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Livestock development in sub-Saharan Africa

Post-drought vegetation in the Niger floodplain

Sheep mortality in highland Ethiopia

Sheep mortality in Ethiopia: Specific causes

Millet/cowpea intercropping in Mali

The *ILCA Bulletin* is a quarterly publication of the International Livestock Centre for Africa. Contributions to the Bulletin are invited from livestock researchers in Africa whose work is related to that of ILCA. The *ILCA Bulletin* is distributed to more than 3000 researchers, policymakers, donors and extension agents throughout sub-Saharan Africa and elsewhere in the world.

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Preface

Why is livestock research in sub-Saharan Africa important? There is an urgent need to improve food self-sufficiency and rural incomes in the region, and increased livestock output helps.

Livestock play diverse economic and social roles in the national economies of sub-Saharan Africa: they produce milk and meat for subsistence, supply draught power and manure for cropping, and provide fibre, skins and transport. Sales of livestock and their products provide farmers with cash to purchase household necessities and farm inputs. In good years, surplus cash from crop sales is invested in livestock, thereby preserving and often increasing current savings. In many traditional societies, livestock are also the currency in which social transactions are expressed. And last but not the least, export of livestock and their products can be an important source of foreign exchange.

Over the years, the development of the livestock subsector in sub-Saharan Africa has not lived up to expectations: per person production of most livestock commodities has declined, and where milk or meat production has increased, it was mainly due to increases in animal numbers rather than a higher yield per animal.

Both technical and socio-economic constraints are responsible for the slow progress in the subsector. The means commonly believed to help alleviate the key non-technical problems are discussed in the first paper of this *Bulletin* issue, which also gives a comprehensive picture of the external environment in which ILCA operates.

Availability of adequate animal feed is one of the major technical determinants of successful livestock development. In sub-Saharan Africa, feed supplies are seasonal, fluctuating in the long term according to climatic conditions. The effects of the 1983/84 drought on rangeland productivity in an area traditionally reserved for livestock production, the Niger floodplain in central Mali, are discussed in this issue.

Other technical constraints are disease and high mortality. A review of sheep mortality in the Ethiopian highlands during 1982–86indicated that neonatal losses, fascioliasis and coenuriasis are serious problems in the area (pp. 19–22). High neonatal mortality is a common constraint in sub-Saharan Africa, underscored by the fact that there is little direct evidence of its specific causes. To gain better understanding of the problems resulting in frequent deaths in young lambs in highland Ethiopia, ILCA carried out field and laboratory studies in 1986/87; their results are discussed in this issue.

Forage legumes enhance soil fertility, thereby benefitting crop yields, and improve animal nutrition through their high protein content. In the semi-arid zone of Mali, one legume in particular, the cowpea, is also valued as human food. The cowpea is frequently intercropped with millet, the staple cereal in the area. ILCA's study of the system showed that manipulating the millet/cowpea association pattern, planting density, and cropping sequence can improve the yields of both the cereal and the legume despite the adverse climatic conditions experienced in recent years.

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Policy, finance and technology in livestock development in sub-Saharan Africa: Some critical issues*

*This is a revised version of a paper presented at 'The International Conference on Africa: The Challenge of Economic Recovery and Accelerated Development', Abuja, Nigeria, 15–19 June 1987.

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SUMMARY

THE MAJOR *technical constraints facing the livestock subsector in sub-Saharan Africa are inadequate animal feed and nutrition, diseases, and a genetic structure specially geared to survival. The main non-technical constraints are insufficient non-staff expenditure for both services and research, underinvestment in adaptive research, poor infrastructure, and lack of qualified manpower to conduct research, analyse policies and implement development projects.*

While some progress has been made in the field of animal health, the future development of sub-Saharan Africa's livestock subsector depends largely on the availability of increased investment, more appropriate producer incentives, improved institutions (e.g. for marketing and input supply), stronger capacity to plan and monitor, improved technology and strengthened national research capacity.

ILCA contributes to national and international efforts by making available adoptable livestock-related technology and relevant information to improve policy formulation and planning. The Centre plans to strengthen its partnership with national institutions through more collaborative research, intensified training and better information exchange.

INTRODUCTION

The Lagos Plan of Action, Africa's Submission to the Special Session of the United Nations' General Assembly on Africa's Crisis, and the ensuing Programme of Action for African Economic Recovery and Development, provided both explicit and implicit references for the development of the livestock subsector in sub-Saharan Africa. These three international initiatives differed in some elements and emphasis, but shared a number of perceptions of the means needed to achieve common objectives.

The common objectives relevant to the livestock subsector were increased domestic food output, reduced dependence on food imports, and higher producer incomes. Among the shared perceptions of the means required to improve the livestock subsector were increased investment; improved producer incentives, including prices; improved institutions for marketing, credit, input supply and land tenure; improved capacity to plan and monitor; improved technology, particularly in the area of livestock diseases; and strengthened African research capacity.

This paper examines the performance of the livestock subsector in sub-Saharan Africa during the past two decades. The major constraints limiting livestock production are highlighted, as well as the means perceived to form the basis for future progress.

THE ROLE OF THE LIVESTOCK SUBSECTOR

Livestock produce food (e.g. meat, milk) and non-food commodities (e.g. hides, wool), and provide draught power and manure for food and cash crop production, thereby helping to generate income for livestock owners and their employees. Because livestock grow in number and in individual size, they also constitute a form of profitable investment/savings which can be drawn on in time of need. In good years, savings invested in livestock can earn considerably higher rates of return than those obtainable from money deposited in interest-earning bank accounts. However, in times of drought or disease, such savings can be swiftly wiped out.

The livestock subsector accounts for about 5% of the total gross domestic product (GDP) in sub-Saharan Africa, and for 18% of the agricultural GDP which ranges from 2% for Gabon to 99% for Mauritania. Its contribution to the gross domestic product excludes draught power and manure. The proportion contributed by livestock to the agricultural GDP has risen by about two percentage points over the last decade, while in the developed countries livestock account for 45–50% of the agricultural GDP (World Bank, 1982).

Table 1 shows the relative contributions of different forms of livestock output (including draught power and manure but excluding skins and fibre) to the gross value of livestock production in sub-Saharan Africa as a whole and its regions. Meats of all kinds contribute 47% of the total for the subcontinent, traction 31%, and milk only 15%. The proportions for regions vary markedly from the total; for example, draught power accounts for only 3% of the livestock output in central Africa, but for 39% in East Africa.

Table 1. *Relative contributions of food and food-related outputs[1] to the gross value of total and regional livestock production, sub-Saharan Africa, 1975.*

Output	Percent of gross value[2] of output				
	West Africa	Central Africa	East Africa	Southern Africa	sub-Saharan Africa
Animal traction[3]	21	3	39	26	31
Manure[4]	4	1	3	2	3
Meat[5]	56	79	38	58	47
Milk	11	12	17	9	15
Eggs	8	5	3	5	4
Total	100	100	100	100	100
(Total[6])	(1460)	(349)	(3747)	(930)	(6486)

[1] Includes both marketed and non-marketed outputs.
[2] Output is valued at uniform, continent-wide prices in 1975. The prices used are: meat = US$ 1000 t^{-1}, milk = US$ 150 t^{-1}, and eggs = US$ 750t^{-1}. Animal traction is valued at US$ 5.2 per ox-day worked.
[3] Field operations by bovines.
[4] Valued at the equivalent commercial fertilizer prices of the plant nutrients contained.
[5] Includes beef, goat meat, mutton, pork and poultry meat.
[6] Figures in parentheses indicate gross values in 1975 US$ millions.
Sources: FAO (1978); FAO (1979); ILCA (1981).

Exports of livestock and their products can be an important source of foreign exchange. In the mid-1980s, such exports accounted for 2% (by value) of all sub-Saharan Africa's merchandise exports, while for Somalia and Mali they were as high as 55 and 75% respectively (FAO, 1986a; World Bank, 1986).

African livestock production systems are often described as 'subsistence oriented': this may have been true in the past but is much less so now. Forty years ago, pastoralists in northwestern Africa derived about 80% of their calorie intake from food from their livestock (Swift, 1979). About 20 years later, the typical figures for pastoralists were 30–50%, compared with an average of about 8% for sub-Saharan Africa's total population, and world average of 16%.

Table 2 shows the proportion of the total value of livestock output sold from various African farming systems. In pastoral systems, 50–60% of livestock output is sold and 40–50% is retained for household use. In mixed crop-livestock systems, the proportion of livestock output retained for the household is higher.

Table 2. *Examples of sales as proportions of the value of household output of livestock commodities*[a]*, sub-Saharan Africa, various years.*

Region/Country	Zone	Year	Production System	Percent of total output sold (by value)	Source
East Africa					
Ethiopia	Highland	1980/81	Mixed	55	(1)
Kenya	Semi-arid	1980/81	Pastoral	59[b]	(2)
Southern Africa					
Zimbabwe	Semi-arid	1974	Mixed	35	(3)
Botswana	Arid	1981	Pastoral	55	(4)
West Africa					
Nigeria	Humid	1981	Mixed	65[c]	(5)
Niger	Semi-arid	1976/77	Mixed	26[d]	(6)
Niger	Arid	1963	Pastoral	52[e]	(7)

[a] Include live animals, meat, milk and butter.
[b] On 'underdeveloped' group ranches.
[c] Unweighted average of forest and derived-savanna subsystems.
[d] 'Bush Tuareg' system.
[e] Unweighted average of Fulani and Tuareg systems.
Sources: 1. ILCA (Addis Ababa, Ethiopia, unpublished data); 2. White and Meadows (1981); 3. Dankwerts (1974); 4. Botswana –Ministry of Agriculture (1982); 5. Sempeho (1985); 6. Eddy (1979); 7. Niger (1966).

The data presented in Table 2 do not show changes over time from a more subsistence to a more commercial orientation. To demonstrate this we use as an example the data for the Maasai of Kenya, who are often thought of as very traditional. The offtake of Maasai livestock for sale had risen from less than 1% in 1953 to about 8% in 1977 (Meadows and White, 1979), and by mid-1980s, offtake increased to 10–14% (Bekure et al, 1988). In comparison, the sales offtake from European commercial beef ranches in Zimbabwe during 1964–81 averaged about 13% (Sandford, 1982).

An important, but often neglected, aspect of the so-called 'subsistence-oriented' African livestock subsector is the contribution of livestock to the cash income of their owners (Table 3), thereby enabling them to buy both household necessities (e.g. food grain) and production inputs. It is not surprising that pastoralists, who engage in few economic activities other than livestock husbandry, derive a high proportion of their cash income from livestock. It is remarkable, however, that in some of the mixed farming systems, where livestock provide only a proportion of the total value of output (including that consumed on the farm), they are sometimes by far the biggest source of cash. In the Ethiopian highlands, for example, livestock provide about 53% of the value of total farm output[1], but more than 80% of the farmers' cash income (Gryseels and Getachew Asamenew, 1985).

[1] Excluding the value of draught power.

Table 3. *Proportion of total household cash income derived from livestock in selected farming systems, sub-Saharan Africa, various years.*

Production system/country	Ecological zone[1]	Predominant species kept	Percent of cash income derived from livestock	Source
Pastoralists				
Mali	Dry	Cattle	96	(1)
Niger	Dry	Sheep/Goats	96	(2)
Kenya	Dry	Cattle	76	(3)
Agropastoralists				
Kenya	Dry	Sheep/Goats	>90	(4)
Mali	Dry	Cattle	39	(5)
Mixed farmers				
Ethiopia	Highland	Cattle	83	(6)
Northern Nigeria	Subhumid	Pigs/Goats	56	(7)
Southern Nigeria	Humid	Sheep/Goats	2–13	(8; 9)
Zimbabwe	Dry	Cattle	<4	(10)

[1] Defined on the basis of plant growth days (pgds) per year: dry zone = <180 pgds; subhumid zone = 180–270 pgds; and humid zone = > 270 pgds.
Sources: 1. Swift (1985); 2. Swift (1984); 3. Bekure et al (1988); 4. Little (1983); 5. Fulton and Toulmin (1982); 6. Gryseels and Getachew Asamenew (1985); 7. Ingawa (1986); 8. Sempeho (1985); 9. Lagemann (1977); 10. Collinson (1982)

Investment in livestock can have a high rate of return in years without epidemics. Mixed farmers often invest cash surpluses in livestock if their crop output exceeds current needs for subsistence and operating expenses. In bad years, however, livestock are sold to purchase food for household consumption.

Dicko (1986) found in southwest Niger that up to one third of the capital invested in livestock originated from sales of crop produce. In the 1984/85 drought year, the proceeds of about 75% of the livestock sales made by farmers in the same area were used to purchase cereals. This disinvestment resulted in a 45–80% (median about 70%) decline in herd sizes, depending on species and village.

Data provided by Vierich (1979), and quoted in Vierich and Sheppard (1980), show a moderate positive correlation (r =0.62) between average group income from sorghum production 'lost' due to drought and the average group income 'gained' by 'extra' cattle sales. About 42% of the 'lost' sorghum income was recuperated through extra livestock sales; Vierich and Sheppard (1980) inferred from this that "access to cattle buffers a household against the impact of drought".

THE PERFORMANCE OF THE LIVESTOCK SUBSECTOR

In sub-Saharan Africa, but particularly in its drier areas, livestock output is strongly influenced by weather conditions which give rise to considerable year-to-year fluctuations. Consequently, the estimates of growth in output are markedly dependent on the choice of period over which the growth rate is calculated. Drought affects output not only in the years of its occurrence, but also in subsequent years; output declines as a result of loss of livestock, especially breeding stock, and lower calving rates.

The average annual changes in livestock output over two periods during the past 20 years are compared in Table 4. During 1975–84, the aggregate ruminant livestock output in sub-Saharan Africa as a whole and in most of its regions grew faster than during 1963–75. The same trend was observed in the output of separate commodities within the totals.

Table 4. *Annual changes in the livestock output and human population of sub-Saharan Africa, 1963–75 and 1975–84.*

Period	Output/human population	Annual change (%)				
		West Africa	Central Africa	East Africa	Southern Africa	Sub-Saharan Africa
1963–1975	Beef	1.0	5.2	2.4	1.1	2.0
	Mutton	2.3	1.9	0.7	4.0	1.3
	Goat meat	2.3	2.7	2.0	5.6	2.3
	Cow's milk	0.6	1.0	1.5	0.8	1.2
	Human population	2.7	3.0	2.9	2.8	2.9
1975–1984	Beef	2.2	1.4	3.1	1.3	2.4
	Mutton	3.6	0.7	3.0	2.5	3.1
	Goat meat	3.4	1.9	1.9	0.9	2.5
	Cow's milk	2.2	1.8	4.3	1.7	3.5
	Human population	3.6	3.2	3.3	3.3	3.4

[a] The 1963–75 trends are computed on the basis of multi-year averages, i.e. 1961/65 compared with 1974/76. The 1975–84 trends are based on 3-year averages, i.e. 1974/76 compared with 1983/85.
Source: FAO (1963–1986).

Although output during 1975–84 was significantly affected by the droughts in the early 1970s and in 1983/84, the performance of the livestock subsector in this decade was better than in the preceding one. Nevertheless, per caput production of most commodities declined during both periods in most regions and in the subcontinent as a whole; for many products and regions the rate of decline during 197584 was lower than in the preceding decade (Table 4).

The rate of self-sufficiency[2] in the main livestock products has also tended to decline, although there are considerable fluctuations in the ratio in both directions between consecutive years. Self-sufficiency rates in West Africa have improved slightly in recent years, but the decline in imports has been due more to an acute shortage of foreign exchange than to increased domestic production. In fact, per caput consumption has tended to decline during 1975-84, and particularly since 1982.

[2] Defined as percent of total consumption covered by domestic production.

Figures 1 and 2 show per caput production and consumption of meat and milk for sub-Saharan Africa and two of its most important livestock production and consumption regions – West Africa and East Africa. During most of the 1972–85 period, meat and milk production fell short of consumption in both regions. After the mid 1970s, sub-Saharan Africa changed its position from a net exporter of meat to a net importer (Figure 1), while being a net importer of cow's milk over the whole period (Figure 2).

Figure 1. Per caput production and consumption of all meat, 1972–85.

