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Cattle production in the subhumid zone

Pastoral production in the arid zones of west Africa

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ILCA's research focuses on representative livestock production systems in the highlands, the arid and semi-arid zones, the subhumid zone and the humid forest belt. Estimates of current livestock numbers and annual production in these different ecological zones are given in Table 1, based on data from a wide range of sources recently analysed by ILCA scientists. These figures, indicating the multiple uses of livestock in tropical Africa, have a bearing on ILCA's systems-oriented research strategy. For instance, in the semi-arid, subhumid and highlands zones, where ox-ploughing is used for subsistence farming, animal traction appears substantially more important than is commonly appreciated. And animal traction, transport and manure production are likely to become even more important in future with the rise of fuel and fertilizer prices.

The diverse goals of livestock production in Africa point to a research strategy based on an understanding of entire production systems, rather than focused on one or another livestock commodity. This broadly based approach continues to be a central aspect of ILCA's research programme. By the end of 1980, a wealth of data had been collected and the production systems under study were broadly understood, while ILCA's research methodology, with emphasis on relevance to the needs of farmers and livestock producers, had produced a number of improvement packages which were being introduced through ILCA's field programmes with demonstrable success.

The headquarters complex, begun in 1976, was completed and officially inaugurated by the Ethiopian Head-of-State in October 1980. The complex, on the outskirts of Addis Ababa, consists of offices, laboratories, a documentation centre, conference rooms and a herbarium, together with a hostel and staff accommodation, dining facilities, technical buildings and workshops.

Support for ILCA's research programme was further enhanced in 1980 by the installation of a HP 3000/III computer at headquarters. ILCA's computer will support all research, documentation and administrative activities; during its initial installation phase, it has been used primarily for research data processing.

ILCA's library and documentation centre continued a programme of steady expansion in 1980. By the end of the year, non-conventional documents had been collected on microfiche from government documentation centres, universities, agricultural stations and other institutions in nine African countries, with support from the International Development Research Centre (IDRC). Normal library acquisitions brought the total collection to about 20 000 documents on microfiche, 18 000 books and 450 specialized periodicals. ILCA's cartographic and printing facilities were also developed in 1980, with a major expansion of printing capacity, and laboratory facilities were established for plant, soil and animal feed analysis.

Principal field research sites were operating in 1980 in Debre Zeit and Debre Berhan in the Ethiopian highlands, in the arid and semi-arid zones of central Mali around Niono, in Nigeria's subhumid savanna zone around Kaduna and at Ikenne and Fashola in the humid forest belt near Ibadan. Additional sites were located in the pastoral areas of Kenya, Botswana and Ethiopia, where traditional livestock production systems are under the influence of livestock development projects. As of the end of the year, ILCA's professional staff at headquarters and in the field stood at 71.

Table 1. Livestock population and value of annual livestock production in different ecological zones of tropical Africa^a.

	Livestock Population (million TLUs) ^b	Annual Meat Production (million US\$)	Annual Milk Production (million US\$)	Annual Manure Production ^c (million US\$)	Annual I Traction Provision (million US\$)	Annual Transport Provision (million US\$)	Total Production (million US\$)
Arid zone	40.2	1026	951	112	–	830	2919
Semi-arid zone	36.4	1140	577	161	650	413	2941
Subhumid zone	27.6	630	55	92	466	154	1397
Humid zone	7.3	140	21	30	–	100	291
Highlands	23.0	690	495	180	920	299	2584
Total	134.5	3626	2099	575	2036	1796	10132

^a All figures are ILCA estimates from various sources, ranging from 1975 to 1979.

^b This includes estimated populations of cattle, sheep, goats and camels. Combined estimates are expressed in 250 kg tropical livestock units (TLU), taken as equivalent to 1.43 bovines, 8.33 sheep, 8.33 goats or 1 camel.

^c Estimated value of manure marketed commercially or used domestically as fertilizer and fuel.

Smallholder farming in the highlands

The most important agricultural system in the African highlands is smallholder farming, with livestock providing traction for crop production, transport, milk, meat, manure for fuel, and a source of subsistence at times of crop failure. The relative importance of these roles varies in different highland areas: in the Ethiopian highlands, traction and manure are the most important livestock products.

ILCA's research in the highlands is centred on two field stations and the surrounding farming areas near Addis Ababa. Research and experimental work continued in 1980 at Debre Zeit, focusing on 6 research farms under ILCA management and 20 participating farmers who have adopted improvements designed by ILCA but manage their farms independently. Work at Debre Berhan focused on 16 research farms. In both areas, surveys also continued on control groups of 42 outside farmers in the same agricultural zones.

ILCA's improvement package consists of improved farming practices, seeds and fertilizer which make it possible to produce subsistence food crops in a smaller area so that forage production can be introduced to support crossbred dairy cows. The main subsistence crops at Debre Zeit are teff (*Eragrostis tef*), wheat and horse beans; at Debre Berhan, which is higher, teff is replaced by barley. Food crop yields at Debre Zeit were lower in 1980 than in 1978 and 1979, due to late rains and subsequent flooding. Nevertheless, yields of participating farmers

averaged 35% higher than those of outside farmers, and yields on the research farms averaged 80% higher than those of the control group, as shown in Table 2.

Table 2. Average yields (kg/ha) of major food crops at Debre Zeit, 1980.

	Teff	Wheat	Horse Beans
Research farms	1511	1433	1256
Participating farms	1191	1011	917
Outside farms	879	804	597

The overall gross margin per ha for all food crops averaged EB 568 (US\$ 277) for participating farmers, compared with EB 500 (US\$ 244) for outside farmers.

At Debre Berhan, considerable frost damage occurred in 1980, as in 1979, and harvested yields were well below expectations. In 1981, attention is being focused on ways to reduce damage from frost.

Participating farmers at Debre Zeit planted about 37% of their crop lands under forages in 1980, generally reducing the area under pulses. Teff continued to be the most important single crop, accounting for about 50% of cultivated land. Forages included oats/vetch mixtures and fodder sorghum. Yields were affected by flooding, but were still good on research farms, averaging about 7 tonnes dry matter per ha for the oats/ vetch mixture. Green matter samples appeared promising on the participating farms during the growing season, but the farmers cut their forages for hay and left them in the fields until after the teff harvest and so field losses were substantial. More research is required to synchronize hay making and teff harvesting, especially in years with late rains.

Most of the crossbred cows kept by participating farmers at Debre Zeit completed their second lactations in 1980. Adjusted annual milk yields for the second lactation averaged 2 398 litres per cow, a substantial increase over adjusted annual yields averaging 1 714 litres per cow during the first lactation.

Production trials of annual and perennial forages and selected food crops continued in 1980 at both stations. Crop research activities were supported by contributions of seeds from the International Maize and Wheat Improvement Centre (CIMMYT) and potato cultivars from the International Potato Centre (CIF). As in previous years, annual forage varieties proved more productive than the perennials, with oats/vetch mixtures the most successful. However, annual forage seed supplies are inadequate, so research is continuing to identify more productive perennial varieties. Vetch seed, in particular, is currently too expensive for most smallholders, so the Ethiopian Institute of Agricultural Research (IAR) is studying ways to increase vetch seed yields in cooperation with ILCA.

Forage and cereal crop trials were initiated in several locations in Ethiopia under an agreement between ILCA and a number of government research and development agencies.

Research on improved animal traction was intensified in 1980 at both stations under a cooperative agreement with the IAR, the Arsi Rural Development Project (ARDP) and the Debre Zeit Junior College. Cooperative traction trials are being conducted on different soil types, with

different implements and with different breeds and crossbreeds of oxen in several parts of the country. In addition to this joint project, ILCA continued with its own traction research, evaluating different cultivation systems using improved implements.

