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Productivity of N'Dama and N'Dama x Sahiwal cattle in Sierra Leone

Effect of diet restriction on working oxen

Agro-ecological zonation

Animal breeding and productivity studies in Africa

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

ILCA is one of 13 international centres for agricultural research whose work is funded by the Consultative Group on International Agricultural Research (CGIAR). The 13 centres have been established by the CGIAR to provide long-term support for agricultural development in the Third World.

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Preface

This issue of the *ILCA Bulletin* includes papers on the productivity of N'Dama cattle and their crosses with Sahiwals in Sierra Leone, the effects of diet restriction on the work performance of local Zebu and Friesian x Boran oxen in Ethiopia, ILCA's activities in agro-ecological zonation, and on animal breeding and performance studies in Africa.

The first paper examines the productivities of N'Dama cattle, introduced Sahiwal cattle and N'Dama x Sahiwal crossbreds in Sierra Leone. The authors found that the herd productivity of N'Dama cows with Sahiwal-sired calves was higher than that of N'Damas with N'Dama-sired calves, but that the productivity of purebred Sahiwals was not sufficiently greater than that of N'Dama cows with Sahiwal-sired calves to justify their use in Sierra Leone. The performance of the N'Dama x Sahiwal crossbreds needs further evaluation.

The second paper deals with the effects of diet restriction on the work performance and weight loss of local Zebu and Friesian x Boran oxen worked as singles. The crossbred oxen are heavier than the local cattle and generate more force, but also require more feed. In a trial carried out by ILCA it was found that the work performance of the crossbreds was significantly higher than that of the local animals, but that diet did not have a significant effect on this character. All the oxen in the trial lost weight during the 23-week cultivation season. The authors suggest that oxen in good condition at the beginning of the season are able to perform adequately as singles for at least 4 months even when they are poorly fed.

The third article examines ILCA's work in the field of agro-ecological zonation and its potential benefits. In a continent as large and as varied as Africa, much agricultural research is site specific - but with more precise definition of agro-ecological zones it is hoped that the applicability of research results to other areas of similar agro-ecological conditions can be more rapidly assessed. A greater understanding of the climate and its effects on agriculture will also enable increased use to be made of modelling to predict pasture, forage and crop responses to the environment, and hopefully will reduce the need for multilocation adaptation trials. Many other potentially exciting developments from this technology are outlined.

Little information is available in the literature that allows comparative studies to be made of animal breeding and performance in Africa, while much of the research done in Africa on these topics has never been published as journal articles or books with wide circulation. The fourth article in this issue of the *ILCA Bulletin* outlines the work being done by ILCA in collecting such "grey literature" and making it more widely available. It also summarises ILCA's studies of comparative breed performance using data from such "grey literature", and describes "IDEAS", a microcomputer-based animal performance recording system that will simplify the collection and analysis of animal breeding and performance data.

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N'Dama cattle productivity at Teko Livestock Station, Sierra Leone and initial results from crossbreeding with Sahiwal

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Summary

ANALYSES WERE *carried out on the productivities of N'Dama cattle, introduced Sahiwal cattle, and Sahiwal x N'Dama crossbreds at the Teko Livestock Station, Sierra Leone. Data were available for a range of performance traits for the period 1971 to April 1980. All cattle were maintained for meat production. Environmental and genetic effects relating to breed group, month and year of parturition or birth, age, sex, individual cow, etc., were evaluated as appropriate for each performance trait.*

In N'Dama cattle, age at first calving was 46.5 months, calving interval was 17.9 months and cow productive life was 7.4 years in the breeding herd, 11.3 years in total. Calf mortality rates were 2.0% perinatal, 6.4% from birth to weaning at 9 months and 1.5% per 6 months thereafter. The breeding cow mortality rate was effectively zero, and the average generation interval was 7.6 years. Calf growth rate was 194 g per day from birth to 6 months of age and 146 g per day from birth to 18 months of age. Mean cow body weight was 208 kg. The characters of reproductive performance, cow and calf viability, and cow and calf body weights, were combined to build three productivity indices. The overall herd productivity was 35.0 kg of 6-month old calf per cow per year; 19.7 kg of 6-month old calf per 100 kg of cow body weight per year; and 80 kg of 6-month old calf per 100 kg cow metabolic body weight per year.

Herd productivities of N'Dama cows with Sahiwal-sired calves were 10% higher than those with N'Dama-sired calves, mainly due to the 30% faster growth of Sahiwal-sired calves. In spite of very preferential management and health treatment the herd productivity of pure Sahiwals was 3% lower per 100 kg of cow body weight per year and only 12% higher per 100 kg of cow metabolic weight per year than N'Damas with Sahiwal-cross calves. There would appear to be little future for purebred Sahiwals in this environment.

Introduction

There are over 334 000 cattle in Sierra Leone, all of the N'Dama breed. More than 80% of the national herd are found in Northern Province where the Teko Livestock Station is located and where production information has been recorded since the early 1970s. In 1974, 25 Sahiwal cattle were imported from Kenya and crossbreeding work started between the N'Dama and Sahiwals.

In 1982/83, the International Livestock Centre for Africa (ILCA) provided a scholarship for a research scientist from the Ministry of Natural Resources, Sierra Leone, to spend 5 months extracting, analysing and interpreting the data available in collaboration with the ILCA Breed

Productivity and Trypanotolerance Group in Nairobi. This report presents an analysis of the productivity data collected between 1974 and 1980.

The Teko Veterinary Research Station was established in the late 1940s. From then until the late 1960s, research was carried out on disease control in cattle. This consisted of identifying prevalent diseases such as rinderpest, black quarter, contagious bovine pleuropneumonia and anthrax, and, where possible, producing vaccines against them. In the early 1970s, interest grew in the breeding and selection of cattle for increased beef production. In 1974 Sahiwal cattle were introduced and a crossbreeding programme was started with Sahiwal being used on N'Dama cattle, with the aim of increasing the productivity of cattle. Data were collected on reproductive performance, mortality and growth, adaptation to environmental stress and resistance to disease.

Teko livestock station

Environment

The station covers approximately 800 hectares and is situated at an altitude of about 500 m, latitude 8° 50' N, longitude 12° 00' W. It lies 3 miles southeast of Makeni in the Bombali district of the Northern Province of Sierra Leone. The station is basically flat but has a number of streams and swamp areas.

There are two distinct seasons: the dry season lasts from November to April, and the wet season from May to October. The heaviest rain falls between July and September. Table 1 shows monthly rainfall (mm) from 1971 to 1979. The widest daily temperature variation occurs from December to March during the dry season, when both the lowest and the highest temperatures of the year are recorded. The relative humidity is highest from May to October, during the wet season.

Table 1. *Monthly rainfall at Teko Livestock Station, 1971–1979*.

	Monthly rainfall (mm)									Monthly average
	1971	1972	1973	1974	1975	1976	1977	1978	1979	
January	–	–	–	–	–	–	–	9	33	5
February	11	–	–	–	–	10	–	97	–	32
March	4	46	6	28	–	3	4	11	–	11
April	266	97	52	81	105	139	48	153	6	101
May	171	223	289	125	259	147	207	279	235	215
June	229	597	301	332	343	598	471	377	435	409
July	230	545	370	509	573	387	532	475	768	488
August	832	720	635	426	589	318	481	848	545	599
September	569	361	432	455	429	585	752	591	509	520
October	339	480	502	466	449	532	425	442	570	467
November	222	3	194	163	57	208	37	129	203	135
December	61	–	4	–	34	27	3	1	37	19

Annual total	2894	3072	2785	2585	2838	2954	2960	3412	3341	3001

Vegetation consists mainly of bush savanna with trees along the riverbanks. There is plenty of growth during the wet season but during the dry season vegetation becomes fairly sparse. Common grasses include *Chosmopodium* spp., Guinea grass and Pueraria grass. The main source of forage is natural pasture, but in the dry season both quality and quantity are limiting. No improved pastures have been planted. Some maize and sorghum are grown to provide supplementary feed through the dry period but quantities are small. The main supplementary concentrate feed is rice bran. Brewers grains from breweries in Freetown and wheat mill cake and palm-kernel cake from the palm kernel industry have sometimes been fed to the cattle but these are expensive. Cattle are routinely vaccinated against anthrax, black quarter, contagious bovine pleuropneumonia and haemorrhagic septicaemia. Regular blood and faecal examinations are made to identify internal parasites and control measures are carried out. The animals are treated with acaricides to control external parasites. The acaricides are changed regularly to prevent possible build-up of resistance by ticks.

Herd management

Prior to 1974, there was only one herd of N'Damas on the station. Cattle were exchanged or transferred between this herd and herds at the Musaia and Newton livestock stations and at the University farm at Njala. From 1970 to 1980 the number of animals in the herd fluctuated between 120 and 300 due to the issue of cattle on loan to farmers through the extension services.

In October 1974, 25 Sahiwal cattle, comprising 20 heifers and 5 bulls, were introduced from Kenya. A crossbreeding programme was set up to attempt to improve the productivity of the indigenous N'Dama and three herds were formed; herd I consisting of pure-breeding Sahiwals; herd II consisting of N'Damas mated to Sahiwal bulls; herd III consisting of pure-breeding N'Damas.

In all three herds a single bull is used at a time. Cows are pregnancy tested about 60 days after service and, if pregnant, are moved into in-calf herds. After calving, cows are put into dam/calf herds until the calves are weaned. At weaning (6 months in herds I and II, 8–9 months in herd III) the dams are returned to the main herd. After weaning the management system differs slightly in each herd group. In herd I, weaners (heifers and bulls) are kept together until they are 20–24 months old. After selection the best 1 or 2 bulls and all the heifers are kept, the heifers being served at about 24 months old, when they are put into the main herd I. The remaining bulls are used in the extension services. In herd II, weaners (heifers and bulls) are kept together until they are 18 months old. Most of the crossbreds are then used by the extension services. Only a few heifers are kept and served at 22–24 months when they are put into main herd II. Bull calves are castrated only in herd III. At weaning in herd 111, bulls and heifers are put into separate weaning groups. The best 1 or 2 bulls are kept for breeding on the station. Other bulls are used in extension services. The remaining male weaners are castrated at about 9 months old and are either used as draught oxen or fattened for slaughter. The heifers are selected and the best kept and served at 30–36 months old. The remainder go to the Musaia and Newton Livestock stations or are culled. In all herds, selection is carried out on growth and conformation. In herd III the culling age is 10–12 years and in all herds cows are culled on poor performance or health.

The original foundation Sahiwal herd (20 heifers and 5 bulls) was purchased in Kenya and airfreighted to Sierra Leone in October 1974. As considerable expense had been involved it was decided that the pure Sahiwals should get preferential treatment in order to minimise losses and maximise expansion of the herd. The pure Sahiwals were regularly given prophylactic treatment for trypanosomiasis, drenched against intestinal parasites and sprayed for tick control. They were given the best grazing on the station and also received regular supplementary feeding (rice bran, brewers grains), not available to the N'Damas. The performance of the pure Sahiwals therefore cannot be compared directly with that of the pure N'Damas and Sahiwal x N'Dama crosses.

Daily activities, identities of sick animals, mortalities, abortions, post-mortem results, treatments, vaccinations and routine anthelminthic treatments are all recorded. Calving dates are noted and all calves are given their dam's number until weaning. The calf sex and birth weight, and dam and sire breed and numbers are recorded. All animals are weighed monthly except calves which are weighed twice a month until 3 months of age. Rainfall, temperature and relative humidity are recorded.

Data preparation and analysis

Individual records were built up for each cow for each parturition. These gave identification number, date of birth and breed of the cow, the current parturition date, previous parturition date, sex of calf, sire of calf, perinatal and pre-weaning viability of calf, and calf weight at birth and 3, 6 and 9 months after parturition. From these data the age at first calving, calving interval, cow mean weight and three productivity indices were computed. Disposal or death of the cow was recorded. All available causes of death were obtained from periodic reports and treatment sheets.

Based on the rainfall records from 1971 to 1979, the months of the year were grouped into four subseasons; the first and second parts of the dry season and the first and second parts of the wet season:

Months	Season	Average rainfall (mm) per month
Nov–Jan	First part of dry	53
Feb–Apr	Second part of dry	48
May–Jul	First part of wet	371
Aug–Oct	Second part of wet	529

All characters were analysed by least-squares procedures (Harvey, 1977) using both fixed and mixed models. In the analysis, some parameters were measured for further study in their own right and some were measured to account for variation arising, in order that less biased estimates of other parameters could be obtained. Unequal and disproportionate subclass numbers gave unbalanced factorial designs for which conventional analysis of variance techniques were not applicable.

A considerable number of the foundation animals had no sire or dam records. In addition, the use of individual sires was often confounded with season and year of use, so use could not be made of sire group in analyses at this time. Typical models used included the fixed effects of breed type; age at parturition; year of birth or parturition; season of birth or parturition; sex of calf; and the random effects of individual cow. The specific factors included in the model used will be evident when results are presented for each character analysed.