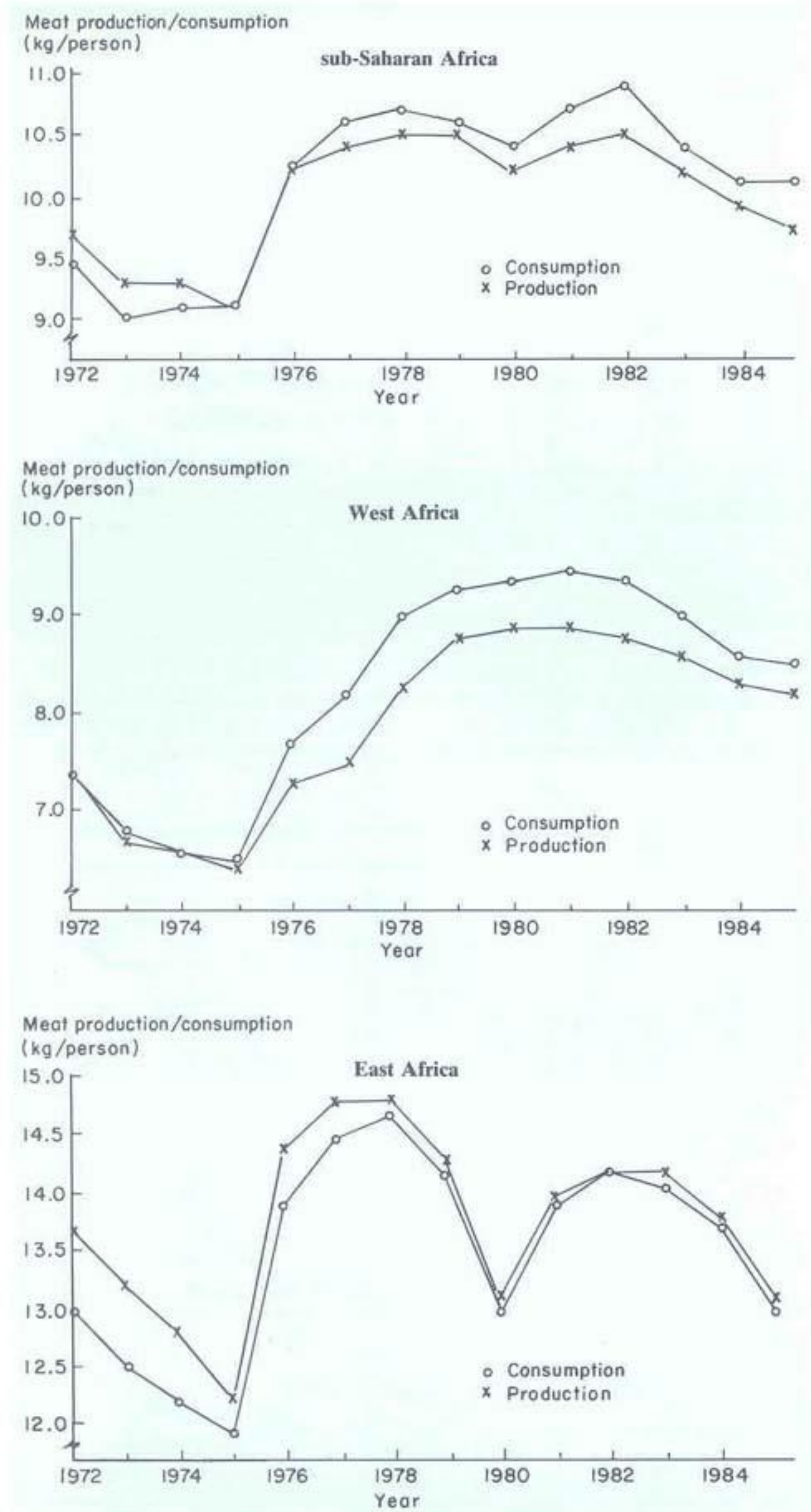
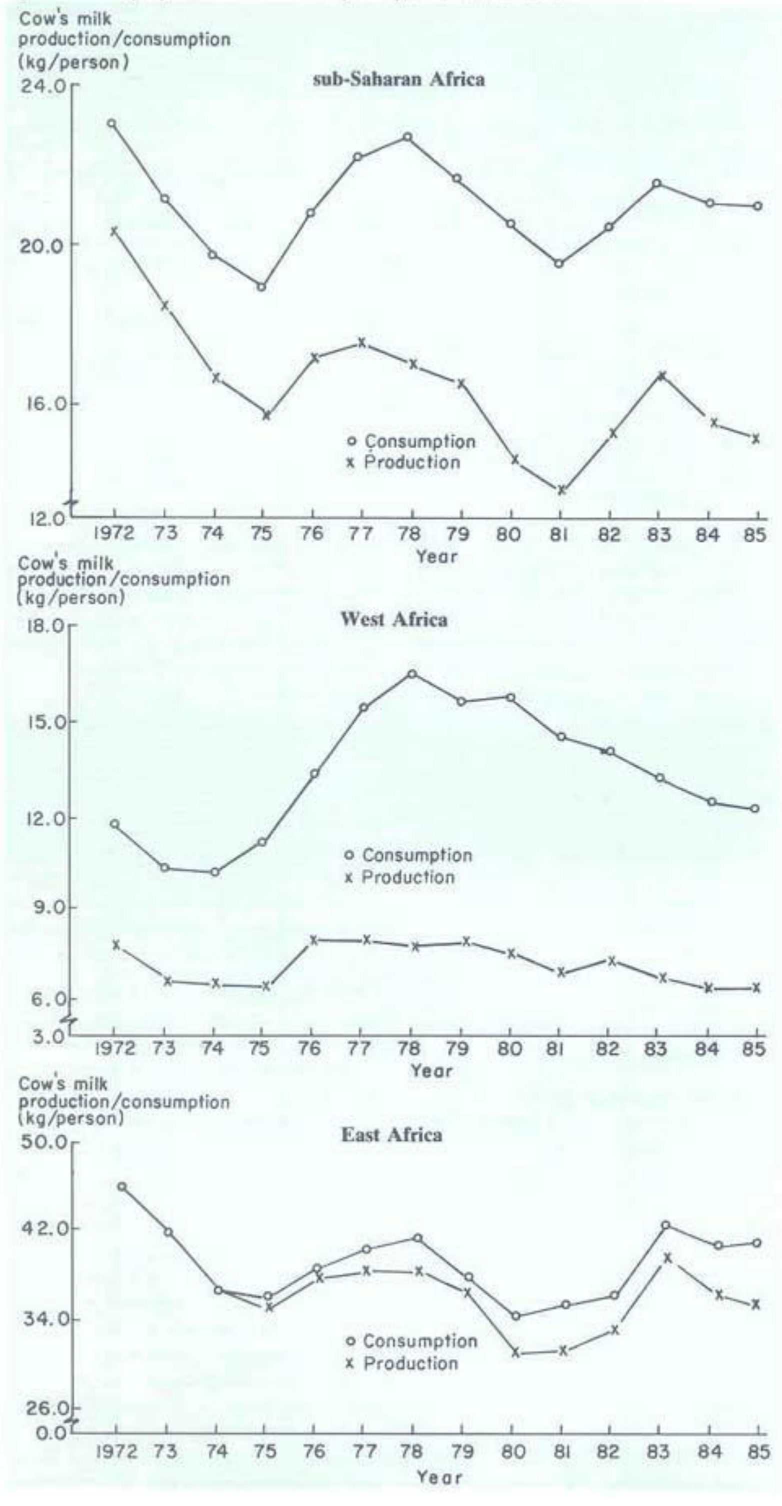


Figure 2. *Per caput production and consumption of cow's milk, 1972–85.*



The production/consumption gap is wider for cow's milk than for meat. West Africa depends heavily on imports for its dairy consumption; and, if the recent declining production and increasing consumption trends in East Africa persist, the gap is likely to grow in this region as well.

Data on the contribution of livestock products to farm income are scarce, because estimates for output prices and production costs mostly do not exist. And the evidence available does not depict this contribution favourably. Over the last decade, world market prices for meat and dairy products have declined substantially in real terms, affecting African meat exports directly, while the availability of cheap imports in Africa's internal markets has also depressed domestic prices.

Africa's livestock subsector does not make much use of purchased inputs, but the real prices of those that are used (e.g. veterinary drugs and fencing wire) have tended to rise. The data available for seven sub-Saharan African countries show that in most of these countries the ratio between livestock prices and feed grain has changed in favour of livestock, but this has had limited impact on incomes since very few livestock enterprises use grain as feed anyway. However, a comparison of trends in the producer prices for livestock with trends in domestic prices generally shows that the real prices of livestock products have been declining, in some countries since 1974 (Table 5).

Table 5. *Trends in the ratios between prices received by beef producers and general retail prices, sub-Saharan Africa, 1974–1983.*

Year	Ratio trends				
	Kenya[1]	Zaire[2]	Zambia[2]	Zimbabwe[3]	Zimbabwe[4]
1974	1.000	1.000	1.000	1.000	1.000
1975	0.849	0.946	0.858	1.018	1.045
1976	0.826	2.448	0.734	0.887	0.855
1977	0.936	2.215	1.284	0.817	0.767
1978	0.816	2.282	1.224	0.764	0.708
1979	0.872	2.000	1.116	0.796	0.671
1980	0.926	2.785	1.066	0.869	0.782
1981	0.946	2.331	1.108	0.958	0.890
1982	0.815	2.288	1.052	1.106	0.929
1983	0.706	2.270	n.a.[5]	0.907	0.808

[1] Based on prices paid by the Kenya Meat Commission.
[2] Based on farm gate prices.

[3] Based on prices paid by the Storage Commission.
[4] Based on auction prices in communal areas.
[5] n. a. = data not available.
Sources: FAO (1984); IMF (1986);Agricultural Marketing Authority (1980, 1982, 1984); Central Bureau of Statistics (1985).

Overall, the performance of sub-Saharan Africa's livestock subsector has not been impressive, and the relatively better performance over most of the recent decade compared with the previous one is largely due to the very low base from which it started. Moreover, almost all of the increase in output which has occurred arose from increases in the number of animals, rather than from increased yield per animal.

Table 6 gives yield indices for 1963–85 estimated in two ways: the first shows yield per productive animal, i.e. per lactating cow or per animal slaughtered, while the second gives yield as total output divided by all the animals of that species in sub-Saharan Africa's herd. The second index takes into account better than the first one does changes over time in the age and sex structure of the herd. The picture is fairly uniform for both indices and for every commodity: yield per animal has increased at most by 10–15% since 1960, or at a maximum of 0.5 % of the annual compound rate.

Table 6. *Yield changes and contribution of yield and numbers to changes in livestock output in sub-Saharan Africa, 1963–85.*

	Beef			Sheep and goat meat			Cow's milk		
	1970	1980	1985	1970	1980	1985	1970	1980	1985
Relative yield[1]									
• per productive animal[2]	102	102	101	103	106	104	99	102	110
• for all animals in herd	109	112	113	104	110	112	97	98	113
	1963–70	1970–80	1970–85	1963–70	1970–80	1970–85	1963–70	1970–80	1970–85
Relative contribution (%) of change in									
• numbers	60.6	80.2	80.3	87.1	69.3	68.1	129.6	94.6	47.7
• yield[3]	39.4	19.8	19.7	12.9	30.7	31.9	–29.6	5.4	52.3

[1] 1960 = 100.
[2] Productive animals are cows in milk and animals slaughtered for meat.
[3] Includes the interaction effect of yield and numbers.
Sources: Addis Anteneh (1984) and data tapes for *FAO Production Yearbooks 1970–1985.*

The changes in total output can be divided into two groups (Table 6): those which would result from changes in the total number of animals while their yield remained the same, and those arising from changes in yield per animal. Table 6 shows that except in the case of cow's milk during 1970-85, changes in output have mainly been due to changes in the number of animals.

CONSTRAINTS TO LIVESTOCK DEVELOPMENT

Socio-economic and institutional constraints

Both technical and non-technical factors constrain livestock development in sub-Saharan Africa. We shall first discuss the non-technical constraints, i.e. those involving socio-economic and institutional issues.

Investment. Investment is usually an essential accompaniment to successful economic development. During the last two decades much of the monetised investment in the livestock subsector of sub-Saharan Africa (other than in indigenous animals) has been financed by foreign aid. This external capital aid to the subsector averaged US$ 80 million year^{-1} in the decade up to 1983 (FAO, 1986b), or just over 1% of the annual total value of output at the beginning of the period (see Table 1). This is an insufficient amount to have had a significant impact.

However, the shortage of investment funds for livestock development has probably not been a critical constraint, even though the funds provided would have been inadequate for significant development if other constraints had not been limiting. If it had been, one would have expected to see a high rate of return to those investments in livestock projects which did take place. This has not occurred, at least in donor-financed projects.

In the World Bank's 'pure' livestock projects, the average rates of return were negative, and most projects (including both 'pure' and those with a livestock component) yielded unacceptable rates of return (<10%). The record of livestock projects in sub-Saharan Africa has on the whole been worse than that of livestock projects elsewhere in the developing world, and of other agricultural projects in the subcontinent.

Recurrent expenditure. Insufficient recurrent expenditure on government livestock services has probably been a more serious constraint than shortage of investment. Lack of satisfactory data on output makes it difficult to demonstrate any causal relations, but a deterioration in animal health services over the last 15 years is evident.

Although average expenditure per animal has risen, recurrent expenditure usually gets a much lower proportion of the total agricultural budget than would be justified by livestock's share in total output. Moreover, much of the increase in real expenditure per animal has been rendered ineffective by the rising share of staff costs in total costs, which have increased at the expense of essential non-staff costs such as veterinary drugs and transport. More numerous and more expensive staff have tended to become less effective (Addis Anteneh, 1987) because of inadequate operating budgets.

Investment in research. A major cause of the poor return to investment in livestock development projects has been the lack of appropriate technical packages into which to channel this investment. This is partly because most of the investments were made in dry zones of low productive potential, and partly because planners overestimated the extent to which the available technology was appropriate to African conditions. Consequently, they underinvested in adaptive research, spending on it proportionately much less in livestock projects than they did in comparable other agricultural projects (Sandford, 1981).

Infrastructures. In some countries there are other problems, including relatively low density of the human population, underdeveloped infrastructures (e.g. roads), and distant final markets. Added to these are high temperature and, in some areas, high humidity, which lead to rapid spoilage of meat and milk. The consequences of all these factors are high costs of transport, storage, processing, and wastage, rendering, for example, surplus milk production in pastoral areas virtually unmarketable.

Economic environment. The economic environment over the last decade has not been conducive to successful livestock development. Many African governments have tried to keep retail prices of meat and dairy products down (see Table 5), and although such attempts were often unsuccessful, they could not but shake the confidence of potential investors. At the same time, ill-judged attempts by donors and governments to interfere in marketing systems have widened the gap between producer and wholesale or retail prices, except where heavy government subsidies have been incurred (for example see Sandford, 1983, Chapter 9). Declining real prices in world markets, aggressive protection and other trade policies by developed countries have upset Africa's export markets for meat and intensified competition for dairy products in its domestic markets. In addition, the real prices of production inputs have risen substantially.

Other major constraints. Lack of adequately qualified and experienced manpower to conduct research, analyse policies and implement development is one of them. Because of worsening economic conditions, governments have been unable to make their planned financial contributions to livestock development. The designs of livestock projects were often grandiose and unrealistic (especially in the light of the lack of qualified and experienced staff), and donor agencies failed to provide firm but flexible supervision of implementation. Institutions set up to provide credit and production inputs have often been neither financially viable nor sensitive to producers' needs. Moreover, several important livestock-producing areas have been affected by war and insecurity.

Technical constraints

The technical constraints to livestock development can be divided into four broad categories: feed and nutrition, genetic structure, health and disease problems, and other constraints.

Feed and nutrition. Adequate livestock nutrition depends on the availability of adequate feed supplies and on good management. Because of poor soil fertility and scant, unreliable and markedly seasonal rainfall, feed supplies in Africa fluctuate in both quantity and quality (digestibility and protein content). Conservation and storage of feed from the time of its growth to the time of its use is therefore a critical issue. In some areas, deficiencies in specific minerals also occur.

In drier areas, feed is widely dispersed in space, involving high energy expenditure in harvesting it by grazing or other means. In wetter areas where soil fertility is often poor, the concentration of nutrients in the dry matter produced is inadequate, such that livestock cannot eat enough to achieve optimum production.

Genetic structure. The genetic structure of African livestock has evolved largely as a result of natural selection, influenced by environmental factors and the level of technology. Selection has been for survival under high disease challenge and fluctuating feed and water supplies, rather than for high levels of production.

