for cereal crops compared with pulses, and therefore higher labour inputs and draught power. Furthermore, the market value of cereal crops is about twice that of pulses. Together these factors mean that farmers with less draught power at their disposal sowed less land, and also had lower incomes than their counterparts with an adequate supply of draught power.

Around Debre Berhan the situation was somewhat different. The dominant crops in that area all require similar labour inputs for land preparation. The effect of ox ownership on the amount of land cultivated was smaller than around Debre Zeit and the cropping pattern remained similar for farmers with different supplies of draught power.

In both study areas there was no apparent effect of level of ownership on crop yields. This suggests that the problem of timely cultivation is largely overcome when a smaller area is cultivated and farmers choose to safeguard yields on smaller areas rather than risk lower yields over a larger area, which can happen if seedbeds are poorly prepared. Thus the availability of draught power is a major factor affecting food production and income distribution in the Ethiopian highlands.

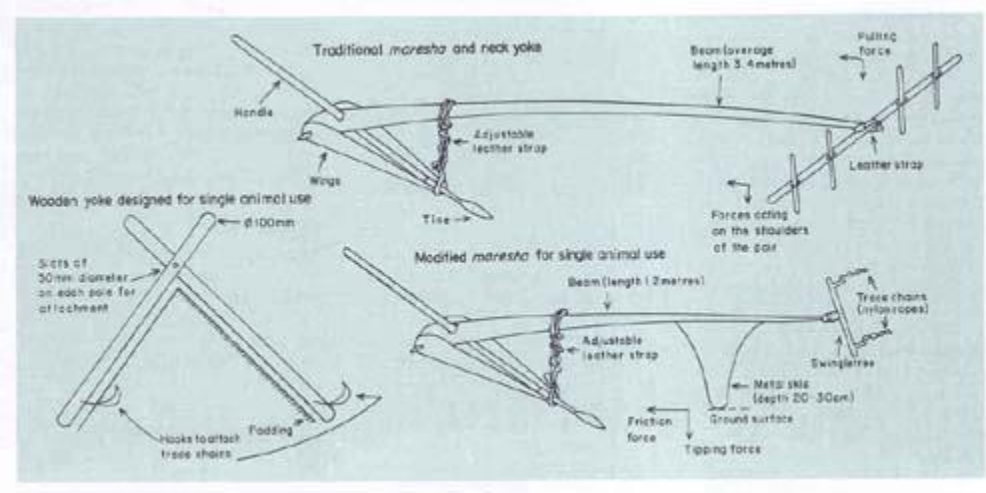
Design and testing of the single ox technique

The tacit assumption by farmers that two oxen are needed for cultivation has precluded solutions to at least some of the production problems associated with a national shortage of draught animals. ILCA had some prior experience in the use of crossbred oxen worked as singles, but these animals are much heavier than local oxen (average liveweight of 500 kg as opposed to 280 kg for local oxen). Elsewhere in the world other animals such as buffaloes and horses have been worked as singles, but their liveweights are also much greater than those of the local Zebu oxen used in Ethiopia. However, ILCA decided to experiment with the use of local Zebus as singles for crop cultivation.

Modified yoke, harness and maresha

During 1983 ILCA developed a yoke and harness and a modified version of the local wooden plough *(maresha)* suitable for use by a single ox of local breed. The traditional neck yoke designed for an ox-pair (Figure 1) was replaced by a simple, 'inverted V'-type yoke and a swingletree joined by two traces made of nylon rope. A simple metal skid was attached under the shortened beam to overcome the tendency of the modified *maresha* to penetrate the ground at an oblique rather than an acute angle.

Figure 1. *Traditional and modified yokes and* maresha *for use in the Ethiopian highlands.*



Testing

No particular technical difficulties were encountered during the on-station trials which showed that an adequately-fed ox could cultivate some 60–70% of the area ploughed by a pair in a day. Depth of cultivation was slightly shallower than with the traditional *maresha,* but the desired depth could be achieved by making extra passes. The work output of the singles was considered to be adequate to warrant starting onfarm trials.

In each of the study areas, ILCA's team then organised field days for farmers of the PAs around the research stations to demonstrate the new technique. Local government officials and extension workers and a total of around 150 farmers attended. After the demonstration farmers were invited to try ploughing with the single ox. Many did so, and although the general consensus was that this modification of the traditional system could have its benefits, farmers were doubtful about the ability of local oxen to work singly for extended periods.

Farmers were invited to try the adaptation of the traditional method on their own farms. They were to do this at their own risk and expense but ILCA was to give technical advice and assist in training of the animals to work singly. For those who did not want to modify the implement themselves, ILCA offered to sell the necessary implements at US$ 5 each, to be paid immediately after the next harvest. At the end of the field day at Debre Berhan 19 farmers volunteered to test the modified *maresha;* at the Debre Zeit field day 12 farmers volunteered.