Dairy cows were also used for traction on research farms at both stations with promising results. A long-term study of the biological and economic efficiency of cow traction was begun at Debre Berhan in 1980, based on 32 cows, with half used for traction as well as milk production and half for milk production only.

Experimental work is also being carried out at Debre Zeit and Debre Berhan using crossbred oxen with improved implements to drain waterlogged land. Local oxen are not strong enough for this work. Seasonally waterlogged areas which could be brought under production with low-cost drainage techniques are typically much more fertile than the upland slopes which have been cultivated regularly, often for centuries. These bottomlands account for roughly 6% of the African highlands, and a much higher proportion of the total cultivated land.

Food and forage crop yields in 1979 and 1980 on drained bottomlands were encouraging. Average annual yields over the two years are given in Table 3 for a number of crops which were planted at Debre Zeit on land drained by different methods

Table 3. average annual grain and forage yields (kg/ha) for drained land at Debre Zeit.

	Drainage Method		
	camber beds	ditches and dykes	camber beds with ditches and dykes
Wheat	1160	1218	1744
Teff	1166	1523	1349
Chick peas	408	507	482
Oats (grain)	947	903	950
Oats (green feed)	11507	25524	22494

In addition to work at the stations, a detailed livestock productivity survey was carried out in 1980, covering 160 small holders in the Debre Zeit area who have not participated in ILCA's improvement programme. This survey is continuing through the end of 1981, and will provide a valuable data base against which to assess the productivity of livestock held by farmers who have adopted the ILCA improvement package. Also in 1980, a study was initiated of the ecotypes of indigenous forage legumes in the Ethiopian highlands. The first field collections carried out in 1980 yielded promising ecotypes of *Trifolium semipilosum* which are being evaluated in 1981.

Village sheep and goat production in the humid zone

Livestock production in the humid zone of West and Central Africa is limited largely to species and breeds which can tolerate trypanosomiasis. In particular, dwarf sheep and goats are kept in small household flocks with a minimum of management.

In 1978, ILCA initiated baseline surveys of village sheep and goat production in the forest and derived savanna zones around Ibadan, Nigeria, and two field stations were established in the following year.

Survey results analysed in 1980 revealed high fertility and mortality rates in local flocks. Annual fertility averaged 210% for sheep and 262% for goats, but mortality to 1 month was also high, as shown in Table 4. The custom of slaughtering newborn animals revealed by the survey warrants further investigation.

Table 4. *Mortality and disposal of young to 1 month (%).*

	Lambs	Kids
Number born	174	767
Mortality	20.7	32.5
Slaughtered	19.5	32.5
Sold	2.3	4.2

Several studies have indicated the importance of *paste des petits ruminants* (PPR) in the area. ILCA's surveys indicated that this disease is particularly important among goats and during the dry season. As shown in Table 5, animals from 5 to 24 months appear especially vulnerable, probably due to loss of premunity at weaning combined with lack of previous exposure.

Table 5. *Effects of four PPR outbreaks on a population of 536 dwarf goats (%).*

	Age in months			Overall
	0-4	5-25	25+	
Disease incidence	14.1	41.0	23.3	26.3
Mortality	10.4	29.2	13.8	17.5

Dwarf sheep and goats in the humid zone subsist on the limited grazing, browsing and scavenging available around the villages, and most animals are fed some household scraps. However, the availability of scraps varies throughout the year with the food supply of the human population, as reflected in figures on scrap feeding given in Table 6. The quantity of household residues available may set an upward limit on the number of animals which can be maintained under present management conditions.

Table 6. Proportions of dwarf sheep and goats (%) fed household scraps at different seasons.

	Early Wet Season	Late Wet Season	Early Dry Season	Late Dry Season
Forest (n = 450)				
goats	6.3	91.3	38.1	27.8
sheep	35.7	65.2	65.0	62.5
Derived savanna (n = 450)				
goats	42.9	87.5	42.1	50.0
sheep	0	77.8	66.7	10.0

ILCA's experimental work in 1980 focused on ways to increase animal productivity under village management through improved health and nutrition. Eventually, increases in sheep and goat populations should also lead to more specialized production systems, with large flocks maintained on natural or planted pastures.

Dipping and spraying facilities have been introduced in the study area for mange and tick control. The control of other diseases, and in particular of PPR, is more difficult, especially in new production situations where the stress of transport and adaptation to a new environment tends to lower resistance. The disease problems which have been encountered in establishing sheep and goat flocks on the ILCA research stations are shown in Table 7. These problems are likely to be encountered by producers at a later stage of development when larger flocks are brought together in more intensive production situations.

Table 7. Disease incidence and mortality (%) among 164 sheep and 195 goats during 1-month quarantine period at ILCA research stations.

	Disease Incidence		Mortality	
	sheep	goats	sheep	goats
PPR	19.5	20.5	3.7	9.2
Pneumonias	17.7	2.1	7.9	1.0
Diarrhoea	10.4	0	0.6	0
Anaplasmosis	3.0	1.0	0.6	0
Abortion	3.7	2.6	0	0
Others	11.6	6.7	4.9	2.1

Most efforts to control PPR have been based on inoculation with tissue culture rinderpest vaccine (TCRV), though this does not give lifetime protection. Inoculation with this live vaccine may bring infection up to clinical levels among animals which are already disease carriers and precipitate an outbreak in the rest of the flock. This reaction, however, has only been observed in new production environments where animals are under stress. In 1980, ILCA monitored 543 sheep and goats under village conditions which had been vaccinated with TCRV: no reaction to the vaccine was observed and no incidence of PPR was recorded.

For animals in new production situations, scientists from ILCA and the University of Ibadan have tested the use of hyperimmune PPR or rinderpest serum followed by vaccination 10 days later. This approach has eliminated the reaction to the vaccine among trial animals at the research stations. In 1981, research will also focus on the pneumonias, which cause considerable losses in new production situations as well as under traditional village conditions. These diseases pose complex problems because a number of different factors contribute to their incidence.

The initial reaction of local villagers to animal health measures introduced by ILCA has been enthusiastic. In fact, farmers from surrounding areas appear to be sending their sheep and goats to the villages where ILCA is working, resulting in a substantial increase in the local small ruminant population. According to customary stock-sharing agreements, outside farmers must give half the offspring to the villagers who look after their animals, but this arrangement is still more profitable than raising sheep and goats under the high disease risks prevalent elsewhere.

ILCA's animal feeding trials have shown that grazing on grass/legume mixtures is inadequate during the 2 to 5-month dry season. Growth rates are not maintained even when pressure on pastures is reduced by the regular offtake of males and excess females. As an alternative to traditional conservation methods to increase fodder availability during the dry season, ILCA is investigating the possibility of interplanting food crops with perennial browse species which would provide the necessary supplementation after the cropping season.

Food crops in this area are normally planted for 4 or 5 years, followed by 4 or 5 years of fallow. ILCA is planting fodder shrubs set close together in widely spaced rows between food crops, according to the alley cropping system currently under study at the International Institute of Tropical Agriculture (IITA) at Ibadan. During the years of food cropping, the leaves from the browse plants are used as mulch. By retaining moisture and returning nutrients to the soil, this practice appears to have a positive effect on food crop yields. Then during the fallow period, a grass/legume mixture is interplanted with the shrubs and the leaves provide a valuable supplement for animal feeding.

The productivity of several browse species is being tested under local conditions, including *Leucaena leucocephala* and *Glyricidia sepium*. Although these plants cannot be used as the sole diet of small ruminants because of their toxicity, they can provide a valuable dietary supplement when other feed is in short supply. Preliminary trials with *Glyricidia* have yielded an average of 400 g of leaf per plant, with 21 % crude protein and 66% in *vitro* digestibility. Given present planting densities, this would result in production of 2 to 3 tonnes dry matter per ha during the dry season.

