ILCA BULLETIN

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Farm energy flows in the Ethiopian highlands

Factors affecting supply levels from African livestock sectors

Screening of plants for anthelmintic activity

The environment of the Rift Valley

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Preface

This issue of the ILCA Bulletin is the first employing a new style. Instead of each Bulletin issue focusing on one topic or theme, each issue in the future will usually contain four or five independent articles of around 5000 words each, although occasional issues focusing on single themes are not ruled out.

The four articles in this issue have been summarised from research papers; three of the papers were written by ILCA staff members, and one by scientists working at an African university under a grant from ILCA.

The first article concerns energy flows on smallholder farms in the Ethiopian highlands. The original paper was commissioned by the Beijer Institute in Stockholm, Sweden, and it is with the Institute's permission that we present a summary of the paper here. The article is based on the work of ILCA's Highlands Programme on farms around Debre Berhan and Debre Zeit where the programme has its two research sites. A study of the energy flows in the traditional farming system of these areas of the highlands effectively highlights the importance of the different components of the production system and their interrelationships. The study also warns against inappropriate interventions into the system.

The second article is a summary of a desk study conducted by a consultant to ILCA's newly formed Livestock Policy Unit at headquarters. The consultant was asked to identify potential causes of increases in livestock output for which published data exist for the period 1965 to 1980, and then to study the correlations between potential causes and increases in output. However, the study was hampered by the lack of satisfactory data on several of the most important potential causes. For example, much of the data specific to the livestock sub-sector was not available, and proxies for the desired data, e.g. data for the agricultural sector as a whole, had to be used. Nevertheless the study revealed one or two interesting correlations and highlighted the need in Africa for more accurate data relating the livestock sector.

The third article is the result of a Nigerian study which ILCA supported financially. The authors are members of staff at the Ahmadu Bello University in Zaria, Nigeria. Much of ILCA's work in West Africa is concerned with the problems of livestock diseases, including the helminthiasis group of parasite diseases. A number of livestock producers in West Africa have used herbal treatments successfully against helmintic diseases—plants or chemicals exhibiting such activity have been termed anthelmintics. The team at Ahmadu Bello University collected plants from the wild and screened them for anthelmintic activity using the *Nippostrongylus–rat* model. A number of these plants showed significant activity, giving deparasitizations of up to 92% compared to untreated controls.

The fourth article is a summarised version of a study made by the Forage Legume Agronomy Group at ILCA headquarters. Part of the work of the Group is to assess the suitability of forage germplasm for introduction into different livestock production systems in Africa. While the Group works in close collaboration with ILCA's field programmes, it was important to determine whether any of the locations near Addis Ababa would be suitable for testing germplasm under varying African conditions. The Ethiopian Rift Valley has been used by the Group to screen germplasm since the team began its research in 1982. It was of interest therefore to identify those locations in the Rift Valley which were agroclimatically comparable with other areas of Africa where ILCA is conducting research. Such locations could then be used in the initial screening of forage germplasm without having to transport germplasm across the continent.

We would be pleased to receive your views on this new-style ILCA Bulletin, and to pass on your comments on any of the articles published to the authors.

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Energy flows on smallholder farms in the Ethiopian highlands*

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** Summary of a paper submitted to the Beijer Institute (the International Institute for Energy and Human Ecology), the Royal Swedish Academy of Sciences, Stockholm, Sweden.*

Summary

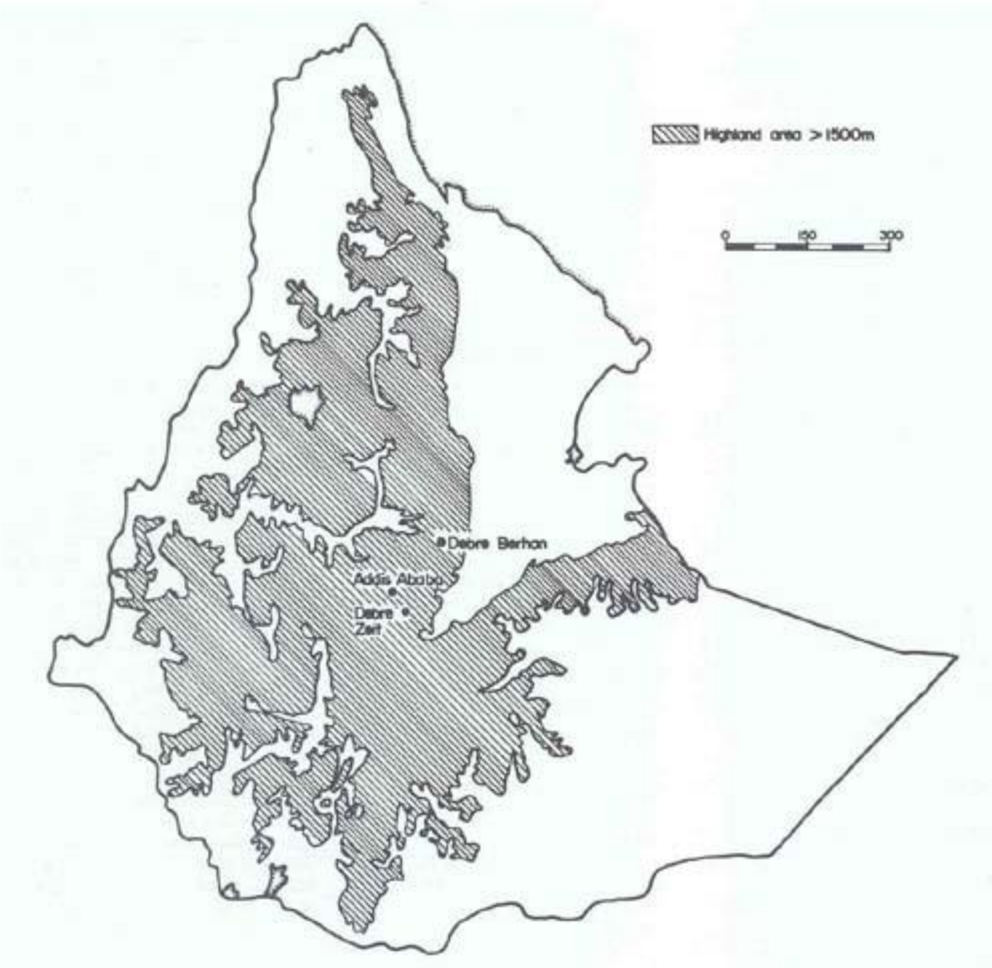
THIS PAPER *studies energy flows on smallholder farms in two areas of the Ethiopian highlands. The overall farming system and the resource base in these areas are described and an outline is given of how these resources are used. The use of energy in the household system is then discussed and the prospects for improvements in energy use in these areas are assessed. The authors conclude that any major improvements in present energy use will have to rely on technologies which are simple, effective and easily implemented and maintained. Energy problems must be seen in the wider perspective of agricultural and ecological development. Changes in the overall energy use on smallholder farms will be slow unless a proper infrastructure and adequate extension and technical support services are established.*

Introduction

Efficient management of energy resources is crucial to survival in subsistence agriculture. Although energy inputs into such farming systems are low compared to western agricultural practices, farmers are often forced into production methods which exploit current energy flows at the expense of a sustained, longer term output. In such situations, productivity is steadily declining. This, combined with an increasing population pressure makes it imperative to increase the efficiency of energy use. Efficiency gains within agricultural systems can be achieved by improving energy transformation in the use of resources and by reducing absolute losses.

This paper describes energy flows on typical smallholder farms in the Ethiopian highlands. These farms are representative of a subsistence agricultural system that has remained basically unchanged for centuries. Surveys were conducted in the two main study areas of ILCA's Highlands Programme: around Debre Zeit, 50 km south of Addis Ababa at 1800 m a.s.l., and Debre Berhan, located 120 km northeast of Addis Ababa at 2800 m a.s.l. (Figure 1).

Figure 1. *The Ethiopian highlands*



Farming system and resource base

Some 70% of Ethiopia's human population of 32 million live in the highland areas. The highlands are ecologically diverse and agricultural conditions vary widely.

In Ethiopia nearly 80% of the population is directly employed in or dependent on agriculture. In many rural areas, people are acutely vulnerable to drought and starvation, and basic social services are seriously deficient. Ethiopia's rugged terrain is a major constraint to economic development because of the inherent transport and communication problems. It has been claimed that three quarters of the population live more than one day's round-trip walk from an all-weather road.

The bulk of agricultural output in Ethiopia is produced by individual subsistence smallholders who have `farming rights' over the land they till. Land is not owned individually but is allocated by the local Peasants' Association (PA), to one of which each farmer necessarily belongs. There is an average of 250 members per PA and each PA regulates the use of approximately 800 ha of land.

Farming system

A subsistence mixed farming system prevails in most of the Ethiopian highlands. Rainfed agriculture is dominated by the production of cereals, pulses and livestock. Average annual rainfall fluctuates between 600 and 1200 mm, with 70% of rain falling in the period between July and September. Temperatures are generally temperate, although extreme diurnal variations can occur in the dry season. Frosts are common at altitudes above 2100 m. The size of individual landholdings ranges from 0.5 to 5 ha. In addition, farmers have grazing rights on the communal pastures of the PA of which they are members.

Traditional agricultural tools and paired oxen are used for producing a wide range of crops including teff, wheat, barley, maize, sorghum, linseed, beans, peas and lentils. Annual crop yields range from 500 to 1000 kg/ha.

Generally, land is scarce and the human population growth rate is high (2.2% per annum; World Bank, 1982). As a result an increasing proportion of permanent pasture land is being cultivated, fallow periods are being reduced and the pressures caused by subsistence crop production on the available arable land are increasing. This has substantially added to erosion and to the decline in soil fertility.

Access to modern inputs such as chemical fertilizers or improved seeds is limited. Extension services are also very scarce and priority in the allocation of farm inputs is given to cooperatives. Most farmers own livestock: a typical inventory is two oxen, a cow, a few sheep and a donkey. Cattle (Zebu type) are kept mainly for draught power and manure. The manure is mainly used as household fuel, while a small amount is returned to the fields as fertilizer. Milk, meat and hides are relatively less important products. Sheep and goats require minimal inputs, they are kept as an investment and provide security in times of need. Donkeys are used extensively to transport agricultural inputs and farm produce.

Productivity is low for all livestock species. Milk offtake from indigenous cows kept under traditional management rarely exceeds 400 kg for a lactation period of 7 months, and calving intervals average 2 years. Various factors contribute to this low productivity, including unexploited genetic stock, extended periods of nutritional stress during the dry season, diseases and endoparasites.

Crops and livestock are closely linked in the smallholder mixed farming system of the Ethiopian highlands.

Labour availability

The labour required to operate a family farm depends on the season. Although most of the labour required is supplied by the family, non-family labour commonly has to be used to overcome bottlenecks.

Each farmer is required to supply labour to the cooperative enterprises of the PA with which he is affiliated. Additionally; farmers are expected to assist aged or disabled farmers and those families whose head is in military service.

Capital

Livestock holdings

The most important contribution of livestock to agricultural production in the Ethiopian highlands is through the use of oxen as draught animals. Table 1 gives average holdings of livestock per farmer as determined from ILCA surveys around Debre Zeit and Debre Berhan. Around 10% of the farmers in these areas have no livestock.