The residual mean square was used as the error term to test the significance of all differences evaluated. Linear contrasts of least-squares means were computed to determine the significance of differences between groups for all characters where the difference among groups was significant in the analysis of variance. More comparisons were made using the least-squares means than there are independent degrees of freedom for the characters where the group differences were significant in the analysis of variance. Therefore, not all of the comparisons are independent and the error rate over the entire set of comparisons may be different from that indicated by the level of probability. Tests of significance associated with the linear contrasts, although not independent, can be taken as guides as to whether the observed values could have occurred by chance. Repeatabilities were calculated using the variance components between and within cows.

Reproductive performance

Reproductive performance is the most important trait in beef cattle enterprises, since if there is no calf, there is no economic return. Clearly, the best cows are those that have their first calf at an early age, have minimum calving intervals and live a long time. Thus, the most important measures of reproductive performance in the females are age at first calving, length of calving interval and length of the productive life of the cow.

Age at first calving

The mean age at first calving for 79 females born between 1966 and 1976 was 43.1± 0.6 months, a coefficient of variation of 7%.

Among the factors studied, only breed of the cow had a significant effect on age at first calving (Table 2).

Table 2. *Analysis of variance of age at first calving*.

Source	d.f.	Mean squares x 10
Cow breed	2	5115**
Season	3	5
Year of birth	10	132
Remainder	63	114

** = P <0.01

The estimated least-squares means show that age at first calving was 46.5 ± 0.7 months for the N'Dama, 37.7± 1.2 months for the Sahiwal and 32.4 ± 2.1 months for the 4 Sahiwal x N'Dama crossbreds. The 46.5 months for the N'Damas is 18% longer than the 39.4 months reported by Touchberry (1967) for N'Dama cattle at Musaia Animal Husbandry Station.

Calving interval

The mean calving interval for 140 records between 1971 and 1978 was 515 ± 11 days, a coefficient of variation of 24%. Only season of calving had a significant effect on calving interval (Table 3), although the effect of cow age approached significance.

Table 3. *Analysis of variance of calving interval.*

Source	d.f.	Mean squares x 10^{-2}
Breed	1	111
Season of calving	3	655**
Year of calving	7	71
Age	4	309
Remainder	124	146

** = P<0.01

Cows that calved at the end of the dry season (February to April) had significantly longer subsequent calving intervals than all others (83 days or 15% longer than average). This was probably due partly to cows calving at this period being 6% lighter at parturition than those that calved during all other periods (see Table 10). The effect of age approached significance, with subsequent calving intervals of cows calving at 3 years of age (actual mean 36.6 months) being 117 days or 23% longer than the average of all later ages. The mean calving interval for the N'Dama breed was 545 days, which is 16% longer than the 467 days reported by Touchberry (1967) at Musaia Animal Husbandry Station.

The distribution of 140 conceptions calculated from the recorded calving dates between 1971 and 1978 showed that 69% of conceptions occurred during the 6-month dry season (November to April). Touchberry (1967) reported that 67% of N'Dama cows at Musaia Animal Husbandry Station calved between September and February, the corresponding figure from Teko of 70% showing close agreement.

Length of productive life of N'Dama cows

As the oldest records are for cows born in 1966, it is rather early to assess this trait completely. However, in 1981 the average age of the first 26 cows born between 1966 and 1970 was 11.3. years, and 70% were still in production. The remaining 30% had either died or been culled. Thus, until more information is available, it is tentatively suggested that N'Dama cows have an average productive life of at least 7.4 years (11.3–3.9). Using the mean calving interval of 545 days, cows would thus have an average of 5 parturitions in the herd. This complete replacement of the cow herd each 7.4 years would represent a turnover of 13.5% per annum.

Mortality

Mortality data were based on 248 calves born over a 9-year period, and included perinatal deaths. The significance of environmental influences on perinatal mortality, preweaning mortality and the two together are indicated in Table 4. The sex of calves that died perinatally was not recorded.

Table 4. *Analysis of variance of calf mortality*.

Source	Perinatal mortality		Preweaning mortality		Perinatal and preweaning mortality	
	d.f.	MS x 10^3	d.f.	MS x 10^3	d.f.	MS x 10^3
Breed	2	54	2	571**	2	678**
Season of birth	3	44	3	144	3	232
Year of birth	8	75	8	42	8	98
Age of dam	4	38	4	231*	4	399
Sex	–	–	1	5	–	–
Remainder	230	52	215	85	230	119

* = P<0.05 ** = P<0.01

Perinatal mortality. The mean perinatal mortality was 5.6 ± 1.4%, a coefficient of variation of 24%. There were no significant environmental or genetic effects.

Preweaning mortality. The mean mortality from birth to 6 months of age was 9.8 ± 3.2%, a coefficient of variation of 32%. Breed and age of dam had significant effects on preweaning mortality. Pure Sahiwal calves had very much higher mortality (25.5%) than both N'Dama and Sahiwal x N'Dama calves, which averaged 2.7%. Calves from younger cows had lower mortality rates than those from older cows.

Perinatal and preweaning mortality. The total perinatal and preweaning mortality was 14.9 ± 6.0%, a coefficient of variation of 40%. Breed and age of dam had significant effects on total mortality. Pure Sahiwal calves had much higher mortality (30.2%) than both N'Dama and Sahiwal x N'Dama calves, which averaged 6.7%. Calves from younger cows had lower mortality rates than those from older cows.

Post-weaning mortality. The mean mortality of N'Dama calves from 6 months to 12 months of age was 1.5%.

Mortality rates in relation to genetic improvement of N'Damas

An appropriate definition of mortality rate in the context of genetic progress is the percentage of females that die before calving. Applying the post-weaning mortality rate of 1.5% per 6 months to the period to first calving gives a total mortality of 17.4% {8.1 + (1.5 x 6.2)}. The rearing proportion is the proportion of births that produce a heifer that survives and is fertile. The rearing proportion here is about 0.41. This means that once in 2.5 calving a cow produces a heifer calf that will reach lactation in the herd. The average length of reproductive life is 5 calving: therefore, approximately 50% of the females born are required as replacements to maintain herd size. High mortality rates slow down genetic progress; if they can be reduced, a higher intensity of selection can be applied.

Genetic improvement per unit of time is more important than per cow generation, and high mortality rates have a marked effect on generation interval. The average age at first calving of N'Dama cows was 46.5 months, and the average calving interval 17.9 months. To replace herself, a cow calves 2.5 times: thus, the average generation interval is 91.2 months or 7.6 years.

Cow mortality

The mean annual cow mortality for 248 cow records from 1971 to 1979 was 3.2 ± 0.6%, a coefficient of variation of 17%.

Only breed had a significant effect on cow mortality (Table 5). While virtually no deaths were recorded among pure N'Dama cows, pure Sahiwals had 16.6 % mortality per year. A mixed infection of demodectic mange and streptothricosis was the main factor involved.

Table 5. *Analysis of variance of cow mortality*.

Source	d.f.	Mean squares x 10^3
Breed	1	793**
Season of calving	3	47
Year of calving	8	37
Age	4	9
Remainder	231	28

** = P<0.01

Body weights

Environmental and genetic effects on calf weights

Weights at birth and at 3 and 6 months of age were available for 180 calves; at 6, 9 and 12 months of age for 145 calves; and at 12, 15 and 18 months of age for 110 calves, born in the years 1974–1979, 1974–1979 and 1974–1978, respectively. Analyses of variance laid out in Table 6 show the significance of effects on calf weight at these different stages. The estimated least squares means for body weight at the different stages are shown in Table 7

Table 6. *Analysis of variance of weights at different ages*.

Source		Mean squares				Mean squares				Mean squares		
	d.f.	Birth	3 mo.	6 mo.	d.f.	6 mo.	9 Mo.	12 mo.	d.f.	12 mo.	15 mo.	18 mo.
Breed	2	95**	6539**	20147**	2	17075**	28920**	42211**	2	39769**	59288**	81368**
Season of birth	3	2	7	462	3	428	613	1176*	3	590	1002	490

Year of birth	5	8	173*	138	5	139	275	341	4	503	1957**	2734**
Age of dam	4	8	61	140	4	138	220	420	4	667	864	824
Sex	1	76**	6	14	1	22	13	1	1	12	1391	1800
Remainder	164	9	75	175	129	167	316	389	95	361	512	612

*= P<0.05
** = P<0.01

Table 7. *Estimated least squares of weights at different ages*.

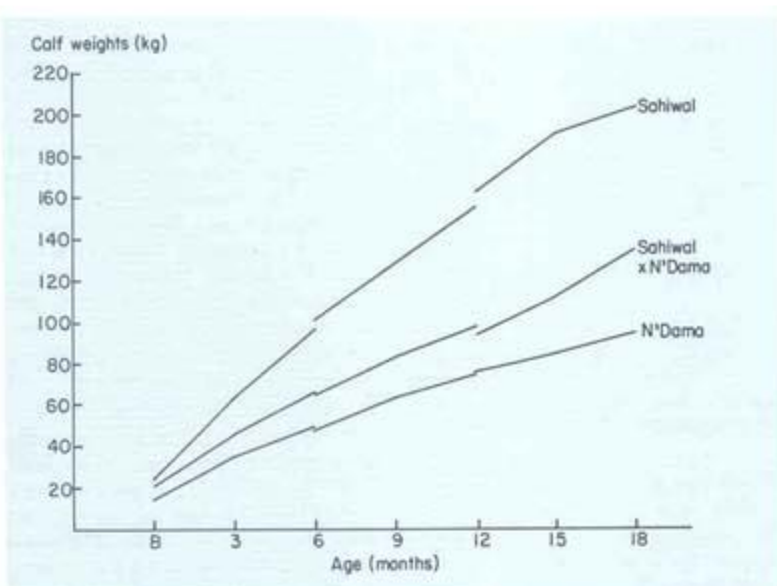
Variable	No.	Estimated l.s.m.[a] (kg)				Estimated 1. s. m. (kg).				Estimated 1. s. m. (kg).		
		Birth	3 mo.	6 mo.	No.	6 mo	9 Mo	12 mo	No.	12 mo	15 mo	18 mo
Overall mean	180	20.3	47.8	71.4	145	71.4	92.0	109.9	110	111.6	129.4	149.3
Breed												
N'Dama	84	14.9a	35.3a	49.9a	69	49.2a	63.0a	75.5 a	55	76.3a	84.5 a	94.4a
Sahiwal	34	23.8b	62.5b	97.9b	28	100.4b	129.6b	152.2b	23	163.9b	191.36	218.8b
Sahiwal x N'Dama	62	22.0c	45.8c	66.4c	48	64.7c	83.5c	98.0c	32	94.5c	112.6c	134.7c
Season of birth												
November–January	74	20.2	47.9	76.3	58	76.6	97.4	118.3b	34	118.9	129.8	148.4
February–April	42	20.0	48.5	71.5	38	73.1	96.7	106.4a	31	110.8	130.6	153.7
May–July	15	20.7	47.5	68.6	12	67.8	82.6	102.9a	11	103.8	119.0	141.5
August–October	49	20.0	47.4	69.2	37	68.2	91.3	111.8ab	34	112.6	138.3	153.5
Year of calving												
1974	13	19.8	44.9ab	69.1	9	71.4	97.1	118.4	9	118.3	146.0a	165.6a
1975	32	19.9	44.1a	68.0	27	67.3	86.5	109.2	22	106.3	123.5ab	145.6ab
1976	26	19.8	46.6ab	73.1	23	74.0	96.0	114.0	23	115.8	136.8a	160.9a
1977	28	21.4	50.7b	73.7	26	74.9	93.0	110.1	26	112.1	125.9ab	140.6b
1978	54	20.2	50.66	70.5	52	71.4	93.1	108.4	30	105.2	114.96	133.8b
1979	27	20.4	50.1b	74.0	8	69.5	86.3	99.2	–	–	–	–
Age of dam												
3 years	18	19.7	44.9	66.2	15	66.4	84.9	98.9	13	98.2	114.2	133.2
4 years	37	19.7	47.4	71.1	31	70.1	91.1	109.8	26	111.3	128.2	150.1
5–6 years	46	20.8	49.0	72.2	40	73.4	95.1	112.2	28	110.9	129.7	150.0
7–8 years	42	20.7	49.7	73.8	31	74.4	94.0	113.1	20	119.9	136.2	154.9
9 + years	37	20.5	48.2	73.6	28	72.9	94.9	115.3	23	117.5	138.9	158.3
Sex												
Male	101	20.9a	47.6	71.1	78	71.0	91.7	109.8	56	111.9	133.1	153.5
Female	79	19.6b	48.0	71.7	67	71.8	92.3	110.0	54	111.2	125.7	145.1

Within variable groups, row means followed by the same letter do not differ significantly (P<0.05). No letter indicates variable group did not show a significant difference in the analysis of variance
[a]Least squares mean.