Cattle production in the subhumid zone

The subhumid zone of West and Central Africa represents one of the largest underutilized agricultural resources on the continent, lying between more densely populated areas to the north and south which are both dependent on imported food supplies. Bush clearing and tsetse control measures are making the area increasingly attractive for expanded cropping and livestock production. Due to its strong potential for increased milk and meat production, the subhumid zone has become a particularly important focus of ILCA's research programme.

Traditional farmers in the subhumid zone cultivate cereals, particularly sorghum and maize, as well as grain legumes, and in the wetter areas, some root crops. Although they keep a few

sheep and goats, mainly for home consumption, most of the livestock in the region are raised by Fulani pastoralists, who concentrate on cattle production. Traditionally, the Fulani have followed an annual transhumant cycle, bringing their herds slowly into the subhumid zone from the north during the dry season when the tsetse population is retreating, and moving quickly back north at the onset of the rains. More recently, partially as a result of government tsetse eradication programmes, the Fulani have been staying for longer periods in the subhumid zone and increasingly settling.

In 1980, intensive research and innovation testing focused on 20 settled Fulani households in two livestock production areas in northern Nigeria, Kurmin Biri and Abet. Although soil and climatic conditions in the two areas are similar, agricultural production is more intensive at Abet and the sizeable farming population provides better market outlets for livestock products. Thus, development strategies are likely to be different in the two areas.

The central focus of ILCA's research has been on increasing milk production through improved dry-season feeding, as nutritional deficiencies at this time of year have been identified as the most important constraint on productivity. Production levels under traditional management were monitored in 1980, and the effects of feeding small quantities of cottonseed cake to selected classes of animals were measured. Possibilities for introducing fodder legumes into the cropping system were also investigated.

The Fulani households in the two study areas subsist largely on milk from their herds, ranging typically from 80 to 100 White Fulani (Bunaji) cattle, while at the same time cultivating limited areas of sorghum and maize. Milk offtake under traditional management is low. At Kurmin Biri, daily offtake per cow in milk averaged 0.74 litres from July 1978 to June 1980, with a maximum monthly average of 1.27 litres per day and a minimum of 0.36 litres. Offtake rises rapidly with the onset of the rains, peaks in the middle of the rainy season and then declines steadily, following the decline of protein in the grasses.

Calving rates under traditional management averaged 53% in the two areas over 236 cow-years. Some seasonality of calving was observed, with peaks in October and March/April. Birth weights averaged 20 kg, ranging from 13 to 27 kg. During the first 3 months, when nutrient intake is almost entirely from milk, calves born during the wet season were heavier on average than those born during the dry season, but from 3 to 6 months this trend was reversed, so that at 6 months calves born during the dry season were marginally heavier. This pattern reflects seasonal forage availability, but it may also partially be due to compensatory growth and disease factors.

At 6 months, calf weights under traditional management averaged between 55 and 60 kg, giving an average weekly growth rate of 1.3 kg. Calf growth rates at the National Animal Production Research Institute (NAPRI), where calves are bucket fed and given supplementary concentrates, suggest a potential 6-month weight of at least 100 kg, while at the Kachia Breeding Ranch, where calves suckle but cows are not milked, calf weights at 6 months average about 80 kg. Calf growth rates under traditional management start to drop below the rates recorded at Kachia at about 3 months.

In 1980, participating Fulani herd owners in the two areas supplemented half of their lactating cows with 1 kg of cottonseed cake daily during the dry season. The milk offtake of the supplemented cows was substantially higher than that of the cows subsisting on natural grazing alone, though offtake for both groups followed a similar curve. A more detailed analysis of the

productivity of cows paired at the time of calving showed that the offtake of those fed cottonseed cake was about 75% higher than that of those who received no supplementation, as shown in Table 8. Calf birth weights and growth rates were also recorded for a smaller sample. The calves of supplemented dams appeared to perform better, but the differences were not significant, probably due to the small sample size. These relationships are being examined further in 1981.

Table 8. Daily milk offtake (ml) with and without daily supplementation of 1 kg cottonseed cake.

	With supplement	Without supplement
Average over full lactation	750	424
Average over first 90 days of lactation	1519	620

The returns in terms of milk offtake alone were not sufficient to cover the cost of the cottonseed cake. However, the supplemented cows were 15.76 kg heavier on average at the end of the dry season and showed greater oestrus activity. Further evidence will be collected on increased fertility, calf survival and growth in order to assess the full economic effects of supplementation.

Given the limited availability and high cost of purchased concentrates, however, long-term improvements in animal feeding are more likely to be based on the introduction of forages into the cropping cycle. If the Fulani are to be encouraged to plant forage crops, research is required on the agronomic aspects of forage introduction and on the local land-tenure situation.

The emphasis in 1980 was on interplanting a fodder legume, *Stylosanthes hamata* cv. Verano, with the staple sorghum and maize crops. At Abet, interplanting was considered an appropriate strategy because of labour constraints, and *S. hamata* was chosen because of the locally available seed supply.

Food crops are normally planted for 3 or 4 years on a plot, followed by 3 or 4 years of fallow. *Stylosanthes* was interplanted during the last year of food cropping at the time of the first weeding. In the first year, 1 270 kg dry matter of fodder were produced per ha. Food crop grain yields were reduced by about 10% due to interplanting, but residues were not significantly affected. However, controlled experiments have revealed a sharper decrease in grain yields when legumes are undersown earlier in the cropping cycle.

At Kurmin Biri, considerable land is available and the government assists Fulani farmers with mechanized seedbed preparation. Thus, in this area, *Stylosanthes* could be planted in pure stands, and good yields were achieved in the first year.

The next concern has been to assess how well fodder legumes persist in subsequent cropping seasons, so that a ley farming system can be established based on a rotation of fodder and cereal crops. *Stylosanthes* reseeded itself and produced much higher yields in the second year, and yields for the third year also look promising. Further experimental work is under way to evaluate various intercropping strategies. After the first season, 40 additional farmers in the two study areas approached ILCA to ask if they could begin planting fodder legumes in 1981.

However, if cropping is to be established on a permanent basis, the settled Fulani pastoralists require secure tenure to their land. At present, they have only temporary users' rights. In 1980, ILCA researchers analysed land disputes in the area from court records over the previous 20

years, to assess the importance of conflicts between the Fulani and the local arable farmers. Disputes over land tenure and conflicts over crop damage by livestock do not appear to have increased over the years, and one-third of all court cases due to crop damage were between arable farmers and did not involve the Fulani.

Land tenure systems among the Fulani were also investigated. Though a traditional land-use system exists, tenure rights need to be clarified and strengthened, and a tenure system needs to be developed which includes both pastoral and arable farming groups. Further research is being conducted on these topics in 1981.

Pastoral production in the arid zones of West Africa

ILCA's field research programme in the arid zones of West Africa, based at the western edge of the Niger River Delta, concentrates on two livestock production systems which are representative of systems widely practised throughout the Sudano-Sahelian region: a transhumant pastoral system focusing on cattle, sheep and goats, and an agropastoral system based on rainfed millet and livestock production.

Early work indicated that cattle productivity in these systems is limited primarily by available animal feed supplies, with disease incidence interacting with inadequate nutrition. Among sheep and goats, however, pasteurellosis was shown to be a significant cause of mortality, and research on a new vaccine is now being carried out by the Malian Laboratoire Central Vétérinaire.