Table 1. *Livestock holdings per farmer on 60 farms around Debre Zeit and 60 farms around Debre Berhan, 1980.*

Livestock type	No. of livestock holdings per farmer (range)	
	Debre Zeit	Debre Berhan
Oxen	1.86 (0–4)	1.02 (0–3)
Cows	0.93 (0–4)	1.45 (0–4)
Heifers	0.33 (0–2)	0.88 (0–3)
Bulls	0.48 (0–5)	0.69 (0–2)
Calves	0.64 (0–3)	0.98 (0–3)
Sheep	1.55 (0–4)	10.69 (0–32)
Goats	1.00 (0–6)	0.12 (0–2)
Donkeys/Mules	0.98 (0–3)	1.81 (0–5)
Horses	0.05 (0–1)	1.12 (0–2)

Fuel sources

Dung cakes, firewood and straw are the major fuel sources available for heating and cooking in rural households. Straw is used as fuel during the harvest season from October to December. Firewood resources (mainly *Acacia* spp. and *Eucalyptus* spp.) are not uniformly distributed throughout the Ethiopian highlands. Ethiopia's forested area has declined from 40% at the beginning of this century to only 4% of its land area (FaWCDA,1982).

Typical weekly use of dung cakes. and firewood in two areas of the highlands of Ethiopia is given in Table 2.

Table 2. *Typical weekly use of dung cakes and firewood around Debre Zeit and Debre Berhan[a].*

Fuel	Fuel consumption (kg/week)	
	Debre Zeit family	Debre Berhan family
Dung cakes[b]	41	48
Firewood	10	13

a. From ILCA surveys during 1980 on 25 smallholder farms in each area.
b. Based on sun-dried weight.

Other capital items

The annual cash income of smallholder farms in the Ethiopian highlands rarely exceeds US$ 200. Surveys have indicated an average gross cash income in the region of US$ 155 per year, with US$ 90 coming from the sale of crops, US$ 50 from livestock and livestock products and US$ 15 from other sources. This modest cash component within the system limits the opportunity for internal financing of improvements and highlights the need for an efficient use of available resources.

Farmers usually possess a dwelling house, stores and livestock sheds. Farm tools and implements are made of wood fibre, leather and sometimes metal. Wood from the *Eucalyptus* spp. is used for ploughs, yokes, winnowing forks and spades; hides and skins are used for ropes, straps, whips and grain bags; and fibre materials are used for storage bins, and ox equipment such as ropes and whips. The value of this traditional agricultural equipment does not normally exceed US$ 60 per farm.

The two most common fertilizers used are diammonium phosphate and urea, with most farmers applying less than the recommended rates.

Resource use

The previous section has described the resource base available to the average smallholder farmer in the Ethiopian highlands. Certain resources such as animal traction have an intermediate role when used for farm production. Others provide end-products that can either be consumed at home or sold. This section describes the intermediate roles within the traditional farming system.

Animal traction: cultivation and transport

Oxen

The traditional agricultural system in the Ethiopian highlands depends on animals for draught power for cultivation and transport of agricultural products. ILCA surveys in 1980 around Debre Zeit and Debre Berhan showed that animal power used for crop-related work averaged 1050 hr/

farm/year. Most of this power was supplied by oxen, but other livestock were sometimes employed for threshing (50 to 80 hr were contributed by donkeys). Some 60 to 70% of the total animal power input was for seedbed preparation and planting, with approximately 350 hr per oxen pair used for these purposes per season.

The availability of draught power determines the size of area cultivated and the cropping pattern. Table 3 summarizes the effect of oxen holdings on crop areas among 42 traditional farmers in Debre Zeit in 1980. It should be noted that cereals are much more labour intensive than pulses.

Table 3. *Effects of oxen holdings on area cultivated and a cereals–pulses cropping mix around Debre Zeit, 1980.*

No. oxen per farm	Area cultivated (ha)	Area under cereals (%)	Area under pulses (%)
0	1.2	54	46
1	1.9	44	56
2	2.7	67	33
3 or more	3.6	92	8

Source: Gryseels (1983).

Cultivation throughout most of the Ethiopian highlands is done with a pair of oxen which pull the locally-made *maresha*. The power output of oxen pulling this traditional plough depends on the animal's body weight, its nutritional and health status, terrain, soil conditions, draught force required for ploughing at various depths, speed of travel, number of passes, training of the animal and skill of the handler.

Studies conducted on traditional farms near Debre Berhan demonstrate that oxen with an average body weight of 280 kg produce power outputs ranging from 0.35 to 0.70 kW/hr while ploughing (Goe,1983).

Energy requirements of mature working oxen vary according to their maintenance needs and actual power output over a given period. Results from trials conducted at the ILCA research stations show maintenance requirements of local oxen weighing between 300 and 350 kg to be 38.5 to 41.8 mega joules (MJ) per day of metabolizable energy (ME). Requirements for the same animals ploughing with the *maresha* were 3.8 MJ ME hr regardless of body weight (Abiye Astatke,1982).

Donkeys, horses and mules

Ethiopia has approximately 7 million horses, mules and donkeys (FAO, 1982). Horses and mules are used primarily for transport, carting and, in some instances, for packing. Mules are more valued than horses due to their temperament and packing ability. Donkeys are mainly used for packing, although carting is not uncommon in certain areas. All are used for threshing crops. Farmers in some regions employ horses and donkeys for draught, either hitching the same species together or in mixed pairs. Horses can also be yoked together with oxen or barren cows for ploughing.

Labour use

A typical subsistence farm with 2.5 ha of land under cultivation employs a total of approximately 1100 hr of labour for crop production per year[1]. This gives an average labour input of around 440 hr/ha/year. Of this total, around two thirds are usually supplied by the family, about one quarter by exchange labour, and less than 10% by hired labour. Most labour for cropping is supplied by adult males.

1. This assumes no quality differences between the labour inputs of the different age and sex groups. Women and children have specific tasks in crop production for which they are often as efficient as adult males.

The labour inputs for different crops vary both yearly and by location because of differences in rainfall, soil and land types, cultivation practices and crop yields. A high yield can be a result of more intensive weeding and better seedbed preparation. However, higher yields in turn require extra labour for harvesting and transport. Teff is the most labour intensive of all food crops grown in the highlands, requiring an average 600 hr/ha while pulses require only half this amount.

Labour inputs needed for livestock production are constant throughout the year. They involve basic management and are generally fulfilled by family members, except in cases where outside labour is hired for herding.

Other intermediate products

Milk for calves

The major role of cows is to produce male calves to be reared as draught oxen. As a result, approximately equal amounts of milk are suckled by calves and milked out for family consumption.

Crop byproducts

Grazing on communal lands and fallow plots is the main source of feed for livestock in the highlands. This is supplemented with hay, stubble grazing, straw and other crop residues. Work oxen and cows in milk are given priority in supplementary hand feeding. In the dry season they are supplemented with hay and straw and in the wet season with straw. Valley bottoms and crop stubbles are grazed during the dry season from December to April. From about May to November, livestock largely depend on fodder on hillsides, in field verges and roadsides.

A typical farm of 2.5 ha, with two thirds of the cultivated area sown to cereals, the remainder to pulses plus an additional 0.75 ha of communal grazing land, produces approximately 6.0 t of dry matter in a normal year. The average farm stock holding is around 3.67 animal units (AU[2]). Assuming 8.1 MJ ME/kg fodder for 4 months and 6.6 MJ ME/kg fodder for 8 months, the annual fodder requirement for maintenance of these AUs is 6.5 t DM. The available feed resources thus fall short of total requirements by 8%. The error in estimating total production, its yearly variation, and animal requirements would indicate that actual feed resources may be adequate for maintenance. However, there are only limited periods during the year when livestock can gain weight without supplementation.

2. One AU equals 250 kg liveweight.

Energy aspects of the household system

Consumption

Ethiopian families in rural areas depend heavily on home production of foodstuffs for consumption. The staple food of most people of the Amhara group—the dominant social group in the ILCA study areas—is *injera* and *wat*. *Injera* is a porous pancake, a few millimeters thick and 40 to 50 cm in diameter, its sourness depending on the length of the fermentation period. Although *injera* made from teff is preferred, it can also be prepared from barley, wheat, maize and sorghum or sometimes a mixture of these, depending on what is available and affordable. The ingredients of *wat*, the sauce which accompanies *injera,* also vary according to their availability as well as fasting requirements and local tastes. Meat *wat* is preferred, but most farmers can afford it only on feast-days. In a normal year farmers produce sufficient cereals and pulses from their own cropped land to have a modest surplus after meeting family requirements. Table 4 presents indicative total production and its allocation for an average household of five persons (two adults and three children) on a farm of 2.5 ha in an average year.

Table 4. *Annual production and disposal of food crops on a 2.5 ha family farm in the Ethiopian highlands.*

Crop	Total production[a](kg)	Seed required for following crop[b] (kg)	Consumption[c](kg)	Available for sale (kg)
Cereals (1.65 ha)	1 320	165	1 000	155
Pulses (0.85 ha)	510	85	250	175

a Assuming harvested yield of 800 kg/ha for cereals and 600 kg/ha for pulses.
b. Values are calculated on the basis of seeding rates of 100 kg/ha for both cereals and pulses.
c. Assuming a family of five with average annual consumption each of 200 kg of cereals and 50 kg of pulses.

Due to the large number of fasting days each year, there is a great demand for cereals, pulses and vegetables to meet household nutritional needs. Table 5 gives daily per caput intake of common foodstuffs and their energy values.

Table 5 . *Daily per caput food intake of basic foodstuffs.*

Foodstuff	g/day[a]	MJ ME/day [b]
Cereals	400–500	6.3–7.9
Pulses	80–100	1.2–1.7
Pepper	15	0.21
Oil-butter	15–20	0.45–0.59
Onions	80	0.12
Other vegetables	15–20	0.23–0.30

a. Source: Asfaw Alemu (1982).
b. Calculated from Agren and Gibson (1968).

Human energy expenditure in household activities

Household duties are the responsibility of women. These duties include food processing and preparation of meals, making *tella* (a local beer), fetching water, collecting dung and wood for fuel, cleaning, washing, taking care of the children and making baskets. Most of the labour inputs for livestock production such as feeding and watering, milking, barn cleaning, manure collection and handling are done by women and children. Women also help to deliver goods to the market place. Younger children are responsible for herding the cattle, delivering milk to collection stations, transporting ashes to the plots near the house, running errands and minor household chores. When boys reach the age of 12 years they begin to help their father with the field work, take goods to the market, make yokes, ploughs and handles for hand implements, collect honey, and learn the management aspects of keeping livestock and general farming. Weaving of the *shama* or *gabi* (a large wrap made from cotton) is done mostly by men. The time spent performing daily household chores and the energy expended on them is given in Table 6.

Table 6. *Time spent on daily household chores and energy expended.*

Activity	Time spent	Energy expended	
	(hr/month)	(MJ/hr[c])	(MJ/month)
Cooking	183	0.28	1.24
Food processing	5[a]	0.91	4.55
Collecting, preparing and drying cow dung	44[b]	0.91	40.04

Collecting firewood	61	0.91	55.51
Fetching water	91	0.91	82.81
Washing clothes	8	0.91	7.28
Herding livestock	213–343	0.28	59.64–68.04
Going to market	20–45	0.28	5.60–12.60

a. Source: Asfaw Alemu (1982).
b. Source: Baygell (1979).
c. Based on calculations from Clark and Haswell (1970), pp. 12–13.