ILCA held training sessions in which the volunteer test farmers were assisted in retraining their ox previously used as one of a pair. Most oxen adapted without difficulty while others needed up to 2 days' retraining. In April 1983 these farmers started their land cultivation.

ILCA closely monitored their performance and started a data recording system. The farmers testing the single ox were visited twice weekly and data were collected on land holding, cropping pattern, inputs and outputs by plot, cultivation details and feeding levels for the work oxen. Farm assets, personal data and livestock inventories were also recorded.

More farmers became interested in the technique as the season progressed and wanted to join the research programme, but in order to have complete records and to allow for a proper evaluation, ILCA's team limited its involvement with these farmers to technical advice on how to make and operate the implement. By early October 1983, over 140 farmers had approached ILCA for assistance in ploughing with a single ox, and many of these had been experimenting on their own.

Results of the 1983 crop year

Farm characteristics

The single-ox farmers were generally young and innovative. Most belonged to the *Amhara* tribe. The average age of the 31 test farmers (i.e. those farmers whose performance was closely monitored through the data recording system) was 32 years. During the previous crop season, 18 of the test farmers had a *makanajo* or *minda* agreement while 13 owned a pair of oxen. All test farmers who previously had *mekanajo* arrangements reported that making this arrangement took much of their available time, and delayed the time of planting, possibly resulting in reduced crop yields.

The average farm size of the farmers testing the single ox in 1983 was 1.9 ha (all cultivated) around Debre Zeit and 2.5 ha (of which 1.4 ha was cultivated) around Debre Berhan.

Around Debre Zeit, because soils are heavy and rainfall is essentially unimodal, cultivation for the main cereal crops has to be done within a very limited period. Around Debre Berhan the rainfall is more uniformly distributed over the year (weakly bimodal) and soils are lighter than at Debre Zeit, so that ploughing can be done almost year-round.

Around Debre Berhan, however, only 50% of the arable farm land is cultivated each year. The shortage of draught power is therefore a much more pressing and crucial problem at Debre Zeit than at Debre Berhan.

Problems encountered

Some technical problems arose during the farm trials. The original metal skid was not strong enough for work in stony fields and it had to be replaced by one of thicker metal. Also, farmers at Debre Zeit initially worked their single animals only 2 to 3 hr/ day for fear of exhausting them. Farmers, however, observed ILCA's nutrition trials where oxen are worked singly for 4 to 5 hr/ day without tiring[7]. As a result the farmers gradually increased the hours they worked their animals.

7. Nutritionally-stressed oxen are worked as singles on farmers' fields under research supervision in these particular trials. Their performance is being compared with the work output of well-nourished oxen. The stressed animals are fed 75 % of the level of the well-nourished oxen.

Animal nutrition was perceived as a problem by the test farmers. The animals worked as singles required extra feed and therefore many farmers supplemented the normal ration with feed concentrates (wheat bran) which are available locally. In some cases, when the farmer was unable to afford these concentrates, ILCA supplied short-term credits to be repaid immediately after harvest.

Concurrently with this on-farm testing, the Ethiopian Government began a drive towards cooperative production in the Debre Zeit area. Farmers had to work 1 or 2 days/week on the land owned by the cooperative. However, these farmers are followers of the Ethiopian Orthodox Church which prohibits field work on around 160 days each year. Thus the number of days available for cultivating their own fields was sharply reduced.

The unexpected reduction in the time available for the preparation of their plots, combined with their natural caution about the new technique, resulted in all the test farmers using a mix of single and traditionally paired oxen.

Around Debre Berhan where farmers can cultivate almost year-round, timeliness is not so important. As a result, farmers have greater opportunities of finding additional oxen for cultivation. However, soil fertility is a major problem in the area and many fields have a high percentage stone cover. Farmers encountered difficulties in using oxen singly on plots where the stone cover was above 50%, so they resorted to the use of pairs on these fields. Also, the first cultivation on land being cropped after an extended fallow phase of 10 to 15 years proved difficult for oxen worked as singles, and several farmers preparing these plots opted to do the

first cultivation with the conventional pair. The 1983 crop year began later than usual at both Debre Zeit and Debre Berhan and was further shortened by comparatively early frosts at Debre Berhan. Grain yields at Debre Berhan observed by ILCA in 1983 were approximately one third of long-term average yields. Yields in 1982 also had been well below average. The combination of poor yields in 1982 and a late start to the 1983 season contributed to the farmers' cautious response to the single ox method of cultivation. This effect was not so pronounced at Debre Zeit where crop yields in both 1982 and 1983 were similar to the long-term average.