The transhumant system

Livestock production strategies of transhumant herdsmen are based on the annual rainy season and the flooding of the Niger Delta. Livestock are moved to upland Sahelian pastures in June at the onset of the rains and back to the delta plains in December with the recession of the floodwaters. Between these two seasons of relative wellbeing, the herds undergo periods of severe stress as they pass through the heavily overgrazed *zone d'attente* at the edge of the delta.

A long-term trend towards increasing grazing pressure was revealed during ILCA's initial research work in the area by comparison of aerial photographs taken in 1852 and 1975. A low-level aerial survey was carried out in October 1980, at a time when grazing pressure was acute in the *zone d'attente* while the transhumant herds were waiting to enter the delta when the flood waters receded. The pattern of local grazing pressure around the delta was shown clearly in cattle stocking levels observed during the survey.

A comparison of the proportions of degraded or bare land observed in 1975 and 1980 is given in Table 9. The earlier observations were made at the end of a severe drought, when ground cover was particularly poor. The much lower proportion of degraded land observed in 1980 reflects the situation after several years of good rains and demonstrates the remarkable regenerative capacity of the natural Sahelian vegetation.

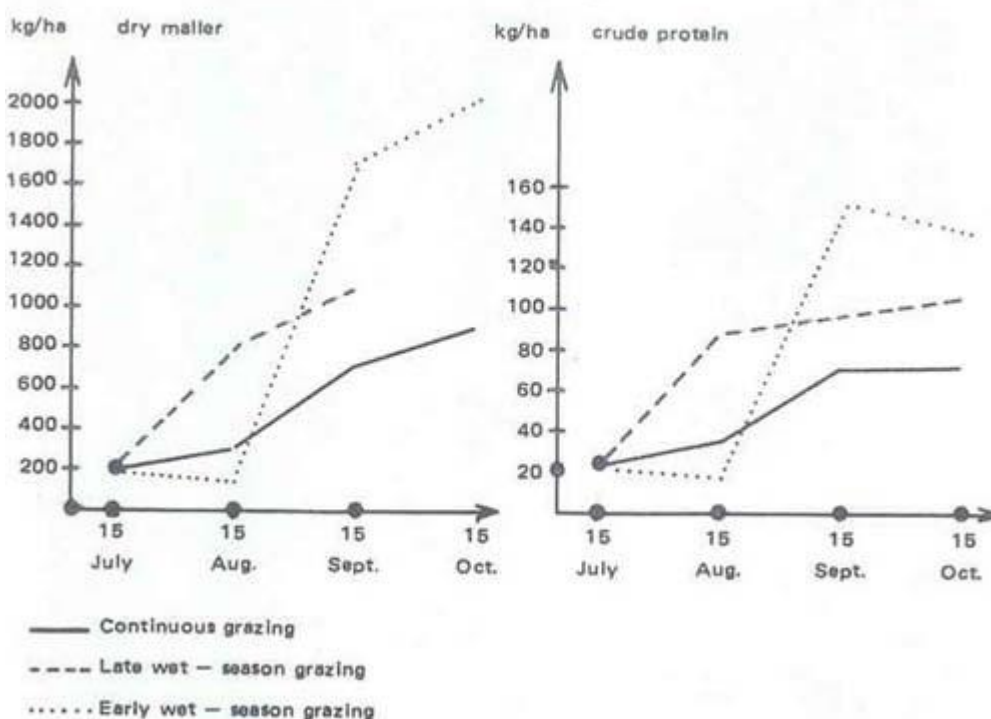
Table 9. Proportions (%) of survey units classified according to percentage of degraded land, 1975 and 1980.

	50% or more of land Unit Degraded		25–40% of Land Unit Degraded		Less than 25% of Land Unit Degraded	
	1975	1980	1975	1980	1975	1980
North of 15° latitude	76	33	34	17	0	0
South of 15° latitude	67	8	34	8	6	5

The maintenance and improvement of pasture productivity are considered crucial in terms of the long-term viability and ecological balance of the production system. ILCA's earlier experimentation with pasture improvement through the introduction of grass and browse species and scarification and fertilization of natural pastures indicated that neither approach is appropriate for widespread introduction: no introduced species was identified which performed better than local varieties under the harsh conditions of the Sahel, and fertilization and scarification proved too expensive in terms of the value of increased production achieved. Thus, attention has focused on modest improvements in productivity achieved through improved management of the natural vegetation.

Grazing trials have indicated that significant increases in dry matter yields can be obtained well into the dry season by a system of intensive grazing early in the wet season, though the quality of the herbage, in terms of crude protein content, is not improved. Grazing pressure during the dry season after the annual grasses have dropped their seed has little effect on subsequent productivity. Dry matter and protein production of Sahelian pastures under three grazing regimes are shown in Figure 1. The crude protein content of the grasses in percentage terms was almost identical during the rainy season, but varied slightly at the end of the dry season. Results are averages over a 3-year period; stocking rates varied, but averaged about 4 ha per TLU (250 kg).

Figure 1. Dry matter and crude protein production of natural Sahelian vegetation under three



grazing regimes.

Table 10. Dry matter (kg/ha) consumed and left standing on natural floodplain pastures during 6-month dry season under two grazing regimes.

	DM consumed	Standing DM after 6 months
Continuous grazing	3500	140
Rotational grazing	4800	800

Similar improvements in pasture productivity were achieved on the Niger floodplains under a system of rotational grazing, as shown in Table 10. Stocking rates were heavier in this area, averaging about 1 ha per TLU.

Although ILCA's experimental work has shown clearly that pasture productivity can be maintained, and even improved, under a system of rotational grazing, the introduction of grazing controls in the transhumant livestock production system will only be possible under a system of territorial organization which guarantees exclusive users' rights to specific groups of livestock producers. In 1980, ILCA specialists analysed land-use patterns in the study zone, based largely on the interpretation of photographs from high-altitude aerial surveys. ILCA field workers also conducted extensive surveys of existing territorial organization, based primarily on interviews with leaders of local transhumant groups. Traditional groupings have been identified which can be more clearly defined and strengthened to serve as a basis for the introduction of grazing controls and possibly other management innovations. By the end of 1980 land-use

patterns had been analysed for about half of the delta area and two-thirds of the Sahel rangelands, while half of the delta had also been covered by ground surveys.

A detailed cattle productivity survey, which was initiated in 1978, was completed at the end of 1980, with results to be analysed in 1981. This survey was designed to reveal the effects of several factors on animal productivity, including ownership patterns, management strategies, seasonal variations and several characteristics of the animal population, such as age, health and parturition status. One finding was the high calf mortality rate, averaging from 20 to 35%.

Animal nutrition and growth studies have indicated that livestock production on natural pastures is not generally limited by the amount of dry matter on offer, but by the level of available crude protein. Data collected by ILCA in Mali confirm the importance of crude protein availability : 42% of recorded variation in cattle weight gain was found to be due to variation in crude protein intake, while only 2% was due to variation in the intake of digestible dry matter. A further 56% was attributable to the interrelationship of crude protein and digestible dry matter intake, reflecting an increased level of palatability and digestibility at the season when crude protein content is high.

Opportunities to increase the level of crude protein available to transhumant livestock are likely to be based on the more efficient use of local browse species. ILCA's analyses have shown that the leaves of local browse plants contain from 3 to 25% crude protein, averaging about 12 to 18%. Possibilities for increasing the productivity of browse by various harvesting regimes have been investigated, and improvements have been achieved by lopping at the end of the dry season, as shown in Figure 2.

ILCA's approach to research on social-territorial organization and pastoral development is depicted in Figure 3. This strategy has been adopted by the Mali Government, resulting in a special project agreement signed by ILCA and the Office du Développement de l'Élevage de la Région de Mopti (ODEM) in October 1980. ILCA will help identify at least four pastoral production units which will serve as the focus of development efforts in the delta and adjacent areas of the Sahel. ILCA will later participate in the evaluation of this project and will train six government officers in the research techniques which have been devised. If these efforts are successful, they will serve as the basis for a much wider development programme.