Prospects for improvements in energy use

Animal traction

Single ox

A major constraint for crop cultivation in Ethiopia is the unequal distribution of oxen per farm household. Data available at the national level indicate that only 37% of the farmers have two or more oxen, 34% have one and 29% own no oxen at all (MOA, 1980). Since oxen are traditionally paired for work, more than 60% of the farmers have to rent or borrow one or two animals for cultivation.

A farmer owning less than two oxen has several options available for securing animals for ploughing. Households that already have one working ox can enter into a *mekanajo* agreement with another household in a similar position, whereby the pair of oxen is used on the partners' fields on alternate days. However this strategy has one serious disadvantage: if the ploughing season is short, the working capacity of the animals may not allow both farmers to cultivate at the optimum time. Moreover, the changing of oxen handlers and yoking of animals not used to each other can result in a loss in daily work output.

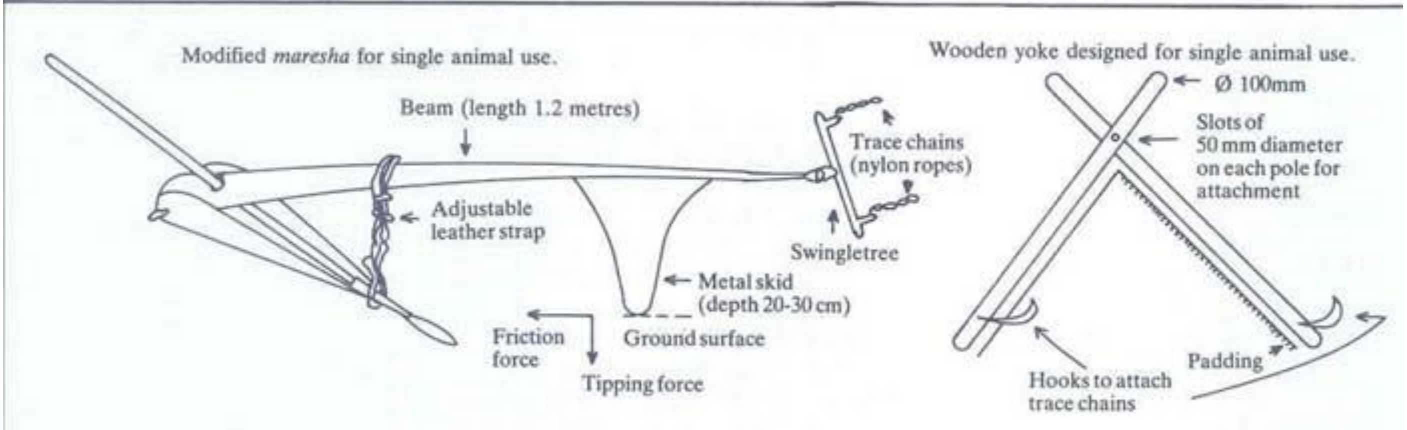
In another arrangement called *minda,* a farmer in need of an ox can rent it from a farmer owning surplus oxen at an annual cost of between 200 and 225 kg of grain, or in exchange for human labour. Sometimes oxen are rented on a cash basis, at US$ 1.50/day/pair or US$ 2.50/day/pair if a handler is included.

Throughout most of the Ethiopian highlands the areas of fallow and permanent pasture have been reduced due to the high demand for food crops from an increasing human population. Thus it is becoming more difficult to maintain the present cattle population, as well as to prevent ecological degradation.

In these circumstances, it is likely that it will become increasingly difficult for farmers to keep the breeding stock required for raising replacement oxen in addition to maintaining a working pair. However, by introducing a change in the farming system, whereby cultivation would be done by a single ox, rather than a pair, it may be possible to substantially increase the productivity of livestock and the smallholder farm. More cattle could be sold, resulting in an increase in farmers' incomes. At the national level such a development would bring more meat supplies to urban areas. Reduced grazing pressures would enable better control of erosion and would help to improve livestock nutrition. Farmers who have to rent or borrow one or two oxen will be able to practise more timely cultivation.

ILCA has developed a suitable yoke and harness, as well as a modified *maresha* plough (Figure 2), for use by a single ox. This technology has been tested at the experimental level, and trials are currently being conducted on traditional farms to test the applicability and effectiveness of this new technology within the Ethiopian highlands.

Figure 2. *Modified* maresha *and yoke designed for single ox cultivation.*



Use of crossbred cows for draught

Another option which may also help to reduce cattle herd size and grazing pressures, and extend stored feed supplies, is the use of crossbred cows for both milk production and draught. ILCA studies with farmers have demonstrated that crossbred cows are able to provide adequate draught power during the cropping season, as well as a higher milk yield and a crossbred calf of higher value compared to local Zebu cows. Although the study is not yet complete, data indicate that cows can be adapted to work without any negative effects on their reproduction rate, lactation length and milk yield, provided that adequate feed supplies and veterinary care are available and proper management is maintained.

The most promising area for the use of crossbred cows as traction animals would be in or around urban areas where the scarcity of land is more acute than in the rural areas. Farmers would be guaranteed a constant market for milk, access to supplements and veterinary services, and high market prices for calves. Such farmers would be more inclined to change or modify their management system since their proximity to urban services would help minimize production risks.

Improved implements

Cultivation trials with improved implements were conducted by ILCA from 1980 to 1982. Trials were carried out on three different soil types—clay, clay loam and silty clay loam. Three cultivation systems were tested using the traditional *maresha,* a conventional mouldboard plough and a spring-tine harrow for the primary passes: Seed covering was done with the same implements and a zig-zag harrow (Abiye Astatke and Matthews, 1982). Dynamometer measurements were made for the three implement/soil combinations to determine the amount of draught power required.

On each soil type, better weed control and crop yields were obtained using the conventional mouldboard plough and spring-tine harrow compared to the *maresha.* The total kWhr/ha required was highest for the mouldboard plough on all soil types, followed by the *maresha* on clay soils and the spring-tine on silty clay soils. In all cases, the zig-zag harrow provided more uniform seed covering in less time and required less draught power than did the three other implements.

Trials to reduce waterlogging of bottomlands have also been initiated. A single winged-tine which can be fitted on the same frame as the mouldboard plough, was used to aerate and drain surface water. Results from the first season of trials demonstrated that natural forage yields (fresh weight) can be increased if the tine and winged-tine are used before the rains start. Further work will be done to better assess yield differences and kWhr/ha requirements.

These improved implements have not yet been tested off-station, the main obstacle being their cost, which is beyond the means of the smallholder. For example, the basic frame for use with a mouldboard plough and a winged-tine costs US$ 100, while the costs of the plough share and the tine are US$ 20 and US$ 25 respectively. The spring-tine unit costs US$ 200 and the zig-zag harrow US$ 35–40. Compared to the total cost of the traditional *maresha* of US$ 15, the above represents a substantial investment for a farmer operating at the subsistence level. Thus unless an effective agricultural credit programme can be developed, most farmers will continue to rely on the *maresha* for cultivation.

Fuel consumption

About 95% of the total energy consumption in Ethiopia is provided by wood, dung, charcoal and crop residues. Biomass consumption for fuel in 1980 was about 24 million m^3 of firewood, 7 million t of dung, 170 000 t of charcoal and 6 million t of crop residues (FaWCDA,1982). Given the current firewood consumption of 1 to 1.2 t/caput/year, it has been estimated that forests in Ethiopia will be completely destroyed by the year 2000 unless drastic measures are taken to reduce the present consumption level and to strengthen both the financial and manpower budgets of the relevant institutions (Beijer Institute, 1981). More efficient ways of firewood utilisation need to be investigated. Substantial savings in firewood consumption could be achieved by the use of improved stoves and different cooking methods.

The major tree species being planted in the highlands is *Eucalyptus globulus*. However, even if present reafforestation programmes attain the projected planting goal of 56 000 ha per year, this will not be sufficient to maintain the existing woodlots which are being cut at an estimated rate of 200 000 ha per year (Beijer Institute, 1981). Furthermore although *Eucalyptus* spp. are highly suitable for woodlot establishment, they are not very effective in controlling hillside erosion.

Urgent reforms are therefore needed. Possible measures to be taken include controlled livestock grazing on hillsides, which should be enforced so that slopes do not become denuded. In areas where erosion has become severe, livestock should be kept off hillsides for at least 3 to 4 years to allow the total biomass to regenerate. In addition, conifer species should be emphasized in these areas.

Wind energy

In the Geleb area north of Lake Rudolf in the Gamo Gofa administrative region, windmills are used to supply households with water and for irrigation (Fraenkel, 1975). Prototype windmills for electrical and mechanical applications are to be built in the Melka Werer area of the Awash valley (Cocks, 1981). By employing windmills for irrigation, it should be possible to grow two or three crops a year instead of one.

The potential for increasing the use of windmills or wind generators in Ethiopia depends on the altitude of the chosen site, the average wind speed and the duration for which a particular wind velocity is maintained. Even very efficient units cannot operate when wind velocities are 3 m/s or less (Earthscan, 1981). As the altitude increases air density decreases. A study done by ILCA at Debre Berhan showed that the power available from wind at a particular velocity was three quarters of what it would be at sea level. In addition, a windmill could be expected to pump the required amount of water only for 2 to 3 months a year because there would either be no wind or average wind speed would be too low during the rest of the year (Campbell, 1982).

Solar energy

In Ethiopia solar radiation is used extensively for drying crops, animal forages, fruits and fish, for the production of salt by evaporation of seawater or inland brines, and as fuel. However, harnessing its power in the form of electricity, heat storage or mechanical energy at the village level has so far been minimal or non-existent, despite the successful research into solar cookers, heaters and distillation plants (Hobbs, 1965).

Potential areas for developing solar energy should probably be limited to passive solar driers and ovens, irrigation pumps powered by photo-voltaics and flat plate collectors (Beijer Institute, 1981). However the cost of such solar apparatus would be prohibitive to smallholders, and the equipment is still complex, difficult to maintain and potentially hazardous to the ill-trained. Therefore, compared with existing sources of energy, the prospects for large-scale introduction of solar power remain poor in the immediate future.

Biogas

Given the scarcity of firewood and the prevalent use of dung for cooking, biogas plants would appear to be an appropriate means of reducing the current usage of these renewable energy resources. However, despite the expensive experimental work undertaken by the Ethiopian National Energy Commission only a few biogas plants have so far been established in the Ethiopian highlands. The major difficulties encountered are maintenance, proper management and public acceptance and cooperation.

Thermal and hydroelectric power

Most thermal plants producing electricity in Ethiopia operate on diesel fuel. While these units generated 26.6% of the total electricity produced in the country in 1970, their output in 1978 fell to 14.7%, largely due to an increase in the number of hydropower plants and problems in operating thermal plants efficiently (ECA,1980a). It is reported that only 2.3% of Ethiopia's hydropower potential has been developed, and that of the electricity generated only 50% is being utilized, primarily because electrical appliances are beyond the reach of most of the population and electrification has yet to reach many rural areas of the country (Varet,1978).

Increased use of electrical power in the country will depend on more accurate long-term planning in all sectors of the economy (especially the industrial sector), better returns on assets and better adherence to projected time schedules for completion of new generating plants. At present, little progress has been made in tackling these problems (Beijer Institute, 1981).

