ILCA ANNUAL REPORT 1987

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA

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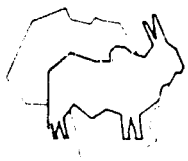

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
P.O.BOX 5689, ADDIS ABABA, ETHIOPIA

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Foreword

The revision of ILCA's research strategy was completed with its acceptance by the Consultative Group on International Agricultural Research (CGIAR) at International Centers' Week in October 1987. Along the way the strategy had been shaped by inputs from ILCA's staff and Board of Trustees, the Technical Advisory Committee (TAC) of the CGIAR, and participants at the 4th Biennial Meeting of Leaders of Livestock Research, Development and Training in Tropical Africa, held at ILCA headquarters in July 1987.

The strategy builds on the strength of ILCA's research, training and information programmes of the past. It focuses our activities on a limited number of commodities, species, zones and target groups.

With the completion of the strategy formulation, we subsequently embodied the principles of the strategy in our programmes and have begun the implementation of specific projects. We held thrust planning meetings late in 1987 at which scientists from ILCA, national agricultural research services (NARSs) in Africa and from outside the continent discussed the implementation of each research thrust and defined the major research priorities and methods. Scientists from 20 countries in sub-Saharan Africa took part in these meetings. The additional involvement of NARSs staff in the Biennial Meeting has ensured that we focus our programmes clearly on the needs of Africa, and on the development of strong and close collaboration with our African partners.

Since finalising our research, training and information programmes, we have completed the advance planning of our programmes and funding requirements for the period 1989 to 1993 inclusive. This process has helped us to clarify the medium-term objectives of our programmes, their expected outputs and the resources we need.

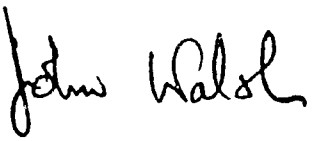
Our strategy emphasises collaborative research with African institutions, the NARSs, and training and information programmes that will help them develop their research capabilities. A major feature of our work now is the accelerated development of our collaborative research networks, which are the main vehicle for collaborative work with NARSs. Major networks are being aligned to each of our six research thrusts. Such networks enable us to collaborate with NARSs in research projects, to identify major funding, training and information needs and to adapt and test technologies.

The success of our collaborative research will depend largely on the NARSs, and we must improve our knowledge of them, their programmes,

problems and needs. In 1987 we surveyed the research activities and human and financial resources of African livestock institutions. Results from this survey are being incorporated in a database on NARSs in sub-Saharan Africa, which is helping us to identify partners for collaborative research and their training and information needs.

ILCA has already established many collaborative research projects and linkages with NARSs. In 1987 collaborative research was underway in 12 countries of sub-Saharan Africa: Benin, Congo, Côte d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Kenya, Mali, Niger, Nigeria, Senegal, Somalia, Togo and Zaire. Research support services (laboratory and computer analyses, aerial surveys) were performed for NARSs in Botswana, Burkina Faso, Côte d'Ivoire, Ethiopia, Ghana, Madagascar, Mali, Mozambique, Niger, Nigeria, Senegal and Sudan. ILCA's Data Entry and Analysis System (IDEAS—a microcomputer program for recording and analysing livestock data) has now been installed in Botswana, Cameroon, Congo, Côte d'Ivoire, Ethiopia, Gambia, Kenya, Malawi, Mali, Mauritius, Mozambique, Nigeria, Senegal, Swaziland, Tanzania and Zimbabwe. ILCA-coordinated networks now involve participants from almost all African countries.

We think that, through the further development of collaboration of this kind, livestock production in sub-Saharan Africa can be improved markedly. Our increasing links with African NARSs, and the realignment of our own research, hold promise for the development of more productive and sustainable livestock production systems for sub-Saharan Africa.



John Walsh
Director General

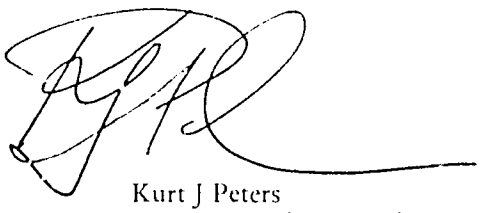
Introduction

1987 was a year of transition for ILCA, from a Research Department based on disciplinary units and zonal research programmes to one that follows the Centre's new thrust-based research concept. Much of the year was spent in refining the research structure outlined in the strategy document, and in assembling the resources to put the new research programmes into place.

This report is structured along the lines of the six research thrusts: Cattle Milk and Meat, Small Ruminant Meat and Milk, Animal Traction, Animal Feed Resources, Trypanotolerance and Livestock Policy and Resource Use. We believe that reporting the 1987 research programme under the thrust framework provides a useful indication of how a large part of the Centre's earlier work fits easily within the thrusts, and how the thrusts help focus ILCA's research at various sites.

The 1987 report is almost equally balanced between the commodity and strategic research thrusts. In future years this balance will change, with more of the report being taken up by commodity-thrust reports, as results from the strategic research feed into the development of improved technologies for the production of milk, meat and traction.

This Annual Report demonstrates the strength and depth of ILCA's research programme, and the focus provided by the thrust framework bodes well for future progress towards sustainable production from livestock in sub-Saharan Africa.



Kurt J Peters
Deputy Director General (Research)

ILCA's addresses

Headquarters

P.O. Box 5689, Addis Ababa, Ethiopia
Telex: 21207 ILCA ET
Tel: (251–1) 183215–25, 181128, 182455, 187047
E-Mail: CG I 804
FAX: 188191

Thrust coordination

Cattle Milk and Meat/
Small Ruminant Meat and Milk/
Animal Traction/
Animal Feed Resources/
Livestock Policy and Resource Use

P.O. Box 5689, Addis Ababa, Ethiopia
Telex: 21207 ILCA ET
Tel: (251–1) 183215–25, 181128, 182455, 187047
E-Mail: CG I 804
FAX: 188191

Trypanotolerance

P.O. Box 46847, Nairobi, Kenya
Telex: 22040
Tel: (254–2) 592066

Zonal research sites

Highlands

P.O. Box 5689, Addis Ababa, Ethiopia
Telex: 21207 ILCA ET
Tel: (251–1) 183215–25, 181128, 182455, 187047
E-Mail: CG I 804
FAX: 188191

Humid zone

PMB 5320, Ibadan, Nigeria
Telex: 31417
Tel: (234–22) 413440

Subhumid zone

PMB 2248, Kaduna, Nigeria
Telex: 71384
Tel: (234–62) 211389

Semi-arid/Subhumid zone

BP 60, Bamako, Mali
Telex: 2459
Tel: 222177

Semi-arid zone

P.O. Box 46847, Nairobi, Kenya
Telex: 22040
Tel: (254–2) 592066

ILCA/ICRISAT
BP 12404, Niamey, Niger
Telex: 5406 Tel: 722509

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Cattle Milk and Meat Thrust

Despite a daunting array of technical, policy and institutional problems, there are major opportunities to increase cattle milk and meat production in many parts of Africa. These opportunities take different forms according to ecological zone and region:

- In humid West and central Africa, the potential is vast in the long term if trypanosomiasis and dermatophilosis can be controlled and the number of cattle of appropriate breeds increased.
- The subhumid zone of West Africa offers perhaps the best opportunity in the medium term, because of its reasonable potential for forage production combined with comparative freedom from tsetse fly, lower cultivation pressure on the land and a relatively large existing cattle herd.
- The highlands of East Africa are well supplied with meat but also offer a major market for milk if forages can be accommodated in cropping systems.
- In southern Africa markets are smaller, but the economic environment appears to be relatively favourable, offering an opportunity for geographical expansion of our efforts in sub-Saharan Africa.

In the first three zones, the need or opportunity to create an impact appears to be greatest. However, we also recognise the need to conduct relevant research in those parts of the semi-arid zone where seasonal milk surpluses are available, indicating that dairy production there can be enhanced.

Objective

The main objective of the Cattle Milk and Meat Thrust in the medium term is to find solutions to the major constraints to increased cattle milk and meat production in the mixed crop–livestock smallholder farming systems of sub-Saharan Africa.

Reproductive wastage and hygiene management

The poor reproductive performance of zebu cattle is primarily attributed to (1) late puberty and sexual maturity in males and females and, therefore, late

age at first parturition, (2) long postpartum anoestrus periods resulting in long calving intervals and (3) overall low fertility rates. These factors which are caused by interactions of poor nutrition and husbandry, and disease, are responsible for high reproductive wastage in zebu cattle.

The main focus of work under this theme is on determining the basic constraints to cattle reproduction so that strategic interventions can be designed to reduce their impact on animal productivity, especially in smallholder farming systems. The effect of health on reproduction and overall livestock productivity is also being researched. At present the work is carried out only in Ethiopia, but research protocols were prepared in 1987 for similar work in Kenya, Mali and Nigeria.

The research is primarily directed towards quantifying the effect of strategic nutritional supplementation on growth and reproductive performance of young animals and the postpartum cow. As part of an evaluation of specific reproductive physiology patterns in zebus, studies were undertaken to characterise the oestrous cycle of the East African Zebu, pubertal development of growing heifers and bulls, reproductive capacity of mature bulls, and the influence of nutritional supplementation and suckling intensity on the postpartum reproductive performance of zebu cows.

Zebu cow reproductive function

Factors affecting oestrous pattern of zebu cows

The oestrous behaviour of the zebu cow was studied in order to better understand its physiology and thereby improve its exploitation in crossbreeding programmes. A study on the sexual behaviour of 28 zebu cows was completed in 1987 at ILCA's Debre Berhan station.

The average length of the oestrous cycles was 22.6 ± 6.5 days, with a range from 17 to 63 days. Most cycles (89%) lasted 18 to 24 days, with no significant ($P>0.05$) difference between seasons. The average duration of oestrus was 7.6 ± 4.6 hours, with a range from 1 to 24 hours. Mean oestrus duration was significantly ($P<0.05$) longer during the dry season than during the wet season (8.9 ± 4.6 vs 7.0 ± 4.4 hours).

More oestrus periods occurred during the day than at night (59.3 vs 40.7%; $P<0.001$). This difference was greater during the dry season (62.5 vs 37.5%) than during the wet season (56.5 vs 43.5%). Irrespective of season, mounting activity was low between sunset and dawn but increased towards sunrise. Similar to oestrus onset pattern, daytime mounting activity showed two prominent peaks: from 0630 to 1030 hours and 1430 to 1830 hours, during which 18.7% and 29% of the mounts occurred (Figure 1). Most mounting activity occurred at the beginning and end of the oestrus period. Ovulation occurred 25.8 ± 5.2 hours after oestrus onset, primarily during the day (62.5 vs 37.5%) and from the right ovary (54.2 vs 45.8%).

Nutrition and pubertal development of heifers

Nutritional supplementation hastens the onset of puberty in both zebu and crossbred heifers, even if the supplementation is limited to the prepubertal dry season. Subsequent pregnancy percentage was almost doubled by supplementation in zebu heifers and increased by 10% in crossbred heifers (Table 1).

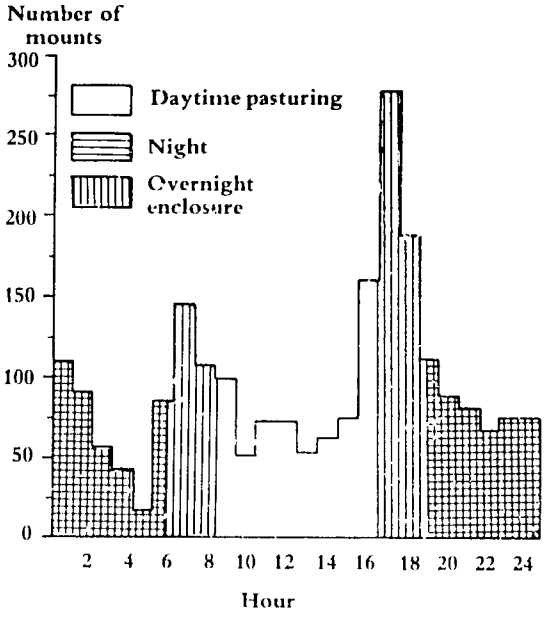


Figure 1.
Distribution of mounting activity in zebu cows over 24 hours (pooled data), Debre Berhan, Ethiopian highlands, 1987

Data are being analysed to determine the relationship between visual observation, ovarian palpation and plasma progesterone values as indicators of the onset of puberty in heifers. A number of blood metabolites are also being assayed to assess their importance in evaluating the nutritional status of animals and the relationships of the metabolites to onset of puberty and subsequent fertility.

Reproductive performance of postpartum cows

Effect of body weight and body condition at mating on postpartum reproductive performance of zebu cows

A 2-year study on the major factors influencing the reproductive performance of the postpartum zebu cow in four single-sire breeding units approached

Table 1. *Growth and reproductive parameters of Boran and Boran-Friesian heifers mated over a 4-month breeding season, Ethiopia, 1987.*

	Boran		Boran-Friesian	
Parameters	Supplemented	Control	Supplemented	Control
No. of heifers	21	24	22	20
No. mated by 120 days	13 (61.9)[a]	8 (33.3)	20 (90.9)	16 (80.0)
No. pregnant	11 (52.3)	6 (25.0)	19 (86.3)	15 (75)
Mean body weight (kg) at beginning of breeding	200	175	230	213
Mean body weight (kg) at end of breeding	236.4	219.8	296.1	282.7
Mean wither height (cm) at beginning of breeding	112.5	113.2	116.1	117.4

[a] Numbers in brackets indicate percentages.

completion at Abernossa ranch. Preliminary analyses of data collected during the 1987/88 breeding season indicate an average pregnancy rate of 84% in Boran cows. Changes in body weight and body condition during the breeding season seem to have a greater effect on pregnancy rate than body weight at the beginning of the breeding season.

The pregnancy rate of non-lactating cows was about 5% higher than that of lactating cows. This difference was small, probably because the animals were all in good condition at the beginning of the breeding season, which coincided with the end of the wet season.

Effect of supplementation and suckling intensity on postpartum reproductive performance of zebu cows

A study at Gobe ranch on the influences of nutritional supplementation and suckling intensity on the postpartum reproductive performance of zebu cows that calved during the dry season was completed in 1987. Preliminary analyses of the data indicate that supplementing feed with urea/molasses blocks (10% urea) shortened the postpartum anoestrus period by 67 days in continuously-suckled Arsi Zebu cattle (199 vs 132 days) and by 46 days in cows suckling their calves only twice a day (159 vs 113 days) (Table 2). Restricted suckling also reduced the postpartum anoestrus period in both supplemented and unsupplemented animals. Supplementation reduced preweaning calf mortality by 8 and 20% in continuously- and restricted-suckled groups, respectively.

Neither cow supplementation nor suckling intensity had a marked effect on calf growth rate or calf weaning weight. Similarly, no differences in cow body weight and body condition changes were observed in the four treatment groups.

Plasma progesterone levels are being assayed to establish the pattern of release of the hormone in postpartum Arsi Zebu cows and its relationship to the resumption of postpartum ovarian activity. Selected blood metabolites are being assayed to determine the nutritional status of cows and its relationship with postpartum ovarian activity and subsequent fertility in these cows.

Table 2. *Postpartum anoestrous interval in zebu cows at Gobe, Ethiopia.*

Treatment group	Postpartum anoestrous period (days)		
	Supplemented	Unsupplemented	Difference
Continuous suckling	132.3	199.0	66.6
Restricted suckling	113.5	159.3	45.8
Difference	18.8	39.7	

Reproductive studies on male animals

Using superior bulls improves herd fertility and hastens genetic progress. Variation in bull fertility can be responsible for large differences in conception rates. Reproductive traits must, therefore, be an integral part of the selection process.

Several studies were undertaken to (1) characterise the effects of scrotal circumference, epididymal weight, epididymal sperm reserve and sperm concentration on the reproductive capacity of bulls, (2) assess the influence

of season on the reproductive capacity of mature zebu bulls, (3) characterise the patterns of sexual development and maturity in zebu and crossbred bulls based on quantitative histology, (4) determine the influence of dry-season nutritional supplementation on growth, sexual development and sexual maturity in zebu and crossbred bulls, and (5) determine the influence of bulls on herd fertility in a single-sire mating system with Boran cattle at Abernossa ranch.

Preliminary results indicate that zebu bulls matured sexually later, had smaller and lighter testes and epididymides, smaller seminiferous and epididymal tubule diameters and fewer sperm reserves than crossbred bulls of the same age. They also tended to produce a smaller volume of ejaculate than crossbred bulls, with lower sperm concentrations at puberty. Dry-season nutritional supplementation reduced age at puberty in both zebu and crossbred bulls, and increased testicular size and semen quality. Nutritional supplementation raised testosterone levels in both genotypes. In a single-sire mating system with Boran cattle, sire-bull had an important effect on pregnancy rate of cows. Pregnancy rate ranged from 78 to 92% for four sire-bulls and was related to some semen traits of the bulls at the beginning of the mating season.

Feeding and management systems

Research under this theme focuses on developing combined feeding and management technologies to increase milk and meat output from smallholder production systems. In 1987 studies were conducted in Nigeria, Ethiopia and Mali.

Supplementary feeding of calves

Phosphorus supplementation for calves in the Ethiopian highlands

In Ethiopia, as in many tropical countries, the diet of calves after weaning is almost exclusively low-quality roughage, either native grass hay or crop residues. This diet is low in protein, digestible energy and essential mineral nutrients, particularly sodium, phosphorus and copper. A study was conducted in 1987 to examine the response of Friesian-zebu crossbred calves to supplementary P.

The calves were fed a basal diet of native grass hay, supplemented with molasses/urea (10% urea) (control group), molasses/urea plus potassium dihydrogen phosphate (KH_2PO_4), or noug cake (*Guizotia abyssinica*). The amount of phosphorus supplied by the KH_2PO_4 was equivalent to that supplied by the noug. All three diets supplied similar amounts of N.

The growth rate of calves receiving inorganic P was significantly greater than that of control group calves (181 vs 119 g d^{-1}; $P<0.01$). The growth rate of calves receiving noug was significantly higher than that of calves supplemented with inorganic P (287 vs 181 g d^{-1}; $P<0.01$). There were no significant differences among the groups in feed intake or digestibility. Supplementary P from noug was used more efficiently for skeletal mineralisation than that from KH_2PO_4.

The results of this study indicate that supplementary P and N provided by protein, e.g. from oilseed cake, are used more efficiently than if provided by non-protein N and inorganic P.

Supplementing calves in the Nigerian subhumid zone

An earlier study on the effects of supplementary feeding on the productivity of cows in agropastoral herds in the Nigerian subhumid zone (see *ILCA Annual Report 1985/1986*) showed that the greatest effect was on calf survival, which increased from 71.8% to 86.3% ($P<0.001$). This was due to increased milk production by the cows. However, milk offtake increased only slightly, from 300.2 to 312.5 litres per annum. Herd owners milked supplemented cows longer than unsupplemented cows and thus extended their lactation anoestrus period. As a result, supplementary feeding had no significant effect on calving percentage (58.1% vs 53.8%). These results indicated the need to supplement calves directly to encourage increased milk offtake and early weaning.

Calves in three herds were therefore supplemented with cottonseed cake and wheat bran during three dry seasons. Measurements taken included calf survival and weight gain, and milk offtake, calving/conception rate and calving interval of the dams.

Supplementary feeding did not significantly ($P>0.05$) affect calf weight gain or survival. Milk offtake was also not affected by calf supplementation. The calving/conception rate of cows with supplemented calves (58.3%) was 28% higher than that of cows with unsupplemented calves. They also had significantly ($P<0.05$) shorter calving intervals than those with unsupplemented calves (Table 3). These results indicate that supplementing the calves reduced lactational and nutritional stress on the dams.

Table 3. *Status of cows with supplemented and non-supplemented calves in 198*, subhumid zone, Nigeria. Observed effects are due to calf feeding practice in 1985 dry season.*

	Supplemented		Non-supplemented	
Class	No.	%	No.	%
Total number	24		11	
Calved	12	50.0	5	45.5
Pregnant	2	8.3		
Open			1	9.5
Sold	6	25.0	2	18.2
Died	4	16.7	3	27.2
Calving interval (days)	745		788*	

* Treatment effect significant at $P<0.05$.

The use of locally available feeds for supplementing calves in southern Ethiopia

During the dry season, grasses available on unimproved grazing lands are deficient in both energy and protein. Although much work has been done on the introduction of legumes to correct this deficiency, very little work has been conducted to determine the usefulness of native legumes already utilised by African agropastoralists for dry-season supplementation of ruminants.

This research evaluated three locally available legumes as protein and energy supplements for calves in the rangelands of southern Ethiopia. The study compared fruits from *Acacia tortilis*, leaves from *A. brevispica*, and cowpea hay (*Vigna unguiculata*) with lucerne (*Medicago sativa*) hay. Initially a growth trial was conducted with sheep to determine the nutritive value of

these feeds when used as supplements to poor-quality hay. Six entire male Menz sheep were assigned to each diet. *Acacia tortilis*, *A. brevispica*, *V. unguiculata*, and *M. sativa* were fed at levels that supplied 50 g of crude protein a day. Unsupplemented hay was used as the control.

All supplements increased the growth rate of sheep over the hay diet alone and there was no significant difference in growth rates among the supplements (Table 4). All supplements had a substitution effect on hay intake (Table 4). Total intake was highest for the cowpea treatment and lowest for hay. These results indicate that locally available feed resources in southern Ethiopia are equal to lucerne as supplements to diets of poor-quality grass hay.

Further experimentation is being conducted to validate these results. A metabolism trial with sheep will determine the utilisation of protein in the feeds. A calf growth trial under simulated pastoralist management will validate the use of the feeds as supplements for calves.

Table 4. *Intake and growth rate of sheep fed locally available feed resources as supplements to poor-quality grass hay, Ethiopia, 1987.*

	Acacia tortilis (fruits)	*Acacia brevispica* (leaves)	*Vigna unguiculata* (hay)	*Medicago sativa* (hay)	Grass hay
Growth rate ($g\ d^{-1}$)	52.6a	53.1a	56.5a	53.1a	31.2b
Grass hay intake ($g\ d^{-1}$)	423b	510b	470b	488b	680a
Total intake ($g\ d^{-1}$)	759a	747a	810a	790a	680b

Within rows, means followed by the same letter do not differ significantly ($P<0.05$).

Partial suckling

The effects of partial suckling on the productivity of F_1 Friesian×Boran crossbred dairy cows were examined at Debre Berhan, in the Ethiopian highlands. Although it is generally recognised that the calf must be present to stimulate milk letdown in zebu cows, this is not thought to be necessary with these crossbred cows. Under Ethiopian Ministry of Agriculture recommendations, calves are not suckled other than immediately after parturition, and the calves are reared by bucket feeding. In practice it is common for them not to be suckled at all. However, work elsewhere has demonstrated that partial suckling increases milk offtake, reduces calf mortality and morbidity, increases calf growth and improves udder health.

In this experiment, partially-suckled calves were allowed to suckle their dams for 2 minutes before each milking until weaning at 3 months of age, while bucket-reared calves received a total of 255 kg of milk over the same period. The treatment of bucket-reared calves was comparable to current Ministry of Agriculture recommendations. Dams in each group were fed grass hay *ad libitum* and supplements of 2 kg of noug cake per day and *ad libitum* molasses/urea (10% urea). Key results are shown in Table 5.

Partial suckling significantly increased calf growth rate to weaning, from 0.31 to 0.53 kg $head^{-1}\ d^{-1}$ ($P<0.01$). There were no differences in calf growth after weaning, and the 20 kg difference in liveweight achieved by weaning persisted until the calves were 9 months old, when observations on them ceased.

Total milk offtake was not significantly affected by treatment, although the lactation milk offtake from partially-suckled cows exceeded that of unsuckled cows by 15%. Partial suckling delayed return to oestrus after calving, but this was partly compensated for by the fewer services per conception needed by partially-suckled animals, and calving interval was not significantly increased.

Table 5. *Mean productivity characteristics of crossbred cows and their calves, subjected to either partial suckling or bucket rearing, Debre Berhan, Ethiopia, 1987*

	Treatment	
	Partial suckling	Bucket rearing
Milk offtake		
Pre-weaning (litres)	459.6	455.6
Whole lactation (litres)	1894.1	1644.6
Lactation length (days)	341	305
Calf growth		
Birth to weaning (kg d^{-1})	0.53	0.31**
Weaning to 9 months (kg d^{-1})	0.42	0.41
Reproductive data		
Calving to first oestrus (days)	101	41*
Services per conception	1.3	1.9
Calving interval (days)	391	355

* Difference significant at $P<0.05$

** Difference significant at $P<0.01$

The total milk production of the cows with bucket-reared calves (i.e. offtake plus calf allowance) was virtually identical to the total milk offtake from the partially-suckled cows (2000 vs 1894 litres).

A second trial was started to examine the effects of basal ration quality on responses to partial suckling. Over the first 60 days of lactation, partial suckling significantly increased calf growth rate (0.55 vs 0.41 g d^{-1}; $P<0.05$). Preliminary results indicate that milk offtake is increased by both partial suckling (20%) and by feeding a higher-quality basal ration; cows fed oaten hay yielded 15% more milk than those fed native grass hay. Final results, including the effects of partial suckling on feed intake of cows, will be compiled at the end of the experiment in 1988.

In a comparison of the effects of partial suckling on first-calf F_1 Friesian × Arsi heifers and 75% Friesian heifers, partial suckling had a greater effect on milk offtake in the F_1 heifers. This was due to milk letdown problems in F_1 heifers when they were milked in the absence of the calf.

The results accumulating from these studies indicate that partial suckling offers substantial advantages for smallholder dairying using crossbred cows, especially where feed quality is sufficiently high to support high levels of milk production.

Heifer rearing using crop residues and byproducts

An experiment was conducted at Debre Zeit, Ethiopia, to determine whether poultry litter can replace urea in molasses/urea mixtures given as a

supplement to growing heifers fed a ration based on *ad libitum* maize stover. Replacing urea with poultry litter would reduce feed costs and increase adoption at the smallholder level.

Two weight classes of crossbred heifers, initially weighing 165 and 230 kg, were used. Control animals were fed 500 g a day of a 10% urea/molasses mixture. In the treatment groups the 50 g of urea were replaced by 250 or 500 g of poultry litter, which supplied approximately 45 and 90%, respectively, of the quantity of N supplied by the urea. Over 4 months there were no significant differences in rates of weight gain among the groups. Daily weight gains were 310, 233 and 270 g, respectively. The slightly lower rates for the poultry litter groups were commensurate with the lower levels of supplementary N.

It appears that poultry litter can substitute for urea in such rations, and work is in progress to establish the optimal inclusion rate of poultry litter for post-weaning calf-rearing packages in which the major feed resource is low-quality crop residue.

Feeding strategies in the Nigerian subhumid zone

Improving cattle nutrition continues to be the major focus of ILCA's research at Kaduna in the Nigerian subhumid zone. The main innovation under test is the fodder bank package, aimed at providing supplementary protein during the dry season.

Herds with access to reasonably well established and managed fodder banks are significantly more productive than those without access to fodder banks, but their productivity is still far below breed potential. There are three possible reasons for this:

- lack of protein in the herbage is not the only constraint on animal productivity;
- the quantity or composition of the protein supplement may be inadequate; or
- the feeding regime might not be appropriate.

Research has now started on mineral nutrition and on an alternative source of protein to supplement the legumes. The feeding regime is also being reassessed.

Mineral nutrition

Earlier chemical analyses of soils and plants indicate that deficiency of minerals, particularly phosphorous, may be seriously limiting the productivity of cattle. A trial was set up in cooperation with the National Veterinary Research Institute, Vom, to investigate the incidence of mineral deficiency in agropastoral herds, determine the extent to which mineral supplementation is traditionally practised and determine the effect of regular mineral supplementation on the productivity of herds with and without access to fodder banks.

The study covers about 600 animals in 16 herds belonging to agropastoralists in three locations. The locations differ in the proportions of land under range, cropping or flood plain and thus differ also in feed resources. These differences facilitate assessment of the impact of mineral supplementation under a range of feeding conditions. Animals are offered complete mineral blocks supplying all essential elements. Control-group animals are offered sodium chloride blocks since salt is traditionally provided by the herd owners. Table 6 shows the treatment groups and cattle numbers. Another group of animals that receive no supplement was added later.