The agropastoral system

Sedentary farming, based on rainfed millet and livestock production, has grown rapidly in recent years, and is now one of the most important production systems in the Sahelian region. ILCA scientists have conducted broad surveys of farm households throughout the study zone in Mali, while focusing attention on about 100 households in five representative villages.

Millet is grown in fields around the villages, and livestock are maintained largely on natural grazing. Given limited and unreliable rainfall, cropping practices are strongly geared towards minimizing risk. Nearly all households keep cattle, sheep and goats: work oxen comprise a substantial proportion of household herds, while other livestock are kept largely as a form of investment.

Research in 1980 focused on animal productivity levels and associated nutritional factors, and techniques were refined for assessing feed intake from natural grazing. It was found that a substantial proportion of the diet of small ruminants is provided by browse, but browse is much less important for cattle: goats spend approximately 87% of their daily feeding time browsing and sheep about 74%, but cattle only about 4%.

Figure 2. Monthly dry matter availability from leaves of *Pterocarpus lucens* with and without lopping at the end of the dry season.

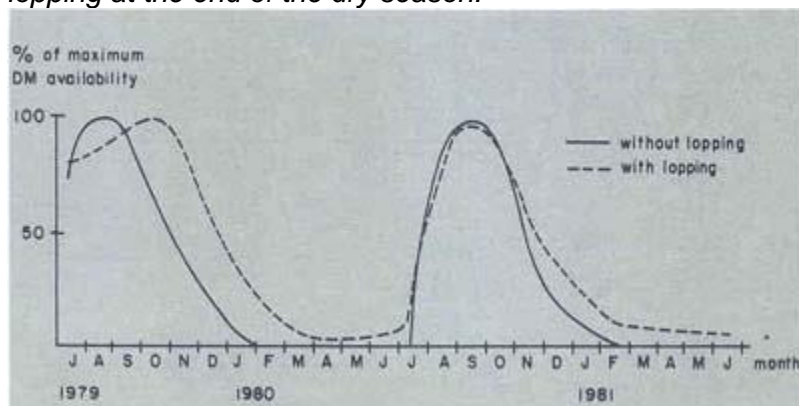
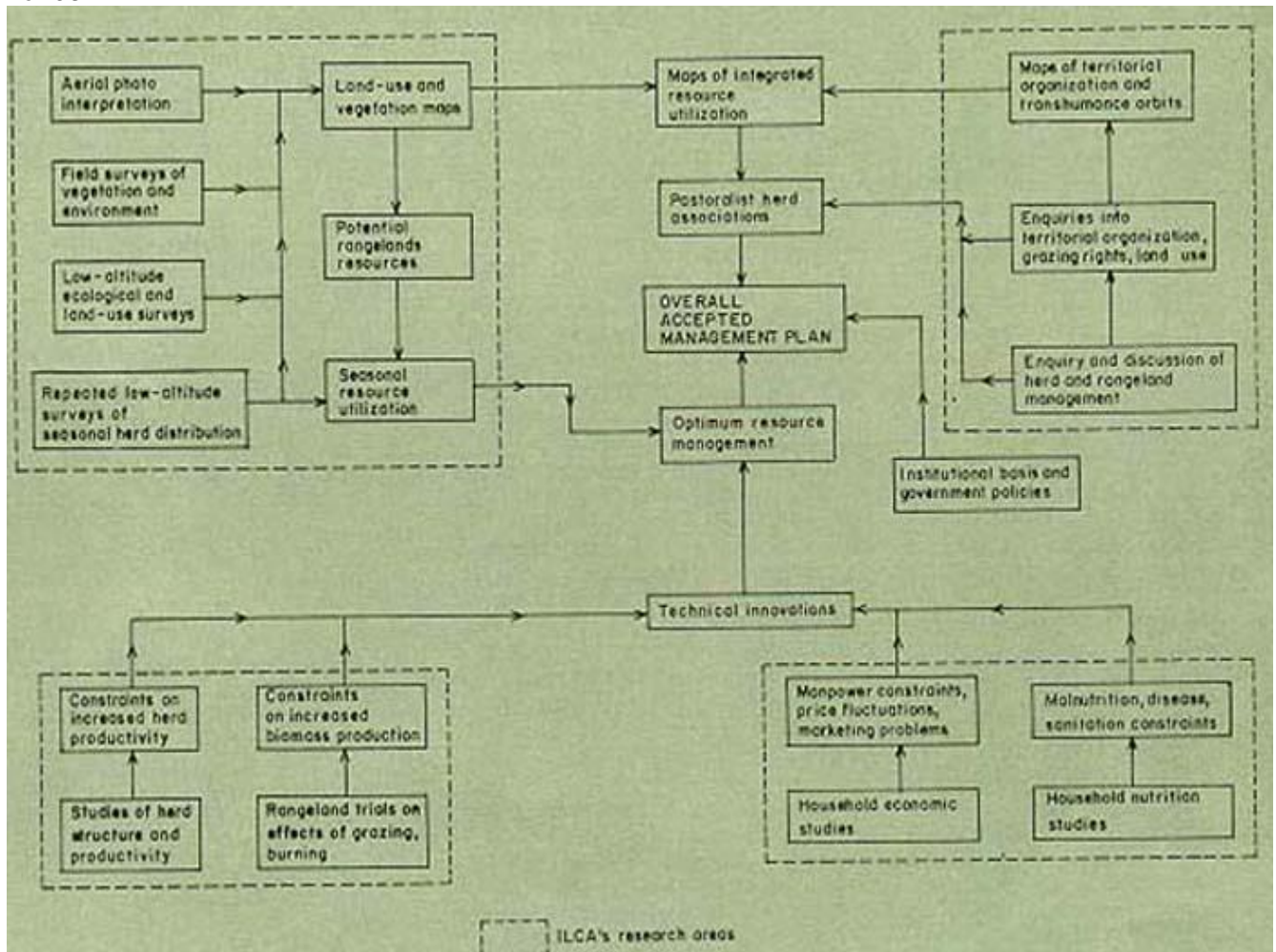


Figure 3. ILCA's research on social-territorial organization and pastoral development in the arid zones.



Preliminary results indicate the effects of nutrition on fertility among cattle, but not among sheep and goats. High preweaning mortality rates were recorded for small ruminants, however, averaging 35% for goats and 30% for sheep, due partly to inadequate nutrition and partly to pasteurellosis and other diseases. Nutritional stress is particularly important among work oxen, which tend to be in poorest condition at the onset of the rains when traction requirements are greatest. In March, a 300 kg bovine consumes on average 37 MJ of energy a day from natural pastures, while daily energy requirements are of the order of 58 MJ, indicating a serious shortfall.

The main focus of ILCA research in 1980 was on possibilities of overcoming such shortfalls in animal nutrition through the introduction of forage crops. Earlier work revealed that labour would be a constraint on planting forages in pure stands, so introduction has been based on interplanting with the staple millet crop. After initial trials with a number of fodder legumes, research has focused on cowpeas (*Vigna unguiculata*), particularly for dry-season feeding to work oxen. The first introduction of the most promising cowpea variety increased average dry matter available for animal feeding from 945 to 1600 kg per ha. The effects of interplanting on millet grain and straw yields appear to vary widely, depending on rainfall levels over the cropping season; these relationships are currently the subject of further experimentation.