The mean weights of all calves at birth, 3, 6, 9, 12, 15 and 18 months of age were 20.3, 47.8, 71.4, 92.0, 109.9, 129.4 and 149.3 kg, respectively, with corresponding coefficients of variation 16, 19, 20, 21, 19, 20 and 19%.

Effect of breed. Breed had a highly significant effect on calf weight at all stages from birth to 18 months of age (Table 6). Sahiwal x N'Dama calves were heavier than N'Dama calves by 7.1 kg (47%) at birth, 10.5 kg (30%) at 3 months old, 16.5 kg (33%) at 6 months old, 20.5 kg (32%) at 9 months old, 22.5 kg (30%) at 12 months old, 28.1 kg (33%) at 15 months old and 40.3 kg (42%) at 18 months old. Similarly, Sahiwal calves were heavier than N'Dama calves by 8.9 kg (60%) at birth, 27.2 kg (77%) at 3 months old, 48.0 kg (96%) at 6 months old, 66.6 kg (105%) at 9 months old, 76.7 kg (101%) at 12 months old, 106.8 kg (126%) at 15 months old and 124.4 kg (131%) at 18 months old. The mean growth of all three breeds from birth to 18 months of age is illustrated in Figure 1.

Figure 1. *Mean body weights from birth to 18 months of age for Sahiwal x N'Dama and Sahiwal calves.*



Effect of season of birth. Season of birth had a significant effect on calf weight at 12 months of age only (Table 6). The effects of season of birth on later body weights are usually related to the stage in the wet and dry weather cycle at which an animal reaches a given age: and relative rankings of season of birth groups might be expected to change from stage to stage.

Effect of year of birth. Year of birth had a significant effect on body weight of animals at 3, 15 and 18 months of age (Table 6). The weight differences between extreme years at the three stages were 14%, 24% and 21%, respectively, of the mean weights. Causes of variation between years in this environment can be the effect of annual rainfall on pasture availability or on disease incidence, changes in management practices, genetic progress etc.

Effect of age of dam. There were no significant effects associated with age of dam at any stage from birth to 18 months.

Effect of sex. Sex of the calf had a significant effect on birth weight only (Table 6), when males were 1.3 kg (6%) heavier than females. At 15 and 18 months the effect of sex approached significance, males being 6% heavier than females at both ages.

Repeatability of early calf weights. The repeatabilities of calf birth, 3-month and 6-month weights considered as a characteristic of the cow were small and non-significant, being 0.08 ± 0.13 for birth weight, 0.05 ± 0.13 for 3-month weight and zero for 6-month weight. Data were from 146 calves born to 66 cows.

Phenotypic correlations between calf weights at different ages. The phenotypic correlations between calf weights are shown in Table 8. These were all positive, correlations among birth and early weights being lower than those between weights at all other ages.

Table 8. *Phenotypic correlations between calf weights*.

Trait	3 mo.	6 mo.	9 mo.	12 mo.	15 mo.	18 mo.
Birth	0.77	0.75	0.71	0.69	0.67	0.69
3 mo.		0.92	0.87	0.82	0.75	0.76
6 mo.			0.95	0.91	0.84	0.85
9 mo.				0.95	0.88	0.87
12 mo.					0.95	0.93
15 mo.						0.97

Cow body weights

Weights at calving, and at 3, 6 and 9 months after calving, were available for 89 cow records from 1976 to 1979. The mean cow weights were 267 ± 26 kg at calving, 229 ± 25 kg 3 months after calving, 227 ± 30 kg 6 months after calving and 234 ± 31 kg 9 months after calving. Coefficients of variation were 10%, 11%, 13% and 13%, respectively. The significance of genetic and environmental influences on cow weights at these four stages is indicated in Table 9.

Table 9. *Analysis of variance of cow weights at calving and 3, 6 and 9 months after calving.*

Source	d.f.	Mean squares			
		Calving	3 mo. After calving	6 mo. After calving	9 mo. After calving
Cow group	2	159680**	112995**	92263**	113270**
Season of calving	3	1888*	2139*	737	299
Year of calving	3	645	1002	1797	1953
Cow age	3	3668**	2558**	2595**	2280
Calf sex	1	68	93	1410	563
Remainder	76	682	613	928	959

* = P<0.05
** = P<0.01

Cow group effects were significant at all stages, season of calving had a significant effect at two stages and cow age had a significant effect at three stages. The estimated least-squares means for cow weights are laid out in Table 10.

Table 10. *Estimated least squares means of cow weights at calving, and at 3, 6 and 9 months after calving*.

Variable	Number	Cow weights (kg)			
		At calving	3 mo. After calving	6 mo. After calving	9 mo. After calving
Overall mean	89	286.2	245.4	240.1	247.4
Cow group					
N'Dama with N'Dama-sired calf	29	225.1 a	192.6a	188.7 a	191.1a
N'Dama with Sahiwal-sired calf	42	238.4a	206.9a	210.3b	213.3b
Sahiwal with Sahiwal-sired calf	18	395.2b	336.7b	321.3c	337.7c
Season of calving					
November–January	39	281.9b	234.6b	231.7	247.3
February–April	20	274.0b	237.9b	237.6	248.4
May–July	7	289.8ab	251.4ab	248.2	240.6
August–October	23	299.3a	257.7a	243.0	253.2
Year of calving					
1976	18	287.7	250.4	257.4	264.3
1977	24	279.9	241.0	240.9	251.6
1978	39	292.5	253.9	240.7	240.2
1979	8	284.8	236.3	221.5	233.4

Age					
4 years	19	265.2a	229.6a	223.0a	229.4
5–6 years	28	286.6b	245.8ab	243.4ab	247.2
7–8 years	19	289.6b	245.4ab	240.0ab	253.2
9+years	23	303.6b	260.8b	254.1b	259.8
Calf sex					
Male	51	285.3	246.5	244.4	250.1
Female	38	287.1	244.3	235.9	244.7

Within variable groups, row means followed by the same letter do not differ significantly ($P<0.05$). No letter indicates variable group did not show a significant difference in the analysis of variance.

Effect of breed. At 3, 6 and 9 months after parturition, N'Dama cows were 31 kg (13%), 32 kg (14%) and 29 kg (13%) lighter than at parturition, respectively. Corresponding values for Sahiwal cows were 58 kg (15%), 74 kg (19%) and 57 kg (14%).

Effect of season of calving. Season of calving had significant effects on cow weights at calving and at 3 months after calving (Table 9). Cows that calved in August–October (the second half of the wet season) were significantly heavier at parturition and at 3 months after parturition than cows that calved during the November to January and February to April dry seasons.

Effect of age. Age of cow had significant effects on cow weights at calving and at 3 months and 6 months after calving (Table 9). Four-year-old cows were significantly lighter at calving than all other age groups, and significantly lighter than 9-year-old cows at 3 months and 6 months after calving (Table 10).

Repeatability of N'Dama cow weights. The repeatability of cow parturition weight and weights at 3, 6 and 9 months after parturition were 0.62 ± 0.15, 0.66 ± 0.14, 0.16 ± 0.30 and 0.02 ± 0.34, respectively. Thus, repeatability of cow weight was high and significant at parturition and 3 months after parturition only.

Phenotypic correlations between N'Dama cow weights. The phenotypic correlations between cow weights at the four stages were high and ranged from 0.96 to 0.89.

Phenotypic correlations between calf preweaning weights and N'Dama cow weights. The phenotypic correlations between calf preweaning weights and cow weights ranged from 0.72 to 0.49.

Productivity

Indices of cow productivity

The characters of reproductive performance, calf viability, calf 6-month weight and cow weight, were combined to build three productivity indices. Index 1, the weight of 6-month-old calf per cow per year, was computed for each cow parturition as the product of weight of 6-month old calf x 365 ÷ the interval to the next parturition. Index 2, the weight of 6-month-old calf per 100 kg of cow per year, was computed as index 1 ÷ average weight of the cow x 100. Index 3, the total weight of 6-month-old calf per 100 kg of metabolic weight of cow per year, was computed as index 1÷ cow average weight$^{0.73}$ x 100. Data were available on 83 parturitions between 1975 and 1978.

The mean productivity indices were:

Index 1: 50.1 ± 14.8 kg of 6-month-old calf per cow per year

Index 2: 22.3 ± 5.4 kg of 6-month-old calf per 100 kg of cow per year

Index 3: 96.0 ± 23.8 kg of 6-month-old calf per 100 kg $^{0.73}$ of cow per year.

The significance of environmental influences on the three productivity indices is indicated in Table 11.

Table 11. *Analysis of variance of productivity indices*.

Source	d.f.	Mean squares		
		Index 1	Index 2	Index 3
Cow group	2	8622**	135*	6516**
Season of calving	3	653*	91 *	1852*
Year of calving	3	30	18	262
Age	4	938*	58	1388
Remainder	70	219	29	567

* = P<0.05
** = P<0.01

The estimated least squares means for the three productivity indices are laid out in Table 12.

Table 12. *Estimated least-squares means for productivity indices*.

Variable	Number	Index 1 (kg)	Index 2 (kg)	Index 3 (kg)
Overall mean	83	52.0	22.2	97
Cow group				
N'Dama with N'Dama-sired calf	35	35.0a	19.7a	80a
N'Dama with Sahiwal-sired calf	31	39.6a	21.8ab	90a
Sahiwal with Sahiwal-sired calf	17	81.3b	25.3b	121b
Season of calving				
November–January	31	58.8a	24.8a	108a

February–April	18	45.9b	19.9b	86b
May–July	9	53.5ab	22.8ab	99ab
August–October	25	49.7ab	21.5ab	93ab
Year of calving				
1975	14	51.2	22.0	96
1976	21	50.5	21.0	92
1977	25	52.4	22.4	97
1978	23	53.8	23.6	102
Age				
3 years	7	29.5 a	19.3	77
4 years	15	54.4b	22.8	100
5–6 years	23	54.8b	24.0	105
7–8 years	16	63.8b	24.6	110
9 + years	22	53.7	20.5	92

Within variable groups, row means followed by the same letter do not differ significantly ($P<0.05$). No letter indicates that the variable group did not show a significant difference in the analysis of variance.

Effect of breed on cow productivity. Breed group had highly significant effects on the productivity of surviving cows (Table 12). N'Dama cows with Sahiwal-sired calves produced 13% more 6-month-old calf per cow per year, 11% more 6-month old calf per 100 kg of cow per year, and 12% more 6-month-old calf per 100 $kg^{0.73}$ of cow per year than N'Dama cows with N'Dama-sired calves. Surviving Sahiwal cows with Sahiwal-sired calves produced 105% more 6-month-old calf per cow per year, 16% more 6-month-old calf per 100 kg of cow per year, and 34% more 6-month-old calf per 100 $kg^{0.73}$ of cow per year than N'Dama cows with Sahiwal-sired calves.

Effect of season of calving on cow productivity. Season of calving had a highly significant effect on all three productivity estimates (Table 12). Cows that calved in the first part of the dry season (November–January) had significantly higher productivity than those that calved in the second part of the dry season (February–April). Cows that calved in November–January produced 28% more 6-month-old calf per cow per year, 24% more 6-month-old calf per 100 kg of cow per year, and 25% more 6-month-old calf per 100 $kg^{0.73}$ of cow per year than cows that calved in February–April.

Effect of age on cow productivity. Cow age had a significant effect on index 1 only, cows aged 4 years or over producing 95% more 6-month-old calf per cow per year than 3-year-old cows.

Herd productivity

Adjustment of the three cow productivity indices to account for cow viability gives the most accurate estimates of overall herd productivity. The effect of breed is indicated in Table 13, the effect of season of calving in Table 14.

Table 13. *Herd productivity indices (kg) by breed group*.

Breed group	Index l[a]	Index 2[b]	Index 3[c]
N'Dama cows with N'Dama-sired calves	35.0	19.7	80
N'Dama cows with Sahiwal-sired calves	39.6	21.8	90
Sahiwal cows with Sahiwal-sired calves	67.8	21.1	101

[a]Weight of 6-month-old calf per cow per year.
[b]Weight of 6-month-old calf per 100 kg of cow per year.
[c]Weight of 6-month-old calf per 100 $kg^{0.73}$ of cow per year.

Table 14. *Herd productivity indices (kg) by season of calving*.

Season of calving	Index l[a]	Index 2[b]	Index 3[c]
November–January	53.8	22.7	99
February–April	40.2	17.4	75
May–July	52.0	22.2	96
August–October	46.3	20.0	87

[a]Weight of 6-month-old calf per cow per year
[b]Weight of 6-month-old calf per 100 kg of cow per year
[c]Weight of 6-month-old calf per 100 kg 0.73 of cow per year.

Implications for beef cattle breeding

With the amount of information available, herd productivity indices 2 and 3 provide the most meaningful way of comparing overall productivities. The important traits of reproductive performance, cow and calf viability, growth and cow body weight, have been used to build up the indices of weight of 6-month-old calf produced per 100 kg of cow and per 100 kg metabolic weight of cow, per year. Their merit is that they relate all the important performance traits back to the actual weights of breeding cow that have to be supported, these being closely connected with maintenance costs.