In some higher-potential areas of East Africa, where disease control and artificial insemination are commonly used, a changed genetic structure has emerged, sometimes incorporating exotic genes and resulting from selection for high production. In lower-potential and marginal environments the ability to survive is still the dominant selection criterion. This is reinforced by social institutions (particularly land tenure) which encourage competition for scarce feed and water resources, rather than adjustment of herd size.

Health and disease problems. Although modern technology has reduced some disease risks, animal health problems still form a major category of constraint. For example, trypanosomiasis transmitted by tsetse flies is considered to be a serious problem over 46% of sub-Saharan Africa's surface area. Internal and external parasites can also be important causes of low productivity and high mortality, and there are often significant interactions between nutrition, disease and reproductive performance.

In some instances, technical solutions to health problems are available (e.g. control of internal parasites) but only at an uneconomic cost, such that the problem is better tackled through improved herd management rather than new technology. In others, for example streptothricosis, new technology may be the only way to substantially improve productivity and profitability.

Sometimes the disease issue may not relate to physical productivity but to price and market outlets. Unless the disease is eliminated in a particular way (e.g. by slaughter and quarantine rather than by vaccination, as in the case of foot-and- mouth disease), relatively high-priced export markets cannot be entered, and much lower prices will be received in domestic or more saturated export markets.

Other constraints. These include particularly water shortage, toxicity and poor management. The first constraint has been addressed in water development programmes in most of sub-Saharan Africa. However, although lack of watering points is no longer as serious a problem as it used to be half a century ago, the unreliability of water supply and equipment and poor maintenance continue to cause crises from time to time. The persevering water shortage is as much an institutional as a technical issue.

Poor management can also be a major problem, although this is often caused more by shortage of herding labour (a social or economic problem) than by ignorance or inefficiency. Nevertheless, differences in productivity are sometimes extremely large between herds and flocks with apparently equal access to the same feed and water resources and equal exposure to the same health risks. They may be due to differences in management practices not yet properly identified, and our ignorance of these constitutes a constraint.

PAST DEVELOPMENT OF TECHNOLOGY

Some of the constraints mentioned in the previous section have been at least partly overcome by 'non-traditional' technologies which have been tried over the last half-century. Among those which were wholly or largely 'developed' (i.e. designed, researched and applied) in sub-Saharan

Africa are rinderpest vaccination, tick control (especially for theileriosis), control of tsetse and trypanosomiasis by bush-clearing, and control of trypanosomiasis by chemotherapy.

Rinderpest vaccination, which is applicable across zones and regions of sub-Saharan Africa, can by and large be considered a success. Tick control, which has been most important in combatting East Coast fever (ECF–a form of theileriosis) in subhumid and semi-arid East Africa, has been a partial success, but with continuing problems of implementation. Tsetse/trypanosomiasis control is still under development and, if successful, could have a substantial impact throughout the humid and subhumid zones. Most of these 'African' technologies were developed during and immediately after the colonial period and implemented mainly in the post-colonial period.

A number of other technologies largely developed outside sub-Saharan Africa have been adapted and applied within it. Modern techniques of water extraction (boreholes) and storage (stockponds) have, together with rinderpest vaccination, been largely responsible for the increase in livestock numbers and output in sub-Saharan Africa over the last half-century. Naturally, water technology was of greatest use in the drier areas, with outstanding impact in Botswana, Sudan and the Sahel. Vaccinations against anthrax, foot-and-mouth disease, blackquarter and contagious bovine pleuro-pneumonia (CBPP) were developed outside sub-Saharan Africa, but were also applied with some success within it.

Natural genetic change in Africa's livestock herds has occurred as a result of human migration, inter-tribal theft, market exchange of stock, and livestock diseases such as trypanosomiasis and rinderpest. Deliberate genetic change has occurred only on a small scale, principally on ranches in Botswana, Zaire and Zimbabwe, and on smallholder dairy farms in highland Kenya. The proportion of sub-Saharan Africa's total cattle herd which has been significantly affected by such deliberate change is probably less than 3% (i.e. less than 5 million head).

Widespread scientific evaluation of the performance and potential of different exotic and indigenous cattle breeds and their crosses (see Brumby and Trail, 1986) shows that introducing exotic genes concurrently with improved animal health and nutrition can increase milk production. This has not, however, been demonstrated in increased meat production and draught power in any of the ecological zones.

Particularly in East and southern Africa, research and extension departments made considerable efforts to improve livestock feed supplies from forage crops and natural range or pasture. Where a commercial dairy sector has emerged, it has usually done so in conjunction with the development of forage crops. Otherwise, this effort has not led to much on-farm/on-range adoption, except in the irrigated areas of Sudan and on commercial ranches. Range management research has not led to the development of economically viable techniques enabling substantial increases in primary or secondary productivity per hectare.

The discussion of technology so far has dealt mainly with single components rather than complete production systems. Three 'modern' systems – commercial feedlots, commercial ranching (including parastatal ranching), and commercial dairying –have been tried on a fairly large scale in sub-Saharan Africa in the last half-century. Commercial feedlots appeared promising initially, but were badly hit by the collapse of international beef prices in the mid-1970s.

Commercial ranching was adopted in Angola, Botswana, Kenya, Nigeria, Tanzania, Zaire, Zambia and Zimbabwe. Well-managed ranches have higher productivity per animal than traditional African livestock systems in similar environments, but apparently not higher productivity per hectare (de Ridder and Wagenaar, 1986). As a rule, ranches have been successful only when there is privileged access to land, and where no opportunity cost has to be paid for diverting that land from other uses.

Commercial dairying, which involves a complete package of breed, health, feed and other production innovations, as well as modern transport, marketing and processing facilities, has been successful on large farms in Zimbabwe, and on large and small farms in Kenya. Otherwise, the system has not been successful for a variety of political, economic and technical reasons, such as low producer prices, shortage of breeding stock, and disease problems, particularly dermatophilosis.

THE BASIS FOR FUTURE DEVELOPMENT

The relevant means required to increase livestock production in sub-Saharan Africa include:

- increased level of investment
- better producer incentives
- improved institutions
- improved capacity to plan and monitor, and
- strengthened research capacity to generate technology

These means are discussed below in detail.

Investment pattern

No published data are available on aggregate *investment* in sub-Saharan Africa's livestock subsector. We can make some very crude guesstimates, at any rate in relation to ruminant livestock species which account for about 80% of the value of domestic livestock output in the subcontinent. We assume that ruminant meat is worth US$ 1300 t^{-1} carcass weight (at international prices), which is equivalent to about US$ 600 t^{-1} liveweight, or US$ 150 per tropical livestock unit (TLU) of 250 kg. Valuing livestock as breeding animals or milk producers might raise this amount slightly.

In 1985 there were about 145 million TLUs in sub-Saharan Africa, growing in number at 1.7% per annum, so the capital stock was worth about US$ 22 billion. The annual net investment in 1985 was worth US$ 370 million, having grown (assuming unchanged real prices) from just over US$ 300 million 10 years ago.

Over the last decade, the value of donor assistance (which we shall define as being all investment) to the livestock subsector averaged US$ 80 million per annum at current prices, with some decline in real terms. There are no data on the value of the public sector's direct investment financed from domestic sources, but it is our impression that it cannot be more than 50% of donor-financed investment and is probably of the order of 20% (ECA, 1987). Similarly, no estimate is available of producer-financed investment other than in the livestock themselves, but most livestock enterprises in Africa involve very little investment in anything except animals. Even in modern ranching enterprises the ratio between investment in livestock and in nonlivestock assets other than land is 4:1 (Jarvis, 1986). A very rough estimate of the pattern of investment in sub-Saharan Africa's livestock subsector over the last 10 years is given in Table 7.

Table 7. *Investment[1] pattern in sub-Saharan Africa's livestock subsector, 1975–85.*

Source of investment	1985 US$ million[2]	
	1975	1985
Producers' incremental investment in livestock	310	370
B. Other investment by producers (10% of A)	30	40
C. Donor-financed investment[3]	140	90
D. Public-sector-financed investment from domestic sources (25% of C)	30	20
Total	510	520

[1] Excluding investment inland.
[2] Rounded to the nearest 10 million.
[3] FAO (1986b). Values are adjusted to 1985 prices according to the industrial countries' GDP deflator index. The 'current prices' value for 1975 is US$ 70 million.

Different sources and approaches suggest that, excluding land, the overall capital: gross output ratio in the livestock subsector is between 3.5:1.0 and 5.0:1.0, but is perhaps more in the region of 2:1 with modern dairy enterprises. These ratios are based on aggregated data for sub-Saharan Africa, on studies of specific systems (e.g. see Sandford, 1983, p.125), and on comparisons with other developing countries (e.g. see Jarvis, 1986).

The value of the food, traction and manure output of the subsector is of the order of US$ 7000 million year^{-1} (estimated at 1985 prices); it needs to grow by about 3.1% year^{-1}, which is about US$ 220 million, just to keep up with population growth. Unless current capital:output ratios are substantially reduced, the present level of investment in the subsector will need to be about doubled to achieve the required level of output.

The general economic crisis, particularly the debt problem, has adversely affected the trends in savings and investment rates in sub-Saharan Africa in recent years. Consequently, investment levels are unlikely to be doubled, unless a substantial amount of the investment funds currently used elsewhere in the economy is diverted to the livestock subsector.

If the performance of the subsector can be improved, such diversion would be justified. For example, although the livestock subsector contributes about 15% to the agricultural GDP in developing countries collectively, it receives only about 3% of the donor aid to the agricultural sector (FAO, 1986b), and the proportion has declined over the last decade. Separate data are not available for sub-Saharan Africa, but the position is probably the same and is unlikely to change until there is evidence of improved performance.

Producer incentives

Producer incentives can be directly affected by prices of inputs and outputs, by factors which raise or lower risk, and by levels and methods of taxation. African governments have some influence on all of these, but prices and risks are also greatly affected by other factors, principally developments in the international financial and commodity markets, and weather. For example, the world market price (in current US$) for skim milk powder (which Africa imports) fell from about US$ 900 to US$ 600 t^{-1} between 1974 and 1985, a decline of about 70% in real terms. In 1985, the price for beef (which some African countries export) in non-protected world markets was at almost exactly the same level in current US$ (i.e. US$ 1300 t^{-1} carcass weight) as in 1974, which corresponds to a decline in real terms of about 56% (FAO, 1985).

Not surprisingly, the producer prices for beef in the countries that export it (e.g. Botswana, Ethiopia, Kenya, Sudan, Zimbabwe) are fairly well in line with the world market prices[3]. For this to be otherwise would require either an export subsidy, which no African government could afford, or a devaluation of the local currency. In countries which do not export meat, producer prices are often considerably higher than the price at which meat could be imported (ILCA, Addis Ababa, Ethiopia, unpublished data). The situation is the same for milk of which there are no significant African exporters.

[3] Based on data in the first half of the 1980s.

African governments have tended to give substantial protection (in absolute terms) to domestic livestock production against the depressed world prices. Whether they have protected it relatively more or less than other forms of production is an issue which has been insufficiently studied. In Kenya, where such a study was made (Schluter, 1984), the nominal protection rates varied markedly between different kinds of commodities, but not in a systematic way.

Prices determined in world markets will continue to exert a very strong influence on the incentives for African livestock producers, particularly those that sell to these markets. The agricultural policy of the EEC, which is currently the major determinant of world prices, offers little prospect of significant price rises in the short and medium terms (FAO, 1986c). A calculation of the potential effect of a full liberation of agricultural trade policies by the world's market economies indicates that dairy prices might rise by up to 67%, and beef and lamb prices by 15% (World Bank, 1986, quoting Tyers and Anderson, 1986). Such a complete liberalisation is unlikely to take place in the foreseeable future, but the calculation shows the direction and ultimate limits to which (other things being equal) trade liberalisation might lead.

Institutions

Land tenure. This was identified as a constraint in a number of studies. In the drier areas, where several imaginative experiments have been carried out, it is still unclear which forms of land tenure will be efficient and equitable. In the higher-potential areas, where the solutions are clearer, many governments have not yet grasped the nettle of land reform.

Marketing institutions. During the 1960s it was fashionable to decry the operations of 'traditional', i.e. existing, marketing institutions and to seek to impose much closer government control on them, or to establish new parastatal substitutes or competitors. Thanks to several academic studies of traditional livestock and meat marketing systems, and some painful experiences with parastatals (reviewed, for example, in Sandford, 1983), there is now greater recognition of both the merits of the traditional system and the difficulties government intervention may entail. Nevertheless, given the present degree of government intervention in the international meat trade in all the economic blocs, a totally 'hands-off' position by the governments of African meat exporting countries is not feasible.

The nature and performance of dairy marketing systems in sub-Saharan Africa are not well understood. ILCA has started some studies on these systems, but more work by others on the subject is desirable.

Input-providing institutions. Except for ranches in Kenya and Zimbabwe, ruminant livestock production in sub-Saharan Africa tends to use few inputs besides land, natural forage or crop residues, herding labour, and capital in the form of livestock. A partial exception to this are veterinary services: there have been some experiments with using 'para-professionals' to deliver such services, and some use of professionals in the private sector. On the whole, however, the method of delivering veterinary services has not changed much over the last two decades, while the delivery of other inputs has not been developed, partly for lack of economic demand, and partly because appropriate organisational forms have not been devised.

Capacity to plan and monitor

Progress in planning and monitoring has been patchy. The technical abilities of many African officials have been improved by relevant academic courses, and about 80 individuals have had specific training in livestock planning issues, provided in the past by the joint ILCA/World Bank Project Planning Course and, more recently, by ILCA's annual Livestock Policy Analysis Course.

Individual training will, however, be ineffective if the right political and organisational environment is lacking. That political support is not yet available can be judged from the fact that the livestock subsector probably receives only 20% of the capital expenditure and 65% of the recurrent expenditure which even its food-commodity contribution to the agricultural GDP would justify (Addis Anteneh, ILCA, Addis Ababa, Ethiopia, unpublished data). If the animal power and manure that livestock contribute to cropping were to be taken into account, the budgetary allocation to the subsector would be even more inadequate.

In many African countries, livestock development has either been inadequately incorporated in the general planning of the agricultural sector, being sometimes left to animal health departments or to commodity-oriented parastatals with objectives that only partially cover the subsector, or else it has been incorporated spasmodically, being sometimes the responsibility of the ministry of agriculture and sometimes of a separate ministry. This spasmodic approach has been inimical to the desirable continuity of planning personnel, methodology, and policy.

Technology and research capacity

Inadequate technical basis is another cause of the unsatisfactory performance of livestock projects in sub-Saharan Africa (see e.g. Sandford, 1981). Technical constraints and past technology development were discussed above; this subsection deals with national research capacity to generate technology in the future.

There are some data of variable completeness and accuracy on agricultural research in sub-Saharan Africa in the first half of the 1980s, and on livestock research within the agricultural total. The total annual expenditure on national agricultural research in the subcontinent was roughly US$ 400 million, and there were about 6000 scientists (defined as having at least a B.Sc. degree) working on agricultural topics and commodities in national research organisations and universities (ILCA, Addis Ababa, Ethiopia, unpublished data).

About 49% of agricultural scientists are in West Africa (which has 42% of the human population), 27% in East Africa (30%), 17% in southern Africa (12%), and 7% in central Africa (16%). About 15% of these scientists have Ph.D. degrees, and a further 35–40% have M.Sc. degrees.

Incomplete data suggest that 18% or 1100 of the 6000 agricultural researchers work in livestock-related fields including veterinary medicine, animal husbandry, and forage crops and pasture. Of these about 30%, say 350 individuals, are working on veterinary issues. Although data indicating expenditure on livestock-related research are not available for most countries, we assume that this expenditure will be proportional to staff costs – of the order of US$ 70 million per annum (at 1980 prices).

There are 24 countries for which the number of scientists involved in livestock-related research is known (ILCA, 1987). These countries account for 64% of sub-Saharan Africa's TLUs. Seven of them (33% of TLUs) have more than 35 livestock scientists, another seven (23% of TLUs) have 15–35 scientists, and the remaining seven (7% of TLUs) have less than 15. No data are available for five countries which account for 37% of the region's TLUs. Of these 'unknowns' Sudan almost certainly has over 35 livestock scientists.