Geothermal energy

Geothermal exploration began in Ethiopia in 1967. Three sites were selected for drilling, two in the Afar depression and one in the Rift Valley (ECA, 1980a). Depending on the outcome of the drilling in the Lake Langano area of the Rift Valley, additional wells may be drilled (ECA, 1980b). The use of geothermal energy would extend electrification to isolated rural areas where the supply of electricity through other means may not be feasible.

Conclusion

Any major inroads to be made in changing the present energy usage will have to rely on technologies which are simple and effective, and easily implemented and maintained. In addition, these technologies should be well tested to determine whether by improving the efficiency of one resource a reduction in another does not occur.

However, although improvements in the use and availability of energy sources play a major part in improving agricultural productivity, other aspects also need to be considered. Energy problems must be seen in the wider perspective of agricultural and ecological development. The energy base necessary for this development will have to be both animal and human power. In the short term there is no scope for the mechanization of Ethiopian agriculture. Cultivation will continue to be carried out using animal traction. Improvements in the animal traction component, as discussed above, will not only lead to direct increases in agricultural productivity, but will also make it possible to drain and cultivate valley bottomlands, which are presently seasonally flooded and used only for dry-season grazing and hay production. At present food crops are mostly cultivated on hillsides. If appropriate short-seasoned or frost-resistant varieties can be found and if bottomlands can be drained, a major review of this agricultural practice could be considered: food crops could be cultivated on drained bottomlands, and the less fertile slopes could then be used by livestock, thus reversing the present situation. This would improve the fertility of soil on the degraded slopes and ensure the future survival of the local farming community. Studies done by ILCA have demonstrated that it is feasible to construct ponds with locally made earth scoops drawn by animals. Ponds would not only provide water for human and animal consumption, but could also be used for irrigation.

One important area in which energy inefficiency could be reduced is that of post-harvest losses. Introduction of improved threshing and storage methods could substantially improve the welfare of subsistence farmers. Other areas where progress could be made are veterinary and extension services. Reducing livestock mortality, and improving animal nutrition and management would allow for increased energy use throughout the traditional agricultural system.

Regardless of the approaches taken to improve the overall energy use on smallholder farms, changes will be slow to take place unless a proper infrastructure and adequate extension and technical support services are established. Until this is accomplished any so called improvements in energy use will be short-lived, and ultimately have a negative impact on the selected target population.

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Factors affecting output levels from African livestock sectors: An analysis of available data*

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Summary

CORRELATIONS *between aggregate national data on livestock output and possible causal factors were examined for the period 1965 to 1980 in order to explain differences between the performances of the livestock sectors of the countries of sub-Saharan Africa.*

Significant positive correlations were found between increases in output of all livestock products considered in the study (with the exception of pig meat) and increases in cereal output. Unless stated otherwise, increases and decreases throughout the study were measured in proportion to the size of output in the base period (1964–1966), but not in absolute terms.

The growth rate of GNP was not significantly associated with growth in meat output, but was moderately associated with growth in milk output, albeit at a modest level of statistical significance (6%).

None of the following factors were found to be associated with increases in output of any livestock products:

public expenditure on agriculture;
number of research scientists in agriculture;
density of research scientists in agriculture;
increases in the number of research scientists in agriculture;
increases in the density of research scientists in agriculture;
absolute research expenditure in agriculture;
relative research expenditure in agriculture;
increases in absolute research expenditure in agriculture;
increases in relative research expenditure in agriculture;
veterinary expenditure by government in 1965;
veterinary expenditure by government in 1977; and
increases in veterinary expenditure by government form 1965 to 1977.

It also appeared that none of the following macro-economic variables were associated with increases in output of any livestock products:

level of gross domestic investment;
change in level of gross domestic investment;
level of public consumption;
growth rate of public consumption; and
public expenditure on roads.

Whether marketing of agricultural inputs is handled by governments, by private operators or by a combination of the two, appears to make no difference to the output level of livestock products, with the exception of poultry meat.
Changes in output levels for all products, except pig meat and cow milk, were found to be associated with the rate of growth of the associated livestock population.

Introduction

This paper presents the results of a desk-study undertaken to examine changes in the output levels of livestock products from 1965 to 1980 and to give explanations for them. The purpose of the study was to discover why some countries in sub-Saharan Africa have performed appreciably better than others in terms of increasing their output of livestock products. Easily available aggregate data on livestock output (from FAO Production Yearbooks) were used, and data on factors that may affect livestock output were drawn from FAO Production Yearbooks and additional sources. The study covered 35 countries, and the following seven products were considered: beef, sheep and goat meat, pig meat, poultry meat, all meat (i.e. beef, sheep, goat, pig and poultry), cow milk and all milk (i.e. cattle, sheep and goat milk).

It was assumed that any causal relationships existing between factors would be reflected in statistical correlations at levels of significance less than 10%. For most of this study the working assumption was made that the data used were reliable. However, as the source of data varied, the quality of data is discussed in the final section and the possible impact of suspect data on the results of the study is considered.

Time period and countries studied

The study covered the period 1964/6 to 1979/81; this is subsequently referred to as the period 1965 to 1980. The starting point of 1965 was chosen in preference to 1970 to avoid exaggerating output and population growth rates for those countries that were affected by the 1968–73 Sahelian drought. The analysis focused on five different 'country sets' which ranged in size from 21 to 31 countries. To be member of a country set, a country needed to:

1. be included in the report *Accelerated development in sub-Saharan Africa* (World Bank, 1981) since this was the main source of macro-economic data; and
2. support a 'reasonably sized' population of animals from which the product in question is derived. This condition was set to avoid distorting the analysis with spurious estimates of computed variables (such as growth rates, offtake rates etc.) derived from small base estimates, since the latter are subject to large proportionate errors due to rounding.

Table 1. *Minimum population conditions (1979/81) and size of country sets.*

Commodity	Minimum population (million head)	Size of country set (No. of countries)
Beef	0.5 cattle	31
Sheep and goat meat	0.5 sheep and goats	29
Pig meat	0.1 pigs	21
Poultry meat	2.0 chickens	29
All meat	0.5 cattle and 0.5 sheep and goats	28
Cow milk	0.5 cattle	31
All milk	0.5 cattle and 0.5 sheep and goats	28

The minimum populations specifying each country set and the size of the country set are given in Table 1. It will be noted that the same country set is used for beef and cow milk. For the commodity 'all meat', minimum populations were specified for cattle and small ruminants only, since for all countries, except Nigeria, a great proportion of meat is produced by these species. If conditions relating to the minimum size of pig and poultry populations had also been applied, the country set would have comprised only 15 members, which was felt to be unsatisfactorily low. The country set for all meat is therefore the same as that for all milk. The members of each country set are listed in Table 2.

Table 2. *Members of country sets.*

Country	Beef cow milk	Sheep and goat meat	Pig meat	Poultry meat	All meat all milk
Angola	+	+	+	+	+
Benin	+	+	+	+	+
Botswana	+	+			+
Burundi	+	+		+	+
Cameroon	+	+	+	+	+
C.A.R.	+	+	+		+
Chad	+	+		+	+
Ethiopia	+	+		+	+
Ghana	+	+	+	+	+
Guinea	+	+		+	+
Guinea-Bissau			+		
Ivory Coast	+	+	+	+	+
Kenya	+	+		+	+
Lesotho	+	+			+
Liberia			+	+	
Madagascar	+	+	+	+	+
Malawi	+	+	+	+	+

Mali	+	+		+	+
Mauritania	+	+		+	+
Mozambique	+		+	+	
Niger	+	+		+	+
Nigeria	+	+	+	+	+
Rwanda	+	+	+		+
Senegal	+	+	+	+	+
Sierra Leone				+	
Somalia	+	+		+	+
Sudan	+	+		+	+
Swaziland	+				
Tanzania	+	+	+	+	+
Togo		+	+	+	
Uganda	+	+	+	+	+
Upper Volta	+	+	+	+	+
Zaire	+	+	+	+	+
Zambia	+		+	+	
Zimbabwe	+	+	+	+	+

Livestock in the context of Africa's food crisis

Table 3 shows the annual rates of increase for cereal, meat and milk output during the 1970s for sub-Saharan Africa. While the output level of each commodity rose, their rates of increase were less than that of the human population, which expanded at a rate of 2.9% p.a. Consequently there was a decrease in output per head over this period.

Table 3. *Growth rates in agricultural output, 1970–1980.*

Agricultural supply commodity	Growth rate (% per annum)
Cereals	1.2
Meat (all types)	1.8
Milk from cows	1.3

If food output per head is not to deteriorate still further during the present decade, then governments, development agencies and research institutes must have a clear understanding of how they can best promote increases in output levels from both the crop and livestock sectors.

Performances of African countries from 1965 to 1980

During the period 1965 to 1980 African countries seemed to have performed better with pig and poultry meat than with meat or milk from ruminants. Throughout this study, except when otherwise specified, performance is expressed in terms of increases and decreases measured in proportion to the size of output in the base year (1965), and not in absolute terms. Unweighted inter-country mean increases for pig and poultry meat were 153% and 125% respectively, compared to those for beef, 59%, and sheep and goat meat, 84%. The unweighted mean increase for cow milk was the lowest of all products at 28% while that for all milk was 64%. Although the coverage of countries is much lower for pig and poultry meat, it is notable that none of the countries for which data exist recorded decreases in either of these two products.

A second important feature is that reductions in output have occurred in some countries. What is particularly surprising is that these deteriorations have tended to occur outside the Sahel. The most serious reductions in meat production occurred in Uganda and Lesotho for sheep and goat meat, with output falling by one half. Both countries also suffered reductions in beef output—by a third in Lesotho and a fifth in Uganda. Tanzania too experienced a fall in sheep and goat meat production of 19%. Two other countries suffered decreases in beef output—Madagascar (28%) and Ethiopia, the continent's largest beef producer (6%).

Reductions in milk output have been even more common - for both cow milk and all milk 40% of countries recorded a decrease. Moreover, milk output decreases appear to be of a greater magnitude than those for meat products: the decrease of 81% in cow milk output in the, Central Africa Republic is the largest reduction of any product, and is closely followed by Zaire with a decrease of 70% in cow milk. Decreases in cow milk output occurred in a further 11 countries. Data for all milk are available for fewer countries; and of these Guinea (44%), Mali (29%), Upper Volta (27%), Sudan (24%), Niger (23%) and Rwanda (12%) experienced reductions.

On the brighter side, increases in production have occurred, the largest being that of pig meat for Ivory Coast (333%). Indeed, Ivory Coast appears to have been remarkably successful in terms of all meat products with the following increases: 218% for beef, 100% for sheep and goat meat, 258% for poultry meat, and 228% for all meat. The increase in cow milk, however, was only 22%. Somalia also appears to have achieved good results in both meat and milk products (although data for poultry meat do not exist). Its production of beef increased by 196%, sheep and goat meat by 316% ,all meat by 259% , cow milk by 86% and all milk by 310%.

Sudan and Rwanda can be regarded as rather unusual cases. Both these countries have made notable progress in improving their output of beef and sheep and goat meat. But they have both experienced decreases in cow milk and all milk output, suggesting a shift from milk production to meat production.

Unfortunately data on 1965 meat output do not exist for Kenya, and only exist in the case of beef for Botswana, which attained an increase of 81% in meat output. These two countries appear, however, to have achieved the highest increases of all sub-Saharan countries in the output of cow milk—Kenya 266% and Botswana 255%. In terms of all milk they are surpassed only by Somalia where sheep and goat milk is very important and increased substantially, resulting in an increase in all milk of 310%, compared to 280% for Kenya and 267% for Botswana.