The results reported here have a number of implications for beef cattle breeding work in this trypanosomiasis-risk situation.

1. In N'Dama cattle, the levels of the important performance traits at Teko (except calf growth) are generally similar to those in other comparable situations throughout West Africa (ILCA, 1979, Volume 1, p.91). Calf growth at Teko appears, however, to be considerably lower, and is, for example, 35% to 45% lower at all stages from 3 to 18 months than the values reported by Touchberry (1967) at Musaia Animal Husbandry Station. The biological reasons for these particularly low growth rates must be identified.

2. The herd productivities (indices 2 and 3) of N'Dama cows with Sahiwal-sired calves are 10% higher than those of N'Dama with N'Dama-sired calves, mainly due to the 30% faster growth of the Sahiwal-sired calves. Considerable effort should be put into evaluating reproductive performance and maternal ability of these F_1 crosses in this environment.
3. In spite of very preferential treatment, the herd productivity of Sahiwal cows is 3% lower for index 2 and only 12% higher for index 3 than the productivity of N'Dama cows with Sahiwal-sired calves.
4. Cows calving in the first part of the dry period (November–January) show markedly superior herd productivity, 14% above the rest of the year for indices 2 and 3, and 30% above the poorest quarter (February to April). This major effect must be carefully taken into account when planning development operations.

Acknowledgement

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Effect of diet restriction on work performance and weight loss of local Zebu and Friesian × Boran crossbred oxen

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Summary

EAST AFRICAN *Shorthorned Zebu cattle are the main source of draught power in Ethiopia. Recently, crossbred Friesian x Ethiopian Boran oxen have become available as a result of a programme to provide crossbred dairy cattle to small-scale milk producers. Crossbred oxen are heavier than local cattle and produce more force but also require more feed.*

In 1983 a 23-week experiment was conducted by ILCA to determine the effect of diet restriction on the work performance and body weight loss of crossbred (X) and local zebu (L) oxen worked as singles with a modified maresha *in farmers' fields. Digestibility trials were carried out at the end of the experiment.*

Control animals (LC and XC) were fed 100% of the metabolisable energy requirements for maintenance plus 5 hours of work per day; restricted animals (LR and XR) were fed 75% of the control ration for the first 5 weeks of the experiment and 50% thereafter. All oxen lost weight during the experiment but LC lost significantly more than XC. LR and XR lost weight at the same rate. Breed had a significant effect on force but not on power. Force exerted by both XC and XR was significantly higher than that exerted by LC and LR.

The digestibility of rations by LC oxen was significantly higher, and that of LR significantly lower, than for the rest of the animals. Feed restriction had no measurable effects on work performance in this experiment.

Introduction

Oxen are important suppliers of draught power for land development, tillage, threshing and transport in many developing countries. Draught performance may depend on the breed of the animal and on the quantity and quality of available feed. The cropping pattern in relationship to soil type, rainfall and feed resources may also affect the condition of oxen and their work performance (Goe and McDowell, 1980).

East African Shorthorned Zebu oxen are the major source of draught power in Ethiopia. A typical farmer uses a pair of oxen for 450 hours per year for cultivation and threshing (Gryseels, 1983). The main feed resources available are cereal crop residues and natural pastures. The amount and quality of forage available from natural pastures depend on season and stocking rates. In the cereal cropping zone around Debre Zeit, central Ethiopian highlands, local oxen weighing on average 280 kg at the beginning of the cropping season lost 9 to 18% of body weight by the end of the season (Mukasa-Mugerwa, 1983).

Friesian x Boran dairy cattle have recently been introduced into this area to increase the income of smallholder farmers from the sale of milk. The crossbred oxen produced on these enterprises are heavier (450 to 500 kg) than the local oxen (c. 280 kg) and need more feed. In trials conducted by ILCA at Debre Berhan, Ethiopia, crossbred oxen were found to require more energy per unit of body weight for maintenance and work output than local oxen (Abiye Astatke, 1983). Although the work was not definitive, the difference in energy requirements could be important in a system where feed is in short supply.

The aim of the experiment described here was to determine the effect of diet restriction on work performance and body weight loss in crossbred and local oxen worked as singles in farmers' fields around Debre Zeit during the normal cultivation season. Its results are discussed in the light of the implications for the management of draught animals, as well as from the point of view of the practical limitations in the performance of this type of research.

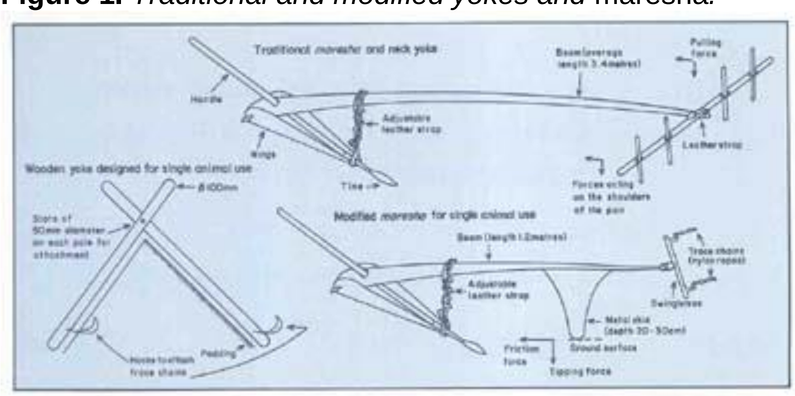
Methods

Animals and treatments

Ten local Zebu and four Friesian x Boran oxen—more crossbred animals within the required weight range were not available at the start (April 1983) of the experiment—were trained as singles for ploughing with a modified *maresha*[1]. Compared with the traditional *maresha,* which is pulled by a pair of oxen, the improved implement has a shorter draught pole (1.5 m), a 0.4 m metal skid attached under the shortened beam, and a swingle-tree to balance the trace ropes of a simple, inverted 'V'-type yoke designed for single-ox use (Figure 1).

1. A pointed, steel-tipped tine attached to a draught pole at an adjustable shallow angle.

Figure 1. *Traditional and modified yokes and* maresha*.*



Both the local (L) and crossbred (X) oxen were divided into control (LC and XC) and restricted (LR and XR) groups. The control animals were fed 100% of the estimated metabolisable energy (ME) requirements for both maintenance and 5 hours of work per day. The restricted animals received 75% of the control ration during the first 5 weeks of the trial and 50% during the rest of the trial period.

Estimates of ME requirements for maintenance and work were obtained from equations derived from feeding trials in Debre Berhan. For local animals the estimated ME (MJ) requirements for maintenance and work were 19.24 + 0.06W (where W = liveweight in kg) and 3.85 MJ/ hr, respectively; the ME requirements for crossbreds were 29.82 + 0.059W for maintenance and 6.7 MJ/hr for work (Abiye Astatke, 1983).

Breed and treatment combinations were: local oxen on control ration (LC); local oxen on restricted ration (LR); crossbred oxen on control ration (XC); and crossbred oxen on restricted ration (XR). Average body weights at the beginning of the trial were 309 ± 49 kg (LC), 302 ± 36 kg (LR), 372 ± 32 kg (XC) and 465 ± 85 kg (XR). The oxen were walked to farmers' fields and worked for about 5 hours per day; no work was done on weekends and religious holidays. On non-working days, LC and XC were fed a maintenance ration only and LR and XR received either 75% (first 5 weeks) or 50% of their maintenance requirements. All oxen were weighed weekly on the same day prior to watering.

Diets consisted of 20% concentrate and 80% hay; their chemical compositions are given in Table 1. The concentrate mix consisted of 35% wheat bran, 32% wheat middlings, 30% *noug (Guizotia abyssinica)* cake, 2% bone and meat meal, and 2% salt.

Table 1. *Composition of the concentrate and hay used during the trial, Debre Zeit, 1983.*

	Estimated ME (MJ/kg)	N content (% DM)	Fibre (NDF)[1](% DM)	Lignin (% DM)
Concentrate	9.2	3.0	46.9	5.4
Hay	7.8	0.9	70.9	5.7

[1]Neutral detergent fibre.

Measurement of force and power

Force exerted by each ox was measured with a battery-powered dynamometer[2] consisting of a load cell secured between the drawbar of the *maresha* and the swingle-tree, and an indicator connected to the load cell by a cable. The average minimum and maximum force (kN) over a 20-m distance was recorded, as well as the time taken to travel the 20 m. A damper was used to minimise variations in force readings.

2. Novatech Measurements Ltd, Beddington, Croydon, UK.

The working height of both the yoke and the implement hitch and the length of the draught chain were measured, and the force parallel to the ground, which is the force actually used for cultivation, was calculated using a trigonometric relationship. Power was calculated by multiplying actual force (kN) by speed (m/sec). Force was measured for each ox on one day a week, at hourly intervals during the working period, resulting in 4 to 5 recordings per ox per week. The total time worked and the area cultivated were measured for each ox on every working day.

Digestibility trial

At the end of the experiment a digestibility trial was conducted. All four crossbred oxen were fed a maintenance ration because they were in poor condition and it was undesirable to prolong the period of undernutrition, while the LC animals were fed at maintenance and the LR group received 50% of the control ration.

Statistical analysis

Analysis of variance was used to test the effects of breed and diet restriction on parameters of work performance and weight loss. The parameters of work performance were force, power output, cultivation rate, turn-around time and depth of ploughing.

Weight loss over the working period was linear for all groups. The rate of weight loss for each ox was calculated using linear regression. The effects of breed and diet restriction were tested using analysis of variance.

The T-test was used to test the significance of differences in digestibility between the XC, LC and LR groups.

Results

Weight loss

The rate of weight loss is shown in Table 2. Both restricted groups lost weight at the same rate over the 23-week trial period. The LC group lost weight at twice the rate of the XC group. Breed did not have a significant effect on weight loss whereas diet had a significant effect ($P< 0.001$). There was a significant interaction between diet and breed: local animals lost weight at a significantly higher rate than crossbreds on the control diet. Restricted animals had a higher rate of weight loss than control animals. Weight loss as a percentage of body weight was greater for the restricted groups across breeds, and greater for local oxen across diets (Table 2). The fact that even the control animals lost weight indicates that the estimated ME requirements must have been too low, reflecting those of oxen working in pairs rather than as singles.

Table 2. *Rate of weight loss and weight loss as percentage of body weight for local control, local restricted, crossbred control and crossbred restricted oxen.*

Treatment group	Rate of weight loss (kg/week)		Weight loss (% of body weight)	
	Mean	SD	Mean	SD
LC	1.8	±0.3	10.0	±3.9
LR	3.1	±0.3	16.7	±4.3
XC	0.9	±0.5	4.0	±0.4
XR	3.1	±0.5	13.7	±0.7

Work performance

Breed had a significant effect on depth of ploughing, area ploughed and cultivation rate (Table 3), but diet did not have a significant effect on these parameters of work performance. Operation (first, second or third cultivation pass) and soil moisture had significant effects on depth of ploughing, area ploughed and cultivation rate (Tables 4 and 5). Average cultivation rates for all passes were 220 m^2/hr and 242 m^2/hr for local and crossbred oxen, respectively.

Table 3. *The effects of breed on depth of ploughing, area cultivated and cultivation rate.*

Breed	No. of observations	Mean depth (cm)	SE	Area (m^2/day)	Cultivation rate (m^2 /min)
Crossbred	256	14.6	±0.3	998	4.04
Local	613	13.9	±0.2	920	3.67
F-ratio		7.4***		4.4*	6.3**

* P<0.1; ** P<0.01; *** P< 0.001.

Table 4. *The effects of soil moisture on depth of ploughing, area cultivated and cultivation rate.*

Moisture level	No. of observations	Mean depth (cm)	SE	Area (m^2/day)	Cultivation rate (m^2/min)
Dry	386	13.5	±0.2	1009	4.0
Moist	242	13.1	±0.3	764	3.2
Wet	241	16.2	±0.4	1103	4.4
F-ratio		45.9***		28.0***	17.9**

Table 5. *The effect of operations on depth of ploughing, area cultivated and cultivation rate.*

Pass	No. of observations	Mean depth (cm)	SE	Area (m^2/day)	Cultivation rate (m^2/min)
1	73	12.7	±0.4	1001	4.3
2	158	13.8	±0.3	935	3.7
3	143	14.2	±0.3	930	3.8
4	90	15.4	±0.4	1181	4.8
5	33	14.6	±0.6	1041	4.0
6	8	16.7	±1.1	1037	3.8
7	364	12.6	±0.2	585	2.8

Breed had a significant effect on force but not on power, while diet did not have a significant effect on either force or power (Table 6). The LC and LR groups developed the same average force over the working period. XR animals developed a higher average force than XC animals, probably because the XR group weighed more than the XC group and force developed is dependent on ox weight.

Table 6. *Average force, power developed and the F-ratio for breed and diet of local control, local restricted, crossbred control and crossbred restricted oxen*.