The condition of all animals improved through the end of the wet season in October (Table 7). Although mineral supplementation was started only in August it appears to have already had an effect on animal condition by November.

Table 6. *Treatment groups and cattle numbers, mineral supplementation trial, Nigeria, 1987.*

Location	Treatment	Mineral supplement	Salt supplement only	Total
Kurmin Biri	+F/B (A)	110	159	269
Kurmin Biri	−F/B (B)	52	33	85
Madauchi	−F/B (C)	75	55	130
Ganawuri	−F/B (D)	70	56	126
Total		307	303	610

Treatment: A Kurmin Biri – animals with fodder bank.
B Kurmin Biri – animals without fodder bank.
C Madauchi – animals without fodder bank.
D Ganawuri – animals without fodder bank.

Table 7. *Mean condition score of mineral- and salt-supplemented animals, Nigeria, August–November 1987.*

	With minerals		With salt only	
Treatment	August	Nov	August	Nov
A	3.1	4.1	3.4	3.6
B	2.9	4.4	2.9	4.1
C	3.4	3.0	3.5	2.8
D	3.7	4.5	3.8	4.3

Feed supplementation and cattle productivity in agropastoral herds in Mali

The aim of this study is to determine the impact of dry-season feed supplementation on the productivity of cattle herds in the agropastoral systems of Niono region, in the semi-arid zone of Mali.

The study was conducted in two villages, Kala Nampala in the millet subsystem and B10 in the rice subsystem. Pregnant cows were fed 3.5 kg of cowpea daily at Kala Nampala and 1 or 2 kg of coarse rice flour daily at B10. The basal diets were bush hay at Kala Nampala and harvested rice residues at B10. The supplementary feed was provided for approximately 3 months before calving. Feed supplementation:

- improved the physical condition of animals at Kala Nampala;
- increased total milk production by 17% at Kala Nampala and by 37% at B10;
- reduced calving interval at Kala Nampala;
- increased birth weight by 27% at Kala Nampala and by 17% at B10; and
- increased calf growth up to 90 days at Kala Nampala and up to 60 days at B10.

Feed resource assessment in semi-arid Kenya

The semi-arid region in Kenya constitutes about 20% of the land mass (11.4 million ha), contains 18% of the human population (2.8 million) and 35% of the livestock biomass (4 million cattle, 3 million sheep and 4 million goats). Smallholder farmers occupy 25% of the land, comprise over 70% of the total population and keep 1 million cattle and 3 million small ruminants.

Since 1986 ILCA has participated in on-farm research started by the National Dryland Farming Research Station and UNDP/FAO in Machakos District. The emphasis is on developing feeding systems for crossbred dairy cows in order to achieve increased and sustained production of milk for domestic use and sale.

The farms being studied are in the southeastern part of Machakos District and are representative of smallholder mixed-farms in the semi-arid zone of eastern Kenya. The area receives 700–800 mm mean annual rainfall, with 250–300 mm in each of the two growing seasons. Overall farm size ranges from 4 to 15 ha. The area of cropped land increases from 2.5 to 5.0 ha with increasing farm size. Most cropped land is planted with maize/grain legume intercrops. The amount of land potentially available for grazing ranges from about 1 hectare on small farms to 6–10 hectares on larger farms.

Assessment of feed resources

The principal components of the feed resources were sampled during 1987 to provide a basis for the development of feed budgets and feeding strategies. Sampling concentrated on rangeland vegetation, maize residues and planted forages.

Rangelands and pastures. Early in the wet season grazing pressure on the rangelands was high and standing biomass ranged from 0.3 to 1.0 t DM ha^{-1}. On ungrazed land accumulated yields of up to 5 t DM ha^{-1} were measured after a growing season of 3 months. However, a grazable yield of 1.2 t DM ha^{-1} per season was assumed in budgeting feed resources.

Terrace bunds occupy an average of 10% of the cropped land on most farms. On well-managed farms, indigenous perennial grasses (*Cenchrus ciliaris, Panicum maximum, Cynodon dactylon, Chloris roxburghiana* etc) growing on the bunds yield up to 5 t DM ha^{-1} at the end of the growing season. Thus, 3 ha of terraced cropland could produce 1.5 tonnes of hay twice a year.

Maize residues. The maize crop in the 1987/88 short rains provided an estimated 1.64 t DM of edible residue per hectare (Table 8), compared with about 1 tonne per hectare for maize crops in the 1987 long rains.

Planted forage. Bajra (*Pennisetum purpureum*×*P. typhoides*) was planted as a forage crop in late 1984 but was not exploited for cut-and-carry fodder until crossbred cows were issued in early 1986.

Early in the short dry season (February 1987) farmers had an average of 2.2 t DM of standing grass crop per hectare. Heavy exploitation of the crop for feed had reduced the standing crop to 0.6 t DM ha^{-1} in July. Applying farmyard manure at the end of the long dry season, in late October 1987, increased plant cover and plant height and doubled yields (Table 9). However, the increase in edible leaf was less because of the increase in the proportion of stem in taller plants.

Although the potential production of planted forage is much higher, a realistic estimate of forage output is 3 t DM ha^{-1} per season, 6 t $year^{-1}$.

Table 8. *Average yields of maize residues in cluster farms in semi-arid eastern Kenya.*

Components	Total yield (t DM ha^{-1})	Edible yield	
		Percent of total	t DM ha^{-1}
Grain	1.0	20[1]	0.20
Husks and cobs	0.4	60	0.20
Leaves	0.8	90	0.76
Stalks	1.6	30	0.48
Total	3.8	41	1.64

[1] Spilt grain and bran.

Table 9. *The effect of manure on yield parameters of bajra grass (Pennisetum purpureum × P. typhoides)[1], semi-arid eastern Kenya, 1987.*

Parameters	Manure application (t fresh weight ha^{-1})		
	0	4	8
Plant cover (%)	52	96	91
Canopy height (m)	0.8	1.4	1.5
Green yield (t ha^{-1})	10.3	24.7	24.2
Dry yield (t ha^{-1})	3.2	7.4	7.3

[1] Mean of two farms with three replicates in each.

Feed budgets

Estimated annual fodder production ranged from 15 t DM a year on 5-hectare farms to 40 t DM a year on 15-hectare farms. On small farms crop residues and planted forages provided 80% of all fodder, compared with only 30–40% on the larger farms. Feed availability per TLU varied from 2.1 to 4.0 t DM per year (5.7 to 11.0 kg DM d^{-1}). Thus feed availability was generally adequate.

Condition scores of cattle at the end of the long dry season (September) also indicated that feed supplies were generally adequate. Only 12% of cattle scored were in poor condition, while 54% were in fair condition and 33% were in good condition. Cattle on larger farms tended to be in better condition than those on smaller farms.

Feeding strategy

The current feeding system cannot support high-yielding crossbred dairy cows. The planned feeding strategy is based on supplementing the basal diet of grazing, maize stover and grain-legume residues from 1 ha of planted forage (0.5 ha grass, 0.5 ha leucaena). The planted forage would provide 4.5 t DM, which would be sufficient to supplement two crossbred cows and their followers, delivering a diet averaging 55% digestibility and 8% crude protein throughout the year.

At current milked-out yields of 5–7 litres a day over 9 months, annual output from a crossbred cow is approximately 1100 litres of milk and 100 kg

of calf liveweight. At KShs 3.5 per litre of milk and KShs 40 per kg liveweight this production is valued at KShs 4850 (US$300). The maximum productivity that could be expected from a zebu cow is 450 litres of milk and 70 kg of calf, for a value of KShs 2300 per lactating cow per year.

Changing systems and the role of cattle

Cattle in the derived savannah of humid Nigeria

A survey of cattle in the derived savannah of the Nigerian humid zone was started in the dry season 1986 and continued during the 1987 rains. It showed a large and relatively settled and stable population of cattle based permanently in the zone. Most of the cattle were of non-trypanotolerant northern breeds. The predominant management and ownership system is that of the Fulani-owned herd managed by the extended family. There is little seasonal migration, feed supplements are used relatively little and the use of veterinary inputs is variable. Nevertheless, herders consider disease and poor feed quality to be the main constraints on productivity.

In a concurrent study, trypanosomiasis infection rates varied between 3% and 28% in cattle herds in various states in southwest Nigeria. The overall infection rate was 14%. Rates were higher in the wet season than in the dry season.

Bunaji-Friesian crossbred cattle grazing a pastoralist's fodder bank in the late wet season, Kurmin Biri, Nigeria. Better feed resources allow use of more productive crossbreds for milk and meat production.

Crop–livestock interactions in northern Nigeria

A survey in northern Nigeria during 1987 showed that crop–livestock interactions vary widely among agro-ecological zones. The value placed on crop residues is higher in drier zones. Residues are grazed free in the subhumid zone around Kachia, while in the drier areas of Bauchi and Katsina pastoralists have to pay farmers for access to crop residues. Manure is cheap in Kachia but expensive in Bauchi and especially in Katsina, where there is a well-defined market for manure. Animal traction is not used in Kachia but is widely used in Bauchi and Katsina.

The demarcation between ethnic groups that own livestock and those that are crop farmers is most prominent in Kachia, where they form separate communities. In contrast, many of the farming groups in Bauchi and Katsina trace their ancestry to sedentarised pastoralists. These differences are reflected in land ownership patterns, which can influence the adoption of technologies that involve the use of land. Settled pastoralists in Bauchi and Katsina own the land they farm and hence may find it easier to adopt fodder banks and other forage technologies than the FulBe, such as those in Kachia, who have to negotiate with local farmers for land on which to plant forages. These problems may not be readily evident in the short run when, for example, there are only a few fodder banks but they are likely to affect adoption in the long term.

Combined farming and livestock ownership in northern Nigeria

As noted above, the typical situation in the subhumid zone around Kaduna is ethnic specialisation into cultivating and agropastoral communities. However, at Ganawuri, adjacent to ILCA's other case study areas, although the people are typically cultivators some own cattle. It was thought that ownership of cattle by cultivators is increasing and ILCA, in cooperation with the University of Bergen, has been investigating the implications of this trend for innovation.

In contrast to earlier assumptions, it was found that the proportion of Aten households in Ganawuri that owned cattle in 1987 was similar to that reported in the early 1960s (12 vs 13%). Thus there is no apparent increase in the ownership of cattle by cultivators in the area. The agropastoral FulBe still own more than 90% of the cattle in the area. There is little integration of herding with cropping. About 70% of the land is cultivated, which provides ample crop residues and weeds for dry season feeding. However, during the rainy season there is a shortage of grazing, made worse by the lack of access between cropped fields to fallow lands. As a result, the FulBe move their herds to areas as far away as Gombe and Bauchi to find grazing during the crop growing season. Cattle belonging to farmers are restricted to hillsides which, although in the neighbourhood of the farms, are too far to allow integration of herding with cropping. Fields owned by family units are small and widely dispersed. It is thus unlikely that forage innovations for cattle will be widely adopted, and true mixed farming is not practicable.

Although the importance of cattle to the Aten farmers seems to be declining, that of small ruminants, mainly goats, is increasing. Fifty-five percent of Aten households own goats. Innovations aimed at small ruminants therefore have a much larger target audience. They are also easier to adapt to the current farming practices because, for example, fodder banks for small ruminants are smaller than those for cattle.

A Fulani pastoralist with a day-old calf and its dam, Nigeria. Shorter calving intervals and higher calf growth rates are needed to increase cattle productivity.

Herd management and productivity in Mali

This study aims at identifying the causes of differences in productivity among herds in the same production system. Data on herd productivity and management were collected at the village level.

Sixty household flocks of small ruminants in four villages and 37 cattle ownership units in three villages were routinely monitored with a view to identifying the causes of productivity differences among herds in the same production system. Data on herd productivity and management (feeding, health etc) were collected and the analysis of the 1986/87 data is underway. Meanwhile, farmers in six of the study villages were surveyed to determine:

- their perception of the factors that influence herd productivity
- what they perceive as evidence of productivity and
- their principal purpose for keeping small ruminants.

Preliminary results show that farmers believe herd productivity is influenced by geographical location, availability of natural forage, self-sufficiency in cereals, and management system and species raised. Evidence cited for increased productivity includes:

- increased milk production and total number of animals cited by farmers in the millet subsystem, and
- weight gains cited by farmers in the rice subsystem.

The production goal mostly cited by livestock producers in the millet subsystem was to have animals as a store of wealth that can be used during periods of drought, to pay taxes and during religious ceremonies. In the rice system, the most important goal is to increase the size of the herd.

The agropastoralists in the sample believed herd productivity depends to a large extent on the herder and that a good herder is an assurance of high herd productivity.

Milk production in Mali

The importance of milk production in Mali was investigated as part of a joint project between ILCA and the Institut national de recherche zootechnique, forestière et hydrobiologique (INRZFH). A survey of 450 households in subhumid Mali at the end of the 1987 rainy season showed that daily milk offtake averaged 2.9 litres per family, 72% from cattle and 28% from small ruminants. The households milked an average of 1.38 cows and 1.54 small ruminants. Average daily offtake was 0.9 litres per cow and 0.31 litres per small ruminant.

Although 18% of the total milk offtake was sold, only 11% of families sold milk. Milk was primarily sold by the traditional herder group, the Peul. Other ethnic groups retained almost all their milk for home consumption. Little milk was processed because producers generally thought that total offtake was too small to justify processing. Where milk was processed it was allowed to sour or was churned to provide butter for home consumption.

CATTLE MILK AND MEAT THRUST STAFF

P Chigaru, *Thrust Coordinator*
A N Atta-Krah, *Agronomist*
P Bartholomew, *Forage Agronomist*
R Brokken, *Economist*
S Debrah, *Economist*
M Diagayete, *Animal Scientist (Post-doctoral Associate)*
A K Diallo, *Animal Scientist*
P A Francis, *Agro-economist*
O B Kasali, *Veterinarian*
R von Kaufmann, *Agricultural Economist*
P de Leeuw, *Ecologist*
D A Little, *Animal Nutritionist*
M Mattoni, *Veterinarian*
M A Mohamed-Saleem, *Forage Agronomist*
E Mukasa-Mugerwa, *Veterinarian*
J D Reed, *Animal Nutritionist*
L Reynolds, *Animal Scientist*
W Thorpe, *Animal Scientist*

Small Ruminant Meat and Milk Thrust

Meat from sheep and goats accounts for almost 30% of the meat consumed in Africa, and is an especially important marketable commodity for the poorer farmers in sub-Saharan Africa. Consumer demand is particularly high during religious festivals and cultural celebrations.

ILCA's research on small ruminants is located in three major areas:

- The semi-arid zone—perhaps the most important, in terms of both need and potential payoff, and where there is room for considerable growth in 'exports' of live animals to major consumer areas.
- The highlands of East Africa, selected because they provide a major opportunity for increasing the production and marketing of sheep.
- The humid zone, and to some extent the subhumid zone, of West Africa, where we seek to raise the productivity of both sheep and goats and where both the markets and the potential for forage production exist.

Objective

The objective of the Small Ruminant Meat and Milk Thrust in the medium term is to develop solutions to the constraints to increased production of small ruminant meat and milk in the mixed crop-livestock farming systems of sub-Saharan Africa.

Economics of small ruminant production

Innovations aimed at increasing small ruminant production will only be widely adopted if they are closely linked to the socio-economic environment in which they are to be used. Work under this theme is aimed at providing greater knowledge of the socio-economic conditions under which increased small ruminant production is feasible.

Small ruminant marketing in humid Nigeria

Price data from southwest Nigeria were used to assess the efficiency of the small ruminant marketing system. Regression analysis showed that between 65% and 84% of the variation in animal prices was accounted for by animal characteristics (i.e. species, breed, sex and weight), the time of sale and the market in which the animal was sold. This indicates that traders are not able to use privileged knowledge to obtain inflated margins. The correlations be-

tween the price of animals in pairs of markets at particular times were also relatively high, with coefficients of about 0.8. Although this does not prove that markets are integrated, it provides no evidence for their segregation.

The price margins between markets are considerably higher than the direct costs of transporting animals between them. But the difference is largely accounted for by the other costs involved in marketing, such as storage and traders' commissions.

Livestock systems in the Republic of Benin

ILCA assisted the Direction de la recherche agronomique of the Ministère du développement rural et de l'action coopérative, Peoples Republic of Benin, with methodology for rapid appraisal surveys of livestock systems in two of the southern provinces of Benin, and with a more detailed survey in Mono Province.

A clustered sample of 480 farmers was interviewed at 16 sample points spread across the four zones of the province. This was supplemented by open-ended interviews and discussions at village, district and provincial levels. Data were collected on livestock types and numbers, their management and integration with the farming system, and constraints on improved productivity.

Goats were the most numerous species after poultry in all zones, followed by pigs or (in the savannah area) sheep. Most cattle were managed by Fulani. Kitchen waste and foliage cut from fallow land were the major sources of feed for small ruminants, although sheep were often tethered and grazed. *Peste des petits ruminants* (PPR) appeared to be a major cause of small ruminant mortality. Constraints were identified relating both to the system of production and to the socio-economic environment. The former included disease, feed scarcity, lack of water, and housing. Socio-economic constraints included an inadequate extension service and livestock theft.

Genetic resource evaluation and breed improvement

More information is needed on the genetic potential for meat and milk production of African small ruminant breeds. ILCA's activities are aimed at filling this gap in knowledge by collecting and classifying production data on indigenous breeds of sheep and goats under a range of environments.

Performance of Ethiopian sheep breeds

Male lambs of the Arsi, Menz and Wello breeds were fed high or low planes of nutrition to determine their genetic potential for growth and to investigate whether they differ in maximum liveweight attainable or in their response to differences in levels of feeding.

Groups of 36 animals, initially averaging 6 months old, were fed a concentrate mixture either *ad libitum* or at 100 g per head per day, in addition to a basal diet of *ad libitum* grass hay. Six representative animals from each group were slaughtered at 6, 10 and 12 months old and their carcase composition studied. Initial slaughter data are shown in Table 10.

Over the first 6 months of the trial, Arsi, Menz and Wello animals on the high plane of nutrition gained an average of 115, 98 and 109 g a day, respectively. These growth rates did not differ significantly ($P>0.05$). The low-

plane animals gained approximately 40 g a day, again without any significant difference between breeds (Figure 2).

The animals continue to gain weight steadily, and it appears that the Arsi and Wello breeds will reach a liveweight of more than 40 kg. The Menz breed will probably be smaller.

Table 10. *Initial slaughter data from Arsi, Menz and Wello lambs at 6, 10 and 12 months old, after being fed high or low planes of nutrition from 6 months old, Ethiopia, 1987.*

	Arsi		Menz		Wello	
	HP	LP	HP	LP	HP	LP
Age 6 months						
Mean liveweight (kg)	16.0		13.2		16.0	
Mean carcase weight (kg)	5.7		4.6		5.6	
Mean dressing percentage	35.6		34.8		35.0	
Age 10 months						
Mean liveweight (kg)	28.2	18.6	23.8	18.2	25.5	21.2
Mean carcase weight (kg)	13.9	6.5	10.9	6.3	11.8	7.5
Mean dressing percentage	49.3	34.9	45.8	34.6	46.3	35.4
Age 12 months						
Mean liveweight (kg)	32.4	20.9	28.6	20.8	34.5	22.0
Mean carcase weight (kg)	15.8	7.4	13.8	7.6	17.2	7.9
Mean dressing percentage	48.6	35.0	48.2	36.5	49.8	35.6

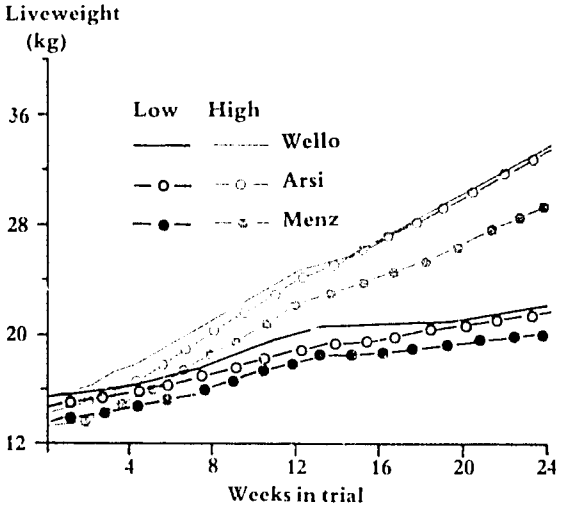


Figure 2.
Liveweight changes in Arsi, Menz and Wello sheep on high and low planes of nutrition, Ethiopia, 1987.

Comparison of productivity of highland sheep in Rwanda and Ethiopia

A comparison of the productivity of indigenous sheep in the highlands of Rwanda and Ethiopia was completed in 1987. The types studied were the East African long fat-tailed sheep in Rwanda and Menz sheep in Ethiopia.

Data were collected on 780 lambings at stations belonging to the Institut des sciences agronomiques du Rwanda (ISAR) and on 933 lambings at ILCA's Debre Berhan station in Ethiopia.

The flocks differed in breeding management. Young ewes at the ISAR stations were mated only when at least 16 months old, or when weighing at least 23 kg, whereas those at Debre Berhan were mated at first heat. In addition, rams ran with the flock for only 2 months a year (January and July) at ISAR stations, whereas they ran with flock throughout the year at Debre Berhan.

These management practices had a large effect on ewe productivity. Average age at first lambing was 646 days at ISAR stations, compared with 473 days at Debre Berhan. Subsequent lambing intervals were also longer in Rwanda than in Ethiopia (395 vs 262 days). Thus, despite the larger litters of Rwandan sheep (1.42 vs 1.08), the annual productivity of Rwandan ewes in terms of weaned lamb weight was lower than that of Menz sheep (15.5 ± 0.75 vs 23.1 ± 2.45 kg of weaned lamb per ewe per year). When expressed in terms of weaned lamb weight per kg of ewe body weight the difference was even greater (0.486 ± 0.024 vs 0.995 ± 0.109 kg of weaned lamb per kg ewe postpartum body weight), because of the larger size of the Rwandan sheep (31.4 vs 22.7 kg postpartum ewe weight).

Further studies are needed to determine the long-term effect of management practices on the lifetime productivity of ewes in both Rwanda and Ethiopia.

Forage production and feeding systems

Inadequate nutrition is one of the most serious constraints to small ruminant production in sub-Saharan Africa. Work under this theme is aimed at alleviating this constraint by increasing the efficiency with which available feed resources are used and by introducing forage legumes into farming systems to provide high-quality supplementary feed.

Milking a goat, northern Nigeria. Sheep and goats are important sources of meat and milk for subsistence and sale in sub-Saharan Africa. They are especially important to resource-poor smallholders.

On-farm sheep fattening with teff straw and *Sesbania sesban*

Previous on-station research indicated that leaves from the fodder tree *Sesbania sesban* are an excellent supplement to straw-based diets in sheep-fattening systems. An on-farm trial was conducted at a producers' cooperative in the Ethiopian highlands to verify these results under farmers' conditions.

Ten entire male sheep were kept in a pen with a shed roof made with local materials and construction techniques. Another 10 entire male sheep of similar body weight were managed under the traditional sheep-rearing system. The penned sheep were fed a diet comprising *S. sesban* leaves (300 g head^{-1} d^{-1}), teff straw (800 g head^{-1} d^{-1}) and salt (approximately 1% of daily intake). The traditionally managed sheep were grazed on natural pastures. Both groups were watered daily. Penned sheep had access to a water trough and the traditionally managed sheep were taken to a nearby lake for watering. All sheep were treated for both internal and external parasites. The trial was designed so that the fattening period would finish just prior to Ethiopian Christmas (early January) when fattened sheep have a high price.

Growth rates of the penned sheep (64 g d^{-1}) and traditionally managed sheep (60 g d^{-1}) were not significantly different, as determined by Student's T test ($P=0.54$). These results indicate that supplementing teff straw with *S. sesban* produces growth rates similar to those achieved under traditional management during the wet season. Research is being continued to determine the profitability of the straw-based feeding system relative to the traditional system in the dry season and the specific effect of parasite control.

Evaluation of acacia fruits for growing sheep

Farmers in Africa are aware of the value of acacia fruits as livestock feed. The fruits are high in crude protein and provide moderate levels of digestible energy. However, little research has been conducted on the utilisation of these fruits in ruminant diets.

An experiment was conducted at ILCA headquarters to determine the nutritive value of fruit from four *Acacia* species (*A. albida*, *A. nilotica*, *A. sieberiana* and *A. tortilis*) fed to sheep as a supplement to maize stover. These were compared with noug cake (*Guizotia abyssinica*), an oil seed cake widely used as a protein supplement in Ethiopia. The experiment consisted of a 70-day growth trial to measure daily feed intake and weekly weight gain and a 20-day metabolism trial to measure digestibility, nitrogen (N) balance and parameters of rumen fermentation. Forty entire yearling male sheep (18 to 20 kg initial body weight) were assigned to the five treatments (eight animals per treatment).

Growth rate was highest in animals fed *A. tortilis* fruits and noug and lowest in those fed *A. sieberiana* fruits (Table 11). Maize stover intake was highest for the noug-supplemented diet and lowest for the *A. sieberiana*-supplemented diet (Table 11). True digestibility of N was highest for the noug-supplemented diet, similar among the *A. albida*-, *A. nilotica*- and *A. tortilis*-supplemented diets and lowest for the *A. sieberiana*-supplemented diet.

Seeds from acacia fruits can pass through the animal undigested and the proportion of whole seeds in the faeces was measured in this experiment (Table 11). Seeds that had been damaged by Bruchid beetles were not observed in the faeces. The proportion of whole seeds in the faeces was greatest for *A. tortilis* and least for *A. sieberiana*.

Table 11. *Growth rate, intake, true nitrogen digestibility and appearance of whole seeds in the faeces of sheep fed noug cake and fruits from four acacias, Addis Ababa, 1987*

Diet	Noug cake	*Acacia tortilis*	*Acacia albida*	*Acacia nilotica*	*Acacia sieberiana*
Growth rate ($g\ d^{-1}$)	32.6a	32.3a	21.6ab	16.1b	0.4c
Maize stover intake ($g\ d^{-1}$)	483a	430b	401b	347c	320c
Fruit intake ($g\ d^{-1}$)	80	206	194	204	211
True N digestibility (%)	86a	81b	80b	80b	70c
Whole seeds in faeces (% of seeds eaten)		45a	15b	9b	1c

Means followed by the same letter do not differ significantly ($P \leq 0.05$).

There are large differences in the growth rate of sheep fed fruits from different *Acacia* species. These differences are related to the polyphenolics content of the acacias. Polyphenolics alter the digestibility of N and carbohydrates. Levels of polyphenolics were highest in *A. sieberiana* and *A. nilotica* fruits. Although *A. tortilis* fruits gave the best growth response, the appearance of a large proportion of whole seeds in the faeces indicates that these fruits would be better utilised if the seed coat were destroyed to facilitate their digestion.

The use of sorghum bran in sheep and goat diets

Bird damage is a major constraint to sorghum production in Africa. Crop breeders are, therefore, selecting for bird resistance, which depends on the presence of tannins in the grain. The tannin is located in the pericarp, and this must be removed to improve the food value of the grain for human consumption. Appropriate equipment for dehulling sorghum at the village is being developed and bran from bird-resistant sorghum varieties will become available for use as feed on smallholder farms. The value of the bran is important to the economics of commercial milling of sorghum.

Brans from a bird-resistant variety (MW5020) and a non-bird-resistant variety (Melkamash) were compared as supplements to hay diets for sheep and goats at headquarters. At the low level of supplementation (150 $g\ d^{-1}$) there was no significant ($P>0.05$) difference in growth rate between animals fed Melkamash bran and those fed MW5020 bran (Table 12). However, at the higher level of supplementation (300 $g\ d^{-1}$) the growth rate of sheep fed Melkamash bran was 62% greater than that of sheep fed MW5020 bran. In goats, the rate of growth of those fed Melkamash bran was more than double that of animals fed MW5020 bran. The high level of supplementation with MW5020 gave similar rates of gain to supplementation with both varieties at the low level. Sheep fed the high level of MW5020 also had low intake of hay (Table 12).