Rather arbitrarily, we define countries with more than 35 scientists as 'well-endowed', i.e. capable of conducting a fairly comprehensive set of adaptive experiments with several components. Countries with 15–35 scientists are defined as 'modestly' endowed, and those with less than 15 as 'ill-endowed'. These terms are used relative to conditions in sub-Saharan Africa, not in an absolute sense.

Implicit in this categorisation is that a certain critical mass is needed to make progress, irrespective of the size or complexity of a country's livestock sector. Given current Ph.D./M.Sc./B.Sc. ratios, a total of 15 'scientists' implies only about three Ph.D. holders, i.e. individuals formally trained to conduct research. This low figure suggests that national research capacity is not yet adequate to generate the required flow of new technology.

The key issue is the rate at which research capacity is being increased in Africa – and on this we have no reliable information. In a number of important livestock-producing countries, brain drain from research, either abroad or into non-research fields, appears to prevent the accumulation of a strong core of experienced livestock researchers. The main reasons for this drain appear to be frustration over inadequate support (e.g. equipment), inadequate incentives, and lack of performance recognition.

In some countries, researchers lack adequate operating funds to be fully effective.

Several international organisations and donors are now directly involved in livestock research in sub-Saharan Africa. Some of them, including the International Livestock Centre for Africa (ILCA), were established partly in response to the lack of impact of national research on livestock production in the region.

ILCA's efforts

ILCA has now been in existence for 14 years. The first years were spent in institution building and establishing the necessary infrastructure, while the research programme was aimed at acquiring a better knowledge of the factors influencing the performance of different farming systems in sub-Saharan Africa.

Between 1981 and 1986 ILCA concentrated on strengthening technical expertise at headquarters, and on designing and testing technological interventions. Some of the Centre's more successful work has included water-harvesting and soil-conservation techniques using simple animal-drawn implements, simple milk processing technology, improving the cultivation and productivity of Vertisols, studies on the productivity of trypanotolerant livestock, testing of fodder banks and alley farming, collection and distribution of forage germplasm, and provision of training and information services.

In 1987 ILCA recharted its strategy in the light of its past experience. The Centre plans to focus its research on cattle, sheep and goats, on the major food commodities (meat and milk) produced by livestock, and on intermediate livestock inputs (traction and manure) to crop production. Its priority target groups are smallholders and agropastoralists. The research on commodities is supported by 'strategic' research on animal feed resources, trypanotolerance, and issues related to livestock policy and resource use.

ILCA plans to strengthen its partnership with national agricultural research systems (NARS) through applied and adaptive collaborative research, and by providing more training opportunities and better information services. The strengthened partnership with NARS and intensified training are expected to lead to an increased availability of suitable new technology. It is also expected to enhance the exchange and dissemination of relevant information to improve planning and policy formulation in the livestock subsector.

CONCLUSION

The past performance of sub-Saharan Africa's livestock subsector has generally not been impressive. Because of the nature of the production process and the institutional intricacies involved, the constraints facing the subsector are complex, but it would seem that they have been rendered even more so by national and international policies attempting to direct the course of development in the subsector. Yet the problems are not insurmountable, even though past development of technology has had relatively little impact on productivity.

The means discussed in this paper appear to be well-oriented towards solving the constraints identified, but a word of caution is necessary: we should not expect dramatic breakthroughs, rather aim at incremental gains over time to reverse the trend of past performance. A longer-term commitment to increased investment in research and to the development of scientific manpower is essential to achieve common objectives, as is stronger partnership between African and international institutions such as ILCA.

It is in this framework that the role of policy, finance and technology in the development of sub-Saharan Africa's livestock subsector would be more meaningful in the long run. It is also in this framework that intensified national and international efforts to put in place the means necessary to increase livestock production in the region will have the greatest payoff.

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Changes in *Vetiveria nigritiana* and *Eragrostis barteri* grasslands in the Niger floodplain, central Mali

*Translation of the original French paper entitled 'Evolution des savanes à *Vetiveria nigritiana* et à *Eragrostis barteri* des plaines d'inondation du fleuve *Niger* au Mali de 1980 à 1986'.

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SUMMARY

THE RAINFALL *and flood deficits during 1980–86 changed the floristic composition and biomass production of eragrostis and vetiveria grasslands in the Niger floodplain in central Mali. Low residual soil moisture limited growth, thereby influencing seed production. The dominant perennial species regressed or disappeared, giving way to unpalatable annual grass species, some bushes and termite mounds. Dry-season forage production on the grasslands decreased, resulting in lower stocking capacity while livestock herds were increasing. Following the 1983/4 drought, cultivation pressure in the Niger floodplain also increased as rice-growing farmers moved into the lower foodplain traditionally used for livestock production.*

INTRODUCTION

The grasslands in the Niger floodplain play an important part in livestock production in central Mali. They are grazed extensively during the dry season (November–May); in early June, the herds start the trek to the wet-season pastures in the Sahel, and return to the floodplain in October. From October to March, they gradually drift from its southern fringes northward into the elevated plains, where they remain until early June. They then fan out in search of forage before beginning another journey to the rainfed pastures.

The low rainfall in central Mali during 1980–86 caused flood deficits, which in turn affected the floristic composition of the floodplain grasslands. This led to lower primary production and, consequently, lower carrying capacity. The extent of the ensuing catastrophe is illustrated by using as examples grasslands dominated by the perennial grasses *Vetiveria nigritiana* and *Eragrostis barteri.*

METHODOLOGY

Data on plant composition and primary biomass production were analysed. Two sets of data were compared: data collected before and immediately after the 1983/84 drought.

Plant composition

Ecological profiles of the floodplain grasslands were established during the 1979 survey of ILCA's study area in central Mali, using the systematic sample collection method developed by the Centre d'etude phytosociologique et écologique (CEPE, Montpellier, France).

Samples of grass cover were collected over an area of 100 m^2, while woody cover was sampled over 2.5 ha. These samples were analysed to determine plant composition, overall plant cover, cover by species and plant stratification on the study sites. Pastoral and cropping activities were also recorded to define land-use type. The vegetation structure of the floodplain grasslands before the 1983/84 drought is described by Hiernaux et al (1983).

Since 1984, the vegetation of the same sites has been monitored under a remote sensing programme. Observations of plant cover and species distribution were made over 24 randomly selected 1-m^2plots along a 1-km long line.

To determine the stock of viable seed in the upper soil layers, 20 × 20 × 2 cm soil samples were taken from each grassland type and transferred to pots where the soil was watered daily. The number of seeds that had germinated every 3 days was recorded.

Biomass production

Changes in biomass production were monitored by regularly cutting the grass on three, replicated 4-m^2 plots. The plots were randomly selected within a 1000-m^2 enclosure in each grassland type, and ground measurements were made both before and after the drought. After 1984, the biomass was also measured on 24 one-m^2 plots randomly distributed along a 1-km long strip.

RESULTS

Vetiveria grassland

Before the 1983/84 drought, the vetiveria grassland was dominated by tussock grasses, including *Vetiveria nigritiana, Sorghum trichopus, Panicum anabaptistum* and, occasionally, *Hyparrhenia exarmata* and *Panicum fluvicola.* The hollows between the large, spaced-out tussocks were covered by annuals, chiefly *Panicum wallense* and *Setaria pallide fusca* (Figure 1).

Figure 1. *The condition of the vetiveria grassland in November 1980, Niger floodplain, central Mali.*

Maximum biomass (6–8 t DM ha^{-1}) was produced at fructification in October and November. In the dry season, production continued through leafy regrowth. Vetiveria grasslands were intensively grazed when enough dry-season regrowth was available, usually stimulated by burning the previous year's stubble.

Eragrostis grassland

Before the drought, the dominant species in this type of grassland was *Eragrostis barteri,* interspersed with tussocks of *Hyparrhenia rufa, Paspalum orbiculate, Oriza longistaminata* and *Setaria anceps* (Figure 2). Species such as *Panicum fluvicola, Andropogon africanus, Crotalaria ochroleuca, Brachiaria jubata* and *Acroceras amplectans* occurred rarely.

Figure 2. *The condition of the eragrostis grassland in December 1981, Niger floodplain, central Mali.*

The range produced maximum biomass (3–6 t DM ha^{-1}) in October, which was usually utilised by transhumant cattle returning from wet-season pastures. Dry-season regrowth after burning was grazed by small ruminants.

THE EFFECT OF DROUGHT ON VEGETATION

Drought indicators

Decreased annual rainfall and changing flood regime are the early indicators of drought. Although rainfall on the study sites was not recorded, data from neighbouring meteorological stations in Djenne and Mopti show that except in 1979 and 1980, annual rainfall during the remainder of the study period was considerably lower than the average rainfall over the period 1930–80 (Table 1).

Table 1. *Annual rainfall at Mopti and Djenne meteorological stations, central Mali, 1979–86.*

Year	Rainfall (mm)	
	Mopti	Djenne
1979	460	525
1980	625	436
1981	414	371
1982	318	379
1983	462	414
1984	275	282
1985	437	539

1986	450	530
50-year average to 1980	528	574

Source: Hiernaux and Diarra (1986).

The flood deficit was even more acute: apart from a slight improvement in 1981, the inundation level decreased progressively from 1979to 1984, reaching an all-time low in the second year of the drought (Table 2).

Table 2*. Changes in flooding conditions observed on eragrostis and vetiveria grasslands at Kara and Kouakrou, central Mali, 1979–84.*

Year	Eragrostis grassland		Vetiveria grassland	
	Maximum flood height (cm)	Flood duration (days)	Maximum flood height (cm)	Duration of soil moisture[1] (days)
1979	+ 40	59	0	90
1980	0	0	–40	32
1981	+ 25	17	–15	50
1982	+50	0	–90	14
1983	–65	0	–100	0
1984	–170	0	–200	0

[1] To 1-m depth. Since vetiveria develops after the flood has receded, the appropriate measurement is the period of soil moisture availability, rather than flood duration.
Source: Hiernaux and Diarra (1986).

Plant composition

A major change in the plant composition of the floodplain grasslands followed the drought: the perennials that previously dominated the eragrostis grassland regressed, giving way to annual species such as *Panicum subalbidum, Setaria pallidefusca, Borreria choetocephala, Borreria filifolia, Eragrostis pilosa,* and *Leptadenia hastata* (Figure 3). The vetiveria grassland was invaded by *Panicum laetum, Panicum subalbidum* and *Setaria pallide fusca.* Most of these annual grass species were present in both grassland types before the drought, but they covered a considerably smaller area (Table 3).

Figure 3. *Eragrostis grassland invaded by* Panieum subalbidum, *Niger floodplain, central Mali, November 1985.*

Table 3. *Changes in vetiveria and eragrostis grasslands by area covered by component, Niger floodplain, central Mali, 1979–86.*

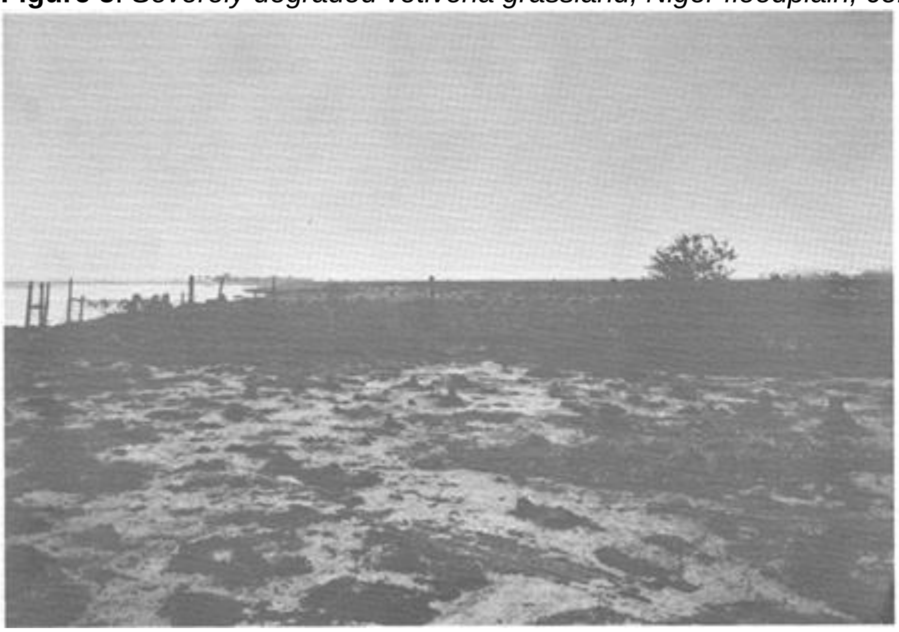
Grassland/Component	Area covered (%)				
	1979	1981	1983	1984	1986
Living vetiveria tussocks	60.0	40.0	20.0	4.6	0.3
Dead vetiveria tussocks	2.0	5.0	9.0	9.6	4.2
Annuals	7.0	8.5	10.0	13.6	15.1
Termites' nests	n.a.[1]	0.5	1.0	1.2	1.3
Bare ground	33.0	46.0	60.0	71.0	78.9
Eragrostis grassland					
Eragrostis barteri	n.a.	55.0	3.5	3.5	3.1
Oriza longistaminata	n.a.	7.4	7.4	7.4	7.1
Leptadenia hastata	n.a.	0.0	1.0	2.0	3.7
Annuals	n.a.	7.6	15.0	16.1	34.0
Bare ground	n.a	30.0	73.1	70.0	52.1

[1]n.a. = not available.

The negative effect of the 1983/84 drought on the vetiveria grassland was exacerbated by increased termite activity after the drought, which was no longer curtailed by regular and sufficient flooding. The gradual transformation of verdant grassland into unproductive land is depicted in Figures 4 and 5.

Figure 4. *The beginning of degradation on the vetiveria grassland, Niger floodplain, central Mali, November 1983.*

Figure 5. *Severely degraded vetiveria grassland, Niger floodplain, central Mali November 1985.*



Seed stock

The germination trial in 1985 showed that the floodplain soils contained few viable seeds of perennial grasses. In the vetiveria pasture, for instance, merely 19 and 32 seeds per m^2 of grazed range and protected enclosure respectively were likely to germinate; and all were *Oriza longistaminata* (Table 4).

Table 4. *Estimated number of viable seeds per m^2 of enclosed and grazed vetiveria pasture, Niger flood-plain, central Mali, 1985.*

Grass species	Number of viable seeds per m^2	
	Enclosure	Grazed range
Perennial grasses		
Oriza longistaminata	32	19
Annual grasses		
Setaria pallide- fusca	285	168
Panicum subalbidum	29	6
Panicum laetum	0	3
Sesbania leptocarpa	0	3
Total for annual grasses	314	177

In the eragrostis grassland no perennials were observed to germinate (Table 5), indicating a highly random dispersal of seed which would make it difficult for the range to regenerate. Thus if this grassland is to provide sufficient green fodder for livestock during the dry season in the future, regeneration must be stimulated by other means, including seeding of perennials.

Table 5. *Estimated number of viable seeds per m² of enclosed and grazed eragrostis pasture, Niger floodplain, central Mali, 1985.*

Grass Species	Number of viable seeds per m^2	
	Enclosure	Grazed range
Perennial grasses	0	0
Annual grasses		
Setaria-pallide-fusca	134	3
Panicum subalbidum	157	122
Schoenefeldia gracilis	16	0
Acroceras amplectans	10	0
Micrococca mercurialis	10	0
Total for annual grasses	317	125

For both types of grassland, the number of seeds germinating within the enclosures was higher than that in the grazed areas; this suggests that the regeneration of the floodplain grasslands may also be hampered by grazing and trampling.

Biomass production

The replacement of the perennial herbaceous cover by annual grasses resulted in a sharp decline in biomass production, especially on the vetiveria grassland (Table 6). The quality of fodder also decreased, since the dry-season regrowth of perennials was substituted with dry straw from annuals.

Table 6. *Biomass production on vetiveria and eragrostis grasslands, Niger floodplain, central Mali, 1980–82, 1984 and 1986.*

	Biomass (kg DM ha^{-1})				
	1980	1981	1982	1984	1986
Vetiveria grassland					
Vetiveria nigritiana	6000	7741	1405	126	0
Annuals	n.a.[1]	n.a.	135	299	250
Total	6000	7741	1540	425	250
Eragrostis grassland					
Eragrostis barteri	n.a.	5735	4855	0	4
Oriza longistaminata	n.a.	358	198	99	194
Annuals	n.a.	n.a.	n.a.	2365	714
Total	n.a.	6093	5053	2464	908

[1]n.a. = not available.