	Force (kN)	Power (kW)
LC	0.59	0.30
LR	0.60	0.31
XC	0.66	0.33
XR	0.71	0.36
F-ratio for breed	23.22***	2.86
F-ratio for diet	2.33	0.91

***P<0.001.

Digestibility

The LC group had the highest dry-matter digestibility (DMD), and this was significantly higher than that for the LR group (P<0.025) (Table 7). The average DMD for the LR group was 17 and 12 units lower than those for the LC and crossbreds, respectively. The lower digestibility for the LR group indicates an overall nutrient deficiency in animals on the restricted diet.

Table 7. *Mean digestibility of the diet on offer for crossbred, local control and local restricted oxen*.

	Digestibility (% DM)	
	Mean	S.D.
Crossbred	52.4a[1]	2.7
LC	57.5b	2.7
LR	40.2c	6.8

[1]Means followed by different letters are significantly different.

Discussion

Power developed is a function of force and rate of work. Since the daily cultivation rate and force exerted by crossbreds were higher than those for local animals, a significant effect of breed on power would be expected. Although restricted oxen of both breeds lost more weight than control oxen, feed restriction had no measurable effect on work performance.

Work demand may have been similar for both the local and crossbred animals, as it is determined by the type of cultivation and the keenness of the ox handler. Therefore, relative to body weight it would be greater for local oxen, and this may explain why these animals lost a greater percentage of body weight than crossbreds on both diets. Alternatively, the feed requirements of local oxen for work and maintenance may have been underestimated.

Weight losses, even on the restricted diets, were within the range observed for oxen worked as pairs by farmers in the Debre Zeit area (Mukasa-Mugerwa, 1983). Dicko and Sangare (1984) found that improved nutrition prior to the working period had a significant effect (although only at the 10% level) on the efficiency with which work was performed. They concluded that supplementation before the cultivation season was desirable for oxen with a body weight less than that required to generate the power necessary for cultivation. The results given above indicate that the oxen did not lose sufficient weight during the experiment to reach this threshold.

Breed, soil moisture and operation had a significant effect on the depth, area and rate of cultivation, as shown in Tables 3, 4 and 5. The crossbred animals had a greater depth of ploughing, ploughed larger areas, and had a higher cultivation rate than local oxen. Operation type is related to soil moisture: the first pass or operation is made just after the first rains when the soil is friable enough to be ploughed. The furrows made in this pass are wider-spaced than those made in the consecutive passes when the soil is wetter. Passes made on very wet soils for teff cultivation resulted in shallower ploughing and a slower rate of cultivation.

Conclusions

The lack of any significant effect of diet restriction on work performance suggests that oxen in good condition at the beginning of the cultivation season are able to perform adequately as singles for at least 23 weeks even when they are poorly fed. Both restricted and control oxen lost weight during the working period, which indicates that they used body reserves for work.

A possible strategy would be to let oxen lose weight during working periods and regain condition over the non-working periods. Using this strategy, work performance would probably not be affected over a working period of about 4 months provided the oxen were in good condition at the beginning of that period. Since it appears that cereal crop residues and grazing on natural pastures cannot meet the energy requirements of oxen during short intensive cultivation periods, farmers are probably already using this strategy.

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Determination of agro-ecological zones in Africa: ILCA activities and expectations

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Summary

EFFECTIVE LAND-USE *planning is necessary if optimal use is to be made of land for sustained and increased agricultural production. Agro-ecological zonation can help in the process of planning development strategies and research programmes by providing comprehensive information on land resources.*

This paper outlines some of the work being done by ILCA in the field of agroecological zonation and the use of models to predict the effect of environment on pastoral and agricultural systems. Plans for future developments and the potential benefits of the work are also given.

Research results from a particular site can be expected to be applicable to other areas with similar agro-ecological conditions, and knowledge of agro-ecological zonation will help to speed up the process of transfer of research results from the research station to the farmer. In addition, research can be more accurately targeted on the basis of agro-ecological zones rather than on the basis of broader agroclimatic zones as previously used.

Introduction

Optimal use of land for sustained and ultimately increased agricultural production requires effective land-use planning. This in turn requires comprehensive information on land resources so that development strategies and research programmes can be assessed in terms of geographical and climatic realities.

The land and climatic factors that influence agricultural potential can be quantified or estimated and used to cluster environments into classes or agro-ecological zones (AEZs). Research results from sites representative of a particular AEZ can be expected to be applicable to other areas with similar agro-ecological conditions. Thus knowledge of agricultural zonation will facilitate the transfer of new technologies from the research sites on which the research is done to other areas. ILCA is establishing a land resources data bank on Africa, which will be used to classify environments and determine AEZs.

Many of the components that are used to delineate AEZs are highly variable in time and space. Spatial variability when mapping soils, land form or vegetation is normally accommodated by appropriate sampling density and convergence of any additional evidence on trends between locations, and procedures for this are well established. Methods for overcoming the problem of location-specific sampling and approximation of discrete phenomena by continuous modelling of climatic variables are less well established.

Temporal variability in environmental factors that are used to delimit AEZs can be approached in two distinct ways. Firstly, probabilistic models of highly variable environmental factors, such as climatic variables, can be used to study the long-term effects of agricultural management strategies in relation to the known variation in these factors. ILCA is developing this type of agroclimatic model.

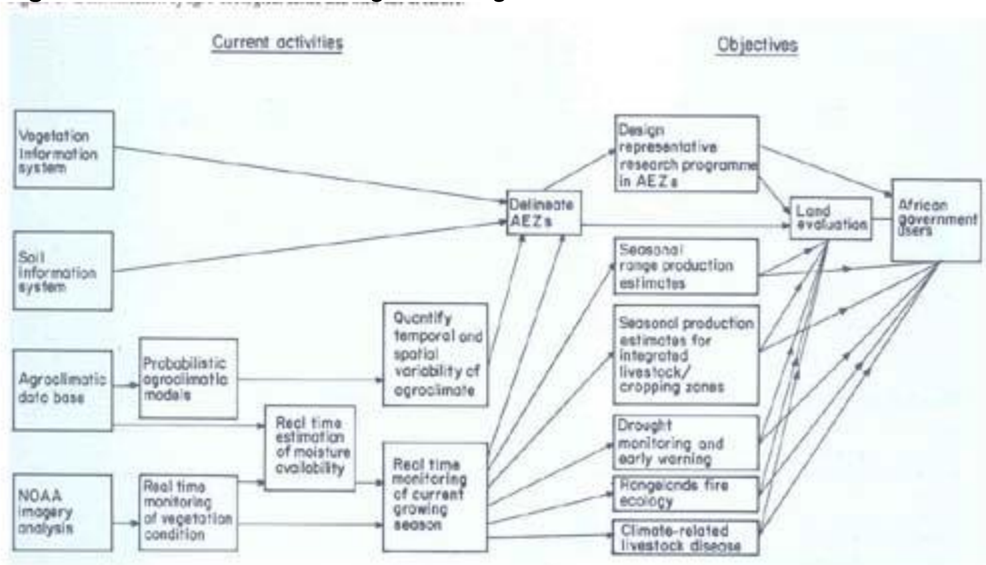
While probabilistic models give an indication of the likelihood of the success or failure of a particular agricultural strategy in a given environment, they do not provide information on the normality or otherwise of a particular production season. Thus there is a need for the second approach of monitoring agro-ecological conditions during the season to determine the progression of those events that influence agricultural production. This is particularly important in relation to factors that have a negative effect on production, such as drought or climatically induced livestock diseases.

ILCA's activities in agro-ecological zoning

In much of Africa there are no established, reliable data bases on which to develop effective regional planning of agriculture, and, without external assistance, assembling a resource inventory of the type needed is beyond the means of many African countries. ILCA is in a unique position to assist in this respect, as it is assembling a data base for Africa of meteorological, vegetation, soil, landform, production and socio-economic information. These data can be used to define AEZs. Representative research sites can then be identified, which will facilitate the extension of research results to other areas through land evaluation studies.

The relationships between the various components of ILCA's AEZ programme are represented schematically in Figure 1.

Figure 1. *Determination of agro-ecological zones and their use at ILCA.*



Agroclimatic data base

An extensive agroclimatic data base for sub-Saharan Africa is being assembled at ILCA with the help of African governments and international organisations such as the Food and Agriculture Organization of the United Nations (FAO). The data available are mostly for monthly periods, which limits their usefulness, but efforts are being made to collect all available data for daily and

10-day periods from synoptic stations in the region. These data are being stored on computer at ILCA's headquarters in Ethiopia.

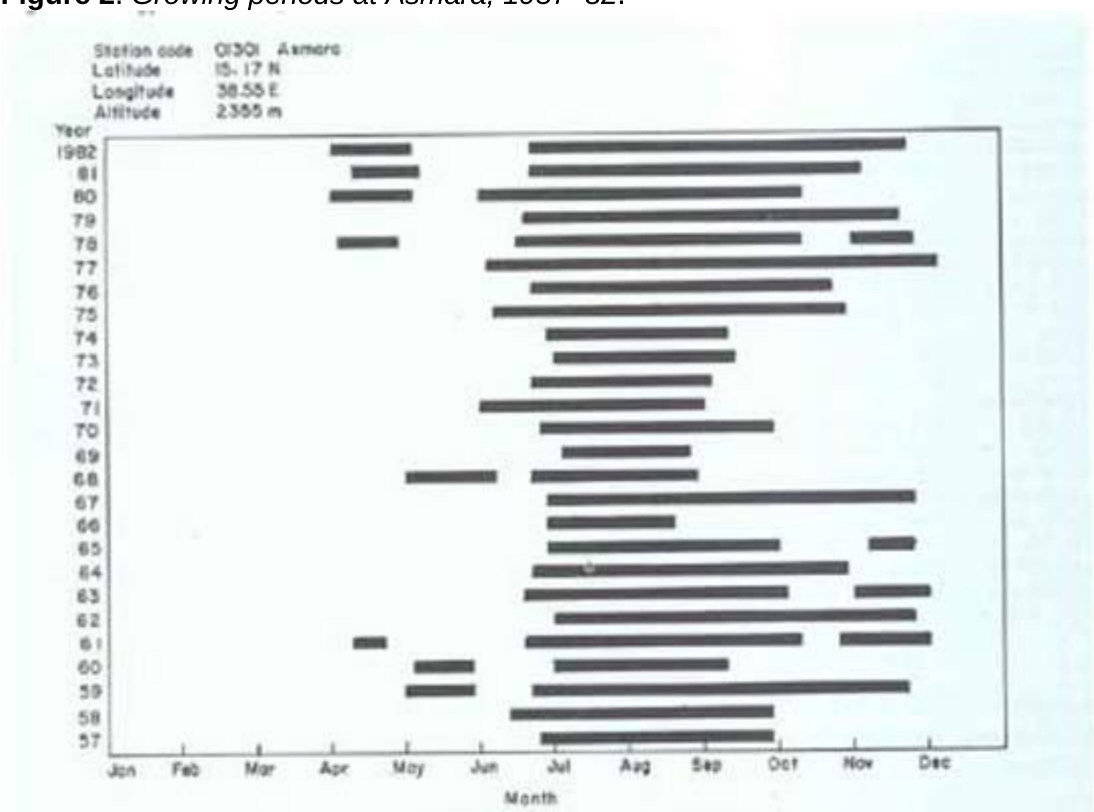
Agroclimatic models used

FAO length-of-growing-period model

A computer model originally developed by FAO for an agro-ecological study of Africa (FAO, 1978) has been installed on the computing system at ILCA headquarters in Addis Ababa. The program can be used to estimate the amount of moisture that is available for crop growth in individual months of the year from monthly precipitation (P), potential evapotranspiration (ETp) and estimated available water-holding capacity of the soils. Estimates of the amount of stored soil moisture (S) can be varied in the program from 0 to 200 mm in 50 mm steps.

Lengths of growing periods (LGPs) in individual years are calculated using linear interpolation for the period of time that P + S exceeds 0.5 ETp. The yields of many common crops decline markedly if the soil moisture falls below this level (Doorenbos and Kassam, 1979). The LGP excludes any period in which the temperature is unfavourable for crop growth. The program has been modified so that threshold values of ETp can be varied on a sliding scale, which may be important in assessing the length of the growing period for certain rangeland vegetation types. Statistical calculations related to the variabity of LGPs over the years for which analysis is possible are included in the package. Bar graphs in Figure 2 illustrate the variability in LGP between years over a 26-year period at Asmara in northern Ethiopia.

Figure 2. *Growing periods at Asmara, 1957–82*.



The main limitations of the LGP-based model in its present form are its inability to analyse moisture availability precisely for periods of less than 1 month and the assumptions in the model concerning runoff and deep percolation.