Apparent and true nitrogen digestibility and nitrogen retention were lower in sheep and goats fed MW5020 bran than in those fed Melkamash bran (Table 12). The digestibilities of acid-detergent fibre, lignin and fibre-bound nitrogen were also lower in sheep and goats fed MW5020 bran. These results indicate that tannin in MW5020 bran forms complexes with protein in the digestive tract and inhibits digestion of both protein and cell-wall

Table 12. *Growth rate, hay intake, apparent and true digestibility of nitrogen, nitrogen retention, and digestibility of acid-detergent fibre (ADF), lignin and neutral-detergent fibre (NDF) in sheep and goats fed bran from a non-bird-resistant sorghum variety (Melkamash) and a bird-resistant sorghum variety (MW5020). Addis Ababa, 1987*

	Melkamash		MW5020	
	Supplementation rate ($g\ d^{-1}$)			
	150	300	150	300
Growth rate ($g\ d^{-1}$)				
Sheep	28.6	53.7	30.8	33.1
Goats	13.2	38.7	14.2	18.6
Hay intake ($g\ d^{-1}$)				
Sheep	555	502	547	400
Goats	413	395	478	382
N digestibility (%)				
Apparent				
Sheep	37	40	30	22
Goats	37	55	23	27
True				
Sheep	86	86	79	82
Goats	84	85	80	86
N retention ($g\ d^{-1}$)				
Sheep	1.2	1.2	0.7	0.4
Goats	0.8	1.3	0.3	0.9
Fibre digestibility (%)				
ADF				
Sheep	59	58	52	51
Goats	58	57	49	50
Lignin				
Sheep	18	14	−10	−13
Goats	3	8	−20	−8
NDF-N				
Sheep	75	75	59	61
Goats	71	72	62	64

carbohydrates. The negative effects of tannin on fibre digestion may also explain the low hay intake of sheep fed the high level of MW5020 bran.

Bran from non-bird-resistant varieties does not appear to inhibit digestion and should have an economic value equivalent to brans from other cereals. Bran from bird-resistant varieties may reduce animal performance when fed at high levels, but at low to moderate levels may be useful for feeding ruminants. More research is required to determine the level at which bran from bird-resistant varieties can be included in diets for ruminants.

Browse supplementation to small ruminants

Browse supplementation trials were conducted at Ibadan, Nigeria, over two reproductive cycles. Sheep and goats were offered leucaena and gliricidia for the last 2 months of pregnancy and during lactation, as supplements to a

basal diet of *Panicum maximum*. The effects of supplementation on growth and survival rates of the offspring are shown in Table 13.

Survival rates of offspring, and their growth rates, increased with the level of supplementation. Productivity (kg offspring weaned per dam per year) of sheep increased by 1.41 kg for each additional 100 g of browse DM consumed per day, while for goats the increase was only 0.64 kg (Figure 3). Selection of browse in preference to *Panicum maximum* was more marked with goats than with sheep. However, although goats selected feed of a higher nutritive value they were unable to utilise the nutrients as effectively as sheep.

Table 13. *The effects of supplementary leucaena and gliricidia browse on the growth and survival rates of small ruminants, Ibadan, Nigerian humid zone, 1986–87.*

Species	Browse intake (g DM d^{-1})		Growth rate (g d^{-1}) to		Survival to 24 weeks
	Dam[a]	Offspring[b]	Weaning[c]	24 weeks	
Goats	143	39	17.4	14.0	0.36
	251	83	28.7	20.1	0.46
	554	160	25.9	20.9	0.82
	719	246	31.9	28.3	0.94
Sheep	0	0	39.0	25.4	0.50
	120	34	46.7	30.7	0.62
	239	77	57.2	34.0	0.70
	441	136	66.3	44.5	0.89
	741	250	84.0	50.3	1.00

[a] During the final 2 months of pregnancy up to weaning.

[b] From weaning to 24 weeks.

[c] Weaning at 12 weeks for lambs and 16 weeks for kids.

Small ruminant feed in villages in humid Nigeria

The productivity of confined animals in southeast Nigeria is half that of their free-roaming counterparts in southwest Nigeria (*ILCA Annual Report 1985/86*). Malnutrition appears to be the major factor.

A survey in southwest Nigeria into the uses of leucaena and gliricidia from alley farms showed that farmers offered the cultivated browse to free-roaming small ruminants on an average of 8.8 days a month. The total quantity of supplementary browse consumed was 1.1 kg DM per animal per month. Concurrent researcher-managed trials showed that the combined productivity of leucaena and gliricidia on 10 farmer-established alley farms ranged from 1.4 to 7.0 t DM per ha per year, of which an average of 2.0 t DM was edible material (leaf plus petiole). The productivity of farms planted in the savannah was about 90% greater than that of alley farms in the forest, largely because they did not suffer from shading by tree crops and by the cassava and yam commonly grown on forest plots.

Prunings cut by farmers were shorter than those cut by researchers, indicating that farmers were cutting the trees prematurely to feed their animals. As reported in the *ILCA Annual Report 1986/87*, premature cutting reduces overall tree productivity.

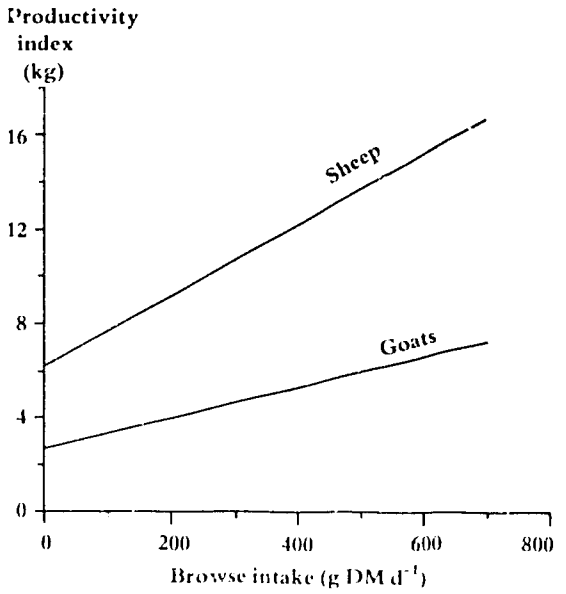


Figure 3.
Effect of browse intake on the productivity of sheep and goats, Ibadan, Nigerian humid zone, 1986/87.

On smallholder farms in southeast Nigeria with alley farms or intensive feed gardens, more than 50% of feed fresh weight for confined animals was household wastes, mainly cassava peels. Local browse cut from the bush, leucaena and gliricidia, and grasses comprised the rest of the diet, in decreasing order of importance. Local browse was offered twice as often as cultivated browse (8.5 vs 4.2 days a month). Consumption of leucaena plus gliricidia was low at around 1.0 kg DM per animal per month. Total daily feed intake was estimated to be less than 350 g DM per animal. Adult goats at the ILCA station offered *ad libitum Panicum maximum* plus limited quantities of browse and cassava peels consume more than 1 kg DM a day.

Effect of legume browse supplementation on small ruminant manure

A trial was initiated at Ibadan, Nigeria, in 1986 to determine the effect of mixed leucaena/gliricidia supplement fed to sheep and goats on the agronomic value of their manure. Manure, collected from animals fed one of four levels of browse supplementation (200, 400, 800 or 1200 g DM per head per day), was dried and used as fertilizer on maize in a pot trial. Preliminary data indicate that manure from animals receiving the highest level of browse supplementation resulted in the largest increase in maize dry-matter yield. Feeding legume tree fodder to small ruminants will, therefore, have an added effect on crop production if their manure is used as fertilizer.

Wet-season feeding of sheep and goats in subhumid Nigeria

Small ruminants play a very important role in the rural economy of the subhumid zone of Nigeria. They are tethered during the wet season to prevent crop damage but this restricts the area over which they can selectively graze and it may also restrict mating as a result of male and female animals being physically separated for most of the day.

An on-farm experiment was carried out in 1986 and 1987 to determine the effect of grazing fodder banks, free-range grazing and tethering on the

performance of goats and sheep in Abet, northern Nigeria. Figures 4 and 5 show the trends observed in goats for the two years.

In 1986 the fodder banks were not adequately established and the goats were removed in mid-season. This seriously reduced weight gains (Figure 4).

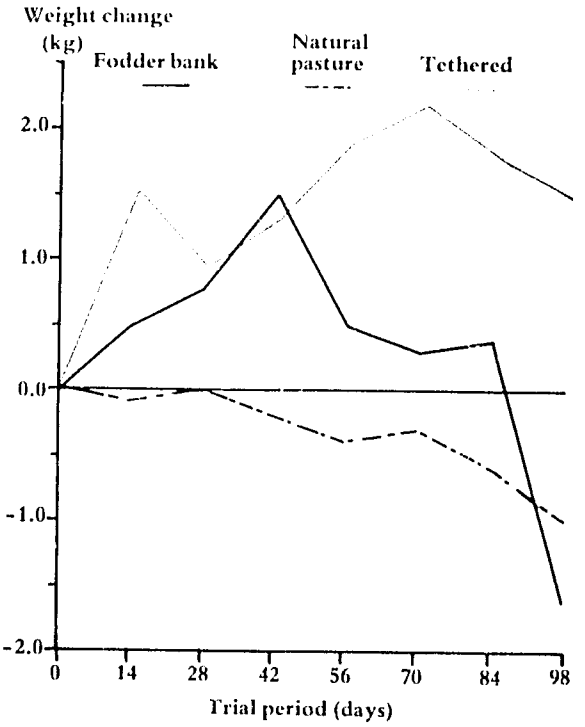


Figure 4.
Effects of tethering on natural pasture and grazing on natural pasture and fodder banks on weight changes in goats, Abet, Nigerian subhumid zone, 1986.

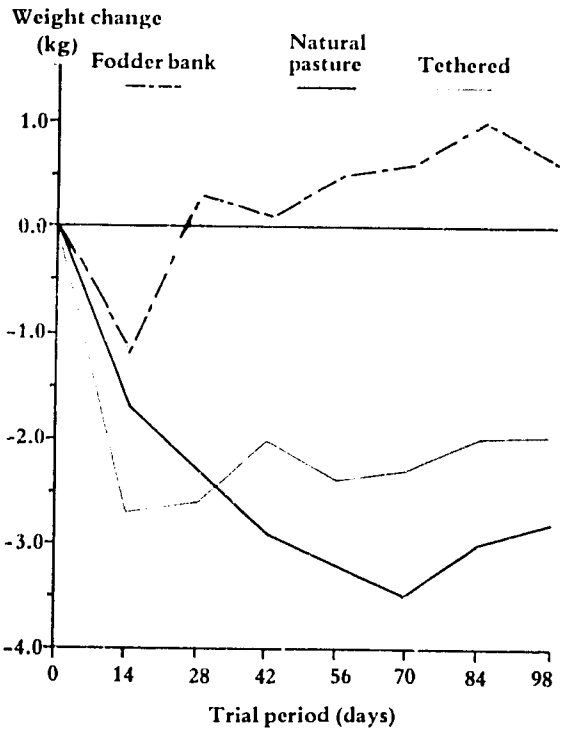


Figure 5.
Effects of tethering on natural pasture and grazing on natural pasture and fodder banks on weight changes in goats, Abet, Nigerian subhumid zone, 1987.

Contrary to the hypothesis, tethered goats performed better than goats grazing freely on natural pasture. It would appear that the owners are able to select the best grazing for tethered animals. In 1987 the goats grazing fodder banks maintained their body weights while free-ranging and tethered goats lost weight (Figure 5). Tethered goats again performed better than free-ranging goats. The results for sheep were similar to those for goats.

Reproductive wastage and health management

Reproductive wastage due to infertility, embryonic mortality, perinatal and postnatal losses, and morbidity seriously limits small ruminant production in sub-Saharan Africa. Work under this theme is aimed at determining the epidemiology of potential causes of mortality in small ruminants and, ultimately, the development of management techniques to reduce reproductive wastage.

Animal health improvement in the Ethiopian highlands

Knowledge of the causes of mortality and morbidity, and their spatial and temporal importance, is essential in order to design management improvements. For example, studies showed that fascioliasis, neonatal lamb losses and coenurosis accounted for 88% of sheep deaths at ILCA's Debre Berhan station between 1982 and 1986. Management interventions (based on strategic drenching, watering and hay feeding practices) have reduced flock mortality from 38 to 14% and significantly ($P<0.005$) increased the average body weight of sheep from 26.5 to 32.7 kg. Studies are in progress to establish the extent to which similar interventions can reduce prenatal and postnatal reproductive wastages and improve prepubertal growth, sexual development and subsequent reproductive performance in male and female lambs.

Fascioliasis, caused by *Fasciola hepatica*, is a major constraint to sheep production in the Ethiopian highlands. The prepatent period, as determined by faecal examination, is long, i.e. 12 weeks, and faecal egg counting is not a very reliable method for detecting infestation. An attempt is therefore being made to adapt the enzyme-linked immunosorbent assay (ELISA) technique for diagnosing fascioliasis in sheep.

Preliminary results indicated that significant ($P<0.05$) levels of *F. hepatica* antibodies appeared in all six tracer lambs within 55.2 ± 10.3 days of exposure to a metacercaria-contaminated environment and eggs were found in their faeces by 119.8 ± 15.1 days. Levels of antibody activity peaked 2 months after exposure and declined to pre-infestation levels towards the third month, when parasite eggs became detectable in the faeces by the Dorsman technique. The possibility of utilising *Fasciola* secretory-excretory antigen to diagnose early ovine fascioliasis is being pursued.

Hygiene management in humid Nigeria

In the humid zone, small ruminant production is a low input adjunct to the farming enterprise, receiving little attention relative to crop production. A re-analysis of entries to and exits from village herds in the Nigerian humid zone following the implementation of dipping and vaccination against *Peste des petits ruminants* has shown changes in the way farmers manage their herds.

Over a 2-year period, animal numbers increased by 162% in villages where dipping was practised and by 86% in villages where animals were both dipped and vaccinated. This compares with a 46% increase in control villages where neither treatment was applied. Changes in birth and mortality rates due to the treatments explained some of the differences but in the dipping villages, particularly, a smaller proportion of the animals were sold or loaned out. This suggests that farmers were choosing the long-term benefits of larger numbers of breeding animals over the immediate benefit from sales, in the knowledge that health measures had reduced the likelihood of disease wiping out their investment.

Changes in farmers' attitudes are a prerequisite for successful implementation of management and nutritional improvements that require action by farmers themselves, rather than passive acceptance of assistance provided by the veterinary extension service. The results of this trial indicate that farmers' attitudes do change if animal disease is controlled, creating an environment in which further measures to improve animal productivity are more likely to be accepted.

Epidemiology of lung diseases in small ruminants in Mali

The epidemiology of lung diseases in small ruminants in Mali was studied in 1986 and 1987. The study covered flocks in both the pastoral and agropastoral zones. The research was carried out jointly with the Laboratoire central vétérinaire in Bamako and the Laboratoire national d'élevage et de recherches vétérinaires in Dakar.

Analyses of nose and throat samples from 50 sheep and 32 goats showed associations of *Pasteurella*, *Streptococcus* and *Staphylococcus* in 76.66% of sheep and 71.87% of goats. Lung lesion samples from 21 goats and 20 sheep revealed associations of *Pasteurella*, *Streptococcus*, *Staphylococcus* and *Mycoplasma* in 28.57% of goats and 40% of sheep. With the exception of *Mycoplasma*, the germs were found in almost all nose and lung samples. *Mycoplasma* were only isolated from a few lung lesions. Previous studies showed that these organisms are responsible for 54% of cases of morbidity in sheep in the pastoral zone and 28.04% of cases in goats. The corresponding rates in the agropastoral zone are 7.4% for sheep and 2.5% for goats. Lung diseases accounted for 30.43% of all sheep deaths and 58.50% of goat deaths in the pastoral zone, and 10.6% and 42.4% of deaths of sheep and goats, respectively, in the agropastoral zone.

All the main viruses affecting lungs, and against which serums were tested, were endemic in Mali (Table 14). Although contagious ecthyma and the sheep and goat pox viruses usually affect the mucous membranes, in serious forms they affect the lungs and are generally fatal.

The presence of antibodies was more marked in adults than young animals, regardless of virus type and animal species. In the case of PPR, for instance, the 1/80 antibody titre was detected 20 times in adult goats, compared with only once in young goats. In adult sheep, this titre was four times as frequent in adults as in young sheep. Thus, in the case of PPR, direct losses are heavier in young animals than in adults.

In a collaborative study between the Institut national de recherche zootechnique, forestière et hydrobiologique and ILCA, the effect of deworming and vaccination against pasteurellosis and *Peste des petits ruminants* was started in May 1987. The study will continue until mid-1988. Approximately 750 small ruminants are being weighed monthly and feed supplies and other inputs are being determined.

Table 14. *Serological analysis of blood samples for virus diseases, Mali, 1986-87*

Virus type	Number of serums tested	Number of positive serums	Percentage positive
Para Influenza III	1591	420	26
Type 5 Adenovirus	1591	1207	76
Blue Tongue	1591	964	60
Contagious ecthyma	1591	1053	66
Sheep pox	1592	200	13
Peste des petits ruminants	1590	536	34

Management systems

Management practices can have a large effect on the productivity of small ruminants. This work evaluates smallholder production systems and management practices, prior to the development of improved forage and feeding systems and management practices.

Livestock systems in southeast Nigeria

Data were collected on farming systems in four states in southeast Nigeria. Livestock management differed by state, climatic zone and farming system. Confinement of animals was most common in the drier zones and in Anambra State. It increased with population density and agricultural intensity (of which compound farming was taken as an indicator), particularly with goats. Disease problems were greater in the drier areas.

Patterns of disease and mortality were also related to management system (Table 15). Animals confined during the growing season, when labour demand for cropping is at its peak, seem especially vulnerable to disease. This may reflect a failure to adjust management (especially housing and feeding) strategies to this transitional phase of confinement. Animals are more likely to be confined as population density and agricultural intensity increase, both in southeast Nigeria and throughout the humid zone. New management strategies, in particular relating to feed and disease, are thus required.

Table 15. *Effect of management system on disease and mortality of sheep and goats, expressed as percentages of animals present in a 12-month period, southeast Nigeria, 1987*

	Sheep			Goats		
Management system	No.	PEC[1] observed in last 12 months (%)	Mortality (%)	No.	PEC observed in last 12 months (%)	Mortality (%)
Free-ranging	211	34	21	585	29	23
Seasonally confined	17	53	32	47	34	28
Confined all year	72	33	17	364	29	24
All	300	35	21	996	29	24

[1] PEC = Pneumo-enteritis complex.

Network coordination

The Small Ruminant Network (formerly the Small Ruminant and Camel Group) continued to assist national programmes in planning, executing, analysing and publishing research.

Information exchange

Three issues of the Network newsletter were produced in both French and English in 1987. There are now more than 1100 network correspondents, mostly from 48 African countries. Approximately 28% of the correspondents are francophone. Three working documents were produced.

Research assistance

Analysis of Landim goat and sheep data from Mozambique

Network staff, in collaboration with the Mozambique Institute of Animal Production and Reproduction, completed an analysis of Landim goat and Landim sheep data for the years 1954 to 1984. A draft Research Report was prepared. Both species are very prolific, with litter sizes of 1.49 for goats and 1.40 for sheep. These are high compared with most other African breeds, particularly in the case of sheep.

Growth rates to weaning at 90 days were 90 g d^{-1} in goats and 105 g d^{-1} in sheep. Female goats and sheep weighed 43 and 45 kg respectively at 3 years old. Mortality to weaning was 19.3% in goats and 19.2% in sheep. Productivity indices (weight of weaned young per female per year) were 11.9 kg for goats and 13.1 kg for sheep. The performance of females that gave birth in the early dry season was poorer than that of those giving birth at other times of the year. Females that gave birth to twins outperformed those that bore singles by 60%. Indices for the years in which a reproductive cycle of 8 months was adopted were superior to those in other years and this rhythm should be adopted both to improve actual productivity of females in the flocks and to accelerate genetic gain.

Analysis of Sudan desert sheep data

Data on three types of Sudan desert sheep (Dubasi, Watish and Shugor) were prepared for analysis and will be analysed in collaboration with the Sudanese Animal Production Research Administration during 1988.

Collaborative research

Analyses of data on traditional sheep and goat production in northern Burkina Faso

Analyses of data on traditional sheep and goat production in Burkina Faso were completed and a Research Report prepared. This will be published jointly by ILCA and the Institut d'élevage et de médecine vétérinaire des pays tropicaux. The study was conducted in collaboration with the Direction des services d'élevage et vétérinaire, Ministère du développement rural, and covered 12 sheep flocks (345 head) and 11 goat flocks (805 head) in two vil-

lages in the Yatenga province, northern Burkina Faso. The main production characteristics were:

- Age at first parturition: 423 ± 108 days for goats and 455 ± 86 days for sheep.
- Litter size: 1.05 ± 0.2 for both goats and sheep.
- Parturition interval: 328 ± 85 days for does and 290±69 days for ewes.
- Deaths and offtake: 41.2% for goats and 27.1% for sheep.
- Annual reproductive rate: 1.17 for goats and 1.33 for sheep.

Figure 6 shows the seasonal distribution of lambing/kidding throughout the year.

The growth rate of lambs was 83.3 g d^{-1} up to 150 days and 45.4 g d^{-1} from 150 to 365 days (Figure 7). The growth rates for kids over the same periods were 62.7 and 39.7 g d^{-1}. Figure 8 shows the pattern of weight changes in sheep and goats with one to four pairs of permanent incisors.

Productivity indices[1] were 22.6±9.9 kg $year^{-1}$, 776±376 g kg^{-1} $year^{-1}$ and 1.93±0.9 kg kg^{-1} $LW^{0.75}$ $year^{-1}$ for sheep and 13.7±7.2 kg $year^{-1}$, 556±388 g kg^{-1} $year^{-1}$ and 1.34±0.84 kg kg^{-1} $LW^{0.75}$ $year^{-1}$ for goats.

[1] Productivity indices were calculated in kilograms of weaned offspring per dam per year, grams of weaned offspring per kilogram of dam liveweight per year and kilograms of weaned offspring per kilogram of dam metabolic weight per year.

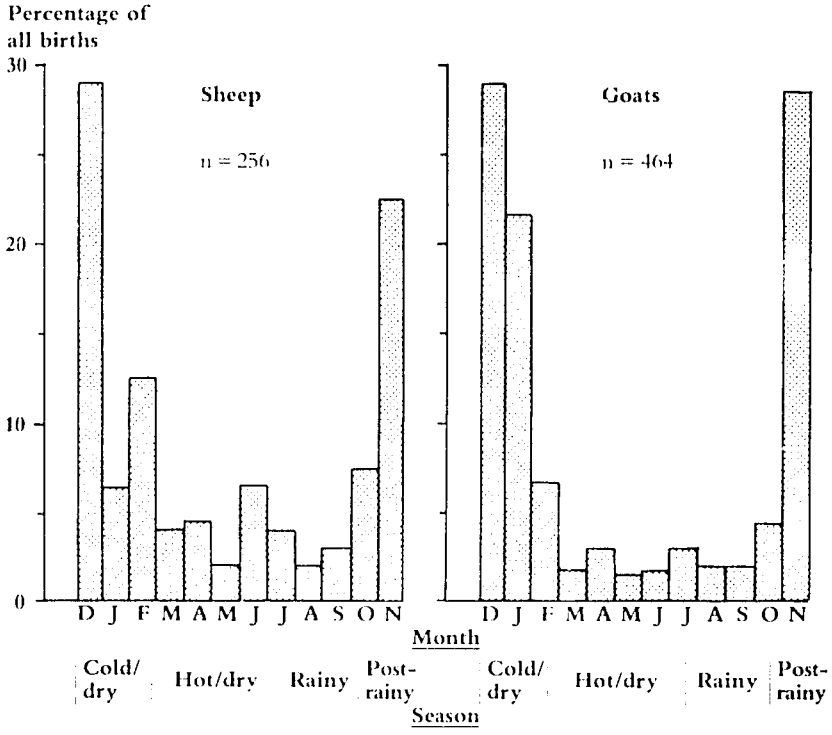


Figure 6.
Seasonal distribution of births in sheep and goats, northern Burkina Faso (cumulative data over 2 years).

Constraint diagnosis and analysis in Congo

This study is being undertaken jointly with the Direction générale de la recherche scientifique et technique, Congo, and is part of a UNESCO/UNDP research project.

Twenty-three villages are covered by the study. In 1987, the heads of 250 households were interviewed to provide background information on

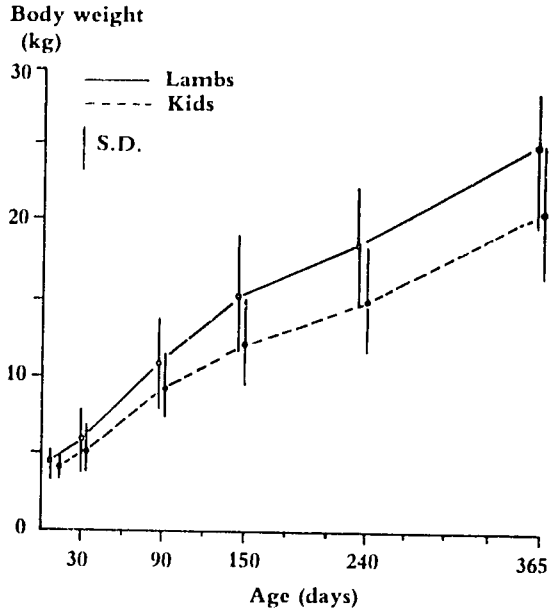


Figure 7.
Weight gain of lambs and kids from birth to 1 year old, northern Burkina Faso.

production systems. Preliminary results of a survey of ear-tagged animals (500 of each species) show large losses due to accidents and theft. Investigations are underway on the use of shelters to reduce these losses.

Studies on tsetse flies in the area were conducted in collaboration with ORSTOM (Institut français de recherche scientifique pour le développement en coopération). Preliminary studies on 216 blood-meal samples from tsetse flies show that most were taken from reptiles and pigs. None had apparently been taken from sheep or goats. Of the flies trapped, 46.3% of females and 27.7% of males were carrying trypanosomes, mainly *Trypanosoma vivax* (71.9%), *T. congolense* (forest type) (8.7%) and *T. grayi* (10.5%).

Constraint diagnosis and analysis in Somalia

This study is being conducted jointly with the veterinary component of the Central Rangeland Development Project, Somalia, which is funded by GTZ (Gesellschaft für Technische Zusammenarbeit). Baseline information is being collected on the farming system, animal husbandry and the productivity of sheep and goats under traditional management. The work is based at Belet Weyne, in the riverine area of the Shebele river in the arid zone of Somalia. The economy of this area is based on pastoral nomadism.

Flocks of sheep and goats belonging to nomadic households were inspected at their night enclosures. Information for each household was collected and collated using standardised herd appraisal sheets. Details of the pastoral and agropastoral production systems, livestock numbers and composition of flocks were recorded using confidential questionnaires. Standardised data sheets were used to record descriptive information and measurements of individual animals in flocks and the productivity of female stock of breeding age.

Forty sheep and 40 goats from each of 60 flocks will be surveyed continuously for 2 years. Preliminary results will be published in 1988.