Dry-matter production on the eragrostis grassland declined from 6000 kg ha^{-1} in 1981 to 900 kg ha^{-1} in 1986, an 85% reduction in standing biomass. Whereas in 1981 the grassland supported 0.8 tropical livestock units (TLU) per hectare for 8 months, its present carrying capacity is only 0.1 TLU ha^{-1}. The carrying capacity of the vetiveria grassland appears to be even lower, as its biomass production declined by 95% over the 1981/86 period.

The 1983/84 drought also had an impact on grazing and cultivation pressures in the floodplain. ILCA's surveys of the livestock population in central Mali in 1981 and 1983 showed that livestock herds increased while grazing resources steadily declined, thus increasing the pressure on the floodplain pastures.

The gradually increasing, successive deficits in flood waters compelled rice-growing farmers to move to the lowest-lying land in the inundation zone, especially the *bourgoutières* (pastures on deeply submerged plains). Their cropping activities in the inner floodplain encroached on the areas traditionally reserved for livestock production, and relationships between farmers and stock breeders have deteriorated.

CONCLUSION

Inadequate rainfall during 1980–86, coupled with frequent flood deficits, considerably changed the plant composition and biomass production on vetiveria and eragrostis grasslands in the Niger floodplain of central Mali. Thousands of hectares formerly under perennial cover were rendered unproductive by unpalatable annual grass species, *Leptadenia hastata* bushes and termite mounds. The stocking capacity of the grasslands decreased drastically as a result of the diminished grazing resources. A suitable programme is urgently needed to regenerate the grasslands on which local livestock production depends.

Unfavourable climatic conditions contributed to increased pressure on land in the inundation zone for cropping; intensified cultivation is an additional factor affecting livestock production in the zone.

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Review of sheep mortality in the Ethiopian highlands, 1982–86

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SUMMARY

THE FREQUENCY *and causes of 1025 deaths observed during 1982–86 in sheep flocks around Debre Berhan, Ethiopia, were analysed retrospectively. Fascioliasis (44.7%) and perinatal losses (18.1%) were the major causes of mortality. Fascioliasis was common during the dry season, and became a major problem during July 1985–June 1986. Perinatal mortality occurred throughout the year, with a peak in the dry season. Five percent of the annual deaths were caused by coenuriasis*

INTRODUCTION

In 1985, the mortality rate in sheep around ILCA's research station in Debre Berhan (2870 m altitude) was 40% (343 deaths; end-of-year population 855). There is evidence that 148 of these animals died after infestation with liver flukes, but there was no direct evidence of the cause of death in most other cases.

Various studies of sheep flock performance provide information on the incidence of lamb mortality in different countries and different farming circumstances, and at different times between birth and weaning. Many authors (e.g. Wiener et al, 1983; Upton, 1985; Wilson et al, 1985) describe the effects of the number of lambs born, parity, management, nutrition and other environmental variables on mortality rate, but only a few (Dennis, 1970,1974; Otesile et al, 1982; Eales et al, 1983) give information on the actual causes of death.

Stamp (1967) suggested that 12–15% of lambs born die during the first week of life, and that perinatal mortality is one of the major factors limiting sheep production. Wiener et al (1983) found that both infectious and non-infectious causes contribute significantly to the 26% of lamb mortality recorded in a grazing flock in the Scottish uplands. The relative importance of these factors changed with the age of the lamb: while disease was the primary cause of death in lambs younger than 6 weeks, it was only a contributory factor in other disabilities causing a large proportion of deaths in lambs older than 6 weeks. Infectious agents also appeared to be the cause of about 5% of deaths occurring in 0–4 month-old lambs in a hill flock in New Zealand (Dalton et all, 1980); the causes of the other deaths in that flock were undiagnosed.

Otesile et al (1983), who studied sheep mortality in the humid zone of Nigeria, reported that 55% of deaths occurred in sheep under 1 year. The most common pathological conditions were pneumonia (23.2%), haemonchosis (16.3%), *peste de petits ruminants* (12.2%), and enterotoxemia (11.3%). In Mali, most sheep mortalities were perinatal (18.5%), occurring on the first day of life (Wilson et al, 1985).

Information on the specific causes of sheep mortality is scarce in Africa. This is because while deaths are easily recognised, their causes are difficult to determine. Reid and Armour (1978) attempted an economic appraisal of the effects of helminth parasites by studying losses due to reduced body growth and condition, liver condemnation, poor grades at slaughter, and mortality. They concluded that a study of deaths alone is likely to underestimate the effects of parasitism on animal productivity.

This paper reports on the most frequent causes of sheep mortality around Debre Berhan, Ethiopia, during 1982–86.

METHODS

Sheep in six flocks, each herded by a shepherd, were monitored daily for signs of ill health. Animals found sick were treated; those that succumbed to illness were necropsied, and the causes of their deaths diagnosed at ILCA's Animal Health and Reproduction Laboratory. In addition, farm records for the period 1982–86 were examined to establish:

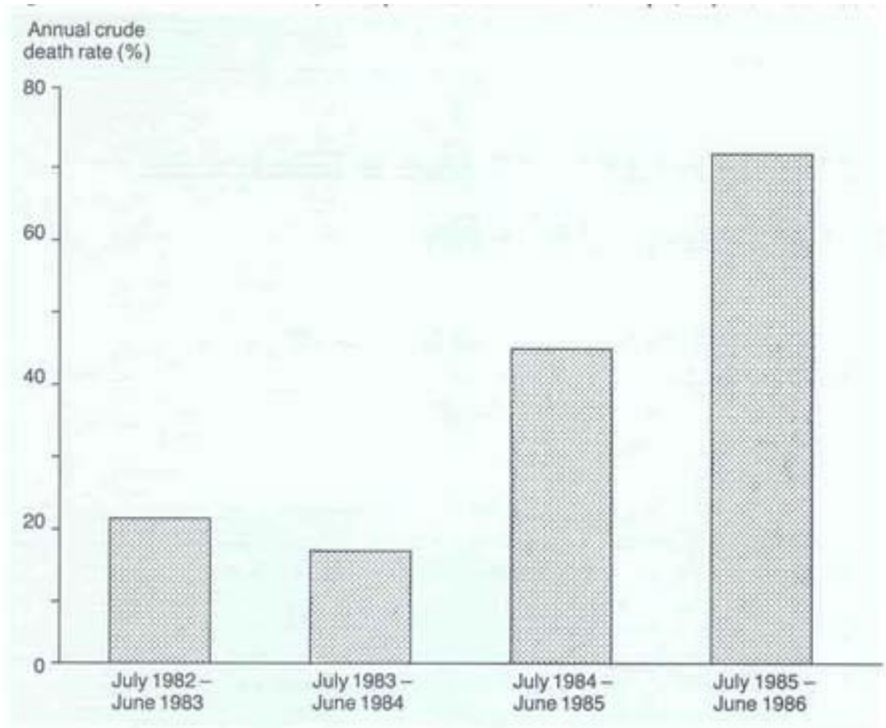
- the total number of sheep in the flocks;
- the year and month of disease;
- the numbers of live and dead sheep in each month during the study period; and
- the ages of the dead animals.

These data were used to calculate annual and seasonal crude death rates. The annual crude death rate was calculated by dividing total annual deaths by the average flock population at the start, middle and end of the year. The seasonal crude death rate was calculated by dividing the total number of sheep that died during a season by the average flock population for that season.

RESULTS

A total of 1025 sheep died in the Debre Berhan area between July 1982 and June 1986. The annual crude death rates for the June–July periods 1982/83, 1983/84, 1984/ 85 and 1985/86 were 20.8, 16.0, 43.0 and 72.2% respectively (Figure 1).

Figure 1. *Annual crude death rates for sheep around Debre Berhan, Ethiopia, July 1982–June 1986.*



Fascioliasis, a trematode infection, caused death in 468 sheep averaging 17.8 months (45.7% mortality rate), while perinatal losses accounted for 186 (18.1%) deaths (Table 1). Perinatal losses were associated primarily with first-lambing ewes. Starvation killed 142 lambs averaging 1.1 months (13.8% mortality). *Coenurus cerebralis* was associated with 51 (5%) deaths and unidentified causes with 118 (11.5%) deaths.

Table 1. *Causes of sheep mortality, their frequency and age of animals at death, Debre Berhan, Ethiopia, July 1982–June 1986.*

Cause	Frequency		Age (months) at death	
	Number of dead animals	Percent of total	Mean	Range
Fascioliasis	468	45.7	17.8	6.9–50.0
Perinatal losses[1]	186	18.1	0.05	< 0.03–0.10
Mismothering/starvation[2]	142	13.8	1.1	0.1–7
Unknown	118	11.5	15.7	0.03–23.0
Coenuriasis	51	5.0	13.3	7.0–24.0

Pneumonia	19	1.9	6.7	1.0–31.5
Diarrhoea	19	1.9	2.8	0.3 – 8.7
Accidents	9	0.8	3.5	0.03– 7.2
Bloat	3	0.3	n.a.[3]	
Congenital defects	3	0.3	n.a.	
Lungworms	3	0.3	n.a.	
Gastro-intestinal parasites	1	0.1	n.a.	
Swayback	1	0.1	n.a.	
Predation	1	0.1	n. a.	
Dystocia	1	0.1	n.a.	
Total	1025	100.0		

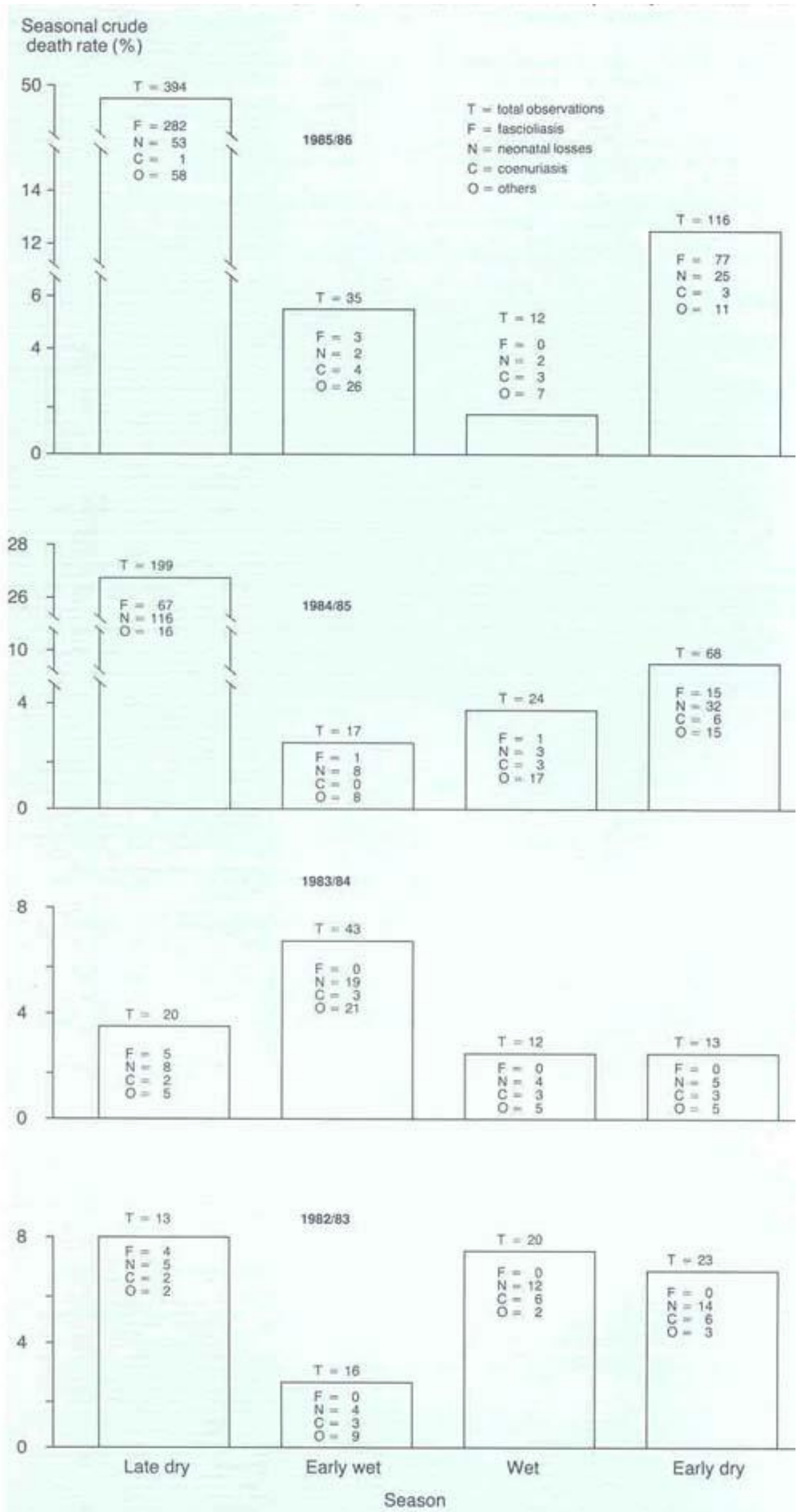
[1] Include stillbirths, abortions and deaths in lambs within 3 days of birth.
[2] Comprises weak lambs at birth, poor mothering and milking ability of the dam, and sick dam.

[3] n.a. = not available.

Sheep that died of coenuriasis had a mean age of 13.3 months. The majority of the sheep that died of unidentified causes had been purchased from farmers and could not be accurately aged, but 21 had a mean age of 4.1 months at death. Ten rare causes of mortality (less than 2%) were identified, including pneumonia, diarrhoea, bloat, dystocia, predation, accidents (due often to molasses toxicity), congenital defects, lungworms, gastro-intestinal parasites, and swayback.

The seasonal crude death rates (Figure 2) were highest in most years during the dry season. Most sheep died during the 1984/ 85 and 1985/86 dry seasons, mainly of fascioliasis. This parasitic disease was diagnosed in 282 (71.5%) and 77 (66.4%) sheep that died in the late and early dry seasons of 1985/86 respectively. Perinatal losses ranked second during this period, while in the previous 3 years they were more serious than fascioliasis. Losses ascribed to coenuriasis were low and, like those of neonates, occurred throughout the year.

Figure 2. *Seasonal crude death rates for sheep around Debre Berhan, Ethiopia. July 1982–June 1986.*



DISCUSSION

Fascioliasis was the primary cause of sheep mortality in Debre Berhan during 1982-86, with the most severe effects from July 1985 to June 1986 (Figure 1). The deaths occurred mainly during the late dry season, following fascioliasis transmission during the wet and early dry seasons. Previous studies in the Debre Berhan area found that fascioliasis transmission was high towards the end of the wet season, resulting in fatalities 8–14 weeks later in the dry season (Scott and Goll, 1977; Jacinta, 1983).

Our data are consistent with data from Nigeria (Ogunrinade and Ogunrinade, 1980; Schillhorn Van Veen, 1979; Schillhorn Van Veen et al, 1980) and suggest that high transmission of fascioliasis in the early dry season, when both feed and animal health are poor, can cause severe mortalities in sheep during the following 34 months.

Severe chronic fascioliasis, which is common in livestock in Africa (Ogunrinade and Ogunrinade, 1980), is aggravated by the poor nutritional status of the hosts (Graber, 1971; Babalola, 1976). Fascioliasis predisposes hosts to other infections, particularly pulpy kidney disease (caused by *Clostridium* spp) and salmonellosis (*Salmonellas* pp Ogunrinade, 1978).

Susceptibility to salmonellosis increases 13 weeks after hosts have contracted fluke infection, i.e. when adult flukes arrive in the bile ducts. This observation is consistent with Jacinta's (1983) observation that sheep mortality in the Ethiopian highlands increases between the eighth and fourteenth week of the dry season. It is therefore possible that the high mortality rate found in this study was due to liver fluke infections acting synergistically with other concurrent infections and poor host nutrition.

Neonatal losses (18.1%) ranked second as the cause of sheep mortality in Debre Berhan during 1982–86. Most of the neonatal deaths occurred in the offsprings of first-lambing ewes within 3 days of birth (perinatal mortality), while 13.8% of deaths occurred in lambs between 4 days and 2 months old (postnatal mortality). The perinatal mortality rate recorded in this study approximates the 22% reported for early lamb mortality in Australia by Dalton (1979). Eales et al (1983) and Haughey (1983).