It is estimated that 2.7 kg of cowpea haulms provide sufficient daily supplementation for a 300 kg bovine. The best variety produced 195 kg dry matter of haulms per ha when interplanted with millet at a density of 8% of the plant population, thus providing 72 days of supplementation. In one of the study villages, 100 ha of millet were interplanted with cowpeas at this density, providing 61 days of supplementation for the village herd of 119 cattle. ILCA researchers are also assessing the impact of increased millet production on human nutrition.

These initial results have stimulated interest among other villagers, so that in 1981 the areas intercropped with cowpeas will be expanded and planting densities increased. ILCA scientists will study the impact of improved feeding regimes on the traction capability of work oxen and the productivity of sheep and goats.

Range livestock production in eastern and southern Africa

Comprehensive livestock development projects are being implemented in many areas of the arid and semi-arid zones of eastern and southern Africa. ILCA's research activities include investigations of rangeland livestock production systems in Kenya, Ethiopia and Botswana which are currently experiencing change under the influence of national development projects.

Kenya

Range livestock production systems in Kenya's arid and semi-arid zones differ from similar systems in West Africa in several respects. Pastoral livestock producers in eastern Africa tend to migrate shorter distances than those in West Africa, in response to more localized climatic conditions. Pastoralists in West Africa are often more closely linked with local farming communities, with transhumant herds grazing on stubble fields after the harvest season and with close trading ties. More importantly, range livestock production systems in Kenya have been the target of substantial development efforts over the past 10 years. With expenditures totalling about US\$ 103 million, the Kenya Livestock Development Project (KLDP) is one of the largest and most comprehensive livestock projects in Africa. Thus, the situation in Kenya provides an opportunity to study range livestock production systems under the influence of various levels of development activity.

Research in Kenya has focused on formulating an appropriate, cost-effective methodology for identifying and following trends in rangeland ecology, animal productivity levels, economic performance of ranches and pastoral production units, and the social organization and production strategies of livestock producers. At the request of the Kenya Government, ILCA's early work covered the commercial, company and cooperative ranches which together account for over half of total development expenditures under the KLDP. In 1980, data were analysed on herd dynamics and financial performance from a sample of 10 of these ranches, selected from a wide range of production environments.

Ranch managers were found to vary widely in terms of training and experience, but performed best when they enjoyed relative autonomy. All but one of the ranches were stocked well below their potential carrying capacity, as determined by ILCA ecologists, but stocking was uneven, and watering points and other central areas on some ranches were overstocked. Most cattle on the ranches were of the East African Zebu type, but herds were slowly being upgraded with Boran and Sahiwal sires. Bull/cow ratios ranged from 1 :4 to 1 :70, with an overall average of

1:35. Data available from 1973 to 1979 indicated a trend towards decreasing bull/cow ratios which implies improvements in breeding management. The proportions of steers in ranch herds dropped substantially over the study period, while the proportion of mature cows increased slightly, reflecting a shift of emphasis from fattening purchased immatures to building up breeding herds. In spite of production policies formulated under the KLDP, it proved difficult to purchase immature stock for fattening due to drought and reduced livestock numbers in the traditional breeding areas.

Calving rates over the period ranged from 52 to 83% on individual ranches, while mortality rates ranged from 4 to 24%. Recorded disease incidence differed widely according to production zone, whereas calving and mortality rates on all the ranches showed the effects of a 4-year drought which peaked in 1976.

In 1978, the emphasis in ILCA's research activities shifted to the group ranches which are being developed in traditional Maasai and Samburu pastoral areas. These ranches have been adjudicated and ownership vested collectively in the traditional users of the land. As an attempt to vest land rights in pastoral communities, the group ranches in Kenya have aroused widespread interest.

Data collected from 1977 to 1979 at Elangata Wuas group ranch were analysed in 1980. Information collected on rangeland vegetation and stocking rates indicated that productivity will be uncertain in the long term unless controls on stocking are introduced. Given the low and highly variable rainfall in the area, the ranch is already fully stocked relative to its longer-term carrying capacity, yet no viable mechanism exists to limit further herd growth.

Large numbers of animals, representing a substantial proportion of total holdings, are sold or traded every year. Net offtake, however, is only a fraction of reported sales, as most transactions are between ranch members. A survey of group ranch members indicated that innovations which are relatively easy to implement, such as dipping and the use of improved sires, are appreciated and readily adapted. However, any proposed improvement requiring major changes in the production system will be more difficult to implement.

As in many other pastoral societies, substantial variation exists among Maasai households on Elangata Wuas, particularly in terms of livestock holdings. Table 11 shows the ranges of observed values for a number of factors. This variability implies that a relatively large sample of households would be required to obtain significant information about the ranch population as a whole. The extreme variability of livestock holdings also has important development implications, though sharing mechanisms partially alleviate the effects of the wide discrepancies in wealth. Fully 25% of the households at the time of the survey had an average of only 6 cattle and 9 sheep and goats not enough to meet their subsistence needs—while the wealthiest 25% of households had an average of 203 cattle and 123 sheep and goats.

The results of early work in Kenya have made it possible to sharpen the focus of current activities. Present research is based on a network covering three Maasai group ranches. Olkarkar and Merueshi group ranches were established under Phase I of the KLDP, but Olkarkar has received more than twice as much development funding. Mbirikani group ranch has only recently been adjudicated and has not yet received any funding. Thus the three ranches, which are similar in many other respects, represent a continuum in terms of development inputs.

Human and livestock populations have been assessed on the three ranches and settlements and infrastructure demarcated. Detailed ecological maps have also been completed. Households have been stratified into three classes based on the ratio of household size to livestock holdings, and random samples have been selected from each class for intensive studies.

Table 11. *Observed variation among households on Elangata Wuas group ranch.*

Family size	0 to 6 wives (median : 1)
	0 to 18 children (median : 4)
	0 to 26 other dependents (median : 2)
Livestock kept at the homestead	0 to 500 TLUs (250 kg) (median : 25)
	0 to 300 sheep and goats (median : 30)
Employment outside of family livestock activities	1 household member out of 7 households
Livestock sales over 1 year	0 to 100% of holdings (median : 15%)

A study was also undertaken in 1980 in a Maasai area where land is being adjudicated and group ranches set up prior to the formulation of development plans. A demographic profile has been made of the human and livestock populations of this area, livestock movements have been described and locally recognized territorial units demarcated. Data on traditional land use are being collected on a regular basis from a sample of 30 households.

A comparative marketing survey was initiated in 1980 in two districts, and in 1981 it is being expanded to include a third. Finally, a study of the use and potential of browse was carried out in 1980 at four sites, focusing on *Tarchonanthus camphorates*, a common invading shrub which is used seasonally as browse by local livestock producers.

Ethiopia

Within the framework of the Ethiopian Government's Rangelands Development Project (RDP), ILCA carried out research in 1980 on the Afar pastoral production system in the northeastern lowlands. A baseline survey was completed, covering approximately 5 500 km² of the project area, where a varying Afar population of 4 000 to 11 500 households keeps cattle, sheep and goats and a smaller number of camels. Useful data were collected on soils, rainfall, vegetation, human and livestock populations and management practices, and detailed maps were prepared. The survey report was completed in early 1980 and submitted to the Ethiopian Government, and an ongoing research programme was established, funded jointly by ILCA and the RDP.

The critical resource in the Afar livestock production system is feed. Though surface water is adequate, pasture production, and thus animal and human nutrition, are limited by low and erratic rainfall, ranging from 600 to less than 250 mm a year eastwards down an altitude gradient. Social organization is not well developed above the household level, which has important implications for the organization of government administrative and development activities. Critical pressure on the system has increased in recent years with the gradual incursion of Oromo farmers into the higher-rainfall hill areas in the west, and the productivity of remaining pastures may also be decreasing due to heavy overstocking in periods between droughts. The Afar are no longer self-supporting: they rely increasingly on food provided through famine relief programmes and in periods of particular stress large numbers of livestock and people may die.