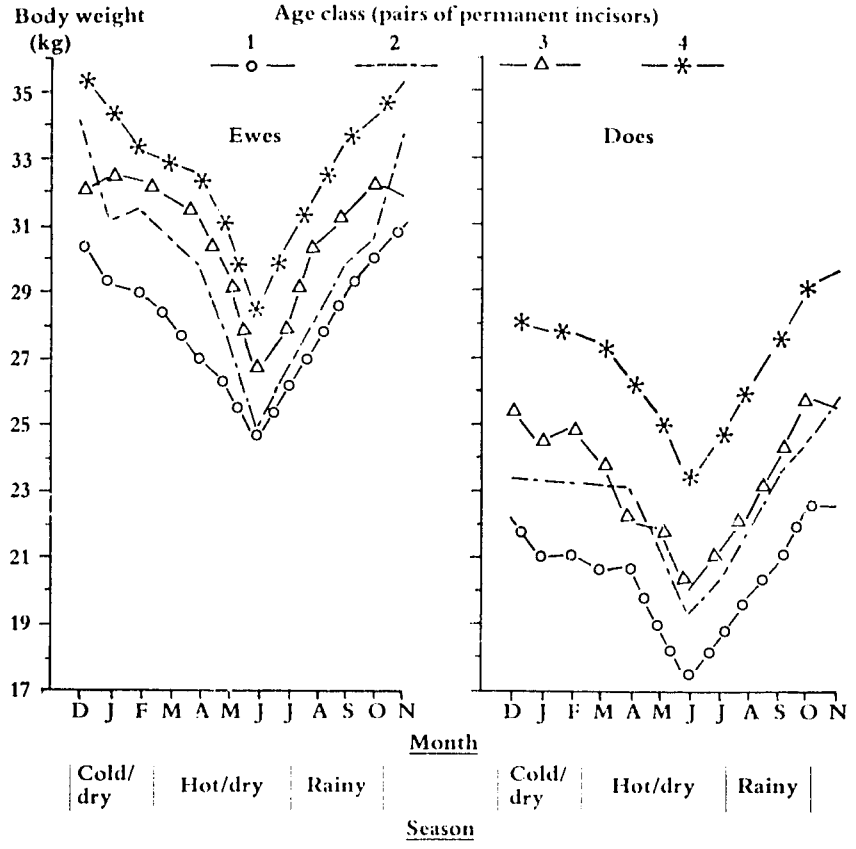


Figure 8.
Seasonal variation in body weight of ewes and does in four age classes, northern Burkina Faso.

Management and breeding systems in subhumid Kenya

Work is in progress in Kenya to investigate the influence of management and breeding systems on endoparasite challenge and productivity in sheep and goats raised in the subhumid coastal zone.

Improving Karakul sheep productivity in the Kalahari desert in Botswana

A study of sheep production in the Kalahari desert in Botswana was started in collaboration with the Smallstock Unit and Animal Production Research Unit, Ministry of Agriculture, Botswana. Data were collected on growth and slaughter characteristics of 9800 Karakul sheep over one year. Data were also collected on wool production and on pelts from auctions in which more than 16,000 pelts were sold.

Preliminary results indicate that the lamb production ability of Karakul sheep is comparable to that of their crosses and to that of Dorper/Africander sheep (Table 16).

Table 16. *Production characteristics of Kanakul, Karakul-cross and Dorper/Africander sheep in Botswana.*

Breed	Weight at first conception (kg)	Weight post-partum (kg)	Lamb weight (kg)		Lamb viability to 5 months (%)	Productivity[1] (kg year^{-1} per ewe)
			3 months	5 months		
Karakul	37.3	41.5	19.1	26.4	92.6	37.4
Karakul cross	35.5	42.3	19.0	26.7	94.0	37.5
Dorper/Africander	33.4	41.4	18.9	26.7	92.5	37.1

[1] Productivity = $\frac{\text{150-day liveweight of lamb} \times 365}{\text{subsequent parturition interval (days)}}$

SMALL RUMINANT MEAT AND MILK THRUST STAFF

K J Peters, *Thrust Coordinator*
A N Atta-Krah, *Agronomist*
D Bourzat, *Animal Scientist*
R Brokken, *Economist*
J Cobbina, *Forage Agronomist (Post-doctoral Associate)*
A K Diallo, *Animal Scientist*
L Diarra, *Ecologist*
P A Francis, *Agro-economist*
K Gautsch, *Animal Scientist (Post-doctoral Associate)*
E Kabaija, *Animal Scientist (Post-doctoral Associate)*
O B Kasali, *Veterinarian*
D A Little, *Animal Nutritionist*
S Maiga, *Veterinarian*
E Mukasa-Mugerwa, *Animal Scientist*
J D Reed, *Animal Nutritionist*
L Reynolds, *Animal Scientist*
B Tarawali, *Agronomist*
A Traoré, *Veterinarian*
R T Wilson, *Animal Scientist*

Animal Traction Thrust

Although estimated to be the second most valuable output of livestock in sub-Saharan Africa, animal traction is used by only 10 to 15% of farmers in the region at present. Most draught animals are found in the semi-arid and highland zones, where they are used primarily for ploughing and threshing. However, in addition to providing energy to power farm operations (primary input function), draught animals also fulfil an important output function by providing meat, milk, hides, manure and income. They are thus a valuable asset enhancing the productivity and stability of smallholder farming systems.

The outcome of past investments in animal traction has often been disappointing because essential inputs have been lacking and animals have been inadequately fed. From this experience, ILCA has identified research needs for two major areas:

- In the highlands and semi-arid zones, where animal traction is established, there is a need to intensify and diversify the uses of draught animals, in order to increase their contribution to the farm economy. Increasing the quantity and quality of feed for draught animals is a priority need, particularly in the semi-arid zone.
- In the subhumid zone, and also partly in the semi-arid zone, where animal traction is as yet seldom used, there is a need to examine more closely the constraints preventing its adoption and to overcome them by introducing draught animal technologies that combine all the necessary inputs.

The main aim in both cases is to develop suitable low-cost technologies that enhance both the profitability and sustainability of African agriculture.

Objective

The objective of the Animal Traction Research Thrust at ILCA is to increase and sustain agricultural production and incomes in smallholder farming systems of sub-Saharan Africa through a wider use of effective draught animal technologies.

Intensified and diversified use of draught animals

Seasonal labour shortage is one of the main factors contributing to low agricultural productivity in sub-Saharan Africa. Intensifying the use of animal traction in the region can release farm labour for activities other than cultivation and provides opportunities for raising farm income. Labour productivity on the farm can be further increased by diversifying the use of draught animals for secondary cultivation, carting, water lifting and other gear-motion operations.

Animal traction for improved cropping of Vertisols

Investments in animal-powered cultivation of clay soils result in a considerably higher payoff than those on light soils, and ILCA's activities under this research line focus on the improved management of Vertisols. These soils cover about 85 million hectares in sub-Saharan Africa, of which 13 million hectares are in Ethiopia. About 8 million hectares of Vertisols are in the Ethiopian highlands, of which 2 million hectares are currently cropped (30% of the Ethiopian crop land).

Five national Ethiopian agencies (the Institute of Agricultural Research, Alemaya University of Agriculture, the Ministry of Agriculture, Addis Ababa University and the Relief and Rehabilitation Commission) and three international agencies (ILCA, the International Crops Research Institute for the Semi-Arid Tropics and the International Board on Soil Research and Management) are cooperating in a joint project to improve management of these cracking clay soils and increase their contribution to Ethiopia's food production capacity.

The project focuses on the use of an inexpensive animal-drawn implement to form broadbeds and furrows—raised beds with shallow drainage ditches between them. These help drain excess surface water and relieve waterlogging, which is the main constraint to plant growth in high-rainfall Vertisol areas.

The first version of the broadbed maker (BBM) required substantial modifications to the local plough or *maresha* (Figure 9). Farmers testing the

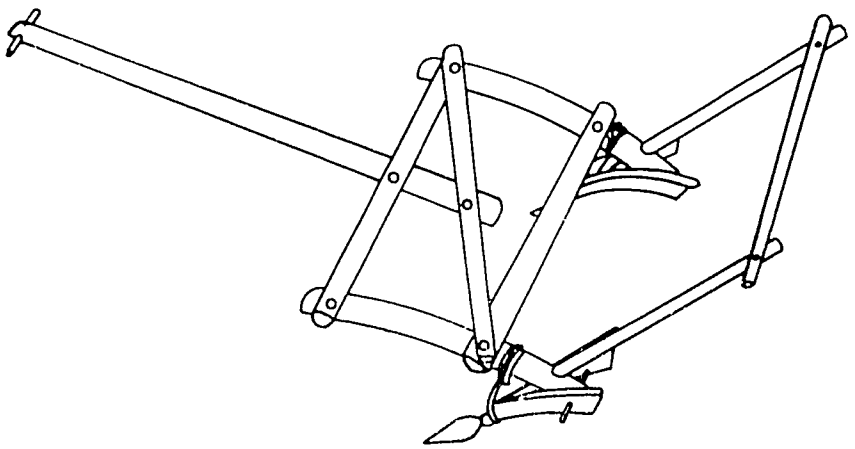


Figure 9.
Diagram of the original broadbed maker, showing the large and permanent alterations to the mareshas *on which it is based. Compare with Figure 10.*

BBM identified a number of problems with it: it was too heavy to transport, difficult to manufacture and could not be stored in the traditional way. In addition, since the modifications to the ploughs were permanent, the BBM could not be used for primary cultivation.

In response to these comments, the BBM was considerably simplified in 1987. The new version is assembled without any change to the *maresha*. Two ploughs are tied together in a triangular form and a pair of sheet metal wings is slipped over the ploughs (Figure 10). A chain hooked to the wings acts as a harrow and leveller.

In on-farm trials, using the BBM significantly increased wheat grain and straw yields under most conditions (Table 17).

The joint project's research and development programme is widely based, covering assessment of the agro-ecological and socio-economic resources of Vertisol areas, soil and water management, harvesting and re-use of runoff water, new cropping systems for drained Vertisols, investigation of power sources for improved soil management, enhanced livestock production from crop-residue based diets, on-farm technology verification, extension methodology, staff training and institution-building.

Pilot-scale extension activities of the technologies developed have been initiated in four Ethiopian Vertisol areas by the joint project in order to prepare larger extension work.

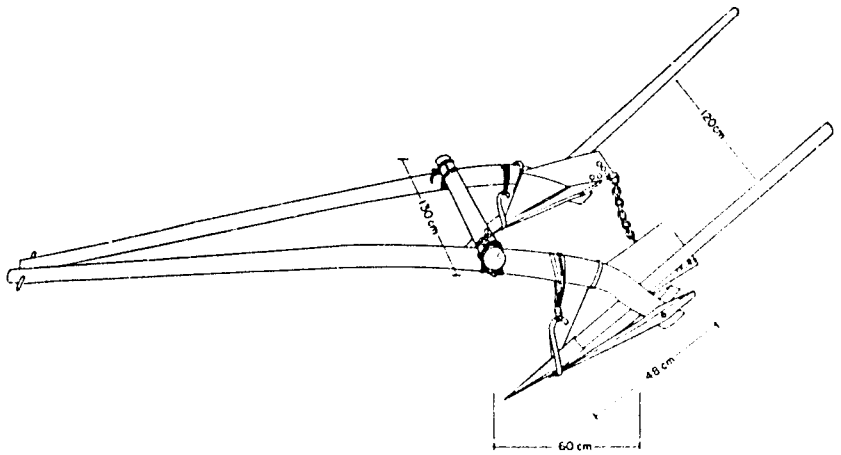


Figure 10.
Diagram of the 1987 broadbed maker. No permanent modifications are made to the two mareshas *used.*

Animal traction in semi-arid Mali

Studies on animal traction in the semi-arid zone of Mali are undertaken as part of the Mali Livestock Sector Project, funded jointly by the United States Agency for International Development (USAID) and the Malian Government. The research is undertaken in cooperation with the Institut national de recherche zootechnique, forestiere et hydrobiologique (INRZFH) in the semi-arid zone of Mali.

Observations in villages during the 1987 cropping season confirmed the findings of a 1986 survey, which showed that farmers use oxen for ploughing for an average of only 2 weeks a year. During this period, the oxen work an average of 4.5 hours a day, 2.9 hours in the morning and 1.6 hours in the

Table 17. *Wheat yields at Wereilu, Wello, and Debre Zeit, Shewa, on Vertisols, as influenced by surface drainage and fertilizer inputs, Ethiopian highlands, 1987*

Crop and land preparation	Number of plots	Fertilizer application[1] (kg ha^{-1})	Average grain yield (kg ha^{-1})	CV (%)	Average straw yield (kg ha^{-1})	CV (%)
Wheat (ET 13), Wereilu						
BBF[2]	21	0	1090*	44	1384*	39
	21	50	1376*	36	1664*	36
	21	100	1696***	27	2062***	31
Traditional[3]	20	0	770	50	990	45
	29	50	1073	39	1302	40
	22	100	1170	40	1415	40
Wheat (Enkoy), Wereilu						
BBF	27	100	816**	37	1052**	35
Traditional	26	100	580	46	765	45
Wheat (Buhae), Debre Zeit (Hidi Producers' Cooperative)						
BBF	5	100	1847**	—	3814	—
Traditional[4]	5	100	1119	—	2690	—

[1] Diammonium phosphate (DAP).

[2] Broadbeds and furrows, 120 cm wide.

[3] Ridge and furrows, 30 cm wide ridge.

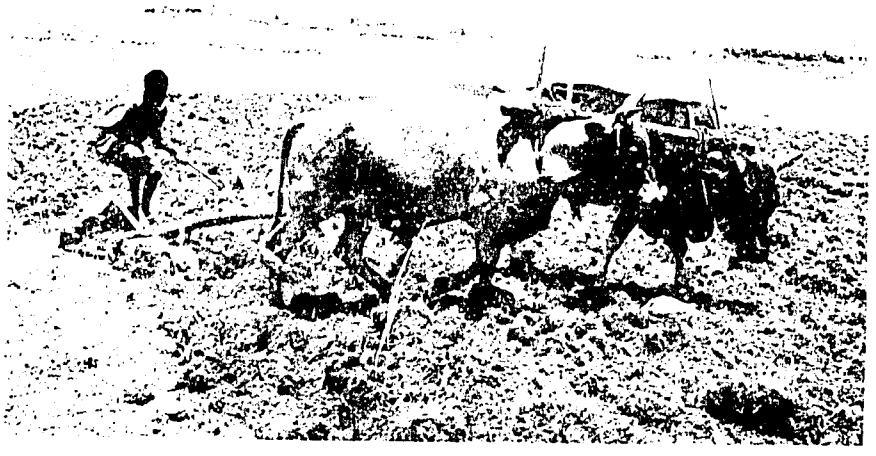
[4] Flat seedbed.

Significance of effects at each DAP level and for each cultivar:
* = P<0.05, ** = P<0.01; *** = P<0.001.

Rainfall June–September 1987: Wereilu 370 mm; Debre Zeit 310 mm.

Local wheat yields (durum wheat ecotype) in traditional system, 1987:
Wereilu 157 kg ha^{-1} (17 plots, CV 98%).

ET 13 and Enkoy are improved released bread wheat varieties; Buhae is an improved released durum wheat variety.



Ploughing with oxen in the Ethiopian highlands. Improving, increasing and diversifying the use of animal traction will help farmers produce more food and feed.

late afternoon, with a rest period in the middle of the day of 3.2 hours. They cultivate 0.32 ha d^{-1}, ploughing to depth of 12.5 cm. The average speed of ploughing using a single furrow plough is 0.78 m s^{-1}. This work output is achieved with minimal supplementation and at the time of year when animals are lightest. Among comparable animals, mean liveweight was 232 kg in mid-July and 270 kg at the end of September.

A trial carried out under controlled conditions showed that over an average working day of 3 hours the working speed of oxen pulling weighted sleds was unaffected by liveweight changes ranging from a loss of 25 kg to a gain of 70 kg during the dry season. All animals, irrespective of body condition at the beginning of the trial, increased their working speed from a mean of 0.82 m s^{-1} during the first week of the trial to 0.91 m s^{-1} during the second week of the trial.

With an average daily work output of 3.08 MJ, the animals lost an average of 2.63 kg d^{-1} during 2 weeks of work when fed a maintenance diet.

Introduction of animal traction into new areas

Despite its many potential benefits, the use of animal traction is highly localised and efforts to introduce the technique into new areas have often failed. This has been attributed to technical, economic and social constraints, which tend to be fairly location-specific.

ILCA has initiated a project for the introduction of animal-powered cultivation of *fadamas* in subhumid Nigeria. These seasonally inundated inland valleys make up about 7% of the land area of sub-Saharan Africa, an area equivalent to Nigeria. Although potentially very productive they are not at present fully exploited for cropping, mainly due to shortage of labour for land preparation. However, grasses growing on residual moisture make the fadamas valuable for dry-season grazing.

In many of the fadama soil types, soil moisture is sufficient for cultivation throughout the year, especially if supplementary irrigation is used. Rice is one of the major crops on these areas and rice cropping is being actively promoted in Nigeria.

Four topics will have to be researched if the productivity of fadamas is to be increased through rice cropping:

- The shortage of labour for timely land preparation;
- The need to regulate the flow of water;
- The need to identify and incorporate short-duration rice varieties to facilitate sequential cropping either with a second rice crop or another crop; and
- The utilisation of rice straws and residues for feeding livestock in lieu of the grazing lost to rice.

ILCA's primary objectives are to increase labour productivity in land preparation, which provides an entry point for animal traction, and to ensure effective utilisation of rice residues, which is critical to the welfare of ruminant livestock in the zone. In 1987 ILCA's efforts concentrated on cooperation with other institutes to find suitable rice varieties for fadama land.

Twelve rice varieties from the Nigerian Cereal Research Institute and the International Institute of Tropical Agriculture (IITA) were acquired through the Federal Agricultural Coordinating Unit (FACU) and were evaluated for grain and straw yield at Kufana, in the Nigerian subhumid zone. Most matured earlier and gave higher yields of better-quality grain and straw than the local varieties (Figure 11). The crude protein content of the

straw ranged from 4.3 to 7.5%. Thus, replacing the local rice variety with an improved variety could increase both the amount and nutritional quality of feed available to livestock.

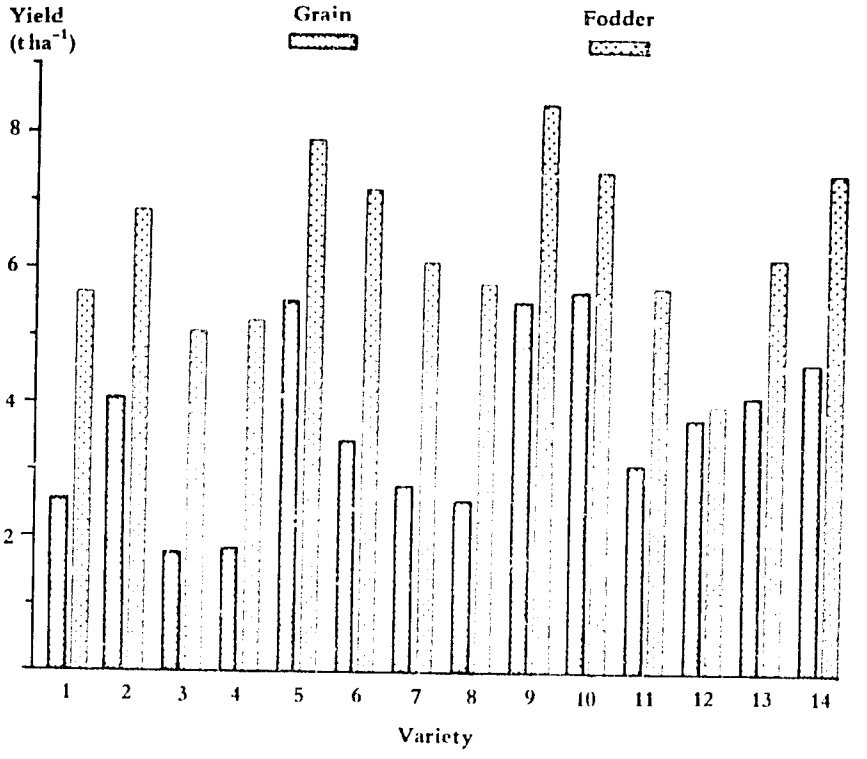


Figure 11.
Grain and fodder yields of rice varieties grown on fadama (flood plain) land, Kufana, Nigerian subhumid zone, 1987

Variety Key:

1 = FARO 228-2-1-1	2 = ITA 212	3 = FARO 239-2
4 = KUFANA local	5 = ITA 234	6 = FAROX 228-4
7 = FARO 29	8 = KUFANA local	9 = FARO 239-3-1-1
10 = ITA 304	11 = FARO 228-4	12 = ITA 222
13 = ITA 230	14 = ITA 306	

Physiology of working animals

In animal traction research, physiological and mechanical performance parameters of animals must be monitored in detail to develop viable draught-animal technologies. A primary objective is to ensure that feed energy is transformed into work energy as efficiently as possible. A contract research agreement between the joint Vertisol management project at ILCA and the Agricultural and Food Research Council's Institute of Engineering Research, UK, aims at developing a comprehensive system for monitoring the performance of draught animals and animal-drawn implements. The equipment, which will be fully operational by early 1989, senses and records the heart rate, breathing rate, stepping rate, draught force, draught angle and forward speed of the working animal. It also records air temperature and wind speed. In its final form, the equipment will also have a gas exchange sensor, which will allow detailed studies on the energy metabolism of the working animal.

The equipment therefore allows working animals to be accurately monitored in the field. Data collected will be used to quantify performance parameters, assess effects of work on animal physiology, assess the suitability of animal-drawn equipment in relation to the envisaged draught animal and generate valuable feedback to engineers working on implement prototypes. It will also make it possible to quantify the effects of different nutritional and environmental stresses on the physiology of draught animals.

Animal traction research network

Successful expansion or intensification of draught-animal use depends on several factors. These include the degree of crop-livestock interaction, the availability of animals, proper animal husbandry and management, adoption of suitable cropping techniques and the supply and maintenance of appropriate equipment. Research is often required to ensure that technologies are adapted to the combination of animals, soils, crops, feed resources and economic and social conditions that characterise a particular farming system.

The inter-disciplinary nature of such research, coupled with the fact that many of the problems it seeks to solve are location-specific, calls for close collaboration with national agricultural research services (NARSs), specialised research centres within the CGIAR and other research institutes with mandates covering such "interface" research areas.

Development of new animal-drawn implements starts from what the farmer already has, such as the traditional Ethiopian plough or maresha.

ILCA has been working to establish an animal traction research network for sub-Saharan Africa. The network will assist in planning, implementing and monitoring animal traction research on common problems in the region. It will provide a medium for information exchange, technical cooperation and research collaboration.

The overall goal of the network is to improve and extend the use of draught-animal power in African agriculture, in order to increase agricultural production and raise rural income. The network will link organisations and individuals with research, development and training activities in the field of draught-animal power. Specifically, the network will:

- facilitate exchange and awareness of both existing and new information through a newsletter and technical reports in English and French;
- improve liaison and cooperation among people and organisations working on animal traction;
- increase technical knowledge and understanding of the potentials of draught-animal power among decision-makers, researchers, extension personnel and farmers;
- encourage widespread field evaluation of non-conventional uses of animal traction that have been successful in some African countries, including water-lifting, oilseed processing, land and water management and forestry uses; and
- strengthen animal traction research in NARSs through research collaboration, logistical support and strategic technical training.

ANIMAL TRACTION THRUST STAFF

S Jutzi, *Thrust Coordinator*
Abate Tedla, *Forage Agronomist*
Abiye Astatke, *Agricultural Engineer*
P Bartholomew, *Forage Agronomist*
S Debrah, *Economist*
Getachew Asamenew, *Agricultural Economist*
M R Goe, *Animal Scientist*
S A Ingawa, *Economist*
R von Kaufmann, *Agricultural Economist*
J McIntire, *Agricultural Economist*
M A Mohamed-Saleem, *Agronomist*
A Panin, *Economist (Post-doctoral Associate)*

Animal Feed Resources Thrust

Feed shortages during the dry season, and sometimes even during the wet season, constrain livestock production in almost every production system of sub-Saharan Africa. Even where feed is plentiful it may be low in nutritive value, may form an imbalanced diet lacking critical elements, or may be inefficiently converted into protein and energy by the animal.

The Animal Feed Resources Thrust seeks to alleviate these constraints by providing adapted forage germplasm and suitable feed and feeding technologies to national agricultural research services (NARSs) and to ILCA/NARSs commodity research programmes. These technologies combine forage legumes, fodder trees and agro-industrial byproducts with natural feed resources. The thrust caters for the needs of all zones except the arid. Special emphasis is given to the integration of legumes in mixed crop–livestock farming systems so as to achieve stable and sustainable feed and food production in sub-Saharan Africa.

Objective

The medium-term objective of the Animal Feed Resources Thrust is to develop suitable forages and other feeds to increase livestock production in sub-Saharan Africa, and to improve the ecological sustainability of mixed farming systems through improved soil fertility.

Assessment of feed resources

Increasing livestock production depends to a large extent on the availability of suitable feed resources. Determining the potential feed supplies in various agro-ecological zones, collection of forage germplasm and its evaluation in Ethiopia and Nigeria, and determination of the quality of feed resources and socio-economic constraints to their improved utilisation, are major tasks in assessing the need for additional and alternative feeds and for identifying means to improve feed resources. Other aspects of the work include support facilities and service activities, such as the genebank, plant and soil laboratories, seed production, and tissue culture/rhizobiology studies.

Agroclimatic studies

Herbarium specimen database

A computerised database is being developed on site of collection and morphological/agronomic characteristics of grasses and legumes stored as herbarium specimens in East African herbaria, and on accessions stored in ILCA's genebank. Accession data for material held in ILCA's genebank have already been entered and data from the East African Herbarium, Nairobi, are currently being entered. The database was used in 1987 in planning a *Sesbania* collection mission. It provided information on areas where diversity of species and morphology is greatest, on their precise locations and suitable collection periods. The database has also been used to analyse the distribution patterns of 16 native African *Trifolium* species in relation to environmental factors. Data can also be extracted for other computer uses, such as computer mapping.

Modelling forage production in Ethiopia

The agro-ecological yield trials established at three contrasting sites in 1986 were continued in 1987. The data were used to check the usefulness of the FAO model for the correlation of peak DM production and length of growing period (LGP). The model gave a correlation of $r = 0.67$ for about half of the accessions analysed but relationships between yield and LGP were clearly non-linear in many cases. The model was also used to test data from trials run over longer periods. It was found that a temperature factor was needed to correct for altitudinal differences. With the inclusion of this total DM yield was well correlated for medium altitude trials (1650–2200 m) but not for high altitude trials (2400–3000 m).

Results from a lowland grass-legume mixture yield trial at Soddo were analysed using the WATBAL model. Correlations between yield estimates at 6-week intervals and the cumulative growth index were excellent for total regrowth (legume plus grass) for 1985 and 1986 but not for 1987, a year of higher rainfall when shortage of P may have limited growth.

Assessment of forage production potential in West Africa

ILCA's mandate covers all of sub-Saharan Africa but its research activities are concentrated in a few sites and countries. Most of the work on improving livestock nutrition in the subhumid zone using forage legumes has been carried out in Kaduna state of Nigeria.

The regional relevance of research conducted at Kaduna was assessed using the agro-ecological zones (AEZ) project methodology, in collaboration with FAO. This involves determining soil-climatic requirements of a land-use type, such as a particular crop variety, and matching these with the land resource inventories of the target area. Comparisons of what is potentially possible with what is actually achievable, in terms of the fraction of the biomass that is economically useful (Harvest Index), helps to rank the land area into different suitability classes for that land-use type. This approach also indicates the type and level of inputs and management practices required to attain optimum productivity.

FAO has information on the extent of land with varying suitabilities for 11 rainfed crops. Assessment of land suitabilities for *Stylosanthes hamata* cv Verano for 8 West African countries using the AEZ principles revealed that the area to which this stylo is best suited falls within the 180- to 210-day growing period zone (Figure 12).