Neonatal mortality occurred throughout the year with peaks during the late and early dry seasons. Lambs born during the dry season were more likely to die than those born at other times of the year (Wilson et al, 1985). Although neonatal losses appeared to be associated with lamb weakness at birth or poor mothering and milking abilities of the dam, their exact causes are frequently unknown (Dalton, 1979). In Australia about 65% of perinatal lamb losses were caused by the so-called starvation-mismothering-exposure (SME) complex (Haughey. 1983), a syndrome comprising birth injuries. cold-induced starvation, abnormal behaviour of newborn lambs. inadequate milk supply and udder and teat abnormalities.

CONCLUSION

ILCA's study of sheep mortality around Debre Berhan during 1982–86 confirmed that fascioliasis and neonatal lamb losses are serious problems in the Ethiopian highlands. Lung-worms, diarrhoea, gastro-intestinal parasites, coenuriasis and swayback were also encountered, causing relatively low lamb losses (<5%). While most of these rare causes of lamb mortality can be circumvented, swayback should be thoroughly investigated because it may be a flock problem. Intensive surveillance at the flock level and accurate diagnosis of the specific causes of deaths are needed if sheep mortality in the area is to be controlled effectively.

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Field and laboratory studies of causes of sheep mortality in the Ethiopian highlands, 1986/87

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SUMMARY

THE SPECIFIC *causes of 99 deaths in sheep in Debre Berhan, Ethiopia, during 1986/87 were investigated. The highest mortality (43.4%) occurred in lambs younger than 1 month, and particularly within 3 days of birth. Neonatal losses were highest in the wet and late dry seasons, and were associated with the starvation-mismothering-exposure (SME) complex, dystocia and abomasal impaction. Coenuriasis was a prominent cause of mortality in adult sheep, occurring throughout the year. Both neonatal mortality and coenuriasis were major constraints to overall sheep productivity in the area.*

INTRODUCTION

One thousand and twenty-five sheep died around ILCA's research station in Debre Berhan during 1982–86, representing an average annual loss of 256 animals, or 21.3 monthly (pp. 19–22 of this*Bulletin* issue). Fascioliasis, neonatal mortality and cerebral coenuriasis caused most of these losses. There was direct evidence that sheep died of fascioliasis and coenuriasis, but no conclusive evidence was found for the causes of the other deaths.

Intensive surveillance of sheep flocks in Australia showed that neonatal lamb losses are the major constraint to the country's sheep industry. These losses were associated with genetic factors, severe deficiency of specific nutrients during pregnancy and after birth, predators, infections (both congenital and acquired after birth), aberrant maternal and neonatal behaviour, and injury to the central nervous system of the foetus at birth (Haughey, 1983).

The survival of young lambs is essential to the success of sheep farming (Upton, 1985). Lack of data on the specific causes of many neonatal losses in Africa (Trail and Sacker, 1966; Wilson et al, 1985) impedes the prevention of neonatal mortality. Clinical, postmortem and laboratory examinations were used to identify the causes of sheep mortality in the Debre Berhan area between July 1986 and June 1987; this paper reports on the major specific causes found.

METHODS

The causes of sheep mortality in Debre Berhan during 1986/87 were investigated in six flocks with an average population of 726 sheep. The sheep were counted on the first day of each month and categorised according to age into three groups: <3 months old, 3–6 months old, and >6 months old. Deaths in the population and the ages of the dead sheep were also recorded.

Dead sheep were examined within 24 hours post mortem. Sections of the lung, heart and liver were preserved in ice and submitted to the Veterinary Diagnostic Laboratory in Addis Ababa, Ethiopia, for bacterial isolation. Abortions and stillbirths were examined using the placenta and a sample of the contents of the foetal stomach. Routine histopathological investigation of such losses was carried out on tissues and portions of the afterbirth fixed in 10% buffered formalin. Aborting ewes were bled, and the plasma and/or serum were separated and screened for brucellosis at ILCA's laboratory.

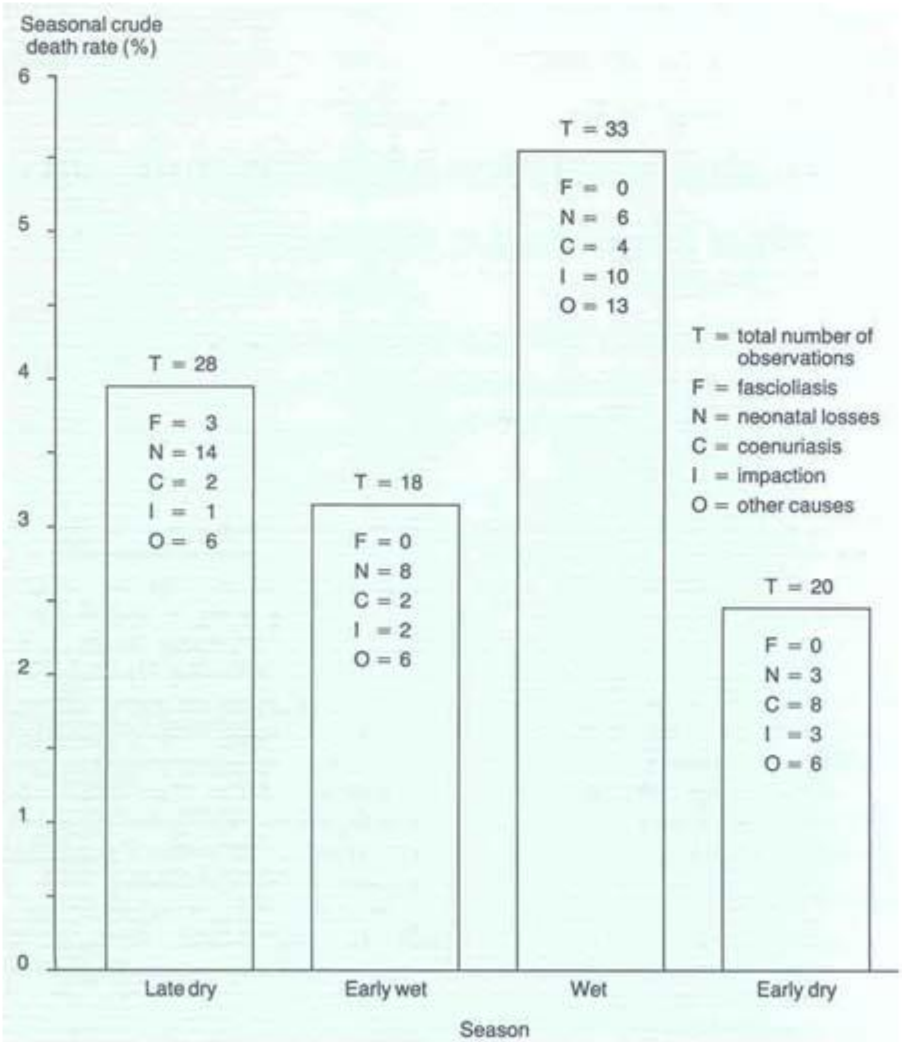
The deaths of neonates were distinguished as described by Eales et al (1983) and Haughey (1983): deaths within 3 days of birth were defined as perinatal while those after 3 days were defined as postnatal. Anteparturient death was indicated by the autolysis of organs and by blood-stained fluid in the serous cavities. Liver haemorrhages (including rupture), haemorrhagic meninges and partial lung expansion were used as criteria for parturient death. Postnatal death was indicated by full lung expansion, swellings on the foetal head (particularly the eyelids and mouth parts) or swollen limbs, shrivelled umbilical cord, and food in the stomach.

The annual and seasonal crude death rates for the period July 1986/June 1987 were calculated as described on p.19 of this *Bulletin* issue.

RESULTS

The 99 sheep mortalities recorded between July 1986 and June 1987 represented an annual crude death rate of 13.6%. The seasonal crude death rates were highest in the wet (5.4%) and late dry seasons (3.8%) (Figure 1).

Figure 1. *Seasonal crude death rates for sheep around Debre Berhan, Ethiopia, July 1986–June 1987.*



One third (33.3%) of the total deaths occurred in newborn lambs within 3 days of life (Table 1). Eight of these lambs had a low birth weight (<1 kg) and failed to suckle, seven had coarse plant and/or animal material in the abomasum, and five had ruptured and haemorrhagic livers. The remaining losses included three abortions, four stillbirths, three deaths resulting from profuse diarrhoea, one starvation due to mastitis, one mortality indicated by meningeal haemorrhages and one by swollen eyelids and mouth parts.

Table 1. *Causes of sheep mortality, their frequency and age of animals at death, Debre Berhan, Ethiopia, July1986–June 1987.*

Cause	Frequency		A ge (months) at death	
	Number of deaths attributed to the cause	Percent of total	Average	Range
Perinatal losses	33	33.3	0.06	0.03–0.1
Coenuriasis	16	16.2	13.4	8.0–19.7
Abomasal impaction	9	9.1	1.0	0.3– 2.4
Pneumonia	7	7.1	15.8	0.3–45.2
Accidents	6	6.1	5.2	4.4– 7.2
Bloat	6	6.1	16.9	5.0–41.0
Gastro-intestinal parasites	6	6 1	5.2	0.8–14.6
Pulpy kidney disease	4	4.0	4.4	1.8-–1.3
Fascioliasis	3	3.0	17.2	6.0–32.5
Unknown	2	2.0	21.5	7.0–36.0
Swayback	2	2.0	5.9	0.6–11.3
Lactic acidosis	2	2.0	4.9	4.7–5.1
Congenital defect	1	1.0	0.5[a]	n.a.[b]
Diarrhoea (salmonellosis)	1	1.0	>50[a]	n. a.
Starvation	1	1.0	0.8[a]	n. a.
Total	99	100.0	n.a.	n. a.

[a] Individual ages. [b] n.a. = not applicable.

Nine lambs (average age 0.98 months) died shortly after developing anorexia. The postmortem examination revealed that they had indigestible plant tissues and/ or hair impacted in the abomasum. These foreign materials were either free or mixed with putrefying milk curds which were sometimes firm and rubber-like and had black spots.

Coenuriasis was diagnosed in 16 (16.2%) of the 99 dead sheep; the disease was a problem in all seasons. Pneumonia accounted for 7.1% of the deaths, while bloat, gastro-intestinal parasites and accidents were each associated with 6.1 % . Accidental death occurred in three lambs dosed with valbazine tablets and in two fed molasses; the sixth lamb was strangulated in a fence. Pulpy kidney disease (enterotoxemia) and fascioliasis caused 4.0 and 3.0% of the deaths respectively.

Swayback, lactic acidosis, a congenital defect, diarrhoea, starvation and unknown causes were each associated with < 2% of the total deaths. One lamb had been born with a cleft palate (congenital defect) and died of milk-inhalation pneumonia 2 weeks after birth. Swayback was noticed in two lambs which died 3 months after birth.

One of the lambs afflicted with swayback had large sections of the spinal cord abnormally soft (malacia), and its meninges were infiltrated with lymphocytes. The meninges contained sequestrated pinkish material enclosed by reactive astrocytes and giant cells, and the surrounding nervous tissues were atrophic. The lateral ventricles of the cerebrum were similarly infiltrated with lymphocytes and reactive astrocytes. These lesions were found also in the other lamb that succumbed to swayback, but were less severe. The copper concentration in the lambs' liver was 66.5 and 64.9 μg g^{-1} respectively.

Pasteurella multocida was isolated from the lungs of four of the six sheep whose infected lungs were examined bacteriologically. A histological examination of the lungs showed that their alveoli were filled with neutrophils and a few oat-streaming macrophages, while the interalveolar spaces were dilated with abundant fibrinous exudate. The lung of the seventh sheep suspected of succumbing to pneumonia had an adenomatous proliferation on the alveoli linings, which is suggestive of chronic progressive pneumonia.

The lambs that died either peri- or post-natally had histologically normal lungs, spleen, livers and abomasal and intestinal walls. However, some had a few lymphocytes and neutrophils in the abomasal submucosa and the bronchi. Gram-negative coccobacilli were cultured from the abomasal contents of two aborted foeti, but no bacteria were isolated from a third foetus lost through abortion.

Some lambs had gram-positive bacteria (rods) in the intestinal contents, and their kidneys underwent rapid autolysis. Both symptoms are suggestive of enterotoxemia type D.

The most common gastro-intestinal parasites found were *Ostertagia spp, Trichostrongy1us colubriformis, Haemonchus contortus, Trichuris ovis* and tapeworm *(Moniezta* spp). One lamb which developed diarrhoea, alopecia and a potbelly, and finally died, had *Moniezia expansa* blocking the intestine.

DISCUSSION

During the 1986/87 study period, the average monthly sheep mortality around Debre Berhan was 8.3. Mortality was highest during the wet (July–September) and late dry (January–March) seasons, particularly in lambs up to 1 month of age (Figure 1).

Perinatal mortality was the primary problem at the station; its relative frequency (33%) was comparable to that (22%) reported for sheep in Australia by Dalton (1979) and Haughey (1983). Trail and Sacker (1966) reported lower perinatal losses: 0.0–2.9% for indigenous sheep and 4.0–11.8% for crossbred East African Blackhead ewes. The highest rate, 11.8%, was observed in single lambs from crossbred gimmers.

Both peri- and post-natal lamb losses occurred year round, with a peak during the late dry season. The primary causes of neonatal mortality were dystocia, anorexia caused by abomasal impaction with phytobezoar and/or trichobezoar, and diarrhoea.

These causes collectively constitute the starvation-mismothering-exposure (SME) complex which is responsible for about 65% of perinatal lamb losses in Australia (Haughey, 1983). Other factors included in the SME complex are cold-induced starvation, abnormal behaviour of newborn lambs, inadequate milk supply and udder and teat abnormalities, all of which caused variable lamb losses in this study.

The offspring of gimmers that suffered from dystocia at lambing had ruptured or patechiated livers (indicated by abdominal haemorrhages), and haemorrhagic lesions in the meninges, ureter(s) and the urinary bladder. According to Dalton (1979), dystocia is the main cause of perinatal mortality in lambs born as singles.

Haughey (1983) reported that foetopelvic disproportion resulting from small maternal pelvis or foetal oversize, or both, is the main cause of injury at birth and subsequent death. This is indirectly supported by Trail and Sacker (1966) who found highest mortality (11.8%) among singles from crossbred East African Blackhead gimmers.

Osuagwuh et al (1980) reported that 5.7% of the dystocia-associated lamb losses observed in their study occurred in outbred West African Dwarf sheep. The losses were attributed to the effects of the breeding sire and poor ewe nutrition during pregnancy. The first may have been a significant factor in our study, as mature rams were used for breeding while the age of gimmers at mating was not controlled. It is possible that the direct relationship that exists between birthweight (the key factor for lamb survival) and dystocia might favour increased lamb survival if the age at mating were controlled (Dalton, 1979).

The frequent association between anorexia and abomasal impaction with phytobezoar or trichobezoar would indicate early exposure of the neonates to pathogenic agents; good hygiene in lambing pens is necessary to avoid this peril.

In very young lambs, the foreign indigestible materials were either mixed among decomposing (black) milk curd, or they were present alone. Similar impactions were found in the stomach of older lambs (aged 1 month on average, Table 1). In these lambs, the indigestible materials were impacted in round, rubber-like coagulated milk curd of 2–5 cm in diameter. Coagulated milk has been found to block the pylorus, thereby causing abomasal impaction and sudden high mortality in neonatal and young buffaloes in Vietnam (Hall, 1962; Sharma et al, 1983). Sharma et al (1983) reported that high calf losses occurred especially in the hot–dry (26.3%) and hot-humid (78.7%) seasons.

The black spots in the milk curd containing indigestible matter are indicative of bacterial rather than host-enzyme fermentation. In neonatal lambs, milk is delivered to the abomasum via the oesophageal groove which bypasses the rumen, thus avoiding bacterial fermentation (Church, 1984). However, since the abomasum of neonates is more developed than their forestomach, it is more accessible to dirty foreign bodies. Neonatal losses could be significantly reduced by maintaining neonates on good-quality pasture, thereby minimising the danger of such bodies being ingested.

The failure to isolate microbial agents in lambs that died suddenly ruled out parasitic causes, as did histopathological examinations. It would thus appear that neonatal mortality in the study flocks was mainly due to complications caused by factors of the SME complex. The absence of inflammatory changes in tissues eliminated infections as a major cause of neonatal mortality, but it may also reflect certain unresponsiveness of the immature immune system to foreign antigens.