In conclusion, therefore, Lesotho and Uganda appear to be the poorest performers on the meat front, with Central Africa Republic and Zaire suffering the greatest falls in milk output. The most successful countries in meat production are Ivory Coast and Somalia. Somalia is also the most successful producer of all milk. Kenya and Botswana have achieved the highest increases in cow milk. Sudan and Rwanda have increased meat output substantially but have simultaneously reduced their milk output.

The effect of climatic zone

Following Jahnke (1982), countries were classed according to six different climatic zones: arid, semi-arid, humid, subhumid highland and Sahelian. An analysis of variance (ANOVA) was then performed to test for significant differences in output increases between zones, the results being given in Table 4 below. In this table 'p' denotes the probability of differences in changes in output occurring by chance in the number of countries included in the analysis.

Table 4. *Increases in output of livestock products and climatic zone: ANOVA statistics.*

Product	p	No. of countries
Beef	0.38	20
Sheep and goat meat[a]	0.06	17
Sheep and goat meat[b]	0,12	17
Cow milk	0.02	29
All milk	0.02	16

p = probability of differences in changes in output occurring by chance.
a Climatic zone according to the distribution of sheep.
b Climatic zone according to the distribution of goats.

The whole of each country was classified as falling into that zone in which occurs the largest proportion of the country's animal population. Since separate distributions by climatic zone were available for cattle, sheep, goats and all ruminants, four different classifications were possible for each country. In the case of beef and cow milk, the classification according to the distribution of cattle was used. For 'all milk' the classification according to ruminant distribution was used, while for sheep and goat meat two different classifications were possible: one according to sheep distribution, the other according to goat distribution. The ANOVA results from both these classifications are given in Table 4. As no zonal distributions of pigs or poultry are available, the analysis does not extend to either pig meat or poultry meat. Finally, 'all meat' is not considered because of the importance, in many countries, of these two latter products in the total meat output.

Table 4 suggests that increases in supply are closely related to climatic zone only for cow milk and all milk. For both these products, the F statistic is significant at the 2% level.

Tables 5 (cow milk) and 6 (all milk) give unweighted mean increases by zone, together with standard deviations and the number of countries classified as falling into each zone.

Table 5. *Variation of increases in output of cow milk with climatic zone.*

Climatic zone	Mean of percentage increases	Standard deviation	No. of countries
Arid	170	120	2
Highland	86	126	4
Sahelian	26	52	6
Subhumid	14	32	8
Semi-arid	5	17	5
Humid	–35	65	4

Table 6. *Variation of increases in output of all milk with climatic zone.*

Climatic zone	Mean of percentage increases	Standard deviation	No. of countries
Arid	208	156	4
Subhumid	99	72	2
Highland	25	36	3
Sahelian	–8	21	6
Humid	–44	–	1

For both cow milk and all milk it appears that arid zone countries have been the highest performers, and humid zone countries the poorest performers.

The effect of the size of livestock population

The question of whether countries with small livestock populations have found it easier to increase output compared to countries with larger populations was investigated by correlating increases in output with the size of livestock population in 1965. The correlation statistics are given in Table 7.

Table 7. *Correlation statistics for increases in output of livestock products and absolute size of livestock populations in 1965.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	–0.35	0.11	22	77.00	*
Sheep and goat meat	0.01	0.95	18	83.01	*
Pig meat	–0.21	0.65	7	175.48	–0.10
Poultry meat	–0.55	0.13	9	177.87	*
Cow milk	0.06	0.73	31	24.68	*
All milk	–0.09	0.75	16	71.94	*

* less than 0.01
p = probability as for Table 4.

Table 7 suggests that there was no association between increases in output and the size of livestock population in 1965. This implies that countries with small populations have not found it any easier to increase proportional output than countries with large populations.

Livestock and cereal production

It is important to recognize any complementarity or competitiveness that may exist between the livestock sector and the cropping sector. In this section, therefore, the existence of correlations between increases in livestock output and increases in cereal production, cereal area and cereal yields is examined.

Calculations were carried out of correlations between increases in the output of livestock products and increases in cereal output, both increases being for the period 1965–1980. The correlation statistics are given in Table 8.

Table 8. *Correlation statistics for increases in output of livestock products (y) and increases (%) in cereal production (x).*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.44	0.04	22	43.42	0.34
Sheep and goat meat	0.74	*	18	45.40	1.25
Pig meat	0.28	0.54	7	108.48	1.28
Poultry meat	0.75	0.02	9	77.01	2.53
All meat	0.78	*	17	40.00	1.06
Cow milk	0.44	0.01	31	8.05	0.44
All milk	0.68	*	16	22.49	0.80

*less than 0.01
p = probability as for Table 4.

Table 8 suggests that significant positive associations exist between the increase in output of all livestock products (except pig meat) and increases in cereal output.

The slopes of the regression lines indicate the percentage increase in cereal output that is associated with a 1% increase in each of the livestock products.

The data were examined further by correlating the increase in the output of livestock products with increases (%) in cereal area and yields. Table 9 gives the statistics for the correlations between increases in supply and increases in cereal area.

Table 9. *Correlation statistics for increases in output of livestock products and increases in cereal area.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.32	0.15	22	48.26	0.27
Sheep and goat meat	0.46	0.06	18	55.13	1.05
Pig meat	0.38	0.40	7	116.34	1.11
Poultry meat	0.55	0.12	9	86.85	1.75
All meat	0.49	0.05	17	48.35	0.92
Cow milk	0.27	0.15	31	15.89	0.27
All milk	0.30	0.27	16	46.09	0.40

p = probability as for Table 4.

The statistics show that for all products, increases in output are positively correlated with increases in cereal area. However, only two of these correlations (those for sheep and goat meat and all meat) are statistically significant at the 10% level.

Table 10 gives the correlation statistics between increases in output of livestock products and increases in cereal yields.

Table 10. *Correlation statistics for increases in output of livestock products and increases in cereal yields.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.16	0.48	22	57.03	0.20
Sheep and goat meat	–0.40	0.10	18	78.28	0.82
Pig meat	–0.44	0.32	7	166.55	2.47
Poultry meat	0.24	0.53	9	125.78	1.57
All meat	0.41	0.10	17	70.29	0.67
Cow milk	0.22	0.24	31	25.23	0.34
All milk	0.70	*	16	46.09	0.40

* less than 0.01
p = probability as for Table 4.

Whereas, in general, increases in meat output are more closely correlated with increases in cereal area than are increases in milk output, the reverse in the case with cereal yields. Except in the case of pig meat, all the correlations are positive.

However, with these data the phenomenon of the 'exceptional country' can be often encountered. When the scattergrams of these correlations are examined, one country may sometimes be found to lie so far away from the remainder that the magnitude and sign of the correlation coefficient can be determined solely by the presence of this single country.

In this particular case the sheep and goat meat correlation and the all meat correlation together with that of all milk, appeared from the scattergrams to be strongly influenced by the case of Somalia which recorded an increase in cereal yields of 181%, greatly in excess of the modal increase. For instance, if Somalia were excluded from the all meat correlation, the statistics would be modified as shown below:

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
All meat	–0.26	0.33	16	61.92	–0.72

If Somalia is excluded, therefore, the data provide no evidence to suggest that an association exists between increases in the output of all meat and increases in cereal yields.

The effect of economic incentives on supply

Livestock output may be stimulated both by giving producers greater incentives to produce and by providing them with the technology and material inputs necessary to remove constraints on output. This section considers economic incentives, while the next section deals with technology and research inputs and the general economic climate surrounding livestock production.

GNP and human population growth

For an accurate representation of economic returns to livestock producers it would be desirable to analyse data on the volume of demand, on the prices of outputs and inputs, on the ease and convenience of marketing outputs and purchasing inputs, and lastly on the risks involved in livestock production. Such data are not readily available for any significant number of African countries. Instead two variables for which data do exist were used as proxies for economic incentives. The growth of GNP is associated with changes in the volume of demand, through the effect of the income elasticity of demand, and probably also with the provision of better facilities for marketing products and inputs, and with an upward pressure on output prices. The second variable considered, that of human population growth, is directly associated with the volume of demand. It has not been possible, however, in this study to take into account changes in external trade, either imports or exports, which for some countries are substantial.

The values of the correlation coefficients between changes in livestock output and GNP suggest that there is no strong association except possibly for poultry meat. In the case of sheep and goat meat and all meat the coefficients unexpectedly have a negative sign. Only for milk are the correlations statistically significant at a modest level.

However, the correlation coefficients for cow milk are wholly dependent on the cases of Botswana and Kenya, which recorded exceptionally high GNP growth rates and increases in cow milk output.

For all milk, the correlation coefficients are wholly dependent on the case of Botswana which recorded an increase in supply of 267%. Table 11 shows the coefficients after the removal of Botswana and Kenya which suggest that no strong association exists between increases in milk supply and the GNP growth rate.

Table 11. *Correlation statistics for increases in output of milk (y) and GNP growth rate (x) (excluding Botswana and Kenya).*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Cow milk	0.05	0..81	29	8.42	1.000
All milk	0.23	0.41	15	–6.99	17.43

p = probability as for Table 4.

The growth of human population may be an important factor stimulating livestock producers to increase output, especially in countries with sizeable pastoral populations. Such populations are largely or wholly dependent on animal products for their nourishment, and therefore express a biological, rather than simply an economic, demand for livestock products. Table 12 gives the correlation statistics for increases in output with population growth rates for the period 1970–80. The results, however, suggest that no statistically significant association exists between increases in supply and population growth rates: output does not appear to be sensitive to human population growth rates.

Table 12. *Correlation statistics for increases in output of livestock products and human population growth rate.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.34	0.12	22	–26.37	32.10
Sheep and goat meat	–0.03	0.92	18	92.83	–3.20
Pig meat	0.46	0.30	7	1.43	48.50
Poultry meat	0.39	0.30	9	13.16	39.06
All meat	0.32	0.20	17	–14.32	32.94
Cow milk	0.06	0.73	31	8.63	7.26
All milk	0.11	0.68	16	–4.77	26.71

p = probability as for Table 4.

The removal of output constraints

Measures to remove output constraints were categorised into two broad types: those which are specific to the agricultural sector (or one of its two components, livestock and crop production) and those which affect the economy as a whole on a wider front.

Sector specific measures

In an attempt to study the effect of sector specific measures on increases in the output of livestock products, the following were examined:

> government expenditure on agriculture:
> the number of research scientists working in agriculture;
> the density of research scientists working in agriculture; increases in the number of research scientists working in agriculture; and expenditure on agricultural research.

However, the calculation of correlations between the above measures and increases in the output of livestock products is not really satisfactory, as all the above measures are related to the agricultural sector as a whole. Data specific to the livestock research and livestock production sectors were not available. The correlations performed could thus be considered, at best, as proxies for the desired correlations.

In the event the results of the correlations which were performed were mainly insignificant. These results may reflect a lack of causal relationships between increases in the output of livestock products and those measures (e.g. government expenditure on livestock production, the number of scientists working in livestock research etc.) which it had been hoped to examine. However, the insignificant correlations were more likely due to the real causal variables being inadequately reflected in the proxies used.