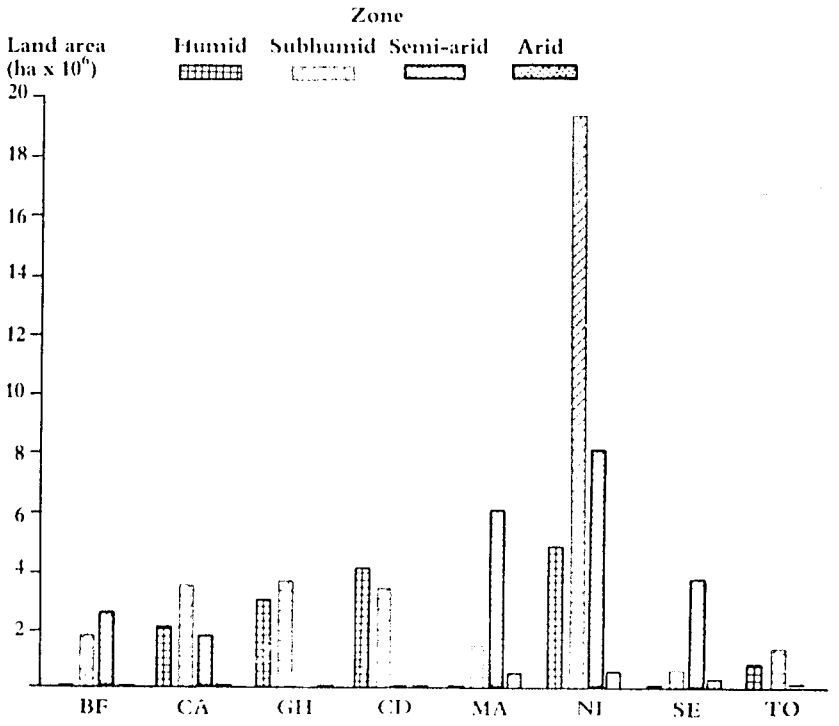


Figure 12.
Area of land suitable for Stylosanthes hamata *cv Verano in eight West African countries.*

BF = Burkina Faso; CA = Cameroon; GH = Ghana;

CD = Côte d'Ivoire; MA Mali; NI = Nigeria;

SE = Senegal; TO = Togo.

The extent of land suitable for a particular crop can then be the basis for estimating production potential by ecological zones or country by using the Harvest Index and yield ranges that separate the suitability classes. Figure 13 provides an example based on the assumption that 25% of the suitable land area in Nigeria for each of the major cereal crops and Verano stylo is actually cultivated. The potential fodder production from these crops varies depending on the location and the level of inputs.

Fodder from rice and maize are of greater importance in more humid areas, while sorghum and millet are increasingly important in the drier zones. In the subhumid zone all crops are equally important. The figures suggest that, if appropriate conservation or utilisation techniques were available, maize could contribute more biomass to livestock from a given land area than the other cereals. However, no conservation technique appropriate to smallholders is available at present.

At the current low level of inputs, production may not be adequate to sustain the growing human and livestock populations and pressure on land will increase. If, however, the level of inputs is raised, West African countries could attain food self-sufficiency.

Forage genetic resources

Genebank

A total of 629 accessions were added to the collection in 1987. The genebank now holds 8642 accessions covering 145 genera and 346 species (Table 18).

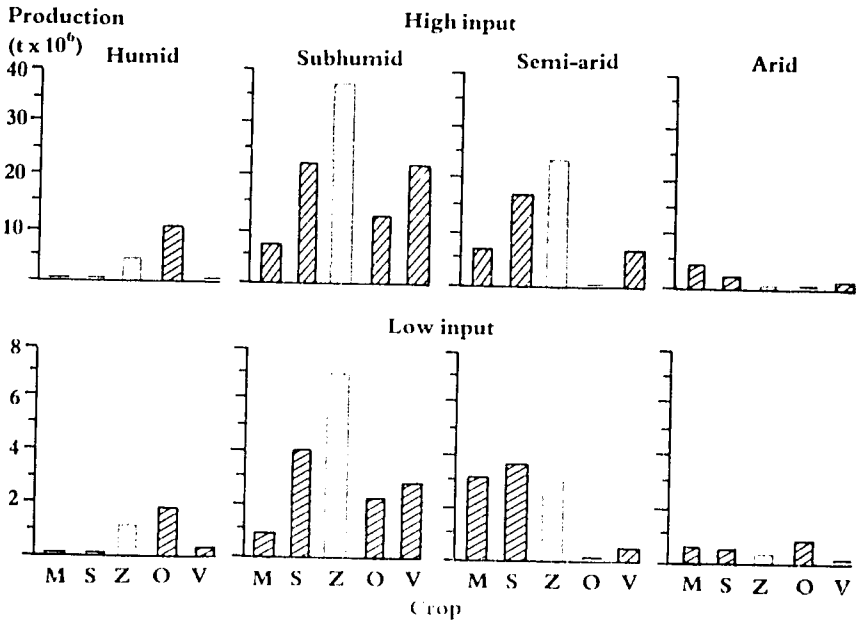


Figure 13.
Potential fodder production from millet, sorghum, maize, rice and Verano stylo under high and low levels of inputs, Nigeria.

Key: M = millet; S = sorghum; Z = maize; O = rice; V = Verano stylo.

The number of accessions held in 1987 is slightly fewer than in 1986 because duplicate accessions have been eliminated from the collection. Seeds of almost 4000 lines were dried and sealed in aluminium foil bags for long- and medium-term storage in 1987. The entire seed collection held at present should be in long- and medium-term storage by 1989.

A total of 5000 seed samples were distributed in 1987 in response to 233 requests. This is an increase of 12% compared with 1986. The proportion of requests from African countries other than Ethiopia also increased.

Most of the grass accessions in the genebank had been tested for germination by the end of 1987. Accessions with low germination percentages will be multiplied in 1988.

Preparation of a new edition of the germplasm catalogue was started in 1987. This will cover about twice as many accessions as the 1985 edition and will give much more data on site of collection for acquired accessions. The catalogue will be published in 1988.

Table 18. *Forage germplasm held in the ILCA genebank, December 1987.*

	Genera	Species	Accessions
Legumes	39	60	6235
Browse	70	196	1150
Grasses	36	90	1257
Total	145	346	8642

Seed multiplication

About 1600 lines of grasses, legumes and browse are being multiplied at Zwai on basic soils. An additional 1600 are being multiplied at Soddo on acid

soils. The Zwai site was further developed by the construction of a large screen-house/nursery and the completion of an inventory database for the materials planted.

The Zwai site is at an altitude of 1650 m on soils with a pH of 8.3. Despite the very high pH most forage germplasm adapted to low and medium altitudes grows well. Data are recorded on morphological and agronomic characters of plants in the multiplication plots. By 1987 about 1600 lines of grasses and herbaceous and browse legumes had been established. These included *Centrosema pubescens* (87 lines), *Stylosanthes hamata* (95 lines), *S. scabra* (33 lines), *S. sesban* (36 lines), *Chamaecytisus* spp. (23 lines) and *Brachiaria* species (459 lines). Selections of particularly promising material have been made from these and other species.

Collection activities

Several short collection missions in Ethiopia yielded 197 lines of grasses, legumes and browse (mainly *Acacia*). A 2-month mission in Tanzania, funded by the International Development Research Centre (IDRC), Canada, and supported by the International Board for Plant Genetic Resources (IBPGR), collected 161 accessions of 12 *Sesbania* species and provided training in collection techniques for two national programme staff, one from each of Kenya and Uganda.

In vitro culture

In vitro culture activities expanded in 1987 following the arrival of an IBPGR-sponsored post-doctoral fellow. In addition to established work on the culture of axillary buds of *Brachiaria* species to provide disease-free material for distribution, work has started on the development of in vitro storage techniques for germplasm of the grass genera, *Digitaria* and *Cynodon*. Both have been successfully cultured and have so far survived for 100 days at low temperatures. Rapid clonal propagation of browse species is also being investigated and *Leucaena leucocephala* callus tissue and plantlets have been successfully cultured.

Herbarium

A total of 304 plant species were identified for several organisations. Work has started on preparing herbarium specimens of all the 8642 genebank accessions, and specimens of 326 accessions were pressed in 1987.

Rhizobium relationships

Rhizobiology

Efforts are being made to identify productive rhizobial associations with perennial *Trifolium* species native to African highlands. This work is in collaboration with the University of British Columbia. Isolation of rhizobia and initial screening is being undertaken in Canada. A rhizobiology laboratory has been set up at ILCA headquarters and a training course on laboratory techniques for ILCA and national technicians was conducted under the IDRC-supported project.

Site characterisation of soil nutrients and water, reviews and analytical services

Soil nutrients and water are major determinants of plant productivity. To achieve a sustained increase in feed and food production, these resources must either be used more efficiently, through increased turnover, or supplemented by applying fertilizer or irrigation.

Characteristics of Vertisols at ILCA research and outreach sites

Eighteen Vertisol profiles were described and their physico-chemical properties determined. Although phosphorus was uniformly distributed through the soil profiles, its availability was low ($<1\ \mu g\ g^{-1}$) in most soils tested.

The amount of soil water available to plants varied from 324 to 686 mm with profile depth of 1.15 to 2.35 m. All the sites were classified as imperfectly drained to poorly drained. The organic phosphorus and organic-matter content decreased with soil depth, while the distribution of other phosphorus fractions within the soil profiles had no consistent trend.

Soil moisture storage along a toposequence at Debre Zeit

Soil moisture was measured at five points along a toposequence at Debre Zeit over 53 weeks during 1986 and 1987 to determine the moisture storage capacity of various soil types. Some of the results are summarised below:

- Alfisol, soil with vertic properties and Vertisol stored 113, 187 and 278 mm per metre depth respectively.
- During the maturity stages of forages crops, Vertisol stored 57% more moisture than Alfisol and remained moist throughout the year at 50 and 100 cm depth. Cracks reached 45 cm depth.
- In the post-rainy season, 98 mm of supplementary irrigation was needed to moisten the upper surface layer to ensure germination of a second crop and enable the seedlings to root to lower soil layers.

Analytical services

The soils service laboratory received 1593 soil samples from various programmes, and made 10 021 determinations. The soil chemistry laboratory received 993 soil samples, on which 3273 determinations were made, and 1489 plant samples (5892 determinations). The soil physics laboratory received 2561 soil samples, and made 5322 determinations.

Crop–livestock interactions

In 1986, a research project was undertaken by ILCA and IEMVT (Institut d'élevage et de médecine vétérinaire des pays tropicaux) staff, with partial support from the World Bank, on crop-livestock interactions in sub-Saharan Africa. The major purpose of the project was to document current interactions throughout the sub-continent, produce economic analyses of proposed technologies aimed at improving interactions, and to recommend research priorities.

A detailed literature review was first undertaken. This was based on earlier papers that had proposed hypotheses about the nature and level of crop–livestock interactions. After completion of a draft literature review, field visits were made to 12 sub-Saharan African countries (Burkina Faso, Burundi, Congo, Côte d'Ivoire, Ethiopia, Kenya, Mali, Niger, Nigeria,

Rwanda, Zaire, Zimbabwe) plus Madagascar to assess crop-livestock interactions and to gather data for analysis. (A questionnaire and computer software were produced in English and in French, and are available upon request.) A book-length manuscript is now in preparation and will be available in mid-1988.

Summary findings of the project are as follows: Crop–livestock interactions are few in the more humid zones, because animal diseases and a cropping pattern based on root crops discourage animal production. Interactions become more frequent and more intense through the subhumid and semi-arid zones. These interactions are based on the use of animal traction and manure in cropping and the use of crop residues as livestock feed. Interactions are most frequent in the highland zones, where cereals are a major part of the cropping pattern. Interactions in the highlands involve intensive milk production, animal traction, manure production, and sown fodder crops.

The nature and frequency of some of the interactions are shown in Tables 19 and 20. Table 19 shows the frequency of certain types of interaction between independent herders and farmers and how the relative frequency varies between environments. Table 20 shows how dependence of livestock on pastures or crop residues varies between environments and seasons.

Table 19. *Principal types of crop–livestock interaction between herders and farmers at 30 sites in sub-Saharan Africa (number of responses).*

Environment and frequency of interaction	Type of Interaction			
	Manuring	Crop residues	Draught power	Herd management
Humid zone				
rare	0	0	0	0
occasional	0	0	0	0
frequent	0	0	0	0
Subhumid zone				
rare	2	0	0	2
occasional	3	4	1	3
frequent	1	1	0	13
Semi-arid and arid zones				
rare	0	0	1	8
occasional	8	4	4	0
frequent	11	3	3	1
Highland zone				
rare	1	2	0	0
occasional	3	10	6	0
frequent	6	5	8	0

Research priorities identified by the project include management of crop residues for soil improvement or for feed; development of fodder crops for milk production in the East African highlands; the need for a shift in animal traction research from primary tillage to weeding; and the need for more emphasis on smallholder fattening programmes, especially with small ruminants.

Table 20. *Dependence of livestock on different feed combinations at 30 sites in sub-Saharan Africa, by environment and season (number of responses).*

	Wet season	Dry season
Humid zone		
pastures only	4	4
pastures plus crop residues	0	0
mainly crop residues or stall-feeding	0	0
Subhumid zone		
pastures only	4	0
pastures plus crop residues	1	3
mainly crop residues or stall-feeding	1	3
Semi-arid and arid zones		
pastures only	11	4
pastures plus crop residues	0	7
mainly crop residues or stall-feeding	0	0
Highland zone		
pastures only	5	2
pastures plus crop residues	2	3
mainly crop residues or stall-feeding	2	4

Initial evaluation of feed resources

Increasing the feed resources available for livestock production depends on systematic evaluation of forages in a range of environments. Under this theme, forage germplasm is evaluated agronomically in Ethiopia and Nigeria, and its performance in production systems assessed under highland, humid and subhumid conditions in the same countries. Research also examines soil-plant-water-nutrient relationships and their influence on forage and food crop yields, and the nutritive value of feedstuffs.

Agronomic evaluation of forage germplasm

Germplasm is screened and evaluated under three agro-ecological conditions: highland (temperate) and mid-altitude (sub-tropical) in Ethiopia and lowland (tropical) in Nigeria.

Highland temperate zone

Adaptation to Vertisol. Ten selected accessions of perennial native *Trifolium* species were screened for their adaptation to a Vertisol at the Shola Vertisol Project site at 2400 m. *Trifolium cryptopodium* and *T. burchellianum* produced about 2.3 and 1.2 t DM ha^{-1}, respectively, from one cut. They were thus much more productive than *T. semipilosum*, which yielded only 320 kg ha^{-1}, and appear to be promising for use in this environment.

Intercropping trials. Intercropping with food crops is one way to introduce forages into farming systems. Thus, intercropping trials were established in 1987 at four Vertisol and two Nitosol sites, in collaboration with the ILCA Vertisol Project and the Institute of Agricultural Research. At each site one line of each of the native annual highland species *T. decorum* and *T. quar-*

tinianum were intercropped with wheat, *Vicia faba* and noug (*Guizotia abyssinica*), a local oilseed crop. In the two trials not adversely affected by drought the grain yields of wheat and noug alone were 2.7 and 0.3 t ha^{-1} respectively. Intercropping with *T. quartinianum* (ILCA 6301) reduced wheat grain yield by 35% and noug yield by 25% but produced an additional 5.4 and 3.6 tonnes of legume dry matter per hectare, respectively.

Mid-altitude, sub-tropical zone

Initial evaluation and agronomic description of accessions for adaptation to mid-altitude, sub-tropical conditions is mainly carried out at the Ministry of Agriculture Welayita Regional Station at Soddo, Ethiopia.

The Soddo site is at 1900 m on a Nitosol. Annual rainfall averages about 1100 mm. The site is representative of the medium altitude, medium rainfall, acid soil areas of western Ethiopia, Kenya, Tanzania, Uganda, Rwanda, Burundi and highland areas of Cameroon.

In the initial introduction plots, of which about 1600 have been planted, collections of *Zornia* (178 lines), *Stylosanthes guianensis* (201 lines), *S. fruticosa* (93 lines) and *Neonotonia wightii* (40 lines) planted in 1985 have been evaluated and promising germplasm selected for further screening.

Of the 40 lines of *N. wightii* planted, the best nine lines were all collected in the region. A number of vigorous, tall lines of *Cajanus cajan* selected at Zwai have performed poorly at Soddo, while a line collected locally has performed well. Thus it appears that at Soddo, at the upper end of the elevational range for sub-tropical germplasm, locally collected material performs better than germplasm collected from sites at lower altitude.

Another aspect of adaptation of locally collected material is in disease response. In 1987 this was illustrated in an initial evaluation trial with 93 lines of *S. fruticosa*, all but 10 of which were collected in southern Ethiopia. Anthracnose severely affected all the Ethiopian accessions during the 1987/88 dry season, while the other lines (9 from Niger, one of unknown origin) were essentially unaffected. Thus, the local race of the disease had apparently evolved along with the *S. fruticosa* genotypes.

The dry-matter production of *Stylosanthes* species under six-weekly cutting has been studied in a replicated yield trial since 1984. *Stylosanthes scabra* cultivars Seca and Fitzroy yielded more than the *S. guianensis* cultivars in 1986 and 1987, particularly in the dry season (Table 21).

Table 21. *Dry-matter yields of* Stylosanthes guianensis *and* S. scabra *cultivars, Soddo, Ethiopia, 1984-87.*

	DM yield (t ha^{-1})				
	S. guianensis			*S. scabra*	
Year (season)	Cook	Graham	Endeavour	Seca	Fitzroy
1984	3.5	1.7	1.2	1.8	1.3
1985	5.5	2.1	4.9	5.0	3.6
1986	3.2	1.7	2.6	5.8	5.1
1987 dry	0.6	0.5	0.4	1.7	2.0
wet	1.9	1.5	2.1	2.8	2.7
total	2.5	2.0	2.5	4.5	4.7
Total	14.7	7.5	11.2	17.1	14.7

Lowland tropical zone

Herbaceous forage legumes for the humid zone. Research on herbaceous forage legumes for the humid zone recommenced in 1987 after a break of several years. Thirty-one lines were screened in observation trials at two sites in southwest Nigeria. This work is aimed at developing forage production systems for medium-scale small ruminant producers and smallholder cattle production in the humid and derived savannah zones. Forage legumes evaluated included six lines of *Stylosanthes*, 10 lines of *Centrosema*, eight lines of *Desmodium* and single lines of *Pueraria phaseoloides*, *Macroptilium atropurpureum*, *Calopogonium caeruleum*, *Desmanthus virgatus*, *Lablab purpureus*, *Cassia rotundifolia* and *Tephrosia bracteolata*.

Most lines grew vigorously and were highly productive during the rains. As the dry season set in a number of lines experienced high leaf drop and mortalities, with some drying-up completely by the middle of the dry season. *Lablab purpureus*, *Stylosanthes scabra* cv Seca, *Centrosema pubescens*, *C. macrocarpum* and *Macroptilium atropurpureum* continued to grow and retained much of their leaf up to the middle of the dry season, and so to a lesser extent did *Calopogonium caeruleum* and *Stylosanthes guianensis* cv Graham. A few of these lines will be selected and used in pasture development and management studies in 1988.

Promising forage legumes for the Nigerian subhumid zone. Twenty-four promising lines of forage legumes from preliminary screening trials were evaluated agronomically at Kurmin Biri and six other sites in the Nigerian subhumid zone in 1986 and 1987. Three species adapted to subhumid zone conditions were identified (Table 22). These compare well with *Stylosanthes hamata* which is currently the most commonly used legume and yields 4 to 5 t DM ha^{-1}. All three species have crude protein contents of 10–15% and are therefore potentially valuable forage species. Evaluation of the ability of these lines to persist in the natural sward will start in 1988.

Anthracnose tolerance. The susceptibility of stylosanthes to anthracnose (caused by the fungus *Colletotrichum* spp.) seriously restricts its adoption, particularly in more humid areas. Although *Stylosanthes hamata* cv Verano has still not succumbed to anthracnose after more than 5 years of continuous growth it is unwise to continue to be solely dependent on it.

In 1987, 17 *S. guianensis* accessions from CIAT (Centro Internacional de Agricultura Tropical) were sown in unreplicated 1×1 m plots, with *S. guianensis* cv Cook and *S. hamata* cv Verano from local supplies as controls.

Table 22. *Production attributes of promising forage legumes for subhumid Nigeria*

Species	ILCA No.	Dry-matter yield (t ha^{-1}) 1986+1987	Seed yield (kg ha^{-1}) 1987	Increase in soil N after 1 year (%)
Cassia rotundifolia	10915	6.43	245	0.028
Cassia rotundifolia	10918	5.60	237	0.019
Centrosema brasilianum	155	6.57	20*	0.023
Centrosema brasilianum	7948	7.88	6*	0.007
Centrosema pascuorum	9858	8.73	124	0.021
Centrosema pascuorum	9864	9.23	230	0.023

* *Centrosema brasilianum* produces seed throughout the dry season. These yields were recorded for the first half of the dry season only.

The accessions were exposed to uniform disease challenge by spraying them with extracts from anthracnose-infected Cook stylo plants. The plots were scored for general plant appearance and sampled for isolation of pathogens and dry-matter yield. In a related experiment, 10 seedlings of each of the accessions and cultivars were planted in four replicates within a previously infected plot of Cook stylo and allowed to grow with the regenerating Cook stylo. Five seedlings per replicate were tagged and scored for disease attack (Table 23).

Three lines died by the end of the growing period. Although *Colletotrichum* was isolated from all lines, CIAT 184, CIAT 136 and Verano stylo showed no symptoms of anthracnose and grew normally. The fungus *Phoma sorgina* was also isolated from most accessions (Table 23). This fungus has

Table 23. *Evaluation of some stylosanthes lines for anthracnose tolerance, Nigerian subhumid zone, 1987.*

Stylo accession number	Fungal association					Disease score	DM yield (kg ha^{-1})
	I	II	III	IV	V		
CIAT 11370			X		X	4	3616
CIAT 11366	X		X	X	X	6	6696*
CIAT 11371	X	X	X	X	X	4	4418
CIAT 11374	X		X			4	4128
CIAT 11372	X		X	X	X	6	5104
CIAT 11369	X	X	X			4	5487
CIAT 11365			X	X	X	4	4058
CIAT 136	X		X			1	7959
CIAT 11375			X		X	6	3880
CIAT 11364	X		X	X	X	6	4950*
CIAT 184	X		X		X	1	8153
CIAT 11362		X	X			3	5218
CIAT 11363			X	X	X	4	4909
CIAT 11373			X		X	5	5202
CIAT 11367	X	X	X	X	X	4	6618
CIAT 11368	X		X		X	3	4875
CIAT 11376	X		X			4	5123
Cook stylo	X	X	X	X	X	6	6423*
Verano stylo	X	X	X	X		1	5345

Pathogens	Disease code scale	Percent of leaf/stem attacked	Remarks
I. Fusarium	1	nil	Resistant
II. Curvularia	2	1–10	Moderately resistant
III. Colletotrichum	3	11–30	Moderately susceptible
IV. Helminthosporium	4	31–50	Susceptible
V. Phoma	5	51–70	Highly susceptible
	6	>70	Highly susceptible

* = died at the end of growing season.

been reported to cause leaf spots in a number of food crops grown in the savannah and black stem spotting on stylosanthes in Nigeria. More work is needed to determine the pathogenicity and inter-host transmission of other organisms, since this may affect the adoption of crop-stylo associations as advocated in fodder-bank cropping.

The plots were cut at the end of the rainy season after 5 months of growth and irrigated in the dry season. None of the surviving stylo lines showed symptoms of anthracnose on their ratoon growth and the fungus was not isolated from any of the plants up to 8 weeks after cutting, when leaf area was still small. This suggests that canopy size and cover are important factors in determining the severity of the disease and these are factors that could be controlled by appropriate management.

Effect of herbicides on fodder production from rice areas. In sub-Saharan Africa inland valleys or "fadamas" account for about 7% of the land area, an area equivalent to Nigeria. Due to impeded drainage these areas are seasonally inundated. Rice is one of the major crops on these areas and rice cropping is being actively promoted in Nigeria. Weeds are a major problem on intensively cropped fadama land. Since weeding has to be timely and there is a shortage of labour the extension services recommend the use of herbicides. However, weeds contribute to the quality of feed available in rice fields after harvest and a trial in 1987 examined the effect of chemical weed killers on rice and weed yields.

Preliminary results show that there was no significant difference in either grain or crop residue yield between hand-weeded plots and plots to which TEER (N-butoxymethyl-2-chloro-2'6-diethylacetanilide) was applied. The proportion of weeds in total fodder was greater in all plots to which the weed killer was applied than in hand-weeded plots (Table 24). This may have been because hand weeding was carried out later than spraying and thus weeds had less time to re-establish in the hand-weeded plots. The results indicate that the use of herbicides will not reduce post-harvest fodder yield or quality.

Table 24. *Grain and total fodder productivity (kg ha^{-1}) from rice plots as influenced by weed control, Nigerian subhumid zone, 1987.*

Treatment	Grain yield (kg ha^{-1})	Crop residue yield (kg ha^{-1})	Harvest index (%)	Total residue including weeds (kg ha^{-1})	Weed yield	
					Percent of total fodder	(kg ha^{-1})
No weeding	1029	3830	27	7107	60	4297
Hand weeding	2917	5634	34	6120	8	486
RONSTAR-EC	2002	6049	25	7428	18	1379
RONSTAR-PL	2230	5714	28	6730	15	1916
TEER	2677	6243	30	7171	13	928
LSD	311	1139				

TEER: N-(butoxymethyl)-2-chloro-2'6-diethylacetanilide.

RONSTAR: 3-(2,4-dichloro-5-1-methylethoxyphenyl-5-1,1-dimethyl-1,3,4-oxadiazol -2(CH)-oie.

Soil fertility and water-use studies on forages

Relative efficiency of various phosphorus sources on forage legumes

A greenhouse experiment in 1987 examined the effectiveness of Togolese and Egyptian rock phosphates as sources of phosphorus, relative to triple superphosphate (TSP), on an Ethiopian volcanic ash soil with high P-fixation capacity. Lucerne (*Medicago sativa*) was used as the indicator crop. The relative effectiveness of Togolese and Egyptian rock phosphates was greatest at 60 and 43 kg P ha^{-1}, respectively. At these rates, Egyptian rock phosphate (ERP) was 92% as effective as TSP, compared with 64% for Togolese rock phosphate (Figure 14).

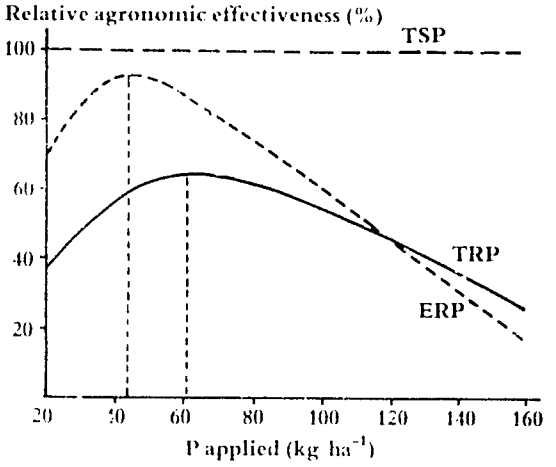


Figure 14.
Effectiveness of Egyptian rock phosphate (ERP) and Togolese rock phosphate (TRP) relative to triple superphosphate (TSP) on a volcanic ash soil, greenhouse experiment, ILCA headquarters, 1987

Applying TSP and ERP at various rates to clovers grown on a Vertisol at the headquarters site resulted in significantly higher cumulative dry-matter yields over 4 years. The cumulative effect of ERP was greater than that of TSP at 15 and 30 kg P ha^{-1}, but TSP was more effective at higher rates (Figure 15).

Effect of two ERP sources (ILCA and Ministry of Agriculture) was evaluated on a Vertisol for 1986/87 cropping seasons on Shola Vertisol. ERP provided to ILCA produced 1.1 t ha^{-1} more dry-matter yield of clovers than the ERP supplied to the Ministry.

Adaptation of forages to soil constraints

Large areas of West African soils that developed on basement complex are characterised by indurated or hard layers within 100 cm of the surface. In many soils this hard pan ... within the plough horizon and therefore restricts the growth of food and forage crops. In extreme cases it can be continuous, impeding root penetration and water infiltration. In order to quantify the effects of the hard pan on crop and forage growth an experiment was set up with three treatments at two sites:

- Disc harrowing and maize or stylo planted on flat land;
- Disc harrowing and maize or stylo planted on ridges; and
- Disc harrowing and soil hard pan broken by trenches 30 cm wide and 40 cm deep to simulate in-row subsoiling; maize or stylo planted on re-filled trench rows.