Current applications of the LGP program in ILCA

Analysis of drought in Africa. The LGP program has been used mainly to study the nature and extent of drought in Africa. It has been used to analyse data for growing seasons both preceding and during severe droughts, and the results are revealing for countries that have been severely affected, such as Ethiopia. A drought early warning system has been devised based on the monthly moisture balance as determined by the LGP model. Additional work is continuing on calibrating the vegetation data derived from the NOAH meteorological satellite using the LGP concept.

LGP and biomass production. Yield data from ILCA research stations in the integrated livestock/cropping zone and dry-matter production data from West Africa are being compared in order to assess the influence of moisture availability on crop and rangeland production. LGPs form the basis of this research.

Productivity of forage legumes under different LGP regimes. ILCA is studying the adaptability of different forage legumes to various agro-ecological conditions. Agro-climatic zoning using the LGP program is an important building block in this research project.

Farming systems and increasing moisture availability. ILCA is studying ways of increasing the availability of moisture through changes in farming systems. LGPs give an indication of the potential increases in productivity of traditional farming systems that could be achieved through improved water management.

Attempts are now being made to use statistical parameters related to the variability of LGPs to determine the reliable onset and end of the main growing seasons in African countries that are affected by substantial rainfall variability. Changes in the timing of land preparation and seeding, and the use of early-maturing forage crops are being studied for their potential in increasing the use of available moisture in relation to estimates of the reliable onset of the growing periods.

Agroclimatic analysis is also being used to examine the potential of water harvesting in ponds to optimise and possibly extend the growing season artificially through small-scale supplementary irrigation. ILCA has developed a system of building surface ponds using animal traction.

CSIRO[1] WATBAL model

The WATBAL model is used to provide estimates of changes in soil-moisture status for use in pasture growth modelling. The program requires weekly or daily precipitation and evaporation data. Evaporation data can be either mean or actual values derived from measurements, estimates from any of the standard instruments, or empirical approximations.

1. Commonwealth Scientific and Industrial Research Organisation (Australia).

Two important assumptions are made in the model. Firstly, unless maximum soil moisture storage is known, a value has to be assumed. Secondly, it is assumed that no runoff or deep percolation occurs until this maximum storage capacity is reached. Rainfall data provide the positive inputs to soil moisture storage in the model, and an estimate of actual water demand is required to determine withdrawals of moisture from soil storage. To determine the actual water demand the relationship between maximum evapotranspiration for the vegetation type considered, given freely available water, and evaporation must be established for each week of the year. These values are expressed as coefficients and must be assumed if unknown (Keig and McAlpine, 1974).

Optional analyses of the various derived parameters are possible. For example, descriptive statistics such as means, medians and deciles can be plotted as well as frequency distributions of soil moisture based on either a long run of data or season-by-season data. In addition, periodicities and probabilities of defined events may be calculated along with the probabilities and standard errors of these events. Such events include estimation of the likelihood of drought or the length and reliability of growing seasons for locations with suitable meteorological data.

At present the main limitation to the use of this model in Africa is the lack of reliable daily or weekly precipitation and evaporation data. However, as the amount of agro-climatic data collected by ILCA grows, the WATBAL model will become more important in the efforts to develop an understanding of the effect of soil moisture availability on biomass production.

Rainfall classification and biomass estimation model for the Sahel

A model developed at ILCA (Hiernaux, 1984) for the Sahel relates daily rainfall data (amounts and duration) to biomass production. Rainfall patterns are classified in terms of amounts over time into six categories: strong or F (40 mm in 2 consecutive days, 60 mm in 5 days or 80 mm in 10 days), moderate or f (less than for strong, but other factors not limiting), interruptions or I (more than 15 days without rainfall), short interruptions or i (less than 15 days without rainfall), discontinuous or d (evapotranspiration falls to less than 3 mm/day) and continuous (evapotranspiration remains equal to or greater than 3 mm/day). Evapotranspiration of more than 5 mm/day indicates that there are no limitations related to moisture availability. Water storage in the soil is assumed to occur when rainfall exceeds evapotranspiration.

These symbols can be combined to describe seasonal patterns, e.g. FI (fd), which translates as strong rains followed by one long interruption, then moderate rains begin again with a discontinuous pattern.

Both runoff and infiltration are estimated to enable calculation of effective precipitation. Runoff is considered to be a function of precipitation, but is also influenced strongly by the topography, soils and geomorphology of the site.

Rains can be characterised quantitatively by two methods, one graphical, involving overlays of the different factors involved, and the other a computer program developed by ILCA specifically for this purpose.

The biomass prediction model was verified using data on biomass production from five sites in the Sahel, and a correlation was found between moisture availability and biomass production (r^2= 0.78).

The importance of vegetation type and complications induced because of the different photoperiodicity, growth cycles etc in, for example, annual and perennial vegetation types, is emphasised. For example, perennials generally have deeper rooting systems than annuals and thus may not respond in the same way as annuals to rainfall. Also, historical analysis of the sites is desirable because species composition in a given year was found to be influenced strongly by the establishment of a particular type in the previous year. In years of good rainfall, annual species tend to predominate; in dry years perennials predominate because of their deeper rooting systems. The predominant species types thus produce more seed, resulting in them being present in a relatively larger proportion in the following season, irrespective of the rainfall of that year.

Climatic surface models

A cooperative programme between ILCA and CSIRO has recently been started to construct 'climatic surfaces' using 3-dimensional plots to estimate the distribution of rainfall, temperature, evaporation, etc between sampling locations. This should help clarify the spatial distribution of climatic variables between discrete sampling points.

Other work is being done in connection with the generation of 'synthetic' rainfall data. Workers in the CSIRO Division of Water and Land Resources have developed a sophisticated suite of computer software that utilises time-series analysis for forecasting rainfall events. The time series are based on probability distributions of historical rainfall data.

Characterising agroclimatic zones on the basis of these activities should prove a valuable adjunct to the techniques that are already being used at ILCA.

Climate-related inputs to a future geographic information system

Climate-related resource data, such as temperature and LGP, will eventually be entered into a grid-cell-based geographic information system which is being developed at ILCA.

Soil information system

ILCA is using survey data to develop an information system on soils in sub-Saharan Africa. Country-wide studies have been made in a number of sub-Saharan countries, and efforts are being made to standardise the information from these, as the different studies use a wide range of map scales, classification systems and report details.

It is hoped that a common core of information can be entered on a grid-cell system for the continent to enable a geographic information system to be built up over time. A grid-cell of 25 km^2 is being used currently for data from Ethiopia.

A soil-related factor that is of considerable importance in defining AEZs is soil moisture storage, which is a critical factor in determining the length of the growing season. ILCA has recently installed soil moisture recording apparatus at its research sites, so that growing season estimates derived from agroclimatic models can now be compared directly with levels of soil moisture recorded under field conditions. This should enable more precise assumptions to be made concerning soil storage capacity in other locations and also in testing the overall validity of the agroclimatic models.

Vegetation information system

Research at ILCA has generated a wealth of information on the quality, quantity and types of vegetation in Africa. This information, and data from other sources, is being used to assess the adaptability and suitability of various forages to different climates and soils. Efforts are being made to provide vegetation-related data for sub-Saharan Africa to complement the geographic information system that ILCA is developing.

One area of research is to try to relate aspects of natural vegetation (e.g. the tolerance of different species to soil salinity, soil pH and drought) to the environmental adaptability of forage species. Preliminary quantitative analyses of native grass and legume floras suggest that the diversity of the spectra of many tribes in these families is related to climatic factors. An analysis of natural vegetation may, therefore, provide a useful tool for relating conventional, climatically defined AEZs to the range of environmental adaptation of both introduced and native forage species. It is hoped that multilocational trials at ILCA field sites and those of national programmes will be used to test the hypotheses about relationships between AEZs and the adaptability of forage species. This should provide ILCA with an objective basis on which to select forage screening sites for the different AEZs and, more importantly, for extrapolating site-specific adaptation data to larger areas of sub-Saharan Africa.

The use of NOAA satellite imagery in refining AEZs

Remote sensing can provide environmental data for large areas of the earth's surface, which can be used to help anticipate natural disasters and to increase food production in the developing world through a better understanding of the environment.

Satellites are a convenient platform for a number of sensors that record environmental data. Their main advantage is their rapid and relatively cheap coverage of large land areas. New technologies have been developed that can be used to monitor vegetation, and these show considerable promise for the development of early warning systems for such environmental changes as drought, and will provide increasingly important input for determining effective long-term land-use planning and agricultural management strategies.

Changes in vegetation cover reflect the individual or combined influence of such factors as seasonal precipitation, temperature, soil moisture conditions, occurrence of fire, floods or the influence of man. NOAA satellite imagery provides an opportunity to determine synoptically rates of change in biotic resources in response to these influences.

Healthy, synthetically active vegetation reflects near infrared light strongly, and it is mainly this characteristic that enables the AVHRR (an advanced very high resolution radiometer) of the NOAA satellite to monitor the dynamics of green vegetation from space. Reflectance measurements are transmitted to a ground receiving station where computers record the data on tape as an intensity array.

Potential benefits of NOAA imagery

Drought monitoring. A cooperative programme between ILCA and NASA/Goddard Flight Centre, USA, has demonstrated close relationships between spectral responses of vegetation (as measured by the normalised difference vegetation index, NDVI) and the occurrence of drought conditions in Africa in 1983 and 1984. This line of research is continuing at ILCA.

Direct measurement of plant biomass. ILCA, in conjunction with NASA, has carried out a considerable amount of research on using NOAA data to measure plant biomass in the rangelands of Mali, Niger, Ethiopia, Kenya and Nigeria. In much of Africa, measuring grassland production is complicated by the presence of perennial grasses and trees, the growth cycles of which are not necessarily geared to annual influences and whose deep-rooting habit allows them to use water that is not available to shallow-rooting annuals and thus to continue to grow during dry periods.

A number of studies have indicated that grazing pressure may reduce the sensitivity of the satellite data to changes in biomass production in areas that otherwise produce large amounts of biomass. Research is being conducted on the use of satellite imagery to follow grazing patterns and intensities over time in areas in which the bio-production is known, in order to overcome these problems.

Monitoring soil moisture conditions and growing season. NOAA satellite data give approximately 1 km x 1 km resolution, and once calibrated from limited ground and aerial survey data, they can be used to assess the total duration of the growing season and the extent of zones with similar lengths of growing season in a given year. This also offers the possibility of forecasting crop yields, since these are closely related to the length of the growing season.

Because the NOAA satellites make frequent observations (the NOAA-7 satellite makes measurements over Ethiopia for 3 consecutive days every 9 days), changes in the vegetation can be monitored during the growing season. While this can also be done using conventional meteorological data, there are drawbacks in that the quality and availability of these data are limited in Africa. The data are also location specific, and inferences have to be made about climatic gradients between collection points.

Meteorological conditions and livestock disease. A number of important diseases of livestock are affected by climatic conditions, prominent among which are trypanosomiasis and East Coast fever. Both of these diseases are transmitted by vectors that are influenced by seasonal changes in vegetation, which are climate dependent. ILCA plans to investigate the possibility of using vegetation and meteorological data from the NOAA satellites to determine bioclimatic and seasonal influences on the distribution and extent of livestock disease vectors such as the tsetse fly and ticks.

Burning and flooding. Pastoral lands in Africa are frequently burned, and NOAA imagery offers a convenient means for monitoring the effects that burning has on the ecology of the continent. Similarly, monitoring of the extent and duration of flooding is important in defining AEZs that are influenced by this phenomenon.

Desertification and deforestation. NOAA data provide a means for determining long-term trends in vegetation patterns in Africa, particularly in relation to such controversial subjects as desertification and deforestation. Until now there has been little verification of trends in desertification and deforestation by a scientifically reliable method and the NOAA data could fill this gap. However, data storage could prove to be a problem in the long term because of the large quantity of digital data recorded on each pass of the satellite.

Refinement of AEZ boundaries. AEZ boundaries derived from ground data may be modified in future as the amount of data on vegetation responses from the NOAA satellites increases. As yet, data from NOAA satellites do not span sufficient time for detailed statistical analysis of seasonal and annual variations in vegetation. However, the problems of data storage noted above will also be an important consideration in this case.

Expectations for the future refinement and use of AEZs by ILCA

Upgrading the climatic data base

The paucity of suitable short-term data on precipitation and related climatic variables is a major constraint on the further development of the agroclimatic models currently being used by ILCA. In an effort to overcome this constraint, ILCA is attempting to compile a comprehensive agroclimatic data base.

Agroclimatic modelling

The probabilistic agroclimatic models currently in use by ILCA will provide baseline data for much of the Centre's research into farming systems and the adaptability of forage species. The WATBAL program can be used on microcomputers, and the FAO/LGP program has recently been modified by ILCA to also run on microcomputers.