One measure specific to the livestock sector for which data were available for some countries was veterinary expenditure. This measure was expressed as expenditure per 1000 head for the years 1965 and 1977 and its correlation with increases in the supply of livestock products, was examined. The results are given in Table 13.

Table 13. *Correlation statistics for increases in output of livestock products and veterinary expenditure per 1000 head, 1965.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.83	*	9	10.03	57.57
(excl. Ivory Coast)	(0.49	0.22	8	15.09	47.39)
Sheep and Goat meat	0.10	0.81	8	63.28	10.03
Pig meat	–0.06	0.96	3	271.90	–0.25
Poultry meat	–0.67	0.21	5	–68.23	29.37
Cow milk	–0.07	0.84	11	19.73	3.73

* less than 0.01
p = probability as for Table 4.

The table shows that the strong correlation for beef is largely dependent on the case of Ivory Coast. When this country is excluded from the beef output figures, then the statistics indicate that the 1965 levels of veterinary expenditure were not associated with increases in output of livestock products at significance levels of less than 10%.

An additional correlation was performed between veterinary expenditure per 1000 head in 1977 and increases in output. The results are given in Table 14.

Table 14. *Correlation statistics for increases in output of livestock products and veterinary expenditure per 100 head 1977.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.79	0.03	7	40.24	19.32
(excl. Ivory Coast)	(–0.15	0.78	6	64.36	–14.89)
Sheep and goat meat	0.39	0.38	7	57.25	15.25
Pig meat	0.81	0.40	3	193.54	6.02
Poultry meat	0.55	0.63	3	–108.12	96.62
Cow milk	0.07	0.85	9	15.31	1.52

p = probability as for Table 4.

Again when beef output figures for Ivory Coast are excluded, the results suggest that little association exists between increases in the output of any livestock product and 1977 veterinary expenditure.

The suggestion that the level of veterinary expenditure does not influence the level of output was investigated further by correlating proportional increases of veterinary expenditure from 1965 to 1977 with increases in output. The results only served to reinforce the hypothesis that veterinary services have had no consistent impact on the output of livestock products.

General measures for removing constrains

The general progress of a nation's economy can affect the output of livestock products, not only by providing economic incentives on the demand side but also by improving the general infrastructure in a way that makes output responses easier. The data for associations between livestock output and four macro-economic variables were therefore tested. The variables were:

1. the level of gross domestic investment;
2. the level of public consumption, which is a proxy for the extent of state participation in the economy;
3. public expenditure on roads; and
4. government control of marketing agricultural inputs.

Clearly in the case of these inputs, the causal chain between the independent and dependent variables is not sharply defined.

The results of examining the correlation between increases in output and the level of gross domestic investment, expressed as the mean percentage of GOP over the period 1960 to 1979, suggest that there is no association between increases in output and the level of gross domestic investment.

Since the 1960s, some countries have experienced increases in the level of gross domestic investment while others have suffered decreases. An examination was made of the effect of this factor on the output of livestock products. It appears that the two variables are not closely associated, except in the case of poultry meat. This implies that increases in the output of livestock products are not influenced by changes in the level of gross domestic investment.

An examination was also made of the association between the level of public consumption (expressed as percentage of 1979 GDP) and increases in output. The results suggest that increases in output occur independently of the level of public consumption, with the possible exception of cow milk.

It is possible that the livestock sector is affected more by changes in public consumption levels than by the level itself. Table 15 gives the results of correlating increases in output with the growth rate in public consumption over the period 1970 to 1979.

Table 15. *Correlation statistics for increases in supply and growth rate in public consumption.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.12	0.63	19	55.68	1.32
Sheep and goat meat	0.08	0.76	16	85.17	1.39
Pig meat	0.29	0.58	6	92.80	6.05
Poultry meat	0.31	0.49	7	87.73	11.10
All meat	0.12	0.66	15	72.09	1.65
Cow milk	0.43	0.02	28	–0.88	5.53
(excl. K, B and M)[a]	(0.12	0.58	25	4.71	0.90)
All milk	0.37	0.21	13	28.51	6.96

p = probability as for Table 4.
[a]K = Kenya, B = Botswana and M = Mauritania.

The results suggest that there is a significant positive correlation between increases in output of cow milk and the growth rate of public consumption. However, when Kenya, Botswana and Mauritania are excluded the figures suggest that increases in the outputs of cow milk are not generally associated with the growth rate of public consumption. For all other products, increases in supply are not associated with the growth rate of public consumption.

No association between public expenditure on roads and increases in output of livestock products was found using data for 1978. In an attempt to study the effect of government control of marketing of agricultural inputs (fertilizer, chemicals and farm equipment) three marketing policies were distinguished: government controlled, private and a mixture of the two. Data available for the period 1965–1980 were scarce, and the results suggested that only for poultry meat did marketing policy have an effect.

The effect of livestock population growth

So far, few factors explaining the increases (and in some cases decreases) that have occurred in the output of livestock products from 1965 to 1981 have been found. The question arises as to whether changes in supply are largely a function of changes in animal populations, which are themselves largely independent of other factors reviewed. To answer this question increases in supply were compared with population increases, and strong correlations were found in all cases except pig meat and cow milk. The statistics are given in Table 16.

Table 16. *Correlation statistics for increases in output of livestock products and increases in population.*

Dependent variable (y)	Correlation coefficient	p	No. of countries	Intercept	Slope
Beef	0.58	*	22	25.77	0.68
Sheep and goat meat	0.76	*	18	1.63	1.32
Pig meat	0.59	0.16	7	57.70	0.51
Poultry meat	0.84	*	9	27.72	1.41
All meat	0.78	*	17	13.76	1.40
Cow milk	0.08	0.69	31	22.44	0.10
All milk	0.69	*	16	–8.82	1.55

* less than 0.01
p = probability as for Table 4.

The above statistics suggest that increases in livestock populations have been an important factor in the increase of all products except pig meat and cow milk. The percentage of variation explained by this single factor is given in Table 17.

Table 17. *Percentage of variation explained by increases in population.*

Variable	% of variation[a]
Beef	34%
Sheep and goat meat	58%
Poultry meat	71%
All meat	35%
All milk	48%

[a] Taken as the square of the correlation coefficients (%) given in Table 16.

The slope of the regression line shown in Table 16 is equivalent to the percentage increase in output that is associated with a 1% increase in the livestock population.

The implications of this conclusion are very serious. It implies that simple increases in population have been a major cause of increased output. Without a major breakthrough in the control of trypanosomiasis, few countries in Africa can continue to support expanding livestock populations, and thus Africa as a whole cannot continue to rely as heavily on thus factor as it appears to have done in the past.

Quality of data

In this study output and livestock population data were taken from FAO Production Yearbooks. The data on climatic zone were from Jahnke (1982) while those concerning veterinary services were provided by Addis Antenneh (I983). Oram and Bindlish (1981) provided the data on scientist numbers and research expenditure. The macro-economic data were taken from World Bank (1981;1982).

IFPRI (1981) draws attention to the problem of inaccurate data on African agriculture. It points out that estimates compiled by different bodies can vary markedly. The example is given of FAO and USDA estimates of cereal production in Africa where, for the countries reported in common by the two systems, differences 'reached 14% for wheat in 1975, 21% for maize in 1970 and as high as 45% for millet in 1965'.

In this study, three-year means (1964 to 1966 and 1979 to 1981) were used wherever possible. This probably reduced the influence of freak years. Where a run of three years was not available, a mean of two years was computed or even just a single year's estimate was used.

A second measure taken in this study to counter spurious results due to poor data was the exclusion of countries with small livestock populations. This was done on the grounds that rounding estimates to the nearest thousand units can distort other variables based on them. By requiring a certain minimum size of population for the inclusion of any country in the set considered, it is hoped that this type of distortion was generally avoided.

Countries with exceptional values were excluded from some of the correlations on the grounds that they may be countries for which a different production function applies. However, their removal may be equally valid on the grounds that the estimates are very inaccurate. In such a case the adjusted correlations would more truly reflect the real situation. Despite these three measures, serious inaccuracies are likely to persist in the data.

The fact that the study revealed few strong or significant relations between causes and effects may reflect that there really are no strong causal relations; but it is much more likely that the lack of correlations was due to problems of analysis. In this study 'easily available' data were used i.e. data published internationally. The model used was therefore determined by the availability of data, and in many cases the 'causal variables' used were at best proxies for the real variables for which data were not available. Another problem was that even where data was available their level of accuracy was extremely low.

The highest correlations occurred between livestock output and livestock populations, suggesting an extension of livestock systems rather than an intensification of them. However, in any one country the same statistician may be estimating the figures for populations and output; and the output figures may be reached by applying a guessed and near constant yield factor to a guessed population. Thus even the livestock output/population correlation cannot be treated as firm evidence of causality.

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Screening of West African plants for anthelmintic activity*

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Summary

EIGHTEEN *plants traditionally used for the treatment of human and animal helminthiasis in Africa were screened for anthelmintic activity using the Nippostrongylus—rat model. Aloë barteri, Terminalia avicennioides, Annona senegalensis, Cassia occidentalis, Anogeissus leiocarpus and Diospyros mespiliformis showed significant activity, giving deparasitizations of 92, 89, 75, 69, 60 and 58% respectively compared to untreated controls.*

Introduction

Helminthiasis has long been recognized as a major constraint to the productivity of ruminants in Nigeria and elsewhere, and has been the cause of serious economic losses (Akerejola et al, 1979; Okun et al, 1980). For example in Nigeria the economic loss due to helminthiasis in small ruminants alone has been estimated to be at least 144 million naira annually, through death, weight loss and liver condemnation (Akerejola et al, 1979). In addition more than 800 million people in the world are affected by helminthiasis (Stoll, 1947). Helminths are more widespread in tropical regions due to climatic and sociological factors (Cavier,1973).

The major control measure against helminthiases in Nigeria is chemotherapy. However, the availability of drugs varies (Okun et al,1980).

The significance of helminthiases has been recognized by local people and herdsmen from the earliest times who have made various attempts at control through the use of medicinal plants. Fulani herdsmen in Nigeria recognize animal helminthiasis to be a problem of greatest significance in calves of less than a year old and routine herbal treatment is started within 1 week of birth (Ibrahim et al,1983a).

Only a few of the plants used traditionally as anthelmintics in Africa have previously been studied. *Hunteria umbellata (Polyadoa umbellata),* which has been used as an anthelmintic for humans in Nigeria, was shown to have the same anti-ascarid potency as pure piperazine base by Onuaguluchi (1964). The plants *Combretum mucronatum* and *Mitragyna stipulosa,* used for the treatment of guinea-worm in African traditional medicine, were found to be effective against helminthiasis and their use has been recommended, as has that of a combination of *Elaeophorbia drupifera* and *Hillarialatifolia* (Ampofo, 1978).

A number of plants, either those used in African traditional medicine as anthelmintics or species closely related to them, have been tested elsewhere and some have been found to be useful. Raw garlic *(Allium sativum),* used in Nigeria as a vermifuge (Dalziel, 1937), was shown to have some activity against *Ascaridia galli* in chicken (Das and Thakuria, 1977) and to inhibit the embryonation of the eggs of *Necator americanus* and *Ancylostoma caninum* (Bastidas,1970). The juice of *Citrus aurantifolia is* used as a vermifuge in Senegal and Sierra Leone and as a treatment for dysentery in West Africa (Dalziel, 1937). A number of *Citrus* species such as *C. decumara, C. acida, C. aromaticum* and C. *medica* have been found to be active against *Ascaris lumbricoides* (Kaleysa, 1975).