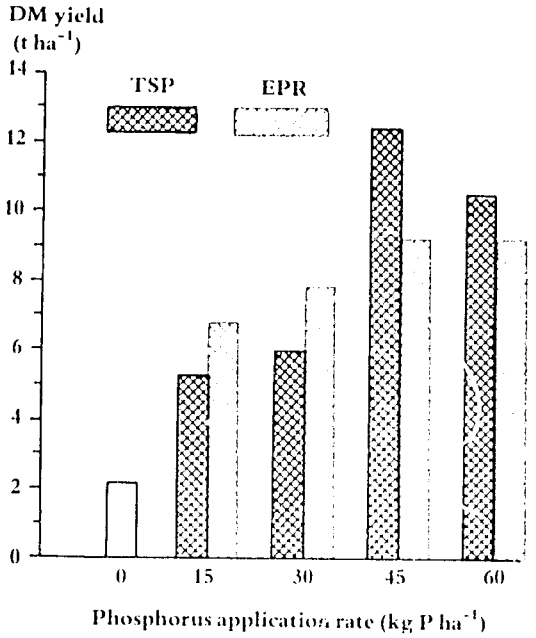


Figure 15.
Cumulative effect of triple superphosphate (TSP) and Egyptian rock phosphate (ERP) on dry-matter yield of clovers on a Vertisol at Shola, Ethiopia, 1984–87

Cracking the hard pan significantly increased grain and stover yields of maize as compared with disc harrowing at site 1 and both treatments at site 2 (Table 25). It also increased the dry-matter yield of stylo by 25% over only disc harrowing.

Table 25. *Effect of tillage method on yield of maize and Cramo stylo, Nigerian subhumid zone, 1987.*

Tillage method	Grain yield (kg ha^{-1})	Stylo DM yield (kg ha^{-1})	Mean stylo root density (g m^{-3})	
			0–30 cm	30–60 cm
Subsoiling	4926	6865	210	77
Disc harrowing	3962	5480	101	8
Ridging	4210	5437	152	19
LSD	838	843		

Breaking the hard pan by manually chiselling and refilling trenches increased the water-holding capacity of the soil and allowed greater proportions of the roots to penetrate deeper layers. Total root density was also greater in both soil layers. This is important especially in areas where rainfall is erratic or dry years are more frequent. The higher soil moisture content resulting from the trenches could effectively extend the length of the growing period and help plants to withstand dry spells during the growing season. Research is now needed to find practical and economical means of breaking the hard pan.

In a related experiment the effect of the hard pan was simulated in a green house by packing a 50:50 soil-gravel mixture in oil drums. This was then mechanically compacted to a bulk density of about 1.6 g cm^{-3}. The soil-gravel mixture was topped with a layer of sandy loam soil, 5 or 15 cm deep.

Scarified seeds of *Stylosanthes guianensis* cv Cook were sown and the drums were watered daily.

Subsoil gravel layer at 15 cm depth had no effect on the dry-matter production of Cook stylo compared with soil without a gravel layer, but dry-matter yield was reduced by 23% when the gravel layer was at 5 cm depth. Increasing the watering interval to 5 days reduced stylo dry-matter production by 55%. The subsoil gravel layer reduced root growth by 20%. Because rooting is constrained by the hard pan, crops growing in such soils can experience moisture stress during short breaks in rainfall, with a consequent reduction in yield.

Nutritive value of feed resources

Effect of variety and site on the nutritive value of sorghum crop residue

In Africa, birds are a major crop pest and limit grain production from sorghum. Bird resistance in sorghum is related to content of proanthocyanidins (condensed tannins) in the grain. Sorghum improvement programmes in Africa are breeding for bird resistance in varieties for semi-arid zones. However, phenolics in the vegetative components of bird-resistant and forage varieties reduce their digestibility. This study was conducted to determine the influence of environment on differences between bird-resistant (BR) and non-bird-resistant (NBR) varieties in content of phenolics and their relationship to digestibility of fibre in the crop residue. This research was conducted in collaboration with the Sorghum Improvement Team of the Ethiopian Institute of Agricultural Research.

Most energy for ruminants fed sorghum crop residue is provided by rumen fermentation of cell-wall carbohydrates. Factors that limit the digestibility of these carbohydrates are the main cause of differences in nutritive value among varieties after N deficiencies have been corrected. Leaf blades and leaf sheaths from BR varieties contain larger amounts of insoluble proanthocyanidins and soluble red pigments than those from NBR varieties (Table 26). Leaf sheaths from BR varieties are higher in lignin than leaf sheaths from NBR varieties.

Environmental factors have a large effect on pigmentation in sorghum leaf blades and sheaths. Leaf blades and sheaths from BR varieties grown at Melkasa (elevation 1500 m) in the Rift Valley of Ethiopia were more pigmented than those from the same varieties grown at Debre Zeit at a higher elevation (1800 m). The effects of these phenolic pigments on digestibility of neutral-detergent fibre (NDF) was greatest in leaf sheaths from the BR varieties grown at Melkasa (Table 26). Average maximum temperatures during the growing season were 2 to 3°C higher at Melkasa than at Debre Zeit. Average minimum temperatures at Melkasa were 5 to 7°C higher than at Debre Zeit. Total rainfall during the growing season was 645 mm at Melkasa and 693 mm at Debre Zeit.

The mean digestibility of leaf sheaths from BR varieties grown at Melkasa was 8.4 percentage units lower than the same varieties grown at Debre Zeit and over 12 units lower than the NBR varieties grown at either site (Table 26). These results indicate that phenolic pigments have a greater effect on the digestibility of leaf sheaths than of leaf blades and that environmental effects may also be greater on this plant fraction.

Table 26. *The effect of site and bird resistance on content of neutral-detergent fibre (NDF), digestibility of NDF (DNDF), content of lignin, soluble red pigments (A550 sol.) and insoluble proanthocyanidins (A550 insol.) in leaf blades, leaf sheaths and stems from the crop residue of bird-resistant (BR, n=6) and non-bird-resistant (NBR, n=8) sorghum varieties.*

	Debre Zeit				Melkasa					
	BR		NBR		BR		NBR		Significance	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Site	Resist.
Leaf blades										
NDF (% OM)	62.3	3.4	64.6	3.2	60.6	3.2	60.0	3.2	**	NS
DNDF (%)	57.1	4.2	61.5	3.8	62.4	5.5	61.9	4.5	**	NS
Lignin (% OM)	3.5	0.4	4.2	0.6	4.2	0.6	4.0	0.6	NS	NS
A550 sol.	0.08	0.02	0.05	0.01	0.16	0.07	0.07	0.02	***	***
A550 insol.	0.04	0.01	0.04	0.01	0.09	0.07	0.06	0.05	NS	NS
Leaf sheaths										
NDF (% OM)	79.1	2.3	79.4	1.5	77.0	2.9	78.3	2.6	NS	**
DNDF (%)	51.2	3.8	56.6	2.6	42.8	10.1	55.3	5.3	***	*
Lignin (% OM)	6.3	0.9	5.7	0.5	6.1	0.8	5.8	0.7	***	NS
A550 sol.	0.14	0.05	0.03	0.01	0.57	0.20	0.05	0.03	***	***
A550 insol.	0.04	0.01	0.02	0.01	0.19	0.11	0.03	0.02	***	***
Stems										
NDF (% OM)	72.2	7.4	74.5	5.5	78.4	6.2	79.8	3.3	***	**
DNDF (%)	52.9	5.6	54.1	3.9	57.4	5.0	57.0	4.7	**	NS
Lignin (% OM)	6.8	1.4	7.0	1.3	6.7	1.1	6.6	0.8	NS	NS
A550 sol.	—	—	—	—	—	—	—	—	—	—
A550 insol.	0.03	0.01	0.02	0.01	0.01	0.0	0.01	0.0	***	***

NS = not significant; * = P<0.05; ** = P<0.01; *** = P<0.001.

Effect of variety on the nutritive value of millet

The nutritive value of millet crop residue has received less attention than that of other cereals. Twelve millet varieties were sampled from an advanced agronomic trial at the ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) Sahelian Centre, Sodore, Niger. The varieties differed significantly in NDF content and digestibility of NDF of leaf blades, sheaths and stems (Table 27). Lignin content of blades and stems also differed significantly among varieties.

Despite these varietal effects the range in parameters of nutritive value was lower than among sorghum varieties. The range in digestibility of NDF within plant parts of sorghum is greater than 15 percentage units, whereas in these 12 millet varieties the range was less than 8 percentage units. Millet lacks the phenolic pigments that are largely responsible for differences in NDF digestibility among sorghum varieties.

The nutritive value of the leaf sheath and stem of millet is well below the maintenance requirements for cattle. In Niger farmers usually leave millet crop residue in the field to be grazed by cattle belonging to pastoralists. However, the low nutritive value of leaf sheath and stem indicate that it may not be worth harvesting and storing the crop residue.

The digestibility of NDF in the leaf sheath and stem fractions of the 12 millet varieties is low. The range in digestibility of millet crop residues needs to be investigated further in the hope of finding adapted varieties with higher digestibility.

Table 27. *The effect of variety on content of neutral-detergent fibre (NDF), digestibility of NDF (DNDF) and content of lignin in leaf blades, leaf sheaths and stems from the crop residue of 12 millet varieties.*

	Mean	Range	Varietal effect
Leaf blade			
NDF (% OM)	59.9	57.7–63.0	**
DNDF (%)	60.1	55.7–62.2	***
Lignin (% OM)	3.9	3.5– 4.5	**
Leaf sheath			
NDF (% OM)	69.2	65.5–70.8	**
DNDF (%)	42.4	38.1–44.9	***
Lignin (% OM)	5.1	4.8– 5.9	NS
Stem			
NDF (% OM)	76.2	72.5–79.6	**
DNDF (%)	30.7	27.6–35.2	*
Lignin (% OM)	8.7	7.6– 9.7	***

Varietal effect significant at: * P<0.05; ** P<0.01; *** P<0.001; NS not significant.

Effect of variety on the nutritive value of cowpea crop residue

Cowpea (*Vigna unguiculata*) is an important dual-purpose crop (grain and forage) in the Sahel. The International Institute of Tropical Agriculture (IITA) cowpea programme at the ICRISAT Sahelian Centre is breeding dual-purpose varieties for Sahelian conditions. Leaves and stems from 15 dual-purpose varieties were sampled and analysed at the ILCA nutrition laboratory to determine differences in the nutritive value of crop residues among varieties.

Nitrogen content and the digestibility of neutral-detergent fibre in leaves and stems differed significantly among varieties, as did neutral-detergent fibre content of stems (Table 28). The range of 10 to 12 percentage units in digestibility of neutral-detergent fibre would have a large effect on the productivity of ruminants fed the crop residue. These varietal differences are also important to cowpea improvement programmes interested in developing dual-purpose varieties.

Management of multipurpose trees

Multipurpose trees provide supplementary feed for livestock, improve soil fertility through mulching and, in the case of leguminous trees, nitrogen fixation, and wood for fencing, building and firewood. The use of *Gliricidia sepium* and *Leucaena leucocephala* in agroforestry is already quite well established in humid Nigeria but other species are needed to spread the applicability of agroforestry to other zones. In 1987 multipurpose trees were screened in humid and subhumid Nigeria, and best-bet lines were evaluated in production systems.

Table 28. *Range in nitrogen and neutral-detergent fibre (NDF) contents and digestibility of NDF in leaves and stems from cowpea crop residue.*

	Range among varieties (n = 15)	Significance of difference among varieties
Leaves		
N (% of DM)	2.8–3.5	**
NDF (% of DM)	30–33	NS
Digestibility of NDF (%)	54–66	
Stems		
N (% of DM)	1.5–2.1	**
NDF (% of DM)	47–56	***
Digestibility of NDF (%)	37–46	*

NS = not significant; * = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$.

Initial evaluation of multipurpose trees

Multipurpose tree legumes for the highlands

Screening of browse species for the highlands was expanded with Debre Zeit as the main research site. Browse species being tested include *Leucaena*, *Sesbania*, *Erythrina* and *Chamaecytisus palmensis*. These have been planted both at Debre Zeit and at a range of sites at altitudes from 1700 to 2800 m. *Chamaecytisus palmensis* grew well at altitudes up to 2800 m and *S. sesban* performed well at up to 2400 m. However, *S. sesban* has been severely attacked by insect pests at altitudes of less than 1900 m and this may limit its usefulness. The genus is thus being screened for resistant species and genotypes.

Indigenous browse in humid Nigeria

Use of indigenous browse was surveyed in southeast Nigeria, in collaboration with five national agricultural research institutions. The most widely used species included *Acioa barterii*, *Dialium guianensis*, *Harungana madagascariensis* and *Microdesmis puberula*. Future work will focus on methods of establishment, productivity in comparison with leucaena and gliricidia, and the nutritive value of these species.

Fertilizer/rhizobium interaction on farmers' alley farms

On some alley farms in southwest Nigeria, leucaena and gliricidia grew poorly and were chlorotic. The causes of this were studied in 1987 in a collaborative project between ILCA and IITA. Soil samples from 'problem' farms and farms on which trees were healthy were analysed for nutrient content. The effects of nitrogen (N) and phosphorus (P) fertilizer and inoculation with two strains of rhizobia were also examined on both soil types.

Soils from 'problem' farms had lower concentrations of N (0.053 vs 0.100), potassium (0.11 vs 0.24) and organic carbon (0.74 vs 0.92) than soil from 'good' farms. These levels were reflected in the nutrient content of the trees growing on the soils.

On the poor soil, fertilizer N applied alone or with P decreased nodulation, but significantly increased shoot dry-matter yield and N content of the trees. Inoculation with rhizobia was less effective than N application in increasing shoot dry-matter yield and N uptake of the tree seedlings. This suggests that the strains of rhizobia tested were not very effective and more strains should be screened.

In the absence of inoculation, fertilizer N is required to boost early growth of leucaena. Gliricidia can be established without inoculation, but phosphorous should be applied to ensure proper nodulation and nitrogen fixation.

Multipurpose tree legumes for the subhumid zone

The regrowth of 3-year-old gliricidia accessions over 5 months in the Nigerian subhumid zone ranged from 1131 to 2703 kg ha^{-1}. Entries HYB, ILG 52 and ILG 50 gave the highest DM yields of 2703, 2025 and 1816 kg ha^{-1}, respectively. The growth of the lines was generally poor compared with their performance in the humid zone. While differences in the amount and distribution of rainfall may have had an effect, the poor growth may also have been due to restriction of root development by the hard pan typical of subhumid zone soils, and other soil-related factors.

Seeds of 22 nitrogen-fixing trees were received from the Nitrogen Fixing Tree Association (NFTA), Hawaii, in 1987 and evaluation trials were established at three sites in the subhumid zone of Nigeria (Kurmin Biri—ILCA site; Jos—Federal School of Forestry; Makurdi—Uni Jos, Department of Animal Production). Performance of the trees was assessed by measuring their height and bole diameter every 3 months. In the first 9 months, *Calliandra calothyrsus*, *Cajanus cajan* and *Flemingia macrophylla* grew well at all sites. *Sesbania grandiflora* performed impressively at Kurmin Biri.

Evaluation of multipurpose trees in management systems—Alley farming

Alley farming with grazed fallows

The first phase of a long-term leucaena alley farming trial to determine the effect of short grazed fallows on soil fertility and subsequent crop yields ended in 1986. In the second phase the cropping period was extended to 4 years, with 2 years fallow, in order to increase land-use efficiency and allow the testing of the sustainability of crop yield levels after the grazed fallow.

Soil fertility and crop yields were still significantly higher 3 years after the fallow. In the third consecutive year of cropping following a fallow, crop yields in alley grazing/cropping rotation plots were 22% higher than yields from continuously-cropped alley plots. In the first year of cultivation following grazed fallows in 1987, alley grazing/cropping rotation plots outyielded continuously-cropped alley plots by 56% (Figure 16). These results confirm the positive effect of short fallows grazed by small ruminants on soil fertility and crop yields in alley farming.

A similar long-term alley farming trial using *Gliricidia sepium* on a degraded soil is comparing the contribution to soil fertility of grazing small ruminants within the short fallow periods to that of fallowing alone without animals. In 1987, maize grown on continuously-cropped alley plots outyielded that on continuously-cropped plots without trees by 75%.

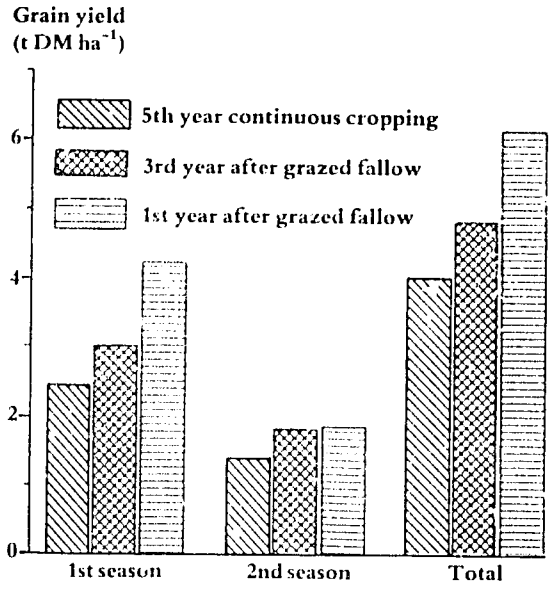


Figure 16.
Grain dry-matter yield of maize under continuous alley cropping and following a grazed fallow, Ibadan, Nigerian humid zone, 1987.

Fodder offtake and crop yields in alley farming

In alley farming, tree foliage can be used either for soil fertility maintenance or as feed for livestock, but there is a trade-off between the two uses. In 1985, a trial was initiated to study the effect on maize yields of removing various proportions of tree foliage as cut-and-carry feed. As in 1986, maize yields rose as the proportion of tree foliage used as mulch increased from zero to 100% of total tree foliage production (Table 29). These results confirm that using part of the tree foliage as feed results in some loss of maize yield. The opportunity cost of using some tree foliage as feed has, however, been found to be more than offset by gains in animal productivity at current prices.

Table 29. *Maize grain yields in alley farming as affected by level of mulch application, Nigerian humid zone, first season 1987.*

Treatments	Maize grain yield (t ha^{-1})	
	Leucaena	Gliricidia
Mulch levels[1] (% of tree productivity)		
0	1.53	1.58
25	1.95	1.79
50	2.29	2.15
75	2.15	2.24
100	2.76	2.52
LSD (0.05)	0.36	0.43

[1] Mean foliage yields for leucaena and gliricidia over the period were 6.2 and 3.5 tonnes per hectare per year respectively. Foliage not used for mulch was fed to sheep and goats.

Evaluation of multipurpose trees in management systems—Intensive Feed Gardens

Management of leucaena trees in Intensive Feed Gardens

In the second full year of a trial to study the effect of inter-row spacing and cutting frequency in intensive production of leucaena fodder, cutting frequency had a greater effect on tree productivity than inter-row spacing. Lower cutting frequency resulted in higher yields (Table 30). As in 1986, the best treatment combination was 50 cm inter-row spacing with a 12-week cutting cycle. In 1987, this yielded 41 tonnes DM per hectare of forage, an 8% increase over the previous year. A cutting cycle of 6 weeks was too intensive and gave much lower forage yields than frequencies of 8 weeks or more. It also resulted in the death of some trees.

In practice a 0.5 m inter-row spacing might be too narrow to allow easy access for the farmer. Doubling the inter-row spacing to 1.0 m reduces tree yield per ha by 25% on a 12-week cutting cycle. However, with more mature trees, as in 1987, no further penalty is incurred if inter-row spacing is increased to 2.0 m. In 1986, the first year of pruning, yields declined progressively with increasing inter-row spacing. The change in 1987 indicates that longer-term studies are needed to clarify the situation.

Table 30. *Effect of cutting frequency and inter-row spacing on leucaena fodder dry-matter yield, Nigerian humid zone, 1986/87.*

Inter-row spacing(m)	1986		1987	
	Cutting cycle		Cutting cycle	
	6 weeks	12 weeks	6 weeks	12 weeks
	t DM ha^{-1}			
0.5	16.90	38.20	12.94	41 08
1.0	11.97	28.27	10.16	31.42
1.5	9.07	20.73	8.34	31.84
2.0	6.77	20.33	6.01	31.30
Mean	11.18	26.88	9.36	33.92

Nutritive value of browse

Effects of polyphenolic compounds in forage from multipurpose fodder trees on growth, intake and digestion in sheep and goats

Polyphenolic compounds in browse reduce feed intake and digestibility and animal performance when fed in combination with cereal crop residues by reducing degradation of fibre and protein by rumen micro-organisms (*ILCA Annual Report 1985/86*). *Acacia seyal*, *A. nilotica* and *Sesbania sesban* have been identified as useful multipurpose trees (MPTs) for semi-arid Africa. A trial was conducted to determine the effects of polyphenolics in these MPTs on growth and N utilisation of sheep and goats fed a diet based on teff straw.

Leaves from *A. seyal* and *A. nilotica* contained twice as much soluble polyphenolic compounds as *S. sesban* leaves. Leaves from *A. seyal* had the highest content of insoluble proanthocyanidins. Sheep had a higher growth rate than goats when fed these MPTs in combination with teff straw. This difference was related to the much lower intake of straw by goats (Table 31). There were no significant differences among browse supplements in growth rates of sheep or goats (Table 31). However, the effect of the polyphenolics in *A. seyal* are apparent in the results of the nitrogen-balance study. Apparent and true nitrogen digestibility were significantly lower in the diets containing *A. seyal*, which was a result of a higher faecal excretion of nitrogen. Both neutral-detergent-soluble and neutral-detergent-insoluble nitrogen were higher in sheep and goats fed *A. seyal* than in those fed other MPT supplements. There were no significant differences among MPTs in nitrogen balance because the nitrogen loss in the urine of animals fed *A. seyal* was lower than that of animals fed *S. sesban* and *A. nilotica*.

These results suggest that polyphenolics in *A. seyal* affect protein utilisation by decreasing urinary nitrogen loss and increasing faecal nitrogen loss.

Table 31. *Polyphenolics content in leaves and growth rate, straw intake and parameters of nitrogen utilisation in sheep and goats fed leaves from three multipurpose trees as supplements to teff straw.*

	Acacia seyal	*Acacia nilotica*	*Sesbania sesban*
Soluble phenolics (% DM)	30	34	16
Insoluble proanthocyanidins (A550)	0.552	0.154	0.059
Growth rate ($g\ d^{-1}$)			
Sheep	40	42	35
Goats	19	17	4
Straw intake ($g\ d^{-1}$)			
Sheep	422	412	478
Goats	328	348	306
Apparent N digestibility (%)			
Sheep	35	58	51
Goats	44	66	69
True N digestibility (%)			
Sheep	82	92	94
Goats	86	94	94
Faecal detergent-soluble N (% of N intake)			
Sheep	47	33	42
Goats	41	28	25
Faecal detergent-insoluble N (% of N intake)			
Sheep	18	9	6
Goats	14	6	6
Urine N (% of N intake)			
Sheep	18	30	30
Goats	25	35	40
N balance ($g\ d^{-1}$)			
Sheep	1.6	2.6	2.3
Goats	1.7	1.7	2.6

The higher excretion of detergent-insoluble nitrogen in the faeces indicates that the proanthocyanidins in *A. seyal* form indigestible complexes with protein. However, the higher excretion of detergent-soluble nitrogen in the faeces indicates that polyphenols also increase the excretion of microbial nitrogen, which may originate from endogenous sources.

Legume forages in crop–livestock systems

Under this theme, improved forages are tested in production systems. The aim is to develop production systems that improve livestock nutrition, increase soil fertility and use these feed resources to improve the utilisation of other available feed resources.

Introduction of forage legumes into cropping systems

Farmers in the Soddo area of Ethiopia have adopted *Stylosanthes guianensis* cv Cook and *Macrotyloma axillare* cv Archer to provide feed for dairy cattle. They are planted as forage crops, undersown in maize and oversown into native pasture. Regrowth yields of Archer are greater than those of Cook, but Cook is more popular with farmers because of its greater palatability.

Desmodium intortum planted under unpruned coffee has also proven to be very successful in the region. Forage yields from farmers' plantings averaged 12.6 t DM ha^{-1} (with a range of 6.2 to 17.8 t ha^{-1}). Results also indicate that

Crop residues and agricultural byproducts form a major part of livestock diets in smallholder farming systems in Africa. ILCA seeks ways to improve their utilisation as feed.

undersowing coffee with *D. intortum* may increase the number of berries borne by the trees. In 1986, an "off" year for coffee production, trees undersown with *D. intortum* had 5% more berries than trees that were not undersown, while in 1987, an "on" year, undersown trees had 19.5% more berries.

Nutrient management and water-use studies in legume-based cropping systems

Nitrogen fixation by forage legumes and their residual effect on wheat

The amount of nitrogen fixed by three forage legumes was determined at Debre Zeit using the ^{15}N technique. Oats were used as the non-nodulating reference crop. *Vicia dasycarpa* fixed significantly more N than *Trifolium steudneri* (131 vs 61 kg N ha^{-1}). *Medicago polymorpha* fixed 77 kg N ha^{-1}. Fixed N accounted for about 78% of total N in *V. dasycarpa* and *T. steudneri* and 73% in *M. polymorpha*.

The grain and dry-matter yields of wheat were significantly higher following vicia, medics and trifolium than following oats (Table 32). The yield of protein in straw was 49% greater from wheat following vicia than wheat following oats. The straw protein yield following medic was 26% greater than following oats.

Table 32. *Effect of previous cropping on dry-matter and grain yield of wheat on an upland soil, Debre Zeit, Ethiopian highlands, 1987.*

Previous cropping	Wheat yield (kg ha^{-1})	
	Dry matter	Grain
Vicia dasycarpa	4015.7a	2612.0a
Medicago polymorpha	3443.2ab	2531.2a
Trifolium steudneri	3543.0ab	2599.5a
Avena sativa (oats)	2320.5c	1752.7b
Fallow	2745.7bc	2090.2ab

Within columns, means followed by the same letter do not differ significantly ($P<0.05$).

Grass density and soil nitrogen under fodder banks

Producer-managed fodder banks in the Nigerian subhumid zone vary considerably in the proportions of legume and grass in the forage biomass. An investigation was carried out to determine the effect of the proportion of grass on stylo productivity and soil properties of a newly established stylosanthes pasture. The proportion of grass had a significant ($P<0.05$) effect on soil N in the second year but not in the first (Table 33). Nitrogen accumulation was significantly greater under all plots containing stylo than under natural fallow.

There was no significant difference in soil N between plots containing no grass and those with 25% grass. Thus stylo pastures can tolerate up to 25% grass without a substantial reduction in benefits to crop production. Soil N increased from 1986 to 1987 at each grass/legume density but the increase was greater in plots that had no grass or low grass densities.

Table 33. *Effect of proportion of grass in a newly established stylosanthes pasture on soil nitrogen, Nigerian subhumid zone, 1986 and 1987.*

Grass proportion (%)	% soil N	
	1986	1987
0	0.0429a	0.0702a
25	0.0407a	0.0660ab
50	0.0464a	0.0647b
75	0.0446a	0.0630b
100	0.0408a	0.0570c

Within columns, means followed by the same letter do not differ significantly ($P<0.05$).

Cropping fodder banks in subhumid Nigeria

One obstacle to the adoption of fodder innovations in the Nigerian subhumid zone is the primary interest of agropastoralists and, particularly, the land-owning cultivators in cropping. This prompted research on the effects of forage legumes on crop yields.

Maize was planted inside and adjacent to five fodder banks in the Nigerian subhumid zone. Treatments were replicated four times at each site. The grain yield of maize grown in the stylo area was significantly higher than that of maize grown on adjacent natural fallow at all levels of nitrogen application (Figure 17).

Maize grown without fertilizer inside the fodder banks yielded an average of 1.5 tonnes of grain per hectare, compared with 750 kg ha^{-1} for maize on adjacent fallow land. There were no significant differences in grain yield between maize grown without fertilizer inside the fodder bank and maize grown on fallow land when 60 kg N ha^{-1} was applied. Thus, a 2-year stylosanthes pasture results in yield increases in maize equivalent to applying 60 kg N ha^{-1}.