Fascioliasis was a minor cause of sheep mortality during 1986/87, accounting for 3% of all deaths. Immature liver flukes (1.8–7 mm long) were recovered from three sheep that died in January 1987; some of the flukes protruded from ruptures in the liver capsule, while a few others were in the peritoneal cavity, the lung, the kidney and the pancreas. Their number in the hosts varied from 9 to 17. Schillhorn Van Veen (1979), Schillhorn Van Veen et al (1980) and Jacinta (1983) found more than 100 flukes in similarly ruptured livers, and Reinecke (1983) reported that as few as 60 flukes can seriously damage the liver capsule and cause acute death. According to Hanna (1976), the presence of flukes of the size found in this study indicates a 4–6 week-old infection. Reinecke (1983) reported that acute fascioliasis occurs in sheep within 4–6 weeks of ingesting infective flukes.

The decreased significance of fascioliasis as a cause of sheep mortality in Debre Berhan in 1986/87 is probably due to the rigorous fluke control measures introduced in March 1986. These involved preventive treatment every 3 months, adjusting the stocking rate, and confining animals during the rainy season when fluke incidence is high. Hosie (1985) reported that during the rainy season, sheep rarely frequent potential snail habitats in the bottomlands, because sufficient feed and water are available elsewhere. Confining animals in this season may not therefore be necessary to control fascioliasis.

CONCLUSION

This study proved that neonatal lamb losses and coenuriasis are serious problems in the sheep flocks around Debre Berhan. While enough is known to control coenuriasis (Karim, 1979; Skerritt and Stallbaumer, 1984), this is not true for neonatal mortality (Trail and Sacker, 1966; Eales et al, 1983). Hence neonatal lamb losses will continue to pose problems for sheep husbandry. Accidents, gastro-intestinal parasitism, dystocia, predation, congenital defects, swayback, pneumonia, bloat, enterotoxemia and lactic acidosis occurred rarely and caused minor losses.

Trail and Sacker (1966), Eales et al (1983) and Haughey (1983) reported that 21.0-38.5% of neonatal losses occur between birth and weaning at 6 months of age. Losses of this magnitude negate efforts to increase ovulation rate and conception (Dalton, 1979), as well as gains obtainable through selection. Veterinary care of neonates is therefore indispensable for profitable sheep farming (Eales et al, 1983; Haughey, 1983).

To reduce lamb losses, special attention must also be given to the nutrition of ewes before the onset of heat, the management of lambing ewes, the diagnosis and treatment of hypothermia, and the management of 2–7 day-old lambs. In addition, prompt diagnosis and treatment of perinatal conditions are imperative.

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Improving millet/cowpea intercropping in the semi-arid zone of Mali

* The original French paper '*Possibilites d'amelioration de 1'association culturale mil-niébé en zones semi-arides au Mali' is* an updated version of a paper published in Haque et al (1986).

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SUMMARY

THE MILLET/COWPEA *intercropping system used in the semi-arid zone of Mali is on the decline. ILCA's studies of the system during 1981-85 showed that grain and biomass yields can be improved by manipulating the planting date, pattern, and density of the crops and by rotating sole millet with millet/cowpea intercrops.*

Sowing millet and cowpea in separate holes on a ridge or on alternate ridges decreased millet grain yields less than when both crops were planted in the same hole. The optimum proportion of cowpea in the mixture was 15% without fertilizer and 45% when rock phosphate was applied. Rotating millet/cowpea intercrops with sole millet increased the grain yield of sole millet by 30%. Delayed sowing of the legume reduced interspecies competition, resulting in good grain and biomass yields. Cowpea proved to be more competitive than millet under dry conditions, while millet benefitted from intercropping in higher-rainfall areas.

INTRODUCTION

Millet *(Pennisetum americanum)* is intercropped with cowpea *(Vigna unguiculata)* on about 60% of the plots cultivated in semi-arid Mali (Diallo et al, 1985). Millet provides 70–90% of the food energy of the human population, and in some cases as much as 95% (Martin, 1985). Cowpea grain, which contains 20–25% protein, is valued as human food (Pugliese, 1984), and its haulms (14–30% net protein) are grazed by cattle during the dry season (Göh1, 1981; Skerman, 1982).

Because of unfavourable climatic conditions, shorter fallowing and declining soil fertility (Cissé and Hiernaux, 1984), millet grain production has stagnated at about 500 kg ha $^{-1}$ in recent years (Mali, 1984). Cowpea yields are also low, as its proportion in the mixture is only about 10% at planting and about half that at harvest when rainfall is poor.

The millet/cowpea intercropping system can contribute significantly to food and feed production, and to soil fertility on which this production depends. ILCA studied the traditional system at its research sites in Niono (200 mm average annual rainfall) and Banamba (700 mm annual rainfall) during 1981–85 to determine the possibilities for its improvement. This paper describes the effect of different planting patterns and densities on grain and biomass yields. The merits of rotating intercrops with monocrops and of delaying the planting of the legume are also discussed.

ENVIRONMENTAL CONSTRAINTS

Rainfall and soil moisture

Throughout the study period, annual rainfall recorded in Niono and Banamba was less than the long-term means for the two sites to 1980 (Table 1). Poor rainfall seriously affected plant growth and biomass yields in 1983 and 1984.

Table 1. *Useful, total annual, and long-term mean rainfall for Niono and Banamba, central Mali,* 1981–85.

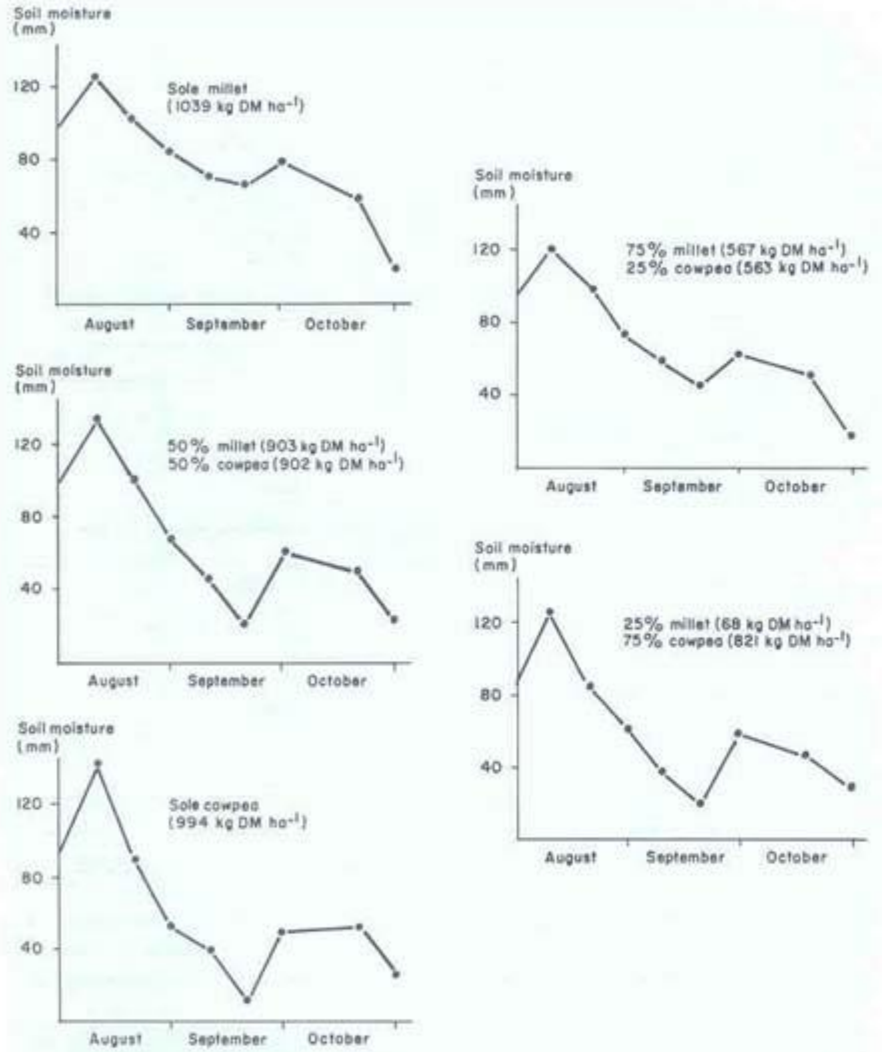
Year	Rainfall in Niono		Rainfall in Banamba	
	Useful[1] (mm)	Total (mm)	Useful (mm)	Total (mm)
1981	n.a.[2]	411	n.a.	555
1982	n.a.	478	n.a	494
1983	196	250	n.a.	388
1984	220	335	406	445
1985	n.a.	350	720	730
Long-term mean	483	573[3]	n.a.	767[4]

[1] Useful rainfall is rain which falls during the growing season.
[2] n.a. = not available.
[3] Calculated over 35 years to 1980.
[4] Calculated over 49 years to 1980.
Sources: Sivakumar et al (1984); Hulet and Gosseye (1986); Hulet (1986).

Soil with plant cover can retain 130–184 mm of moisture per m^2, but the useful rainfall at Niono provides between 100 and 159 mm at pF 4.2 (P.Gosseye, Sahel Programme, ILCA, Bamako, Mali). To determine the availability of moisture under different crop associations at the site, samples were taken in 1984 from a 1-m deep soil profile and analysed using a gravimetric method.

Figure 1 shows the soil moisture profiles under three millet/cowpea intercrops and sole millet and cowpea crops. The profiles varied according to crop and planting ratio: more soil moisture was available under millet (sole or at 75% of the mixture) than under the other cropping systems, but biomass production did not increase. The fact that millet uses soil moisture more efficiently than other crops was confirmed by Natarajan and Willey (1986) who found that sole or intercropped millet is more resistant to water stress than sorghum or groundnut.

Figure 1. *Soil moisture profiles and total biomass yields for three millet/cowpea mixtures and sole millet and cowpea, Niono, central Mali, 1984.*



Soil fertility

Most tropical soils are deficient in essential nutrients, particularly phosphorus (P) and nitrogen (N) (Boyer, 1970; Jones and Wild, 1975). The loamy sand soil in Niono contains <60 mg P kg^{-1}, 0.1–0.3% of carbon (C), and 0.01–0.02% of N, with a C:N ratio ranging from 5:1 to 30:1 depending on the depth of the soil (Hulet and Gosseye, l986).

Intensive cultivation of sole millet on so fragile soils would deplete essential nutrients. The adverse effects of the system on soil fertility can be counteracted by inter-cropping with a legume that can fix substantial amounts of atmospheric N (Agboola, 1975). Cowpea, which was reported to fix N at rates varying from 8 kg ha^{-1} $year^{-1}$ (IRRI, 1974), to 84 kg ha^{-1} $year^{-1}$ (Johnson, 1970, quoted by Skerman, 1982), to as much as 240 kg ha^{-1} $year^{-1}$ (Nutman,1971, quoted by Rachie and Roberts, 1974), appears to benefit soil fertility.

The effect of different fertilizers on soil fertility and yields was also investigated. Commercial fertilizers are expensive and scarce in Mali, but these can be substituted with *tilemsi*, a rock phosphate found in abundance in the country, or with simple superphosphate. *Tilemsi* is not cost-effective in areas with annual rainfall below 700 mm (Pieri, 1971), but simple superphosphate was found to be effective on various types of crops (Wilson et al, 1983; ICRISAT, 1984; Hulet and Gosseye, 1986).

IMPROVEMENTS

Planting pattern

In the traditional intercropping system, millet and cowpea are sown in the same seed hole (additive pattern). However, the two species can also be sown in alternate holes on the same ridge, or each can be planted separately on alternate ridges.

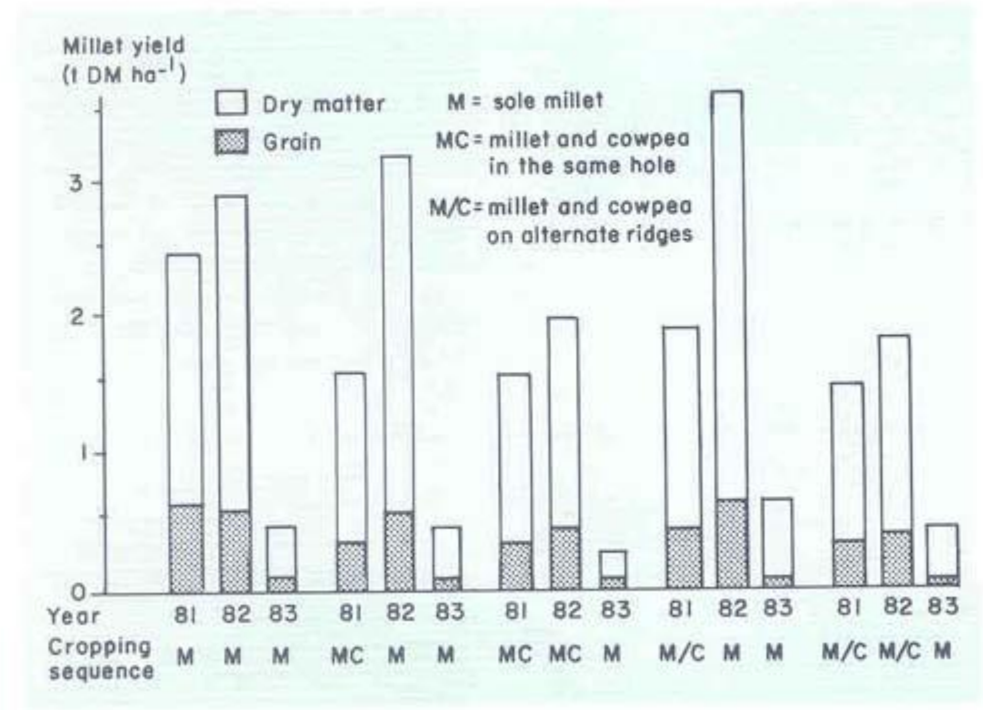
Table 2 shows the species associations and planting patterns tested in Niono during 1981–83 in five cropping sequences. Millet grain yields decreased by 20% when millet and cowpea were sown on alternate ridges, and by 30% when they were sown in the same hole (Figure 2). Since farmers in the semi-arid zone are primarily interested in millet production, the alternate-ridge pattern which resulted in less grain reduction should be promoted.

Table 2. *Species associations and planting patterns tested in five cropping sequences, Niono, central Mali, 1981–83.*

	Species association		
	1981	1982	1983
Cropping sequence			
1	Millet	Millet	millet
2	Millet+cowpea[1]	Millet	millet
3	Millet+cowpea	millet+cowpea	millet
4	millet/cowpea[2]	millet/cowpea	millet
5	millet/cowpea	millet/cowpea	millet

[1] Sown in the same hole
[2] Sown on alternate ridges.

Figure 2. *Grain and dry-matter yields of millet in five cropping sequences, Niono, central Mali, 1981–83.*

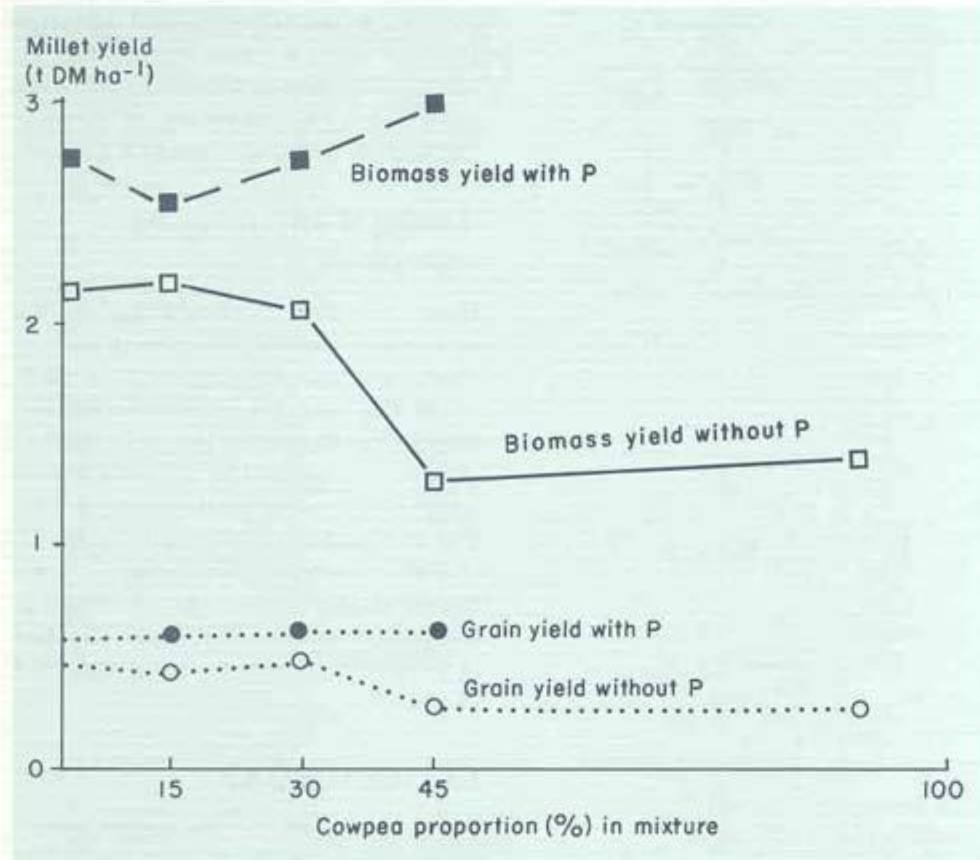


Interspecies competition could also be reduced by planting millet on two ridges and cowpea on the next two (Serafini, 1985). This model was used in Banamba in 1985, and the results of the experiments are discussed below under 'Timing of inter-cropping operations'.