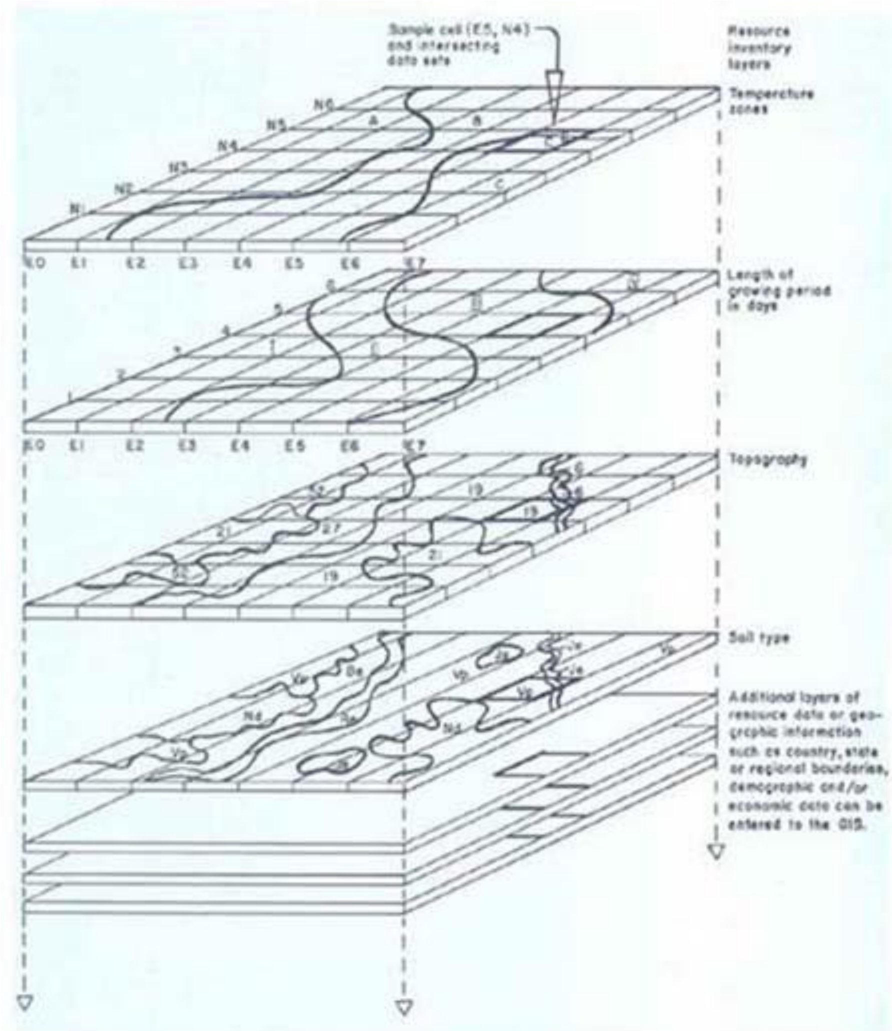
The expansion of climate surface modelling in the future will depend largely on the results obtained initially, but at present this form of modelling shows promise for being able to assess the likelihood of the success of introducing a forage species into a foreign but agroclimatically similar environment.

Geographic information system development

ILCA plans to continue development of the geographic information system (GIS). At present, the system is based on the HP 3000 computer system. The 25 km^2 grid-cell size for entry of soil, vegetation and agroclimatic data is being developed using the available processor capacity.

A schematic representation of the relationships between the various components of the GIS is shown in Figure 3. This represents the minimum expected development of the system. The GIS system should help to refine the definition of AEZs, by making new or more precise data more readily available.

Figure 3. *Schematic representation of the proposed Geographic Information System. The agroclimatic conditions in any grid-cell can be summarised by the computer, which 'looks down' through the different layers of the resource inventory and selects the information required.*



Summary of agroecological conditions in cell E5, N4: Temperature zone – B/C; Length of growing period – III; Topography – land unit 19/6; Soil type – Vp/Je, etc. (Divided grid cells can be described in terms of the relative proportions of each component if desired, eg. 60/40).

Future developments in computer hardware and software will open up the possibility of substantially more powerful GIS formats, operating on vector- or polygon-based software. Machine-based digitising of resource data using a system of this type should greatly increase the efficiency of building a suitably detailed GIS for sub-Saharan Africa. ILCA plans to move gradually across to such a system.

Land evaluation

ILCA has obtained computer software from FAO that was developed for land suitability assessment in the FAO/AEZ study of Africa (FAO, 1978). These programs have been installed on ILCA's computer system, and have been modified to enable crop and livestock farming system requirements to be matched to land inventory data in the GIS. Ultimately, the GIS will be linked with the land evaluation programs, which will permit production of computer-based land suitability maps by grid cell for prescribed land uses.

Establishment of a NOAA satellite-tracking and data-processing facility at ILCA

At present, use of data from the NOAH satellites depends on the cooperative programme between ILCA and NASA. There are a number of limitations to this system, including problems of timely transfer of the data between two continents and constraints imposed on manipulation of the data due to the format and resolution of the material readily available from NASA.

ILCA is hoping to establish its own ground receiving station, so data can be received directly from the satellites. Apart from servicing its own remote sensing research needs, ILCA will act as a distribution centre for raw or partly processed data from the NOAA satellites to interested international, bilateral and government agencies in Africa.

Conclusions

The expectations outlined offer exciting possibilities for agriculture in Africa through more precise definition of AEZs in the future. For example, extension of research results from research stations to farmers' fields will become more rapid. Confidence in the applicability of these results to locations with similar agro-ecological conditions will increase and research targets will be more clearly defined on the basis of AEZs rather than the broad agroclimatic zones previously used. More precisely defined environmental conditions will also enable increased use of modelling to predict pasture, forage and crop responses to the environment and so reduce the need for multilocation adaptation trials.

Establishing a computerised geographic information system will enable agroecological data for sub-Saharan Africa to be rapidly updated and a multitude of economic and demographic information to be interfaced with information on physical resources. This will assist scientists to develop a better understanding of African farmers' needs in relation to the agricultural resources available to them.

The variability of the climate from year to year will be monitored in the future using satellites to cover the vast extent of Africa, enabling more timely early warning of unfavourable conditions for agriculture on the continent. Satellite remote sensing of the environment in support of AEZ studies also offers the possibility of land management advice for farmers and pastoralists, both on a scale and with timeliness previously not possible.

Once defined, AEZs will also provide a clearer picture of land potential through matching of production system requirements with the land characteristics of AEZs stored on computer. Thus it will be possible to estimate the long-term benefits to be gained by introducing new or innovative farming systems using computer modelling techniques, based on AEZ data. Ultimately, the capacity of land to support the human and livestock population in Africa can be assessed.

At present the detail and quality of AEZ data is a constraint to providing reliable assessments of optimal land use. ILCA is therefore committed to improving the AEZ data base of Africa as quickly as possible to ensure that the advantages outlined in this article reach the population as soon as possible.

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Animal breeding and productivity studies in Africa

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Summary

ABOUT 75% of the livestock in Africa are associated with smallholder farms on which the farmers' subsistence is derived mainly from crops, with livestock providing the major source of cash income. The remainder of Africa's livestock are found largely in the herds and flocks of *pastoralists who are dependent upon their animals for both food and income.*

The tsetse-transmitted disease, trypanosomiasis, occurs across about 40% of the land area of the subcontinent, and only small numbers of trypanotolerant cattle, sheep and goats are found in these areas.

About one-third of Africa's livestock are found in the highland areas where temperate conditions prevail. The remainder are in the lower-elevation areas with environments ranging from arid to wet tropical. Crossbreeds between indigenous and imported breeds of cattle perform well in the more favourable areas, particularly in the highlands, but in the lowlands the indigenous cattle usually outperform introduced breeds and their crosses.

Under research station conditions it is prohibitively expensive to attempt to characterise the performance of the many breeds of African livestock and their crosses with imported stock, and to assess their adaptability to different environmental and management conditions. In an attempt to overcome this, ILCA has been collecting and analysing information on breed performance under pastoral and small farm conditions, and this paper presents a summary of this work. The productivity indices obtained allow comparisons to be made across breeds, together with an assessment of the impact of different environments and management practices.

Overall results indicate that the indigenous breeds are well adapted to local environments, and that any increase in the genetic potential of these breeds can only be exploited if nutritional, disease and climatic stresses are reduced.

Introduction

Underlying all animal breeding studies is the fact that neither all animals nor all breeds are equal. There are differences between and within breeds in fertility, size, stress and disease resistance and grazing and mothering behaviour, as well as in many other traits. A few facts, mixed with a considerable number of assumptions, provide the basis of much of our thinking on animal breeding, particularly in Africa. This paper summarises the work that ILCA is doing to assemble what information is available on livestock breeds and breeding in sub-Saharan Africa.

The African environment

There is a wide range of environments in Africa: cool temperate highlands, humid lowland tropics, rangelands and well-watered savannahs. This has resulted in great diversity and localisation of breed types.

Numbers of small ruminants and cattle are approximately equal, and their relative distributions are shown in Table 1. Poultry are ubiquitous, whereas the distribution of pigs is restricted, with a concentration on the west coast.

Table 1. *Distribution of human and livestock populations (millions) in sub-Saharan Africa*.

Zone	Land area ($km^2 \times 10^6$)	Humans	Cattle	Sheep	Goats	Livestock units[a]
Arid	8.3	24.8	31.6	37.1	48.3	41.7
Semi-arid	4.0	65.7	45.4	23.1	33.2	37.4
Subhumid	4.8	59.4	32.7	14.2	20.3	26.4
Humid	4.1	50.3	8.8	8.2	11.6	8.1
Highlands	1.0	38.0	29.0	24.4	11.9	23.6

[a]Livestock unit = 250 kg liveweight.
Source: Jahnke (1982).

Most livestock in Africa are kept by smallholders, whether on mixed crop–livestock farms or in pastoralists' herds. Commercial ranches are relatively unimportant except in a few southern countries. Opportunities for within-herd or -flock selection are greatly reduced by the prevailing ownership patterns (Table 2).

Table 2. *Livestock distribution by farming system*.

	Livestock units ($\times 10^6$)	Percent
Ranching	8	6
Pure pastoralism	29	20
Pure mixed farming	32	23
Agropastoral[a]	74	51

[a]This is a residual classification and reflects the large number of animals that use communal lands for part of the year and farm land for the remainder.

Africa's cattle

The major breeds of African cattle can be classified into three main groups—the humped Zebu of the north, the humpless or taurine breeds of the tsetse-infested zones and the small cervico-thoracic-humped Sanga of the southern and eastern savannahs (Mason and Maule, 1960; Epstein, 1971).

Exotic cattle introduced into Africa also fall into three broad groups—Zebus such as the Sahiwal and Brahman types from Asia, European beef and dairy breeds, and Zebu exotic hybrids such as the Bonsmara and Santa Gertrudis.

Indigenous African cattle are multi-purpose animals. Milk production is universally important, manure usually plays an important role in crop production, draught power and beef production are of localised importance, and all livestock play a key role as a cash reserve and as a source of income. Well-defined beef and dairy industries are not common although they exist to some degree around urban centres. Most stock are kept under extremely simple management conditions and receive little supplementary feed or health care. The ability to cope with environmental stress is the prime criterion for survival. Not surprisingly, Africa's livestock are late maturing, slow growing and modest milk producers.

These animals do, however, respond well to improvements in their environment. Tables 3 and 4 illustrate the changes observed in the calving and growth performance, respectively, of four major breeds of cattle in two distinct environments. The poor weaning weights that commonly occur are the result of the offtake of milk for human consumption; this reduction in liveweight at weaning is never made up. As a result, calf mortality is greatly increased (Figure 1), sexual maturity delayed, mature body weight reduced and efficiency of overall feed use greatly depressed.

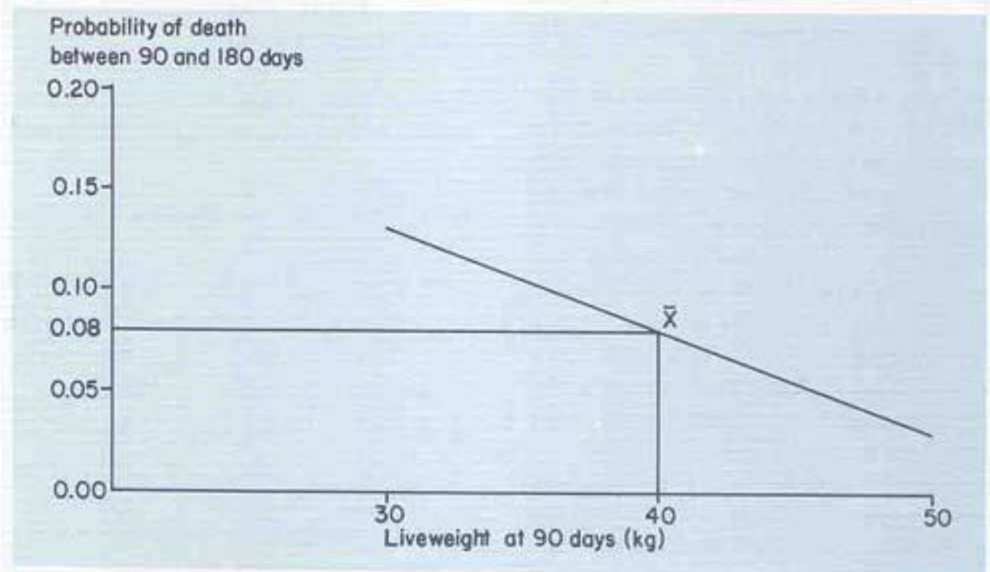
Table 3. *Production system and calving rates*.