Grain yields of acha (*Digitaria exilis*) were generally higher inside the fodder bank than from the corresponding treatments outside the stylo area; the difference was significant ($P<0.05$) in the non-fertilized plots (Figure 18).

Forage activities were set up in 1986 to test fodder banks in West African countries other than Nigeria. Five fodder banks and six accession trials were established in the region. At Sotuba in Mali the fodder bank yielded more than 9 tonnes DM ha^{-1} (80% stylo) during the year of establishment after only 748 mm of rain.

Collaborative programmes

PANESA—Pasture Network for Eastern and Southern Africa

Major steps in the development of the Pasture Network for Eastern and Southern Africa (PANESA) were taken in 1987. The Third PANESA An-

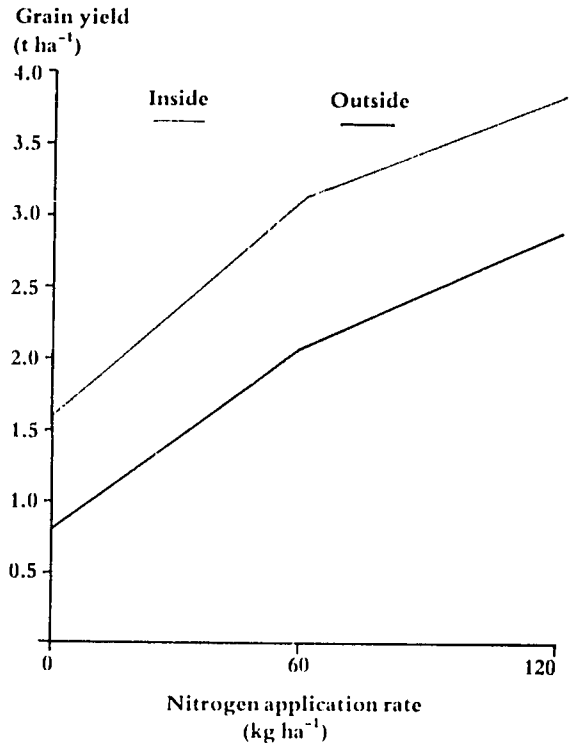


Figure 17.
Effect of nitrogen application on the grain yield of maize grown inside and outside fodder banks, Nigerian subhumid zone, 1987 (mean of five locations).

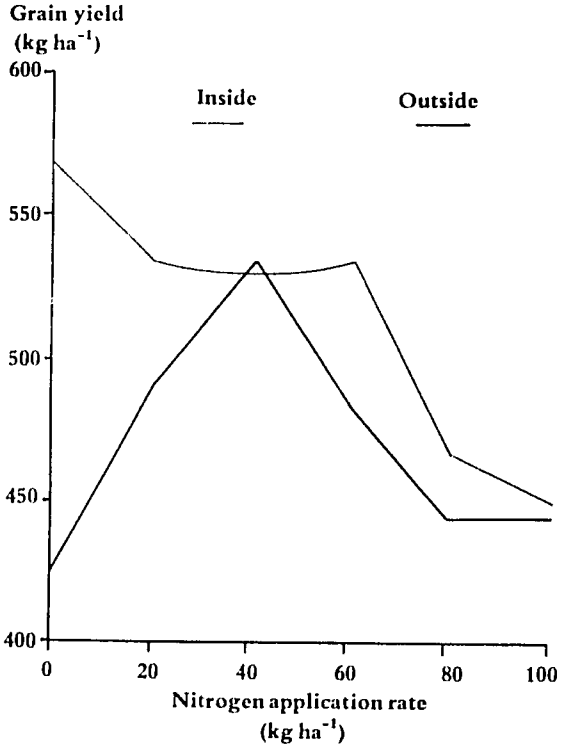


Figure 18.
*Effect of nitrogen application on the grain yield of acha (*Digitaria exilis*) grown inside and outside fodder banks, Nigerian subhumid zone, 1987 (mean of three locations).*

nual General Meeting and Workshop was held at Arusha, Tanzania, in April 1987, and was attended by 65 participants from Botswana, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Somalia, Uganda, Zambia, Zimbabwe and the Tanzanian hosts. Technical papers were presented on African forage plant genetic resources, forage germplasm evaluation, and extensive livestock production systems.

Following the recommendations of the Special Programme for African Agricultural Research (SPAAR)—a body of major donor agencies that promotes networking to address regional agricultural problems—PANESA adopted agro-ecological classifications to focus its research projects. These are: highland tropics, subhumid/humid tropics and the arid and semi-arid zones.

The collaborative research programme for the network was further developed at the Network Planning Meeting at Nairobi, Kenya, later in the year. Participants identified regional problems constraining forage/pasture production, and developed research priorities for each ecological zone. These priorities were matched with the research programmes in member countries and with ILCA's Animal Feed Resources and commodity research thrusts.

Six research areas were developed:

- Introduction and evaluation of forage germplasm to the semi-arid zone.
- Introduction and evaluation of forage germplasm in subhumid plateau and coastal humid areas.
- Introduction and evaluation of germplasm in the highland zone.
- Screening forage germplasm for adaptation to seasonally waterlogged bottom lands.
- Development of feed resources packages.
- Basic farm surveys.

The regional research programme began in 1987, with seed distributed to collaborators in Botswana (Animal Production Research Unit), Kenya (National Dryland Farming Research Station, Katumani, and the Small Ruminant-CRSP-Ministry of Livestock Development Project, Maseno, Western Kenya), Malawi (Ministry of Agriculture, Department of Agriculture Research), Tanzania (Tanzania Livestock Research Organisation, Mpwapwa, and Uyole Agriculture Centre, Tanzania Agricultural Research Organisation), Zimbabwe (Grasslands Research Station, Department of Research and Specialist Services), and Uganda (Crop Science Department, Makerere University). Trials will be conducted in the 1987/88 growing season.

"Seed money" was also disbursed to some of the collaborating organisations to assist their work. These collaborators included the Crop Science Department at Makerere University in Uganda, Uyole Agricultural Centre in the southern Tanzania highlands, Mpwapwa Animal Production Research Institute in the central semi-arid zone of Tanzania, the Animal Production Research Unit in semi-arid Botswana and the National Dryland Farming Research Station, Katumani, in the semi-arid zone of Kenya.

ARNAB—African Research Network for Agricultural Byproducts

The development of the African Research Network for Agricultural Byproducts (ARNAB) continued in 1987 with the appointment of a network coordinator in January. A major task of the coordinator during the year was to continue to develop contacts with NARS scientists involved in work re-

lated to that promoted by the network and to develop collaborative research linkages.

Discussions on collaborative research projects were held with NARS staff from Burkina Faso, Burundi, Cameroon, Egypt, Ethiopia, Gambia, Ghana, Kenya, Malawi, Mali, Niger, Nigeria, Senegal, Somalia, Sudan, Tanzania and Zimbabwe. Several new collaborative projects are now being established.

The proceedings of the 1986 ARNAB workshop were published in 1987 and more than 1000 copies were distributed. The backlog of newsletters was largely cleared, with the production of six issues during the year.

The 5th ARNAB workshop, on "Overcoming constraints to the efficient utilisation of byproducts as animal feed", was held at Bamenda, Cameroon, 20–25 October 1987. The 42 papers presented came from 16 countries—Botswana, Burkina Faso, Cameroon, Egypt, Ethiopia, Ghana, Kenya, Malawi, Mali, Nigeria, Senegal, Somalia, Sudan, Tanzania, Zimbabwe and UK. Workshop sessions covered physical, agronomic, farm-management and feeding-package constraints to the use of byproducts as feed, design of experiments for on-farm research, and dissemination of research results.

A workshop on "Utilisation of research results on pastures, crop residues and agricultural byproducts" has been planned for 1988 in collaboration with PANESA.

Zebu oxen eating barley straw at the threshing site, Ethiopian highlands. Improved crop-residue-based feeding systems are needed for smallholder cattle rearing.

ANIMAL FEED RESOURCES THRUST STAFF

J Tothill, *Thrust Coordinator*
A N Atta-Krah, *Agronomist*
P Bartholomew, *Forage Agronomist*
T Bedingar, *Economist (Post-doctoral Associate)*
J Cobbina, *Forage Agronomist (Post-doctoral Associate)*
M Cissé, *Ecologist*
B Dzowela, *PANESA Coordinator (Kenya)*
P A Francis, *Agro-economist*
J Hanson, *Genebank Manager*
I Haque, *Soil Scientist*
S A Ingawa, *Economist*
J Kahurananga, *Plant Ecologist*
C S Kamara, *Visiting Scientist*
R von Kaufmann, *Agricultural Economist*
J Lazier, *Forage Agronomist*
J McIntire, *Agricultural Economist*
M A Mohamed-Saleem, *Agronomist*
J D Reed, *Animal Nutritionist*
L Reynolds, *Animal Scientist*
A Russell-Smith, *Forage Agronomist*
A M Said, *Animal Nutritionist/ARNAB Coordinator*
Solomon Bekure, *Agricultural Economist*
G Tarawali, *Forage Agronomist*

Trypanotolerance Thrust

Background

Tsetse-borne trypanosomiasis constrains livestock production in an area of humid and subhumid Africa larger than the USA. This thrust contributes to improved livestock production in tsetse-infested Africa through a better understanding of the factors affecting the performance of trypanotolerant livestock and the effectiveness of trypanosomiasis control measures.

Trypanosomiasis occurs throughout much of the best watered and most fertile land on the continent. Much of this region could be used immediately for livestock or mixed agricultural development, without stress to the environment, if trypanosomiasis could be controlled or circumvented.

ILCA and the International Laboratory for Research on Animal Diseases (ILRAD) have been collaborating with national agricultural research services (NARSs) for several years in the African Trypanotolerant Livestock Network, studying livestock breeds that show tolerance to trypanosomiasis, and trying to find ways in which the effects of the disease can be reduced through breeding or chemical control. In 1987 the network operated in nine countries of sub-Saharan Africa, mainly covering the humid and subhumid zones. The objectives of the thrust were pursued under four major themes: Trypanosomiasis epidemiology, trypanotolerance, genetics of trypanotolerance, and biological and economic evaluation of productivity responses to interventions.

Trypanosomiasis epidemiology

Trypanosomiasis is a major disease of livestock in the humid and subhumid zones of sub-Saharan Africa. The factors affecting susceptibility to trypanosomiasis must be well understood in order to develop effective measures to control the disease.

Efforts were made in 1987 to describe the epidemiology of trypanosomiasis where the disease is an important constraint to livestock production. This work was performed in conjunction with our national research colleagues, and with ILRAD tsetse and animal health inputs. Specifically, we made monthly estimates of the components of tsetse challenge (i.e. relative density and infection rate) and the prevalence of trypanosomes in livestock

in the different environmental zones and management systems covered by the Network sites.

Estimates of tsetse challenge (the product of relative tsetse density and mean trypanosome infection rates in the tsetse population) were compared with monthly records of prevalence of trypanosome infection in livestock, and the incidence of new infections, at each Network site. The dark ground/phase contrast buffy coat method was used to determine trypanosome prevalence and to identify trypanosome species. There is a general positive correlation between annual averages for tsetse challenge and the prevalence of infection in trypanotolerant cattle at nine network sites (Figure 19). Tsetse blood meals were collected in 1987 and will be analyzed to determine feeding behaviour. This information will be used to refine estimates of tsetse challenge by taking into account the proportion of tsetse feeds taken from the animals under study.

The method used in 1987 to estimate tsetse challenge was not sufficiently sensitive to show meaningful correlations between monthly averages within sites except where major changes occurred. Thus additional work is planned that will increase the accuracy of estimates of tsetse challenge and make between-site comparisons more meaningful. Three such areas are:

- releasing marked tsetse flies in order to estimate the actual tsetse population density from the number of marked flies recaptured and thus obtain an "index of availability" for each tsetse species;

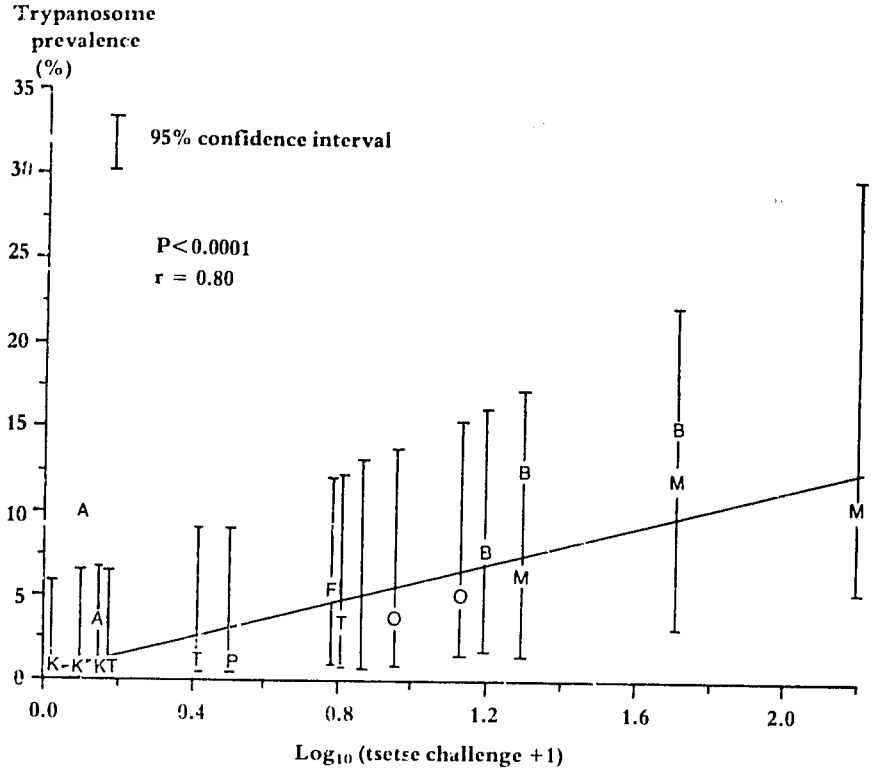


Figure 19.
Relationship between tsetse challenge and trypanosome prevalence in trypanotolerant cattle at nine sites of the African Trypanotolerant Livestock Network, 1984–86.

A = Avetonou, Togo, B = Boundiali, Côte d'Ivoire; F = Idiofa forest, Zaire; K = Kolo, Zaire; M = Mushie, Zaire; O = OGAPROV Ranch, Gabon; P = Idiofa plateau, Zaire; S = Sokode, Togo; T = Tengrela, Côte d'Ivoire.

- determining the nutritional status of tsetse populations by fat haematic analysis; and
- building up detailed information on livestock movements, in order to be certain of measuring the tsetse challenge to which the animals are actually exposed.

Trypanotolerant livestock, such as N'Dama cattle, offer one of the best opportunities for increasing livestock production in the vast tsetse-infested areas of humid and subhumid Africa

Trypanotolerance

If the vast areas of humid and subhumid sub-Saharan Africa are to be used effectively for agricultural development, the effects of trypanosomiasis on animal health and production must be better understood. The prospects for developing a vaccine or new trypanocidal drugs are rather poor; moreover, even if these became available, they would probably be more effective in trypanotolerant animals. Thus it would appear that trypanotolerance is a major approach to solving the problem.

In 1987 we continued to gather information on the health and productivity of trypanotolerant and susceptible livestock breeds and their crosses in our different agro-ecological zones and management systems, under quantified tsetse challenge. Trypanosomiasis is diagnosed by the detection of trypanosomes in the blood and by the presence of anaemia. However, other diseases also produce anaemia. Therefore, when evaluating trypanosomiasis in the field, efforts are being made to quantify the importance of other anaemia-producing pathogens and to evaluate their possible interaction with trypanosomiasis. This work is centred at sites in Cote d'Ivoire and Zaire where other diseases are prevalent.

A study was carried out in 1987 under high natural tsetse challenge at OGAPROV (Office gabonais d'amélioration et de production de viande) Ranch, Gabon, to indicate effects on animal performance of aspects of parasitaemia and anaemia control. Key points from the study are presented in Table 34.

There was a linear effect on growth of the number of months when trypanosomes were detected. A *Trypanosoma congolense* infection reduced

growth by more than a *T. vivax* infection. An above-average parasitaemia score reduced growth by more than a below-average score, and animals maintaining their blood packed cell volume (PCV) above-average for their parasitaemia group had superior growth.

Natural field challenge takes into account possible differences in resistance between animals due to differences in the number of times they are bitten by tsetse flies. This may be related to their attractiveness to tsetse flies, the thickness of their skin, their efficiency at preventing flies from feeding etc. The results in Table 34 indicate that the number of episodes of parasitaemia detected per unit time has at least as large an effect on growth as other aspects of parasitaemia and of anaemia control. This has an important implication for the use of artificial challenge in research on management and breeding methods for the exploitation and improvement of trypanotolerant cattle. With artificial challenge, either by syringe or by captured flies, almost all animals become parasitised. As a result, variation in animal performance due to differences in the number of infections per unit time would be ignored.

Table 34. *Effects of parasitaemia and anaemia-control aspects on daily liveweight gain over 3 months of exposure to trypanosomiasis risk at OGAPROV Ranch, Gabon, 1987.*

Aspect	Effect ($g\ d^{-1}$)
Average daily liveweight gain of non-infected cattle	381
Parasitaemia aspects	
Each monthly *T. congolense* or mixed infection detected	−60
Each monthly *T. vivax* infection detected	−22
Above-average parasitaemia score recorded within a monthly infection, relative to a below-average score	−26
Anaemia control aspect	
Below-average PCV level reached within each monthly infection, relative to an above-average level	−23

Genetics of trypanotolerance

Research on genetic resistance to trypanosomiasis was directed along two main avenues:

- how to exploit and improve trypanotolerant livestock by conventional management and breeding methods, and
- factors associated with their innate resistance, i.e. the control of trypanosome growth, the development of effective immune responses and resistance to anaemia.

If the mechanisms underlying these factors are identified, it might be possible by immunisation, specific drug treatment or transfection of appropriate genes to produce highly productive cattle resistant to trypanosomiasis.

Our immediate aims are anchored in conventional approaches to the genetic improvement of disease resistance, aiming at information of direct practical use in animal breeding. The basic initial requirements include estimation of phenotypic and genetic relationships between disease and production traits and assessment of the feasibility of genetic selection for resistance.

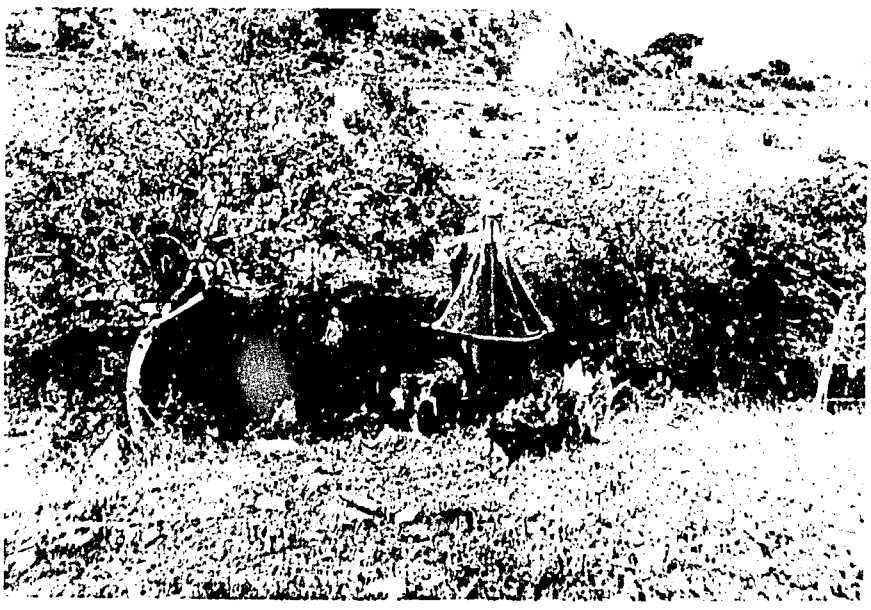
Key points from 1987 work at Mushie Ranch in Zaire, designed to provide indications of heritability levels for aspects of parasitaemia and anaemia control, are indicated in Table 35.

Table 35. *Indications of heritability levels for criteria of trypanotolerance, Mushie Ranch, Zaire, 1987.*

Criteria	Heritability
Parasitaemia aspects	
Number of infections per unit time	0.00
Parasitaemia score	0.00
T. congolense number and score	0.00
T. vivax number and score	0.00
Anaemia control aspects	
PCV levels overall	0.15
PCV levels when no, or low, trypanosome prevalence	0.00
PCV levels when high trypanosome prevalence	0.82

The results indicate that the heritabilities of these aspects are too low to use in practical selection approaches but that ability to maintain PCV levels under high natural challenge could be selected for. Both single-sire matings and blood-grouping techniques are being used to build up paternal half-sib groups in suitable situations in the African Trypanotolerant Livestock Network beginning in 1988. This will significantly increase the availability of information on heritability estimates and relevant genetic correlations.

The major histocompatibility complex (MHC) has been shown to be associated with disease resistance in some domestic and laboratory species. An association between MHC and trypanotolerance, and the identification of individuals with superior trypanotolerance through this association,



Fly traps are used to assess the tsetse challenge that animals are exposed to at sites of the African Trypanotolerant Livestock Network.

would make it possible to develop highly cost-effective selection programmes for trypanotolerance. In 1987 we collected blood samples from N'Dama cattle populations in Gabon and Zaire and, with ILRAD providing all laboratory facilities and expertise, we will use these to test for possible relationships between the MHC and trypanotolerance traits.

Biological and economic evaluation of productivity responses to interventions

The aim of this theme is to develop ways to control trypanosomiasis. These will then be adopted by ILCA's commodity thrusts. An example completed in 1987 is the evaluation of chemoprophylactic regimes at the former African Trypanotolerant Livestock Network site at Muhaka, Kenya. This has allowed the preparation of a project on "sustainable milk production for smallholder farmers in a tsetse-affected subhumid climate" by the Cattle Milk and Meat Thrust. At Muhaka, chemoprophylaxis increased the overall productivity of East African Zebu cattle maintained under village conditions by 20% and that of younger stock by 19% (Table 36).

Table 36. *Effect of prophylactic regime on productivity of East African Zebu cattle in Muhaka area, Kenya*

	No prophylaxis	Prophylaxis
Cows		
Calving percentage	76.4	77.0
Annual cow viability (%)	95.0	95.0
Annual extractable milk yield (kg)	120.5	150.6
Cow weight (kg)	189.0	185.0
Calf weight at 12 months (kg)	58.5	63.4
Calf viability to 12 months (%)	91.3	96.3
Productivity[1] per cow per year (kg)	47.6	56.4
Productivity per 100 kg cow per year (kg)	25.2	30.5
Productivity per 100 kg metabolic weight of cow per year (kg)	103.7	124.8
Youngstock, 12–30 months		
Weight increase 12–18 months (kg)	13.4	18.4
Weight increase 18–30 months (kg)	41.9	46.5
Viability 12–30 months (%)	97.5	98.9
Total performance 12–30 months (kg)	53.9	64.2

[1] Weight of 12-month-old calf and liveweight equivalent of milk extracted for human consumption.

1987 Network meeting

At a meeting of the African Trypanotolerant Livestock Network in Nairobi in November 1987, over 100 researchers reviewed progress in livestock

health and production in tsetse-infested areas of Africa. The meeting was hosted by ILCA and ILRAD. Collaborating researchers from 14 network sites in nine African countries, and researchers from other institutions, heard state-of-the-art reviews from invited specialists. In addition, network scientists from Côte d'Ivoire, Ethiopia, Gabon, Gambia, Kenya, Senegal, Tanzania, Togo and Zaire presented key results from their research during the last 2 years, and evaluated future research plans. Workshop sessions focused on the themes on which the network has concentrated its research.

The major research areas identified were:

- trypanosomiasis epidemiology, including estimates of tsetse challenge, diagnosis of trypanosomiasis, factors affecting susceptibility, interactions with other diseases and tsetse control, and trypanocidal drug interventions;
- trypanotolerance criteria and their genetic parameters relative to genetic improvement of trypanotolerant livestock; and
- effect of trypanosomiasis on animal performance, reproductive cycle, milk extraction, draught power, and possibilities for strategic nutritional supplementation.

Abstracts of the 48 conference papers are available in both French and English.

TRYPANOTOLERANCE THRUST STAFF

J C M Trail, *Thrust Coordinator*
G d'Ieteren, *Network Coordinator*
H Maehl, *Animal Scientist*
W Thorpe, *Animal Scientist*
P Itty, *FAO Associate Specialist*
M Rarieya, *Senior Data Analyst*
A Ouattara, *Assistant to the Network Coordinator*
K Agyemang, *Animal Scientist (ITC, Gambia)*
Woudyalew Mulate, *Veterinarian (Project Supervisor, Ethiopia)*
A Feron, *Veterinarian (Assigned to ILCA by AGCD*, Belgium)*
J McIntire, *Agricultural Economist*

* Administration Générale de la Coopération au Développement.

Livestock Policy and Resource Use Thrust

Better policies and resource management are crucial to livestock development in Africa. Policy problems are ubiquitous and broadly similar throughout the continent. However, there is a need to compare the experiences of different countries in their search for solutions, since these often vary according to the natural and socio-economic environments.

Problems of resource use are most acute in the semi-arid and arid lands, where the long-term future of agriculture appears to be threatened. Here there is a need to develop better methods to assess both resources and long-term productivity trends, and to improve the role of livestock in stabilising and sustaining farm income and crop production in marginal areas.

Research under this thrust therefore focuses on cross-country comparison of the critical policy issues affecting technology uptake, and on the sustainability of crop and livestock production in the rangelands and the semi-arid zone.

Objective

The objective of this thrust in the medium term is to assist national efforts to improve the policies affecting the livestock sector and to increase the efficiency with which natural and other resources are used in sub-Saharan Africa.

Policy services

The main policy services activities undertaken in 1987 were:

- Preparation of a training manual in livestock policy analysis for use on training courses run by ILCA or other organisations;
- Running a training course in French on livestock policy analysis;
- Running the African Livestock Policy Analysis (information) network (ALPAN); and
- Preparation of a handbook on African Livestock Statistics.

Training in policy analysis

Senior African policy makers attending the Livestock Policy Analysis Conference convened by ILCA in 1984 strongly indicated the need to upgrade the policy analysis skills of government staff working in the livestock sector.

This is necessary in itself and also in order to enable policy makers to use the results of ILCA's policy research effectively.

Since 1984 ILCA has run two policy analysis training courses, one in English and one in French, with 20–25 people on each. These will continue annually. Lecture notes and exercises from the courses were used to prepare a training manual in 1987. This will be published in 1989. The manual can be used by trainers and trainees both on ILCA's own courses and on those run by other organisations. It will have sections on:

- Policy concepts
- Identification of policy issues
- Production systems, supply and demand
- Market, price and trade policies
- Livestock marketing structures and distribution systems
- Budget and manpower planning
- Land tenure
- Research resource allocation
- Policy institutions

The manual will also contain case study and exercise material.

Policy research

The main policy research topics addressed in 1987 were:

- Financing livestock services;
- Market systems for dairy products;
- Pricing policies;
- Trends in supply and demand for pork and poultry meat; and
- Milk demand in West Africa.

Financing livestock services

Preliminary findings on this topic were reported in the *ILCA Annual Report 1984*. Since then additional data have been collected. The overall study covers 22 countries in sub-Saharan Africa during the 1970s. The availability of data for specific factors selected for analysis sometimes limits the number of countries considered.

A study of the methods of financing showed that all countries covered financed their livestock services from central government budgets. Eighteen of the 22 countries provided free services for the prevention and control of major epidemic diseases, 12 charged for some drugs and treatments and only 4 charged for all vaccinations as well as treatments. Charges and fees for drugs, treatments and, in some cases, breeding services in East and southern African countries enabled those governments to recover up to 25% of total recurrent expenditure and up to 45% of non-salary expenditure for livestock services. Except in very few cases, revenue from cost-recovery schemes reverted to the central treasury and were not automatically recycled into livestock services.