Area and duration of cultivation

At Debre Zeit the average total area cultivated per farm by the test farmers was 1.9 ha of which 3050 m^2 (16%) was cultivated with a single ox, and 1.6 ha (84%) with paired oxen. At Debre Berhan, the average total area cultivated was 1.4 ha of which just under 1000 m^2 (7%) was cultivated with a single ox and 1.3 ha (93%) with ox-pairs.

Almost all the land cultivated in 1983 with a single ox was sown with cereals: at Debre Zeit with teff or wheat, and at Debre Berhan with barley or wheat.

Table 2 summarises the time taken for land cultivation for teff and barley at Debre Zeit and Debre Berhan using paired oxen and oxen worked as singles. The time taken for cultivation by single oxen was around 30% more than by oxen pairs.

Table *2. Average time taken for land preparation and seeding of principal crops by single and paired oxen.*

No. of oxen in harness	Average time taken (hr/ha)	
	Debre Zeit (teff)	Debre Berhan (barley)
One	260	135
Two	200	100

Crop yields

Crop yields were similar for land cultivated with single or paired animals. These are summarised in Table 3. The slightly higher yields at Debre Berhan on plots cultivated with single oxen could be due to farmers using land of higher fertility for their experimentation.

Table 3. *Average grain yields for test farmers and other outside farmers.*

Farmer group	Average grain yield (kg/ha)			
	Debre Zeit		Debre Berhan	
	teff	wheat	barley	wheat
Test farmers using single oxen	1150	1200	447	252

Test farmers using paired oxen	1160	1000	350	268
Other outside farmers using paired oxen	1125	1175	312	310

Future prospects

Feed requirements

A major problem reported by farmers using oxen as singles was that they required more feed/head/day than paired oxen. This claim is being investigated in station-based studies as it has implications for the subsequent adoption of the change to the traditional system. Additionally, the oxen are usually worked in Ethiopia at the end of an extended dry season when the animals are most prone to weight loss when worked and when animal feedstuffs are at a premium. For these reasons research is planned to investigate whether a short duration forage legume can be sown during the early rains prior to the usual cereal or pulse crops in order to have high-quality feed available for draught oxen when it is most needed. Although the marginal value of feed at this time of year is high, it is expected that this additional crop will be accepted by the farmer if it can be grown without prejudicing the production of staple foods. This forage crop option will be tested on-station in 1984.

The seasonality of animal feed supplies affects the productivity of all livestock, not only working oxen, so the Programme is undertaking other research to minimise the effects of this constraint. This work includes the evaluation of fodder trees and shrubs in the Debre Zeit area where the area of fallow land is minimal and where the strategic location of trees and shrubs will interfere minimally with land sown to annual crops. The Programme is also studying low-cost ways of raising the productivity of fallow land in the Debre Berhan area. The carry-over effect on the subsequent crop phase of higher-yielding fallow lands will allow intensification of both crop and animal production in this higher altitude area.

Advantages

Widespread use of the single ox could dramatically reduce the number of oxen and their attendant breeding and replacement stock needed to support food crop production, thereby increasing the feed resources available for each working animal. Not only would grazing pressures be reduced, lowering the risk of environmental degradation, but the nutritional status of the remaining oxen would improve. Also, more timely cultivation of larger areas of land would lead to increased food crop production and allow more balanced cereal/ pulse rotations to be practised.

The single-ox technique has two other major advantages which make the prospects for its uptake most encouraging. First it does not reduce subsistence crop yields, and second it requires minimum investment—the new yoke and harness can be made cheaply from local materials, while the modifications to the *maresha* can be carried out at home or by the village blacksmith.

If adoption occurs on a large enough scale, the single-ox technique will have far-reaching implications for the smallholder farmers of Ethiopia, who are among the world's poorest people.

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List of abbreviations

ACP	African, Caribbean and Pacific states
CP	crude protein
CREAT	Centre du Recherche et d'Elevage at Avetonou, Togo
DM	dry matter
EEC	European Economic Community
FAO	Food and Agriculture Organization of the United Nations
GTZ	Gesellschaft fur Technische Zusammenarbeit (Agency for Technical Cooperation), Federal Republic of Germany
hr	hour
ICIPE	International Centre of Insect Physiology and Ecology, Kenya
IITA	International Institute of Tropical Agriculture, Nigeria
ILRAD	International Laboratory for Research on Animal Diseases, Kenya
N	nitrogen
PA	Peasants' Association
SODEPRA	Sociéte pour le Développement des Productions Animales, Ivory Coast
t	metric tonne
TCRV	tissue culture rinderpest vaccine
UNEP	United Nations Environment Programme