Diospyros mespiliformis is used in Nigeria as a veterinary vermifuge and as a remedy for dysentery in humans (Dalziel, X937).Diospyrol, from the related plant *D. mollis,* was shown to be superior to bephinium against *Necator americanus* in hamsters and against *Hymenolepis nana* in mice (Sen et al,1975). Decoctions of the berries of *D. mollis* have been used in antihookworm campaigns in Thailand (Sadavongvivad, 1980). Similarly several *Cucurbita* species, such as *C. maxima, C. moschata* and *C. aromatica,* have been shown to be taeniacidal in mice (Albert et al, 1972), in rats (Srivastava and Singh, 1967) and in man (Lozoya,1978; Plotnikov et a1,1973).

Some of the plants used as traditional anthelmintics in Africa have been studied and the chemical basis of their action outlined. The alkaloids pelletierine and isopelletierine are responsible for the taeniacidal action of *Punica granatum* (Oliver, 1960). The main taeniacidal components of the female flowers of *Hagenia abyssinica,* used in Ethiopian traditional medicine, are Phloroglucinol derivatives (α–kosin, β–kosin, protokosin and kosotoxin) (de Carneri and Vita, 1973).

There are also some plants common in Nigeria whose use as anthelmintics elsewhere has been confirmed experimentally. Such plants include *Tribulus terrestris* whose anti-ascarid use in India was confirmed against *Ascaridia galli* (Chakraborty et al, 1979), as well as *Anacardium occidentale,* the oil of which is active against *Ascaridia galli* in chicken (Varghese et al, 1971) and against hookworms in dogs and man (Cavier,1973).

However, most of the plants used to treat helminthiasis in Africa have not been studied. It is important to screen local herbs in order to supplement modern drugs and to provide new chemical leads. Effective herbs may be used where modern drugs are not available, or when the herbs prove to be more effective, safer or less costly. There is also a need to establish standard dosages for herbal preparations, and to investigate their toxicity (Nwude and Ibrahim, 1980; Oliver, 1960) as traditional medicine is still very much in use.

This study was designed to detect and salvage traditional anthelmintic herbs which may be used for the control of parasitic gastroenteritis in animals using *Nippostrongylus braziliensis* as the indicator organism in rats.

Methods

Information was collected from Fulani herdsmen in Zonkwa, Kurmin Biri and Abet in Kaduna State on the plants used in the control of parasitic gastroenteritis in cattle. The plants' vernacular names, parts used, method of preparation, route and frequency of administration, and any side effects resulting from their use in animals or man were also recorded. The plants used were collected and identified.

Similar information was then reviewed from the literature on plants used in man and animals for the control of helminthiasis.

Plants to be screened for activity against helminths were selected from the information collected on the basis of accessibility. Selected plants were collected and their identity confirmed.

Plant material

Selected plants were collected for extraction in the dry season (April 1982 and November 1982 to April 1983). As much as possible the parts used in traditional medicine were collected. Root, leaf, bark, seed and stem material were dried in locally designed and constructed wire trays. The dried material was then pounded to powder in a wooden mortar. Where the juice was used, this was done within one hour of collection.

The dried, powdered material was mixed with methanol in a ratio of 1:5 w/v in large containers and allowed to stand for 48 hours at room temperature. The liquid was then decanted and filtered. The filtrate was evaporated to dryness at 40°C under low pressure using a rotary evaporator coupled to a thermoregulator. The solid extract obtained was removed and stored in bottles at 4°C until required.

Leaf juices were obtained by pounding fresh samples in a mortar and then extracting the juice by straining through several layers of gauze. The juice was filtered and stored at 4°C until required.

The maximum convenient concentration (MCC) of each solid extract was estimated by determining the minimum amount of water that dissolved or suspended 1.0 g of the extract such that the solution or suspension could be easily delivered through an 18 gauge needle at room temperature. A solution of the extract at the MCC was then made and stored at 4°C until required.

It was assumed that the maximum concentration that could conveniently be administered orally to rats was 5 ml/kg. The highest dose that could be administered to rats (HDR) was then calculated by multiplying the maximum concentration by 5 for each extract. In the case of proprietary drugs, it was assumed that the maximum concentration was that used in the commercial preparation, and the highest dose was calculated as above. This dose was used to test the toxicity and activity of the extract. Leaf juices were used at 5 ml/kg as was water in the case of control animals.

Experimental animals

White rats bred in the Department of Veterinary Physiology and Pharmacology at Ahmadu Bello University and weighing 50 to 100 g were used. The animals were maintained on commercial mice cubes (Pfizer Livestock Feed Co. Ltd. Kaduna) and water. Sawdust was used as bedding and was changed every 2 days. Individuals were identified by marks on their tails and cages. Random faecal samples were collected from rats in the animal room and examined regularly for helminth ova, and the entire rat population in the animal room was dewormed by adding piperazine at 7 mg/ml/day to their drinking water for 7 days once every 2 months. Young animals were separated from adults at an early age, and all rats artificially infected were kept in a separate room to prevent contamination of the controls.

Pilot toxicity studies

Prior to screening, the effect of each extract following oral administration with the maximum dose (HDR) once a day for 3 consecutive days was tested. Three to five rats were used to test each extract. For each batch of rats one group of five rats was used as control and the rats were dosed orally with water at the rate of 5 ml/kg for the same duration. Animals were observed for 2 weeks after administering the test substance. Extracts producing a lethal effect at this dose were subjected to further investigation to determine the maximum tolerated dose by dose titration using 5 rats for each dose level and a log interval of 1.6. For toxic extracts, the maximum tolerated dose was used for the chemotherapeutic trials.

Helminth material

A rat adapted strain of *Nippostrongylus braziliensis* Travassos, 1914, (Nematoda: Trichostrongylidae) was used in the laboratory as the primary screen. It was maintained in the laboratory rat by bimonthly passage. Young rats were injected subcutaneously in the cervical region with 2000 infective larvae in a volume of 0.2 ml for maintenance, using an 18 gauge needle attached to an insulin syringe (Standen, 1963).

Coprocultures

The droppings of rats artificially infected with *N. braziliensis* were collected and soaked in water for 4 hours. Excess water was then decanted, the faeces crushed in a glass mortar, transferred to plastic containers in lots of about 5.0 g and shaken with glass beads. The material was then mixed with about 1 litre of water and strained through several layers of gauze. The filtrate was transferred to jars. The supernatent solution was then discarded and the sediment mixed with vermiculite in labelled plastic petri dishes and incubated at 27°C for 7 days.

The infective 3rd stage larvae (L_3) were recovered from 7 to 14 day old vermiculite—faecal cultures using modified Baermann apparatus. The L_3 obtained were washed several times with distilled water and their number determined by dilution counting. The volume was then adjusted to give 200 L_3 in 0.2 ml for screening, and 2000 L_3 in 0.2 ml for maintenance.

Artificial infection of rats

Rats were infected subcutaneously in the cervical region with 200 L_3 per 0.2 ml per rat using an 18 gauge needle attached to an insulin syringe on day 0. Fresh faecal pellets were collected from each rat by squeezing them out of the rectum into labelled plastic tubes 7 days after infection. Helminth eggs were recovered and examined qualitatively by flotation using 33% zinc sulphate at a specific gravity of 1.180. Rats not shedding *Nippostrongylus* ova and those shedding other helminth ova were discarded from the experiment.

Chemotherapeutic trials

This was done essentially as described by Cavier (1973). Trials commenced on the 10th day after experimental infestation. Five rats were used to test each extract. Animals were dosed orally on the 10th, 11th and 12th days of infection with the estimated maximum dose using an 18 gauge needle fitted with a plastic canula. For each batch of trials, five animals were dosed with water at 5 ml/kg and were used as controls.

On the 14th day the animals were starved and were killed on the 15th day in a chloroform chamber. The rats were autopsied and the first 15 cm of the small intestine removed, sectioned longitudinally, enclosed between two plates of thick glass, and examined under a dissection microscope. The number of worms easily visible were counted.

The screen was tested with oxfendaxole (Systamex (R), supplied by the Welcome Foundation Ltd, London, England) at the beginning of the trials.

Interpretation of results

Results were analysed according to .the method recommended by Cavier (1973). The percentage of deparasitization was calculated using the formula

$$\frac{N-n}{N}\times 100$$

where N = average number of worms found in control animals, and
n = average number of worms found in groups of treated animals.
A deparasitization of 50% was considered significant.

Results

Information on about 300 plant species used as anthelmintics in man and his animals throughout Africa was collected. Most of the plants reported in the literature have been used against helminthiasis in man. About 30 plant species were found to be used by Fulani herders in Kaduna State for the control of helminthiasis in cattle.

In the pilot toxicity studies, none of the 18,plants tested had a lethal action in rats at the doses tested.

Chemotherapeutic trials

The results are summarized in Table 1. Table 2 presents a summary of background information on the plants found to be effective.

Table 1. *Summary of screening of plants against* N. braziliensis *in rats.*

Plant or reagent	Part used	Dose (g/kg)	% deparasitization	Activity
1. *Acacia albida*	bark	20.0	34	inactive
2. *Aframomum melegueta*	root	10.0	22	inactive
3. *Afromosia laxiflora*	leaf	20.0	23	inactive
4. *Aloë barteri*	leaf juice	5.0 (ml/kg)	92	very active
5. *Anogeissus leiocarpus*	bark	20.0	60	active
6. *Annona senegalensis*	bark	20.0	75	active
7. *Blumea aurita*	leaf juice	5.0 (ml/kg)	1	inactive
8. *Boswellia dalzelii*	bark	25.0	38	inactive
9. *Calotropis frocera*	root	5.0	7	inactive
10. *Cassia occidentalis*	leaf	12.5	69	active
11. *C. tora*	leaf	20.0	–8	inactive
12. *Diospyros mespiliformis*	bark	20.0	58	active
13. *Guiera senegalensis*	leaf	5.0	–4	inactive
14. *Khaya senegalensis*	bark	5.0	–21	inactive
15. *Lawsonia inermis*	root	5.0	–16	inactive
16. *Tamarindus indica*	root	5.0	–23	inactive
17. *Terminalia avicennioides*	root	2.5	89	very active
18. *Vitex doniana*	root	10.0	14	inactive
19. Oxfendazole (Systamex$^{(R)}$)		0.11	100	very active

Table 2. *Traditional uses of plants with anthelmintic activity.*

Plant	Vernacular names	Comments
1. *Aloë barteri*	Hausa: *zabuwa*	The leaf juice is used in Nigeria topically for the treatment of guinea-worm. (Dalziel, 1937).
2. *Anogeissus leiocarpus*	Hausa: *marke* Igbo: *atara* Yoruba: *ayin*	The bark and seed are used in Nigeria for treatment or prevention of worm infestation in equine species. (Dalziel, 1937; Lely, 1925; Oliver, 1959; Oliver, 1960).
3. *Annona senegalensis*	Hausa: *gwandar daji*Igbo: *uburu-ocha*Yoruba: *abo*	Leaves, bark and roots are used as vermifuge for horses in Nigeria and large quantities of the fruit are eaten in the treatment of guinea-worm. (Dalziel,1937; Oliver, 1960).
4. *Cassia occidentalis*	Hausa: *rai'dore* Igbo: *okamo* Ashanti: *ananse dua*	The leaves are used in West Africa for the treatment of guinea-worm and as a vermifuge for children. (Dalziel, 1937).
5. *Diospyros mespiliformis*	Hausa: *kanya* Igbo: *onye-koji*Yoruba: *kanran*	The bark is used in Nigeria as a vermifuge for horses. (Dalziel, 1937).
6. *Terminalia avicennioides*	Hausa: *baushe*Fulfulde: *bo'di*	The leaves and roots are used to treat gastro-intestinal helminthiasis in calves in Nigeria. (Ibrahim et al, 1983b).