Analyses on the factors affecting the pattern and structure of recurrent expenditure and staffing of livestock services revealed the following: In 15 of the 18 countries for which complete data are available, recurrent expenditure per tropical livestock unit (TLU) increased in real terms during the 1970s. Expenditure on livestock services per caput of the agricultural human population was positively affected across countries by the level of GNP per caput,

by the share of animal protein in total protein consumption, and negatively by the proportion of land area infested by tsetse flies ($R^2 = 0.59$ for the multiple regression). This indicates that richer countries or those with higher animal protein consumption spend more on livestock services in order to meet rising income-related demand for animal products, or to maintain or enlarge the resource base of this protein supply.

Overall staffing densities (measured by the number of staff of the livestock services per TLU) remained stable during the 1970s. However, analysis of ratios of middle- and low-level staff to high-level staff (graduate veterinarians and above), indicate that in most countries more attention was given to increasing the proportion of highly qualified staff—possibly as a consequence of a widening in the range of functions carried out, and so a greater need for skill. The data studied also show that governments tend to give more attention to increasing the proportion of high-level staff in countries where cattle form a large proportion of the national herd relative to small ruminants and other species.

In 12 of the 16 countries for which data are available, the increase in total expenditure per TLU was accompanied by an increase in the proportion of this total spent on personnel. In one case total expenditure per TLU decreased while the proportion spent on personnel increased. Overall, a cross-country comparison found that differences in the amount of non-staff expenditure per TLU (and per staff of all categories) was significantly related to, and could be explained by ($R^2 = 0.80$), the total recurrent expenditure per TLU, the average size of the livestock holding per caput of the agricultural population, and the proportion of the livestock population found in the arid zone. This analysis indicates that non-salary expenditures generally change in the same direction as total expenditure, but that countries with higher average holdings per person allocate relatively more expenditure to non-staff operating costs.

Most of the recurrent expenditure on livestock services in the 1970s was on the prevention and control of major epidemic diseases. More than 60% of the increase in livestock output could be attributed to an increase in animal numbers rather than in yield per animal. However, whatever may have been the governments' intentions, a careful analysis of inter-country differences in expenditure, livestock output and numbers reveals a rather more complex picture than one in which more expenditure leads to more livestock which leads to more output.

In 14 of the 18 countries for which data are available, livestock numbers (expressed in TLUs) increased during the 1970s. Among these 18 countries, in eight of the nine that have small livestock populations (< 1 million TLU) both livestock numbers and expenditure per TLU increased. In four of the nine countries with large livestock populations (> 1 million TLUs) expenditure per TLU grew quite fast (> 5% p.a.) but the livestock population decreased, while in a further two countries with large livestock populations these populations grew fast (> 2.5% p.a.) but expenditure per TLU declined. Overall there was a significant negative relation between growth rates in livestock numbers (dependent variable) and growth rates in both total and staff expenditure per TLU.

Indices of milk and beef yield for 1983 showed an increase, relative to 1970, in 7 and 9 countries out of 18, respectively. Changes in both indices were positively related, significantly ($P \leq 0.05$) in the case of milk, to the growth rate in total and staff expenditure per TLU, the share of livestock output in total agricultural production, and the percentage share of the value of purchased inputs (commercial protein and cereal inputs) in the gross value of livestock output.

Table 37 presents summary data for some of the variables considered in the above analyses. Further work will address the policy implications arising from the study, which is scheduled for completion in mid-1988.

Table 37. *Financing livestock services in sub-Saharan Africa: Summary data for some variables in 18 countries.*

	Mean	SD	Minimum values	Maximum values
Expenditure per TLU (constant 1975 US$)[1]	2.11	2.17	0.06	9.40
Staff to non-staff expenditure ratio[1]	4.21	5.06	0.41	19.44
Average annual growth per TLU in real (% p.a.)[2]				
– total recurrent expenditure	8.15	10.24	–6.60	31.60
– staff expenditure	9.20	18.28	–10.30	37.28
– non-staff expenditure	4.43	14.66	–33.45	39.39
Growth in livestock population (% p.a.)[2]	1.99	2.29	–2.50	6.10
Average TLU per caput (head)[1, 3]	0.71	0.74	0.11	3.43
Proportion of cattle in total TLU (%)[1]	79.50	15.13	42.00	97.00
Proportion of livestock GDP in total agricultural GDP (%)[1]	24.86	20.47	2.30	86.30

[1] 1978/79.

[2] 1970/71–1978/79.

[3] Per caput of the agricultural population.

Sources: Addis Anteneh. 1988. Financing livestock services in sub-Saharan Africa. Forthcoming ILCA Research Report.
Jahnke H. E. 1982. Livestock production systems and livestock development in tropical Africa. Kieler Wissenschaftsverlag Vauk Kiel.
FAO production yearbooks. Several years.

Range trends

Range regeneration trials in Mali

Range regeneration trials were carried out in Mali in 1987. *Panicum laetum* was planted at four sandy sites and at one site on a muddy plain. Four methods of establishment were tested:

- broadcasting on ploughed soil
- broadcasting on unploughed soil
- broadcasting on ploughed soil, followed by mulching with dead branches
- sowing on hills.

The establishment methods were duplicated with pre-soaked and unsoaked grains. Overall, 10 treatments (including controls) were tested on plots each of 0.5 ha. The seeding rate was 15 kg ha^{-1}, corresponding to 750 grains m^{-2}.

Growth on the plots was very poor due to insufficient rainfall in 1987. Although seed germinated on both muddy and sandy soils the seedlings were unable to establish. However, since there had been no plant growth on the trial sites for several years, the initial growth of seedlings from sown seed supports the hypothesis that it is the absence of viable seeds that is limiting the regeneration of these degraded rangelands.

This hypothesis was further supported by the linear relationship found between the ratio of maximum biomass observed (B.obs) to cumulative calculated potential production (cumul P. calc) and the number of seeds germinating in watered soil samples. The linear regression obtained for 23 sites covering all soil types was:

$$B.obs/cumul\ P.calc = 0.94\ ISS + 0.16$$

$$R = 0.63$$

where ISS is an index proportional to the number of viable seeds in the soil, up to a level of 1000 seeds m^{-2}, beyond which the index remains constant.

For 17 sites on sandy soil the relationship was:

$$B.obs/cumul\ P.calc = 1.28\ ISS + 0.13$$

$$R = 0.82$$

The relationship established between seed stock density and maximum herbaceous biomass in the previous year was:

$$Ng = 3(Bmax) - 175$$

$$R = 0.87,\ n = 20$$

where Ng = number of seeds germinating in the current year
Bmax = maximum biomass in the previous growing season

Similar relationships established for 1986 and 1987 indicated that if biomass yield fell below 355 and 263 kg DM ha^{-1}, respectively, plant production in the following year would be reduced by low seed stock.

Resource survey

A major impediment to the better use of natural resources in sub-Saharan Africa is the lack of up-to-date and reliable information on land use, the location and size of the human, domestic livestock and wildlife populations, the status of important ecological variables (e.g. soil erosion or ground cover) and the inter-relations in space and time between these variables.

Low-level aerial survey enables information of acceptable reliability to be obtained speedily and at a reasonable cost. However, there are economies of scale in low-level aerial survey, such that few countries can at present accumulate and fully use the planes, equipment and skills involved.

ILCA has used low-level aerial-survey techniques for more than 10 years, partly in connection with its own livestock systems research in the zonal programmes, and partly as a service to national and international organisations. It has two planes and the other necessary equipment and skills, and can hire additional specialised equipment and skills if required. The Centre, alone or in collaboration with other institutions, has already conducted low-level aerial surveys over nearly 1 million km^2 of sub-Saharan Africa, equivalent to 4% of the area.

In 1987 ILCA was involved in major low-level aerial surveys in two areas. In May it provided plane, pilot and equipment for a survey of 95,000 km^2 in the Niger delta in Mali carried out by Resource Survey and Management Ltd (RIM), with whom ILCA have collaborated over a number of years. In June ILCA provided a complete survey team to survey 31,000 km^2 of the Ferlo region of Senegal. The report of this survey was completed in September and ILCA sent a team to train and induct the staff of the Senegalese Centre de suivi écologique to conduct the second round of the survey themselves during October and November.

LIVESTOCK POLICY AND RESOURCE USE THRUST STAFF

S G Sandford, *Thrust Coordinator*
Addis Antench, *Economist*
Assefa Eshete, *Photo Interpreter*
Michel Corra, *Ecologist*
P Hiernaux, *Ecologist*
J McIntire, *Economist*
Senait Seyoum, *Senior Economic Assistant*
Tassew G. Medhin, *Pilot*

Training and Information Department

ILCA sees training and information as the primary instruments of strengthening the scientific capabilities of national agricultural research services (NARSs) and of disseminating the results of our research. Thus, while the main function of the Centre's training and information programme is to contribute to the enhancement of human resources in the livestock subsector of sub-Saharan Africa, it also facilitates the sharing of scientific knowledge and skills in the continent. Through these functions the role of the training and information programme in improving livestock production in sub-Saharan Africa is as important as that of the research thrusts, and the programme is therefore in many ways regarded as a seventh thrust.

Training

Most training at ILCA is currently aimed at improving the research capabilities of African livestock scientists. However, as ILCA and its NARSs partners develop new technologies the emphasis will shift to instructing

Collection and evaluation of forage germplasm are important aspects of ILCA's feed resources work. Training is given to support the development of germplasm work in African national programmes.

teachers and extension agents on how to promote the use of new production methods.

In 1987, 160 young agricultural researchers attended eight courses and 86 livestock specialists spent time at ILCA as individual trainees. Other training activities were organised by research sections in their fields of specialisation, often in collaboration with NARSs.

Training courses

Five of the eight courses offered in 1987 were given in English and three in French (Table 38). Two courses, Rural Dairy Technology and Standardisation of Livestock Data Collection, were offered jointly with FAO. There were 355 applicants for the eight courses: 169 people (47.6%) were selected. Of those selected, 160 attended the courses.

A system of post-course evaluation was instituted in early 1987. Participants in 1986 courses were sent questionnaires 12 months after leaving the Centre. Responses to the questionnaires will indicate the usefulness of training received at ILCA, both to the trainees and to their employers, and will help determine which course topics are of the most value.

Table 38. *Group training courses at ILCA, 1987.*

Course title	Attendance	
	No. of participants	No. of countries
Forage evaluation techniques	13	10
ILCA/FAO rural dairy technology	14	9
Management of agricultural information	22	9
Small ruminant production techniques*	25	16
ILCA/FAO standardisation of livestock production data	22	12
Economics of animal health and disease control	23	11
African livestock policy analysis*	23	15
Animal nutrition and forage analysis*	18	14

* Course given in French.

Individual training

Eighty-six people took part in individual training activities at ILCA in 1987 (Table 39). Twelve senior scientists (2 Visiting Scientists and 10 Post-doctoral Associates) worked with ILCA staff in Ethiopia, Mali and Nigeria. Twenty-two Graduate Associates worked on their thesis research as part of ILCA research projects. Twenty-seven young, first-degree trainees joined ILCA for 3–9 months to gain working experience in field research, and 25 Africans were given technical training or technical support to complete their own research projects.

Survey of national livestock organisations in Africa

A survey of African livestock institutions was started in early 1987. The purpose was to determine their programmes and training and information status

Table 39. *Individual training by country of origin, 1987.*

Category	Country of origin	Number	Total
Post-doctoral Associate	E. Guinee	1	
	Ethiopia	1	
	Ghana	3	
	Mali	1	
	Nigeria	1	
	Tanzania	1	
	Uganda	1	
	Zimbabwe	1	10
Visiting Scientist	Nigeria	1	
	Sierra Leone	1	2
Graduate Associate	Cameroon	2	
	Ethiopia	10	
	Germany (F.R.)	2	
	Ireland	1	
	Mali	1	
	Nigeria	2	
	Norway	1	
	Switzerland	1	
	Uganda	1	
	USA	1	22
Undergraduate Associate	Ethiopia	11	
	France	1	
	Germany (F.R.)	1	
	Mali	2	
	Nigeria	6	
	The Netherlands	4	
	UK	2	27
Technician Associate	Benin	1	
	Côte d'Ivoire	4	
	Djibouti	1	
	Ethiopia	12	
	Gambia	1	
	Tanzania	1	20
Research Fellow	Côte d'Ivoire	1	
	Mali	1	
	Uganda	1	3
Meeting Fellow	Cameroon	1	
	Ethiopia	1	2
Total		86	86

and needs. Survey forms, in French and English, were sent to more than 950 organisations in 44 countries in sub-Saharan Africa, 20 anglophone and 24 francophone. Information was requested on the functions of the organisation, sites and numbers and species of livestock present, laboratory and information-management equipment, current research projects, funding, staffing, and training needs.

By the end of 1987, 202 completed forms had been returned, 136 from 17 anglophone countries and 66 from non-anglophone countries (18 francophone and 3 Portugese-speaking countries). The data collected are being incorporated with other general and specific data on African countries and their agricultural programmes in an African livestock database. This resource will help ILCA identify the specific needs of national programmes more accurately and to offer better service and research programmes.

Information

The Library and Documentation and Publications Sections were amalgamated in 1987 to form the Information Section in order to provide more coherent information services in support of ILCA's research and training programmes as well as those of our partners in sub-Saharan Africa.

Library and Documentation

ILCA's Library and Documentation services continued to provide a range of information services and products to the Centre's staff and to staff of national agricultural research services throughout sub-Saharan Africa.

Computerised information services

The Selective Dissemination of Information (SDI) service provides 750 researchers throughout sub-Saharan Africa with monthly updates of abstracts from the databases of the Commonwealth Agricultural Bureaux International (CABI) and the FAO agricultural information system, AGRIS. The SDI service is provided free of charge to African users under a grant from the International Development Research Centre (IDRC), Canada.

Seven hundred retrospective literature searches were conducted for staff and outside users on ILCA's internal database, which now contains 49,000 entries, and external databases. A CD-ROM (Compact Disk Read-Only Memory) was also obtained during the year, partly through a grant from the Technical Centre for Agricultural and Rural Cooperation (CTA). The library holds CD-ROMs of the AGRICOLA database (National Agricultural Library, USA) and a sample disk provided by CABI.

Bibliographies for Gambia, Niger and Togo, listing non-conventional literature collected through the ILCA/IDRC microfiche project, were published and distributed to participating centres in these countries and to other users. A bibliography on land and tree tenure in West Africa was also published in 1987.

Library

The library provided a total of 260,000 photocopy sheets and 36,240 microfiches and fulfilled several loan requests from staff and outside users. It continued to provide the "current titles" service, whereby the contents' pages of current periodicals are photocopied, grouped into five subject areas, and dis-

tributed to agricultural libraries in sub-Saharan Africa. The library also donated duplicate materials, comprising 1000 journal issues, 35000 reprints and 133 reference books, to research libraries in Ethiopia. In addition to ILCA publications distributed through the mailing list, the library sent out a total of 9500 Centre publications on request.

The library's collection continued to grow with 1098 books and 128 new periodical titles added in 1987. Seven hundred non-conventional documents were also incorporated into the library's unique microfiche collection through a visit to national agricultural research institutes in Madagascar.

Publications

The Information Section continued to produce the Centre's official publications, including the strategy and long-term plan, annual report, research reports, bulletins, newsletters, manuals and conference proceedings, in both English and French. These are listed in the Annexes to this report. The Centre's mailing list, which is used to distribute ILCA's regular publications, now contains over 8000 addresses, of which 65% are in Africa.

The Section also supported the research and training programmes through photocopy and duplication services, particularly during the thrust planning conferences and for training courses.

Printshop staff were trained in 1987 in colour printing, so that ILCA can produce documents with colour photographs in-house. The Section's typesetting facilities were also upgraded in 1987 to allow page layout on the typesetting machine, which improves the quality and timeliness of publications.

Staff list

(Professional and Supervisory staff as at 1 May 1988)

DIRECTOR GENERAL's OFFICE

J Walsh, *Director General*
R A Stewart, *Assistant to the Director General and Director of the Donor and Board Secretariat*
Antonio Silla, *Internal Auditor*
Tehout Workalemahu, *Executive Secretary*

RESEARCH DEPARTMENT

K J Peters, *Deputy Director General (Research)*
A Tall, *Assistant to the Deputy Director General*

Animal Science Division

Animal Nutrition and Management

P Chigaru, *Head of Section*
E Kabaija, *Animal Scientist (Post-doctoral Associate)*
D Little, *Animal Nutritionist*
J D Reed, *Animal Nutritionist*
A N Said, *Animal Nutritionist, ARNAB Coordinator*
Tekalegn Tadesse, *Analytical Chemist*

Small Ruminant Network

R T Wilson, *Animal Scientist*
D Bourzat, *Animal Scientist (Seconded from IEMVT)*
K D Gautsch, *Animal Scientist (Research Associate)*

Animal Traction Research Network

M R Goe, *Animal Scientist*

Animal Management

D L Coppock, *Animal Scientist*
Belete Dessalegn, *Animal Scientist*

Animal Reproduction and Health

O B Kasali, *Head of Section*
G Cecchini, *Biochemist (Research Associate)*
R Franceschini, *Veterinarian (Research Associate)*
M Mattoni, *Veterinarian*
E Mukasa-Mugerwa, *Animal Scientist*
B Njau, *Veterinarian (Post-doctoral Associate)*
S Sovani, *Veterinarian (Research Associate)*
Tekelye Bekele, *Veterinarian*

Plant Science Division

J Tothill, *Head of Division*

Forage Agronomy

J Hanson, *Genebank Manager*
J Kahurananga, *Ecologist*
J Lazier, *Forage Agronomist*
J Ruredzo, *Tissue-culture Specialist (Post-doctoral Associate)*
A Russell-Smith, *Forage Agronomist*

Soil and Plant Nutrition

I Haque, *Soil Scientist*
C S Kamara, *Visiting Scientist*

Livestock Economy Division

S Sandford, *Head of Division*
Addis Anteneh, *Economist*
T Bedingar, *Economist (Post-doctoral Associate)*
R Brokken, *Economist*
J McIntire, *Economist*
A Panin, *Economist (Post-doctoral Associate)*
Senait Seyoum, *Senior Economic Assistant*

Research Support Division

Computer Science and Biometrics

J Durkin, *Computer Operations and Systems Manager*
T Metz, *Scientific Programmer*
E Richardson, *Biometrician*
A R Sayers, *Biometrician*

Experiment Stations

Aklilu Askabe, *Farm and Grounds Manager (HQ)*
Woldeab W/Mariam, *Coordinator (Debre Berhan)*
Tadesse Tessema, *Coordinator (Debre Zeit)*

Resource Assessment and Management

Assefa Eshete, *Photo Interpreter*
Michel Corra, *Ecologist*
Tassew G/Medhin, *Pilot*

Zonal Research Sites

Highlands—Ethiopia
S Jutzi, *Team Leader*
Abate Tedla, *Forage Agronomist*
Abiye Astatke, *Senior Technical Assistant*
Getachew Asamenew, *Agricultural Economist (Highlands-Vertisols)*

Humid Zone—Nigeria
L Reynolds, *Team Leader*
A Atta-Krah, *Agronomist*
J Cobbina, *Forage Agronomist (Post-doctoral Associate)*
P Francis, *Agro-economist*

Subhumid Zone—Nigeria
R von Kaufmann, *Team Leader*
S A Ingawa, *Economist*
M A Mohamed-Saleem, *Forage Agronomist*
G Tarawali, *Forage Agronomist*
S A Tarawali, *Agronomist*

Semi-arid Subhumid Zone—Mali
A K Diallo, *Team Leader*
P Bartholomew, *Forage Agronomist*
M Cissé, *Ecologist*
S Debrah, *Economist*
L Diarra, *Ecologist*
D Diakite, *Administrator*
K Fofana, *Chief Accountant*
P Hiernaux, *Ecologist*
S Maiga, *Veterinarian*
S Soumare, *Sociologist*
A Traore, *Veterinarian*

Semi-arid Trypanotolerance—Kenya
J C M Trail, *Team Leader*
G d'Ieteren, *Trypanotolerance Network Coordinator*
B Dzowela, *PANESA Coordinator*
P de Leeuw, *Ecologist*
H Maehl, *Animal Production Specialist*
S Nagda, *Senior Biological Data Analyst*
A Okuome, *Administrative Officer*
A Ouattara, *Bilingual Assistant to the Trypanotolerance Network Coordinator*
J M Rarieya, *Biological Data Assistant*
Solomon Bekure, *Agricultural Economist*
W Thorpe, *Animal Scientist*

Semi-arid Zone—Niger/Gambia-Senegal
K Agyemang, *Animal Production Scientist*

Network sites
Network Site—Trypanotolerance, Ethiopia
Woudyalew Mulate, *Project Supervisor*

OUTREACH DEPARTMENT

M Sall, *Director of Outreach*
Alemayehu W/Giorgis, *Travel Officer*
Amde Wondafrash, *National Liaison Officer*
Ephraim Bekele, *Liaison Service Officer*
Tafesse Akale, *Protocol Officer*

TRAINING AND INFORMATION DEPARTMENT

R G Scholtens, *Director of Training and Information*

Training
Admassu Wondafrash, *Draftsman (Training Materials and Methods Unit)*
L Padolina, *Administrative Assistant*
Werqu Mekasha, *Training and Conference Officer*

Information
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Belayhoun Wondimu, *Chief Accountant*
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Negussie Abraham, *Supervisor, General Accounts*

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Livestock and Veterinary Conference, Ahmadu Bello University, Zaria, Nigeria, April 1987.

Mechanization of Field Experiments in Semi-Arid Areas, International Association on Mechanization of Field Experiments (IAMFE)/International Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria, May 1987.

Meeting of Heads of Genetic Resources Units of the CGIAR Centres, CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo), Mexico, October 1987.

Meeting on Animal Production Systems Based on the Utilisation of Local Resources, sponsored by CTA (Centre technique de coopération agricole et rurale), Brussels, September 1987.

Nineteenth Meeting of the International Scientific Council for Trypanosomiasis Research and Control (ISCTRC), Lomé, Togo, March–April 1987.

Office international des epizooties Seminar on Animal Health Information System, Dakar, Senegal, October 1987.

PANESA (Pasture Network for Eastern and Southern Africa) Workshop on African Forage Plant Genetic Resources, Forage Germplasm Evaluation and Extensive Livestock Production Systems, Arusha, Tanzania, April 1987.

Premières journées tunisiennes vétérinaires, sponsored by the Tunisian Veterinary Association, Hammamet, Tunisia, May–June 1987.

Regional Seminar on Forages and Ruminant Nutrition sponsored by IEMVT (Institut d'élevage et de médecine vétérinaire des pays tropicaux) and IRZ (Institut de recherches zootechniques, Cameroon) Ngaoundere, Cameroon, November 1987.

Second Annual Report Hearing and Training of Awraja Livestock Experts of the Ministry of Agriculture Central Zone, Debre Zeit, Ethiopia, June 1987.

Second Pan-African Research Network Workshop for Rural Social Scientists, Owerri, Nigeria, October 1987.

Seminaire sur les systèmes agricoles oasiens, Tozeur, Tunisia, November 1987.

Senior Research Extension Administrators' Workshop, sponsored by CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo), Malawi, May 1987.

Seventh Conference of the OIE (Office international des epizooties) Regional Commission for Africa, on Eradication et Streptothricosis Dermatophilosis, Cairo, Egypt, January 1987.

Seventh Meeting of the Latin American Network for Animal Production Systems Research, Lima, Peru, March 1987.

Sixth KVA/Kenya Veterinary Association) SR-CRSP (Small Ruminant-Collaborative Research Support Program) Scientific Workshop, Nairobi, Kenya, November 1987.

Training Workshop, Department of Animal Resources and Fisheries, Ministry of Agriculture, Debre Zeit/Addis Ababa, Ethiopia, June 1987.

Workshop on Agricultural Mechanisation in Equatorial Africa, Institute of Agricultural Research, Nazareth, Ethiopia, December 1987.

World Bank Appraisal Mission, Multistate Agricultural Development Project II, Kwara and Niger States, Nigeria, 1987.

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
BALANCE SHEET at December 31, 1987

(US$ '000)

ASSETS

Current assets	1987	1986
Cash	2 713	4 252
Receivable from - donors	3 304	1 681
- employees	44	26
- others	461	350
Inventories	735	697
Deposits and prepayments	183	250
Total current assets	7 440	7 256
Fixed assets		
Buildings	9 360	9 300
Research and laboratory equipment	3 125	2 649
Computer	1 284	1 321
Furnishings and office equipment	2 648	2 536
Vehicles and aircraft	2 709	2 405
Other	152	142
Total fixed assets	19 278	18 353
Total assets	26 718	25 609

LIABILITIES AND FUND BALANCES

Current liabilities		
Accounts payable employees	340	329
Other payables and accruals	3 105	3 816
Contributions received in advance	425	839
Total current liabilities	3 870	4 984
Fund balances		
Invested in fixed assets - Core	18 769	17 892
- Special projects	509	461
Working capital	2 834	1 972
Capital development fund	736	300
Total fund balances	22 848	20 625
Total liabilities and fund balances	26 718	25 609

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
STATEMENT OF REVENUE, EXPENDITURE AND FUND BALANCES
for the year ended December 31, 1987

(US$ '000)

Revenue	1987	1986
CGIAR contributions	14 603	15 176
Special project grants	1 969	2 077
Earned income	539	115
Capital development fund	436	439
Total revenue	17 547	17 807
Operating expenditure		
Research	8 478	8 638
Information services	1 434	1 291
Training and conferences	1 278	1 142
General administration & operations	1 516	1 068
Board and management	697	764
Total operating expenditure	13 403	12 903
Capital expenditure	877	1 818
Special projects	1 969	2 077
Total expenditure	16 249	16 798
Excess of revenue over expenditure	1 298	1 009

FUND BALANCES

Opening balances		
Working capital	1 972	1 063
Capital development fund	300	200
Total opening balances	2 272	1 263
Excess of revenue over expenditure	1 298	1 009
Closing balances		
Working capital	2 834	1 972
Capital development fund	736	300
Total closing balances	3 570	2 272

INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
SCHEDULE OF CGIAR CONTRIBUTIONS AND SPECIAL PROJECT GRANTS
for the year ended December 31, 1987

(US$ '000)

CGIAR Contributions	1987	1986
African Development Bank	200	200
Australia	–	295
Austria	175	175
Belgium	727	672
Canada	744	718
Denmark	335	254
Federal Republic of Germany	1 027	746
Finland	675	391
France	270	200
India	25	25
International Development Research Centre (IDRC)	154	268
Ireland	436	343
Italy	1 640	1 487
Netherlands	398	324
Nigeria	35	45
Norway	438	414
Organization of Petroleum Exporting Countries (OPEC)	112	63
Sweden	361	359
Switzerland	1 369	1 091
United Kingdom	482	431
United States of America (USAID)	3 000	3 475
World Bank	2 000	3 200
Total CGIAR contributions	14 603	15 176
Special project grants		
Australia (ACIAR)	24	–
Australia (CSIRO)	–	8
Belgium	–	63
CARE – Ethiopia	5	69
Caritas (Switzerland)	95	63
Christian Relief Development Agency (CRDA)	–	11
City of Bearsel	–	1
European Economic Commission (EEC)	489	622
Federal Republic of Germany (BMZ/GTZ)	338	422
Finland	148	–
Ford Foundation	7	34
International Board for Plant Genetic Resources (IBPGR)	17	22
International Development Research Centre (IDRC)	138	143
Ireland	27	3
Medios (Belgium)	5	10
Nigeria (FLD)	6	11
Norway	300	150
Oxfam America	113	132
Total C/F	1 712	1 764

CGIAR Contributions and Special Project Grants (Cont'd)

(US$ '000)

	1987	1986
Total B/F	1 712	1 764
Royal Shakespeare Company	–	31
United Nations Environmental Programme (UNEP)	40	25
United Nations Sudano-Sahelian Office (UNSO)	–	30
United States of America (USAID)	217	227
Total special project grants	1 969	2 077

Source and application of funds, 1987 and 1986