Planting density

When the traditional additive system is used, the proportion of cowpea in the mixture is about 10% at planting and only about 4–5% at harvest. Our trials in Niono during 1981–83 demonstrated that when rock phosphate was applied at planting at the rate of 21 kg P ha $^{-1}$, the proportion of cowpea could be raised to 45% without significantly affecting the biomass and grain yields of millet. Without fertilizer, 15-30% cowpea in the mixture appeared to be acceptable, but when the cowpea proportion exceeded 30% the biomass and grain yields of millet were greatly reduced (Figure 3).

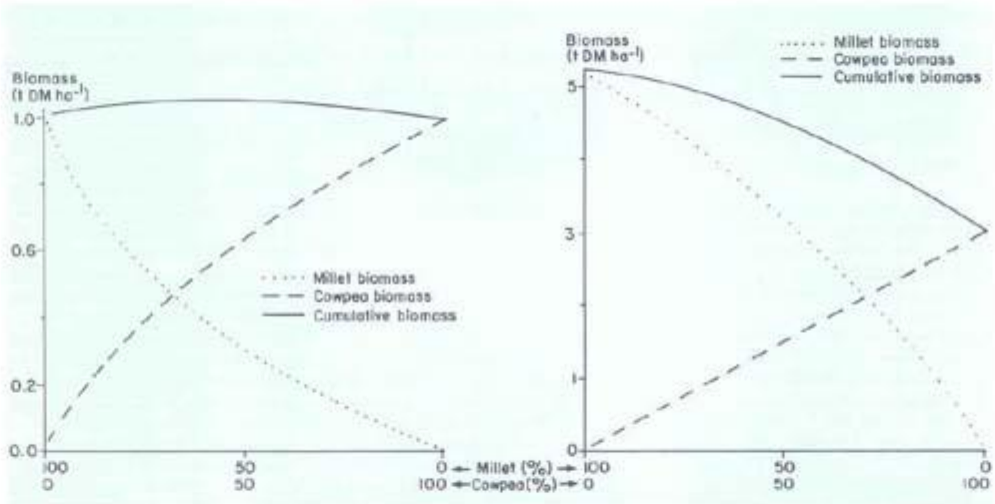
Figure 3. *Effect of cowpea proportion in mixture and P application[1] on grain and biomass yields[2] of millet, Niono, central Mali, 1981–83.*



[1] 21 kg P ha^{-1} applied in 1981.
[2] Yields averaged over the 1981–83 period.

The optimum planting density of intercrops depends also on climatic conditions. Trials in Niono in 1984 (220 mm useful rainfall) showed that at a planting ratio of 50:50, the grain yield of cowpea decreased less than that of millet, indicating that cowpea is more competitive than millet under dry conditions (Figure 4). On the wetter Banamba site (406 mm useful rainfall), cowpea was not affected by the presence of millet, while millet benefitted from intercropping.

Figure 4. *Millet and cowpea biomass and cumulative biomass for different mixtures, Niono and Banamba, central Mali, 1984.*



Crop rotation

Because results were masked by the drought in 1983, the trials failed to establish the extent to which consecutive cropping of sole millet affects soil fertility and yields. Figure 2 indicates that the grain and dry-matter yields of millet during 1981–83 were strongly correlated with rainfall in those years (Table 1). It also shows the beneficial effects of rotating millet/cowpea intercrops with sole millet: the production of sole millet increased by 100% after additive intercropping (sequence 2) and by 97% when sole millet followed intercropping on alternate ridges (sequence 4. Millet production in the third year of the rotation was atypical because of the overriding effect of the low rainfall in 1983.

Timing of intercropping operations

Simultaneous sowing of millet and cowpea has been observed to decrease millet production even when N is applied. The effects of planting date and fertilizer application on grain and dry-matter yields of millet and cowpea intercropped on alternate double ridges were tested in Banamba in 1985 (720 mm useful rainfall). Millet yields increased considerably and cowpea yields were adequate when cowpea planting was delayed by 1 week, and fertilizer was applied at the rates of 15 kg N ha^{-1} and 21 kg P ha^{-1} (Table 3).

Table 3. *Effect of planting date of cowpea and fertilizer application on grain and biomass yields of millet and cowpea intercropped on alternate ridges, Banamba, central Mali, 1985.*

Cowpea Planting (weeks after millet)	Fertilizer application[a]	Millet				Cowpea				Millet/cowpea total biomass (kg DM ha^{-1})
		Grain (kg ha^{-1})	Stalks (kg ha^{-1})	Stubble (kg DM ha^{-1})	Total biomass (kg DM ha^{-1})	Grain (kgha^{-1})	Pods (kg ha^{-1})	Haulm (kg DM ha^{-1})	Total biomass (kg DM ha^{-1})	
0	P_o/N_o	732	289	2079	3100	50	29	1691	1770	4870
0	P_o/N_{15}	686	281	1733	2700	117	59	2077	2253	4953
0	P_{21}/N_o	1115	435	2495	4045	58	33	1991	2082	6127
0	P_{21}/N_{15}	875	351	2400	3626	96	51	2466	2613	6239
1	P_o/N_o	734	276	1586	2594	172	67	1244	1483	4077
1	P_o/N_{15}	1244	401	3048	4693	83	44	1215	1342	6035
1	P_{21}/No	1022	223	2317	3562	140	54	1478	1672	5234
1	P_{21}/N_{15}	1839	628	3557	6023	159	69	1613	1841	7864
F test[b]	n.s.	n. s.	n. s.	n. s.	n. s.	n. s.	n.s.	n. s.	n.s.	n. s.

[a] Subscripts indicate the number of kg of P or N applied per hectare.
[b] n.s. = not significant. The results were not significant because of the high coefficients of variation for millet grain (59 %), millet stubble (54 %), cowpea grain (112 %) and cowpea haulm (42 %).

CONCLUSIONS

The contribution of the millet/cowpea intercropping system to food grain and fodder production in semi-arid Mali can be increased by manipulating the planting date, pattern and density of intercrops and the cropping sequence. The results of this study show that:

- Sowing millet and cowpea in alternate holes within a ridge or on alternate ridges reduced interspecies competition.
- In the traditional additive system, the optimum cowpea:millet ratio was 15:85. Alternate intercropping and a single application of rock phosphate in the first year of cultivation allowed the cowpea proportion in the mixture to be raised to 45% without significantly affecting millet yields. The optimum planting density also varied with climatic conditions: under dry conditions, millet was less competitive than cowpea, while under wetter conditions the cereal benefitted from intercropping.

- Rotating millet/cowpea intercrops with sole millet increased the production of the subsequent millet crop.
- Sowing cowpea 1 week after millet substantially reduced competition between the two species, particularly when moderate amounts of N and P were applied.

To sum up, technical improvements to the traditional intercropping system enable increases in both millet grain production and cowpea yields, particularly in the higher-rainfall areas. This confirms Fisher's observation (1977, quoted in Natarajan and Willey, 1986), but the qualification in terms of climatic conditions is probably more important for intercrops planted at a very high density or those with an increased need for water. Some researchers (e.g. Gregory and Reddy, 1982; Natarajan and Willey, 1986) maintain that because of the complementary utilisation of soil moisture by the root systems of intercrops, the system improves the efficiency of water use under severe water stress.

Serafini (1985) reported that the key issue in intercropping is planting date. Early sowing of millet or cowpea in alternate rows increased yields, particularly of cowpea, as did increasing the proportion of the legume in the mixture to 30%. Intercropping did not reduce millet yields significantly, except under poor rainfall conditions and low soil N. Sowing cowpea later than millet is recommended, but the time lag should not be too long as this might reduce cowpea yields. Moreover, if cowpea is harvested early enough, some N might become available to the cereal through the decomposition of the N-rich nodules of the cowpea.

The introduction of technical innovations into the traditional millet/cowpea intercropping system used in semi-arid Mali can have far-reaching economic and social consequences. Among these labour availability and labour division are factors which need to be thoroughly investigated to ensure that proposed innovations do not disrupt the tenuously maintained balance between the various components of the system.

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Abbreviations

C	carbon
CEPE	Centre d'étude phytosociologique et écologique (France)
cm	centimetre
DM	dry matter
EEC	European Economic Community
FAO	Food and Agriculture Organization of the United Nations (Italy)
GDP	gross domestic product
ha	hectare
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (India)
IMF	International Monetary Fund
IRRI	International Rice Research Institute (Philippines)
kg	kilogram
km	kilometre
m	metre
N	nitrogen
P	phosphorus
pF	logarithmic expression of the water-holding energy of soil
SME	starvation-mismothering-exposure complex
t	tonne
TLU	tropical livestock unit of 250 kg

Authors' style guide

POLICY AND AUDIENCE

The aims of the *ILCA Bulletin* are to present the results of livestock research by scientists at ILCA and at African national institutes, spread the knowledge of results in related disciplines, encourage national scientists to test new research techniques and technological innovations, and stimulate the adaptation to local conditions of applied research carried out by ILCA.

Thus the main audience of the ILCA *Bulletin* is made up by the following groups in sub-Saharan Africa: scientists working in livestock research and related fields, agricultural policy makers, administrators and development workers. The *ILCA Bulletin* is also distributed to scientists working outside Africa and to ILCA's donors.

MANUSCRIPTS

Articles may be submitted in English or French and should be from 3000 to 7000 words. The original, typed double-spaced on one side of the page only, and two photocopies, should be sent to the Director of Training and Information, ILCA, P.O.Box 5689, Addis Ababa, Ethiopia. Papers submitted will be reviewed by two internal referees whose comments will be passed on to authors. If in the referees' opinion a paper is acceptable for publication, the author should send an amended draft to the Editor of the *Bulletin* for editing and publication.

FORMAT AND STYLE

Authors should give their names and initials, titles, programme or department, institute, postal address, and telex number if available. Articles should include a summary and, whenever possible, the following sections: introduction, materials and methods, results and discussion. The findings reported should be discussed in the broader context of livestock and agricultural production in Africa.

Data in figures and tables should be clearly presented and their salient points adequately discussed in text. In the case of figures please send original artwork with the final copy, not photocopies. Sources of figures and tables should be referenced. Abbreviations and symbols used in a figure or table should be explained in footnotes below.

Good-quality black-and-white photographs are acceptable for publication. A full list of references must appear at the end of the paper, and authors may also include acknowledgements, disclaimers and/or a list of less common abbreviations and acronyms.

The International System of Units (SI) should be used to specify the magnitude of physical quantities. SI units are divided into three classes: base (e.g. m, kg, s and mol), derived (e.g. m^2 and m^3), and supplementary units.

The range offered by base units can be expanded by using decimal multiples and sub-multiples described by such prefixes as kilo (10^3), mega (10^6), deci (10^{-1}), milli (10^{-3}), micro (10^{-6}) etc. The choice of the unit will depend on the number of significant figures available: when there are two or more, the numerical component should fall between 1 and 100 (e.g. the mean weight of cereal grain should be reported as 42.6 mg rather than 0.0426 g or 42600 µg), but when only one is available, it should be between 1 and 10 (e.g. yields were between 1 and 2 t ha^{-1}, not between 0.1 and 0.2 kg m^{-2} or between 100 and 200 g m $^{-2}$). Applying this *scale rule will* help eliminate the frequent use of zeros or decimal points. Some SI units and symbols recommended for use in agricultural literature are given in the 'Examples' section.

Articles will be edited to maintain a uniform style; substantial editorial changes will be referred to authors for approval.

EXAMPLES

SI units and symbols

- *Time:* Although the second (s) is the base SI unit for time, it is rarely used in agriculture. The hour (h), day (d)and year should therefore be applied.
- *Area:* m^2 (*appropriate* for studies in crop physiology), km ^{2} (for areas under specific crop), and ha (acceptable to quote the size of a farm or field).
- *Population density:* ha is the conventional reference area for plantation crops and animal stocking densities, but for plant densities m^{-2} is more appropriate. This descriptor conforms to the scale rule since an expression such as to 20 plants m^{-2} is much easier to visualise than, for instance, 100 000 to 200 000 ha^{-1}.
- *Mass or weight:* kg, t (tonne; tolerated in compound units such as US$ 100 t^{-1} product), and mg g^{-1} or g kg^{-1} (weight of dry matter produced by a crop per unit of water).
- *Crop yields:* kg m^{-2} (fresh yields) but g m^{-2} (dry matter yields); t ha^{-1} is convenient when describing agronomic response.
- *Fertilizer application:* kg ha^{-1} and g in^{-1} for experimental plots.
- *Volume*: The base SI unit of m^3 is rarely convenient for agricultural measurement. Thus we will use the litre (1 dm^3) as a more relevant unit, although we will not abbreviate it because of the potential confusion with the numeral 1. Rainfall will be expressed in mm and evaporation rates in mm d^{-1}.
- *Concentration:* mg kg^{-1}, not 'parts per million' (ppm).
- *Force:* 1N (Newton) = 1 kg m s^{-2}.
- *Pressure:* The unit commonly used by crop physiologists and soil scientists for pressure, the bar, can be converted to mega Pascals (MPa), a multiple of the SI unit, the Pascal (Pa), by multiplying by 0.1.
- *Energy:* J (Joule; which replaces the now obsolete erg and calorie), kJ g^{-1} (energy content of animal fodder or human food), MJ d^{-1} (animal energy consumption), and MJ d^{-1} kg^{-n} (in nutritional work).
- *Power:* 1W (watt) = $1Js^{-1}$ (for exchange of thermal energy between plants or animals and their environments).

Note that the product of two units is written by introducing a space between them and that the quotient is indicated by a negative index, thus kg/ha becomes kg ha^{-1} in the SI system.

Treatment of numbers

The numbers one to nine should be written as words, except when used as measurements or units (e.g. 1 kg, 1 month, 1 litre but one cow). All other numbers should be written as numerals:

note that numbers from 1000 to 9999 should be written without a comma or space, while from 10 000 onward a space should be included.

Common expressions and abbreviations

An increase of 6%; milk yield and consumption increased by 5% and 3% respectively; meat offtake decreased by 2 to 3%; 1300 h; 10° C; No.; 1.3 million; 1980/81 cropping season but ... Nigeria, 1980-82 (in table captions); 13 µg Mo; 1 kg N; Figure, *not* Fig.; use Jan, Feb, Mar, Apr, May, June, July, Aug, Sept, Oct, Nov, Dec in tables and figures if space is not sufficient; pp. 12–19, 365 pp. (in references) but 'see page 3' (in text); P = probability ($P<0.05$, $P<0.01$ and $P<0.001$); LSD = least significant difference; SE ± = standard error; d.f. = degree(s) of freedom; MS = mean square; CV = coefficient of variation.

Distinguish between 'East African Shorthorned Zebu' (specific breed) and 'zebu' cattle (humped *Bos indices* cattle); 'Boran' cows but 'Borana' people; 'West African Dwarf goat' (breed) but 'the dwarf goats of West Africa'; N'Dama cattle etc.; sp./spp. = species (sing./pl.); cv(s) = cultivar(s); var = variety.

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General: Do not italicise 'et al'; write 'ed.' for 'editor' and 'eds' for 'editors'; write date of publication without brackets; do not use fullstops after authors' initials; italicise titles of published books or reports; write titles of journals, conferences and their proceedings in full; italicise titles of journals and give the volume, issue and page numbers of articles published in them.

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