A preliminary assessment of the production system, based on the data collected by ILCA, suggests that the present development project, aimed at improving the traditional pastoral system, may prove inadequate. If the Afar are to survive in their hostile and increasingly limited environment, a major reorientation of their production system may be required. ILCA research is designed to assess the potentials and constraints of the present system and to suggest alternatives for future development.

A research network was organized in 1980, based on 54 representative production units in six separate groups from all the major clans of the study area. Each of these groups is being followed by a resident enumerator. An ecological assessment was carried out using previously established transects, and a system was established to collect meteorological data throughout the area. Information is being collected on basic range and animal productivity levels, carrying capacities, utilization patterns, offtake levels, trade links, decision-making patterns and human nutrition factors. Land-use studies are to focus on the hill areas which have traditionally been crucial for Afar survival during periodic droughts in the lowlands. As these areas are increasingly taken over for cultivation by the Oromo, the development project has concentrated on improving pastures in the lowlands through spate irrigation, but it is not known how this effort should best be organized or whether it will be adequate to support the Afar population and their herds.

Once the Afar research network was established and operating, attention was turned to the most important pastoral component of the RDP, the southern rangelands area. Here an initial study was carried out, focusing on a population of approximately 30 000 pastoral Borana households who keep cattle, sheep and goats and smaller numbers of camels and horses in a savanna plateau area of about 95 000 km². With annual rainfall ranging from 500 to 700 mm, this underutilized rangeland represents one of the best remaining pastoral areas in Africa. In contrast to the Afar region, feed resources are plentiful, but their utilization is limited by scarcity of surface water. In contrast to the Afar, the Borana are a highly organized pastoral society, divided into well defined groups based on access to one or more deep wells, which are the only sources of water during the dry season.

Interventions introduced under the RDP during the past 4 years have centred around the construction of rain-fed ponds which extend the grazing period in wet-season areas and thus reduce the pressure on pastures around the permanent wells. This has been supplemented by an animal disease control and vaccination programme, the construction of access roads and the development of a ranch where excess livestock may be sold. An initial assessment indicates that the present project approach is essentially correct, but more detailed information on the traditional production system and on project impacts is required if long-term trends are to be anticipated and possible problems corrected.

A meteorological network was set up in 1979, a basic research model has been developed and a comprehensive data gathering system has been initiated. Information is being collected on human demography, household economics, livestock productivity and management, herd and flock structures and social-territorial factors. Special surveys cover well utilization and organization, animal disease, livestock sales and offtake, and human nutrition levels, particularly as they relate to peak labour requirements.

An essential aspect of ILCA's programme in the northeastern and southern rangeland areas is the integration of research and development activities, based on close cooperation with the RDP. The programme is still at an early stage, but objectives and target systems have been clearly defined and data collection networks are well established.

Botswana

In 1970, the Botswana Government launched a comprehensive Tribal Grazing Land Policy (TGLP) designed to develop the country's livestock industry. The First and Second Livestock Development Projects were initiated under the TGLP, and the government asked for ILCA's assistance in project evaluation and livestock development monitoring.

An ILCA country representative works closely with government officials responsible for planning and implementing livestock development programmes. He is supported by other ILCA scientists, who visit Botswana and advise the government on various aspects of the project. In 1980, the government agreed to contribute to ILCA's operating costs in the country for that year and to cover 80% of the full costs in subsequent years.

Two types of activities have been initiated in Botswana. A comprehensive programme of implementation monitoring is carried out in cooperation with government officers to provide a continuous review of the progress of various project components. In addition, government field staff review project impact on a regular basis to evaluate the effects of development interventions on the livestock production sector.

The implementation monitoring programme, which the ILCA country representative helped design, is based on guidelines and formats for planning annual work programmes and semiannual reports on the progress of project components. The rate of project implementation has been slow, but the monitoring system has helped pinpoint responsibilities for delay and identify administrative weaknesses in the implementation process.

The review of project impact includes regular assessment of range conditions, livestock productivity and ranch economic performance. Two major considerations in designing the programme have been to ensure its cost-effectiveness and long-term continuity. In 1980, ILCA scientists and government officers reviewed past range ecology studies in detail and introduced important modifications to improve the quality of data collected and broaden the coverage to include all the major ecological zones of the country. Range condition score cards already in use were modified and standardized to ensure the compatibility of data collected by all government agencies. Initial ecological surveys were carried out by government in 1980 in several commercial ranching areas in order to determine potential carrying capacity and range conditions. Results were communicated to extension staff who could then advise ranchers on appropriate stocking rates.

Two sets of simplified formats have been developed by government and ILCA staff to record data on livestock productivity and ranch economic performance. Each ranch-owner records his operations in a herd register, while government field staff use another set of formats to build up an extension file on each ranch. Besides providing feedback to government on the progress of development efforts, the information collected is of immediate use to extension staff in clarifying the input–output situation and technical and financial performance of the ranches. These formats were tested in the field, modified and distributed for general use in 1980. ILCA has helped supervise data collection in the field and will subsequently help develop computer programmes for data storage and analysis. Serious overstocking has already been identified on ranches developed under the First Livestock Development Project and proposals have been made for introducing stock limitations in the area.

Breed evaluation and herd modelling

In addition to ILCA's principal field research activities, a small number of research topics have been identified which could have important implications for livestock development across a number of production systems. In 1980, complementary research at ILCA focused on comparative studies of the productivity of indigenous African livestock and on development of a herd-level mathematical model suitable for preliminary screening of research and development alternatives.

Comparative studies of African livestock breeds

In 1980, a Technical Consultation on Animal Genetic Resources Conservation and Management, sponsored by the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Environment Programme (UNEP), concluded that: There is now widespread realization that breed importation is not necessarily the quickest route to increased animal production. Indigenous, adapted breeds should be examined more closely and, where necessary, steps should be taken to ensure conservation of at least some of them. Crossing with imports may sometimes be useful, but crosses should be evaluated against the indigenous breeds in the local environment; indiscriminate crossbreeding, without evaluation, should be discontinued.

Specific recommendations were made for further studies, giving high priority to N'Dama, Sahiwal and Boran cattle, Awassi sheep and Shami goats. ILCA scientists were engaged in comparative studies of Sahiwal and Boran cattle in Kenya in 1980, and a research network was being established in West and Central Africa, covering work on N'Dama and other trypanotolerant breeds. Research was also under way at the Kenya coast, in cooperation with the International Laboratory for Research on Animal Diseases (ILRAD), on the genetic and acquired bases of trypanotolerance.

An evaluation of the potential milk and beef production of Sahiwal cattle was completed at the end of 1980. Productivity data were analysed from five herds, including Sahiwal, Ayrshire, Small East African Zebu and Boran cattle and Sahiwal/Ayrshire crossbreds of varying percentages. The herds were kept across a wide range of production environments and management levels, with production objectives varying from primarily beef to primarily milk production and different levels of emphasis in between.

Examination of environmental and genetic parameters indicated that the formation of composite breeds is a promising approach to producing cattle adapted to the major ecological zones and production systems of tropical Africa. Composites should include an optimum percentage of the highest performing *Bos indicus* breeds, such as the Sahiwal, to achieve adaptability to the production environment, combined with *Bos taurus* breeds which have a high response capability for milk and beef production. Suggestions were presented for specific composite breeds in each of the environmental situations for which data were analysed. The primary objective would be to synchronize the formation of a composite breed with the natural environment in which the herd is to be maintained, including climate, nutrition, disease and parasite conditions, with the level of management which is technically and economically feasible, and with specific production goals. There are strong indications that the optimum contribution by a *Bos indicus* breed would be at least 25% in all of the environments covered by the study.