Country	Breed/system	Calving rate (%)
Mali	Sudanese Fulani/	
	Traditional	54
	Ranch	77
Nigeria	White Fulani/	
	Traditional	46
	Ranch	89
Ethiopia	Boran/	
	Traditional	55
	Ranch	78
Botswana	Tswana/	
	Traditional	46
	Ranch	74

Table 4. *Production system and body weight of cattle*.

Country	Breed/system	Weight (kg) at			
		Birth	Weaning	2 years old	4 years old
Mali	Sudanese Fulani/				
	Traditional	17	55	125	200
	Ranch	21	79	220	280
Nigeria	White Fulani/				
	Traditional	20	55	140	240
	Ranch	24	96	245	350
Ethiopia	Boran/				
	Traditional	20	55	150	260
	Ranch	25	180	265	420
Botswana	Tswana/				
	Traditional	26	120	260	300
	Ranch	31	180	360	400

Figure 1. *Effect of calf liveweight at 90 days on probability of death, Mali, 1981 to 1983.*



Source: Wagenaar (unpublished).

Comparative performance

Valid comparisons of breed performance can be made when sufficient numbers of animals, breeds and performance traits are studied in a single environment. An excellent example of this type of work is that carried out at Matopos station in Zimbabwe, where H. Ward and his colleagues have evaluated a number of breeds from southern Africa against several imported breeds. Table 5, based on their unpublished data, shows some of their results. These studies are, however, exceptional. Trail (1981), in a comprehensive review of breed studies in Africa, lists 500 papers published between 1949 and 1978. Only 20% of the papers contain comparative information on two or more breed types, and only 5% of the reports provide sufficient information to allow breed comparisons based on a productivity index.

Table 5. *Comparative performance data for seven breeds at Matopos Station, Zimbabwe*.

Breed	Calving (%)	Weaning weight (kg)	Annual weaner weight	Annual 18-month Weight
			(kg/500 kg of cow)	
Africander	53	188	113	159
Mashona	68	180	171	231
Nkone	60	197	149	211
Tuli	66	191	151	206
Brahman	65	219	152	212
Sussex	56	188	120	161
Charolais	57	199	115	164

Source: H. Ward, DRSS, Zimbabwe.

Thus there is little information in the literature that can be used to assess breed performance in Africa, while much of the work on livestock production that has been done in Africa has not been published as journal articles or books with a wide circulation and hence remains unknown in the scientific literature.

In an effort to overcome this problem, ILCA, with assistance from the International Development Research Centre (IDRC), is collecting unpublished literature on animal production and health from experiment stations, government departments, educational institutions and libraries in Africa. The aim is to make this 'grey literature' more widely available to livestock researchers, planners and educators. Each institution participating in the project is provided with a complete set of microfiches of the documents collected in their country, a microfiche reader and bibliographies of documents collected in the other participating countries. So far the project has covered Botswana, Ethiopia, Ghana, Kenya, Malawi, Nigeria, Sudan, Tanzania, Zambia and Zimbabwe in anglophone Africa, and Benin, Burundi, Burkina Faso, Cameroon, Ivory Coast, Mali, Mauritania, Niger, Senegal, Rwanda, Togo and Zaire in francophone Africa.

The documents collected have been catalogued, indexed, abstracted and entered onto ILCA's computerised database. Specific literature searches can be conducted on request. The results of such a search are sent to the requester, who can select the documents that are of prime interest and obtain photocopies or microfiches from ILCA's Documentation Centre; this service is provided free of charge to African users. In addition, ILCA can also make searches of the three largest agricultural databases, AGRIS (FAO), CAB (Commonwealth Agricultural Bureaux) and AGRICOLA (US National Agricultural Library).

Comparative breed studies

Based on the data revealed by the Centre's information services, ILCA has been analysing national research data relevant to comparative breed studies, in cooperation with national institutions. The aim is to build up production information on the important livestock groups in Africa so that decisions about specific breeds, and the assessment of production traits within particular production systems can be made more easily. Major joint studies have been carried out and published with researchers in Ethiopia, Mali, Kenya, Rwanda, Senegal, Sierra Leone, Tanzania and Zimbabwe. This work, which has characterised the performance of many breeds of African livestock and their crosses with imported breeds under different environmental and management conditions, has been widely reported (e.g. Trail and Gregory, 1981; Trail and Gregory, 1982; Gregory et al, 1984). The following sections summarise key aspects of those reports.

Genetic resistance to trypanosomiasis

Trypanosomiasis occurs in roughly 40% of sub-Saharan Africa. principally in the humid and subhumid zones. About 5% of the cattle, sheep and goats in Africa are resistant to this disease, and a most promising and important line of research at ILCA is the attempt to identify the conditions under which these breeds produce most economically, and to introduce appropriate production systems that exploit the potential of these animals.

The nature of genetic resistance to trypanosomiasis has been extensively reviewed by Murray and Trail (1982; 1984) and Murray et al (1984). It is now clear that trypanotolerance is an innate genetic characteristic and that trypanotolerant breeds such as the N'Dama and the West African shorthorns are much more productive than previously supposed. The expression of the trait is, however, modified by the environment. High levels of disease challenge and other environmental stresses lower the tolerance of most animals, and previous exposure to the disease enhances it. ILCA has established an extensive network of research sites throughout tropical Africa to study the complex interactions affecting trypanotolerance. A very large body of data is now being built up on various breeds and their crosses under different levels of trypanosomiasis risk in different management and institutional situations.

Upgrading and crossing of indigenous breeds

Inadequate nutrition and the disease situation generally favour the use of the *Bos indicus* breeds of cattle in Africa. Increasingly, however, improvements in the meat and milk production of Africa's livestock are being sought through crossbreeding with imported breeds. Relatively modest increases in output can lead to large gains in the efficiency with which feed resources are used, and this underlies the persistent attempts to upgrade the *B. indicus* breeds by using imported *B. taurus* breeds with higher additive genetic performance for meat and milk production. The theoretical aspects of using heterosis, crossbreeding and composite breeds in the African tropics have been presented by ILCA workers along with a series of reports on crossbreed performance (e.g. Gregory et al, 1982; Trail et al, 1982; Trail et al, 1984).

Genotype x environment interactions

Where breeds of differing degrees of adaptation to stress are managed together in the various environments in Africa, significant interactions among genotypes and environments are usually found. The most practical way to build a database of these differing breed responses is to use the observations made in ongoing studies. Generally, two levels of information can be obtained: direct, such as the interaction observed between different levels of Boran and East African Zebu cross cattle under different pasture improvement and tsetse-clearance situations in Tanzania (Trail et al, 1985); and indirect, when genotype x year effects can be identified and associated with seasonal and yearly climatic differences. An example of the latter approach is noted in ILCA's work with different Sahiwal x Ayrshire crossbreds in Kenya (Gregory and Trail, 1981).

These breed comparisons in different environments confirm the high degree of adaptation exhibited by the indigenous breeds. They also demonstrate that any increase in the genetic potential of these breeds for milk and meat output is only likely to be realised after nutritional, disease and climatic stresses have been reduced.

A microcomputer-based performance recording system

The collaborative efforts that have enabled ILCA to establish the microfiche collection of unpublished research reports and to analyse the data that give rise to the conclusions noted above have also highlighted the need for a simple microcomputer-based system for recording livestock performance in Africa. Such a system needs to:

- handle all important traits for a range of animal species;
- allow the process of data handling and analysis on an individual herd unit to run to the point at which logical herd-level decisions can be made without having to link up with a larger computer facility;
- provide standardised output files for regional and national decisions or comparisons; and
- provide facilities for recording climatic, nutritional and management information to facilitate biological interpretation of the statistical output.

ILCA has developed such a system and it is now available for widespread use. The approach taken and the capabilities of the system are summarised below. Terms that are specific for cattle are used for ease of presentation, but appropriate alternatives for other ruminants are assumed.

The ILCA Performance Recording System uses the dBase III database management system. The system comprises:

- Installation database: one entry for each recording site, giving the name and country of installation, date of last update, etc.
- Climate database: extensive climatic details.
- Core database: basic one-time-only details of each animal, which are used to identify data pertaining to that animal that are stored in the other databases of the system.
- Reproduction database: gives details and result of each parturition.
- Weight database: details of each weighing of each animal.
- Dairy database: details of each dairy measurement for each animal.
- Wool database: details on fleece measurements.
- Traction database: details of each traction measurement for each animal.
- Health database: details of each feed intake measurement or observation for each animal.

Each animal in the system is given a unique identifier. This provides the primary access to the major databases. Secondary access keys are necessary when multiple entries exist for specific animals within a database. For example, to determine the weight of an animal, a weigh date must be given, since the animal will have been weighed more than once. Secondary access keys are used to access either a specific entry for an animal or to access data in sequences other than by animal identification. If, for example, a summary of the weaning weights of all the progeny of one sire is required, the weaning weights are accessed by the sire identification.

Interactive facilities enable the user to add, modify, manipulate and print files for each database. Weaning weights, for example, can be adjusted to a standard age over a specified period; the programme allocates each animal to its relevant class, amalgamates subclasses so each contains a predetermined minimum number of calves, performs a least squares analysis, and corrects the weights for each subclass, thus enabling the animals to be ranked in order of performance.

This livestock recording and analysis system has the acronym "IDEAS" and is available with documentation and manuals at no charge to national research groups in Africa, and at a modest charge to researchers elsewhere in the world. It requires a microcomputer with an MSDOS operating system and 256 Kbytes of RAM. ILCA provides regular training in the use of this programme.

One simple example of the results that this data accumulation and analysis provides is the recent comparison made by Trail (unpublished) of the overall performance of several African breeds of cattle under different environmental conditions using a productivity index as the criterion of comparison (Table 6).

Table 6. *Overall performance of Small East African Zebu cattle at Muhaka compared with other breeds in varying stress situations*.

	Muhaka small E.A. Zebu; low-medium trypanosomiasis risk; no prophylaxis village management	West Africa N'Dama: medium-high trypanosomiasis risk; no prophylaxis		Tanzania grade Boran; High trypanosomiasis risk; prophylaxis ranch management	Kenya Boran; no trypanosomiasis risk; no prophylaxis ranch management
		Village management	Ranch management		
Reproductive performance Calving percentage	61.8	58.4	72.2	75.3	87.0
Viability					
Pre-weaning viability(%)	86.8	73.4	91.1	92.0	94.6
Annual cow viability (%)	95.3	(95.0)	98.0	94.2	98.0
Body weights					
Weaning weight at 8 months (kg)	57.8	72.3	90.4	133.5	174.0
Estimated mature cow weight (kg)	192.0	239.0	258.0	293.0	414.0
Calculated herd productivity[a]					

Productivity per cow per year (kg)	36.5	35.4	58.3	87.1	140.3
Productivity per 100 kg cow per year (kg)	19.8	14.8	22.7	29.8	33.9
Productivity per 100 $kg^{0.73}$ cow per year (kg)	81.0	64.9	101.8	137.8	172.5

Source: Trail (unpublished).
[a]Productivity = weight of 8-month-old calf and liveweight equivalent of milk produced for human consumption.

Conclusions

By reviewing, microfiching and cataloguing an extensive listing of previously unpublished material, by developing simple computer programmes to handle the data in these unpublished studies and building a network of collaborating animal breeding centres in Africa, a vast body of valuable information on breed performance and the factors affecting it is now being established at ILCA. The broad pattern emerging demonstrates the adaptation of specific indigenous breeds to localised environments, and the need to modify environmental stresses of various types if breeds with higher genetic potential are to be introduced.

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List of abbreviations

ADF	acid detergent fibre
AEZ	agro-ecological zone
AVHR	Radvanced very high resolution radiometer
CP	crude protein
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
d.f.	degrees of freedom
DM	dry matter
DMD	dry matter digestibility
ETp	evapotranspiration
GIS	geographic information system
hr	hour
kN	kilonewton
kW	kilowatt
LC	local control (animals)
LGP	length-of-growing period
LR	local restricted (animals)
LW	liveweight (kg)
mo.	month
ME	metabolisable energy
MJ	megajoule
MS	mean squares
N	nitrogen
NASA	National Aeronautics and Space Agency (USA)
NDF	neutral detergent fibre
NDVI	normalised difference vegetation index
NOAH	National Oceanic and Atmospheric Administration (USA)
NPN	non-protein nitrogen
P	precipitation
S	soil moisture
SD	standard deviation
SE	standard error
W	liveweight (kg)
XC	crossbred control (animals)
XR	crossbred restricted (animals)