A similar study was initiated in 1980, focusing on the Boran breed. Eleven breeders were identified throughout Kenya who had maintained production records on their Boran herds over a number of years. Over a 6-month period, components of these record sets were copied and abstracted and analysis began at the end of 1980. This study will provide considerable information on performance traits of Boran and their crosses with many other breed types under a range of management levels and ecological conditions.

ILCA's survey of trypanotolerant cattle, sheep and goats in West and Central Africa, completed in 1979, suggested that the productivity of these breeds may be much higher than previously assumed relative to other indigenous types. Further research, and in some cases wider utilization, were called for. In 1980, further comparative studies were planned in a network covering Benin, Togo, the Gambia, Senegal, Gabon, Zaire, and Congo, where national authorities will record essential data from large numbers of animals with technical coordination by ILCA. In addition, ILCA personnel will support data analysis and the interpretation of results.

ILCA and ILRAD scientists were also engaged in trypanotolerance research in 1980 in Kenya, focusing on Sahiwal x Ayrshire cattle, which are considered susceptible to trypanosomiasis. The study covered a breeding herd of 800 females consisting of two breed types: 2/3 Sahiwal—1/3 Ayrshire and 1/3 Sahiwal—2/3 Ayrshire. The animals are kept on a commercial dairy ranch in an area under low trypanosomiasis challenge, carried by two tsetse species, *Glossina pallidipes* and *G. austeni*.

Periodic examinations of blood specimens revealed the presence of *T. congolense* and *T. vivax*. Animals were treated selectively with trypanocidal drugs, based on measurement of packed cell volume (PCV) in the blood. Samples were taken from each animal in the breeding herd 4 or 5 times a year, and any animal with a PCV of 25% or less, later modified to 29% or less, was treated with Berenii (Dimanozone acetate).

When data collected over a 6-year period were analysed, using the incidence of treatment to indicate infection, it was shown that animals which had received more treatments in the past required fewer treatments subsequently. This pattern was established at a high level of statistical significance and was shown to be independent of the animals' ages. Because of the intervals between treatments, any residual prophylactic effect of the drug was discounted. These results provide significant evidence of acquired tolerance to trypanosomiasis.

Turning to genetic factors, it was found that the 2/3 Sahiwal animals generally required only half the number of treatments as the 1/3 Sahiwals, or an average of 0.6 doses per year compared with 1.4. The heritability of PCV values, as indicators of trypanotolerance, was also demonstrated. Information was assessed from 36 sires, each represented by 16 daughters. PCV values were measured 5 times throughout each of the 2.3 calving intervals recorded for each daughter. The heritability of average PCV values throughout an interval was 0.160.08. As animals with PCVs of 29% or less were being treated with trypanocides, it is possible that heritabilities of PCV values are higher among trypanotolerant livestock in West and Central Africa in situations where drugs are rarely used.

Evaluation of herd productivity using a systems model

ILCA's first application of herd-level mathematical modelling demonstrated the potential contribution of such models to the preliminary assessment of research and development options. A simulation model developed at Texas A & M University was applied to the evaluation of beef cattle production potential in Botswana. While the model proved well suited to certain types of analysis, including comparative evaluation of different animal genotypes in large-scale herding situations, a different formulation is needed to address such issues in most African production situations. For instance, a major fraction of the African bovine population is held in semi-arid areas where annual variability in forage supplies is a key factor determining long-run herd productivity. Additionally, the typical herd in Africa is small relative to the size of commercial production units in North and South America for which the Texas A & M model was principally intended.

Thus, ILCA scientists have developed a herd-level simulation model which is particularly suited—with a minimum of modification—to a broad range of production situations in tropical Africa. The model is time dynamic, stochastic and non-optimizing, and treats simulated animals as individual entities. The parameters used to describe the functions representing the various biological processes are drawn from the relevant literature, modified as needed by observations from particular production systems. Thus, the model is data based where possible and also modularized so that alterations and refinements can be made relatively easily. It was put in operation in 1980 on the computer facilities at ILCA headquarters.

An important feature of the model is that it provides the user with an array of policy options so that herd performance can be studied under a variety of management regimes. These policy options allow for the simulation of common husbandry practices, such as breeding and weaning at different ages and seasons. Additionally, options can be specified with an adequate degree of detail relating to the management of the herd as an economic unit. On the input side, the model allows for the purchase of animals. Furthermore, a range of supplements can be provided for increasing meat and milk production or for strategic reasons, such as improving the survival of the breeding herd during extended feed deficit periods. On the output side, milk and meat offtake can be regulated, as well as the sale of surplus animals over and above a planned herd size, within the constraints of the available resource base.

Initial applications of this model to production systems covered by ILCA's research programme in Botswana, Nigeria and Mali have indicated its validity and utility in screening a range of potential interventions.

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Professional staff

Abate Tedla	Forage Agronomist
Addis Anteneh	Economist
Aklilu Ascabe	Headquarters Farm Manager
Amde Wondafrash	Team Leader/Highlands
Anderson, F	Economist
Aubrac, J-P	Computer Manager
Ayele Guebre-Mariam	Sociologist
Aziza, M	Administrator
Backlund, S	Budget Officer/Auditor
Belete Dessalegne	Animal Scientist
Bille, J-C	Ecologist
Chater, S	Translator/Editor
Cisse, S	Sociologist
Cossins, N	Team Leader/Rangelands Ethiopia
Danel, M-A	Assistant to the Director General/Board Secretary
de Haan, C	Director of Research

de Leeuw, P	Team Leader/Arid Zones
de Montgolfier-Kouevi, C	Economist
Dejene Araya	Chief Accountant
Dicko-Touré, M S	Animal Nutritionist
Diallo, A	Animal Scientist
Dudley, J	Maintenance Engineer
Durkin, J	Programmer
Dyson-Hudson, N	Social Anthropologist
Ephraim Bekele	Station Manager/Debre Zeit
Geerts, K	Administrator
Ghirma Tadege	Director of Administration
Gillard, A	Assistant Editor
Gosseye, P	Agronomist
Gryseels, G	Economist
Haywood, M	Photo Interpreter
Heyward, B	Animal Scientist
Hiernaux, P	Ecologist
Hill, D	Head of Training
Jahnke, H	Assistant to the Director General/Policy and Planning
Kahurananga, J	Ecologist
King, J	Animal Scientist
Konandreas, P	Economist
Larson, I	Personnel Officer
Lazier, J	Forage Agronomist
Le Houerou, H	Principal Scientist
Martin, A	Head of Information Services
Milligan, K	Coordinator/Aerial Survey
Mosi, A	Animal Nutritionist
Mukasa-Mugerwa, E	Animal Scientist
Okali, C	Socio-economist
Okuome, A	Administrator
Opassina, B	Veterinarian
Otchere, E	Animal Nutritionist
Portegies-Zwart, R	Information Specialist
Pratt, D	Director General
Ranaivojoelina, C	Librarian
Sall, M	Assistant to the Director General/Regional Coordination
Sayers, A R	Biometrician
Semenye, P	Animal Scientist
Sihm P	Research Coordinator
Smith, R	Pilot
Solomon Bekure	Team Leader/Rangelands Kenya
Sule, B	Range Scientist
Swift, J	Socio-economist

Thabit, A	Acting Financial Controller
Thersby, J	Warden
Thomas, A	Executive Officer
Trail, J	Animal Scientist/ Research Coordinator
Velez-Nauer, M	Team Leader/Humid Zone
von Kaufman, R	Team Leader/Subhumid Zone
Westley, S	Editor
Whalley, J	Farm Management Specialist
Wilson, R T	Animal Scientist
Wissocq, Y	Coordinator/Trypanotolerance Network