Six of the 18 plants tested showed significant activity against *N. braziliensis* in rats. *Aloë barteri* (leaf juice) and extracts of *Terminalia avicennioides* (root), *Annona senegalensis* (bark), *Cassia occidentalis* (leaf), *Anogeissus leiocarpus* (bark) and *Diospyros mespiliformis* (bark) were found to be effective, with deparasitizations of 92, 89, 75, 69, 60 and 58% respectively.

The alcoholic extracts of the plants *Aframomum melegueta* (root), *Afrormosia laxi*flora (leaf), *Boswellia dalzelli* (bark), *Calotropis procera* (root), *Cassia tora* (leaf), *Guiera senegalensis* (leaf), *Khaya senegalensis* (bark), *Lawsonia inermis* (root), *Tamarindus indica* (root), *Vitex doniana* (root) and the leaf juice of *Blumea aurita* were found to be ineffective.

Oxfendazole (Systamex (R)) gave a deparasitization of 100%.

Disscusion

The results indicate that *Aloë barteri, Terminalia avicennioides, Annona senegalensis, Cassia occidentalis, Anogeissus leiocarpus* and *Diospyros mespiliformis* are effective against adult*Nippostrongylus braziliensis* in rats at non-toxic doses. The chemotherapeutic links between *N. braziliensis* and trichostrongyles in sheep and between *N. braziliensis* and hookworms in dogs and man have been established (Whitlock, 1945; Standen, 1963).

The results therefore justify secondary screening of these plants in sheep and dogs.

The results of this study do not rule out the possibility that some of the apparently inactive plants do possess activity, even against other trichostrongyles, since *N. braziliensis is* more resistant to anthelmintics than most other strongyloids (Standen, 1963; Cavier, 1973). For example had *N. braziliensis* alone been used to screen phenothiazine, the drug might not have been discovered (Gordon, 1957). It is desirable to include several representative groups or families in screening tests before discarding a compound (Standen, 1963).

These plants have not previously been tested for activity against helminths, but species of *Aloë* and *Cassia* have been used extensively as indirect irritant purgatives. In fact these were once considered as the most important drug plants of the African continent (Githens, 1948). Following oral administration, they are absorbed and metabolized, possibly in the liver, to give active anthraquinones., which are then secreted into intestine giving their observed purgative action (Brander and Pugh, 1977).

The synthetic 1:8 dihydroxyanthraquinone is highly effective against all the large bowel parasites of sheep i.e. *Oesophagostomum columbianum, O. venulosum, Chabertia ovina* and *Trichuris spp.,* and to possess moderate activity against *Haemonchus contortus* at non-toxic doses (Gordon, 1955).

It seems possible that the anthelmintic factors in *Cassia occidentalis* and *Aloë barteri* are precursors of anthraquinones. A species related to *A. barteri, A. barbaden*sis, has been shown to be active against plant nematodes (Mahmood et al, 1982).

Although the seeds of *C. occidentalis* are known to contain the heat labile toxic material chrysarobin, the roots, leaves and stems are toxic to cattle only when large amounts are consumed (Nwude, 1977), and no toxic signs were observed with the leaves at the dose tested in rats in this study.

The anthelmintic factors contained in *Anogeissus leiocarpus, Annona senegalensis* and *Terminalia avicennioides,* all of which were found to be effective in this study, are unknown, but related species have been studied for action against other organisms. *Annona squamosa* has been shown to be active against the plant nematodes *Meloidogyne incognita* and *Rotylenchulus reniformis* by Mahmood et al (1982), while *Annona senegalensis* and *Terminalia* mollis are molluscicidal against *Bulinus globosus* (Adewumi and Sofowora, 1980). However, *Terminalia chebula* was reported to be inactive against *Ascaridia galli* in chickens (Sharma et al,1967).

Diospyros Mollis has been reported to be used as a traditional anthelmintic in Thailand and the berries were used in antihookworm mass chemotherapy for more than a decade until implicated as the cause of blindness in humans (Sadavongvivad, 1980). The anthelmintic principle in *D.* mollis is Diospyrol (1,1', 8,8'-tetrahydroxy 6-6'-dimethyl-2, 2'-binapthalene) (Sen et al, 1975). It is possible that the plant *Dios*pyros mespiliformis, which we found to be effective, contains components similar to *D.* mollis. The plant is therefore recommended for detailed toxicological investigation in order to determine its effect on the eye in animals as a prerequisite to its use as an anthelmintic.

Further studies are recommended with other laboratory models both for the plants found to be effective and those found to be inactive against *N. braziliensis* in order to determine the spectrum of activity of the former and possible action against other helminths with the latter. Different parts of the plants found to be effective should be screened and their toxicity and activity tested using secondary screens.

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The environment of the Ethiopian Rift Valley compared to other areas of Africa*

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**Summary of the ILCA Internal Document `The environment of the Ethiopian Rift Valley in relation to other areas of Africa'.*

SUMMARY

THE CLIMATES, *soils and vegetation of the Ethiopian Rift Valley were compared with those of other areas of Africa with reference to the screening of forage species.*

The climates of the Rift Valley are diverse and range from hot and arid to cool (subtropical) and humid. In general most of the Ethiopian Rift Valley is similar to the semiarid and subhumid regions of East Africa with their bimodal rainfall. There is also an area in the north of the valley with a climate similar to that of the Sahel region of West Africa.

The soils of the Rift Valley are largely derived from recent volcanic rocks and, by comparison with many areas of Africa, their base status is generally good. Constraints to forage production include low phosphorus levels, micronutrient imbalances and in some cases poor physical structure. The areas with soils most similar to those of the Rift Valley of Ethiopia are the equivalent rifts in Kenya, Tanzania and Zambia.

Three major vegetation zones are found in the Rift Valley: the subhumid zone, the semi-arid zone and the arid zone.

The grass floras from 20 areas in West and East Africa, including three from the Ethiopian Rift Valley, were compared using Hartley's agrostological index. Classification based on cluster analysis of these sites showed that the semi-arid and arid areas at the northern and southern ends of the Rift Valley were closest to areas in the Sahel region of West Africa, while an area at a higher altitude in the central Rift Valley was close to an area in the Rift Valley of Kenya and to two sites in Sudan.

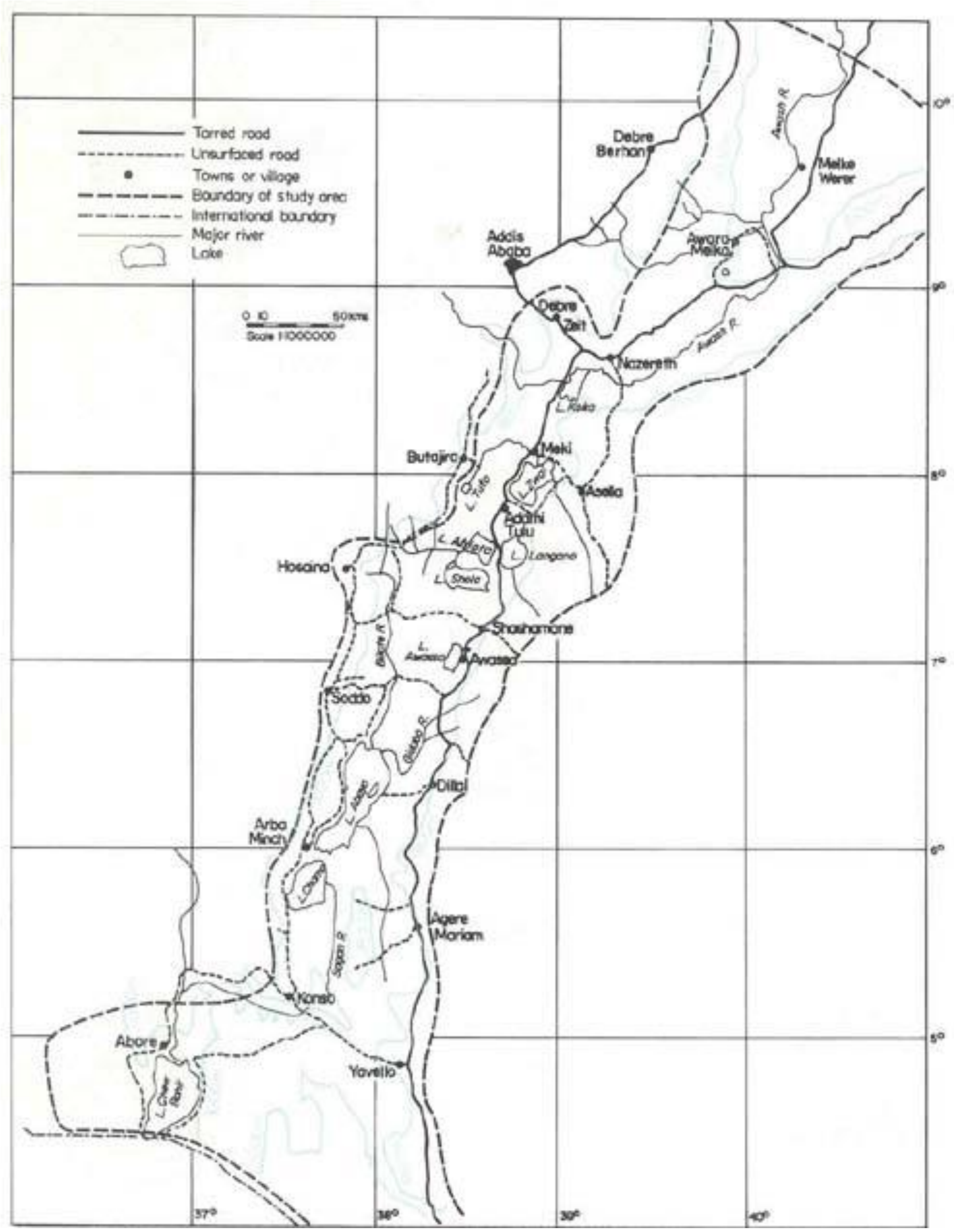
Introduction

ILCA's Forage Legume Agronomy Group aims to evaluate tropical forage and pasture species for potential use throughout Africa. Although the Ethiopian Rift Valley seems attractive as a location for such evaluation, because of its ease of access and range of climates and soils, it was first necessary to establish of which areas of Africa it is representative in terms of plant environments.

The aim of this study was to briefly review the climates, soils and vegetation of the Rift Valley and to relate these to other areas of Africa. Clearly the conclusions reached depend in part on the level of detail at which comparisons were made. For this initial assessment broad-scale comparisons were made; more detailed studies of individual regions within the Rift Valley will have to await the availability of more data.

The limits of the Rift Valley for the purposes of this study are shown in Figure 1. The limits of the study area along the escarpments of the valley correspond to the 1800 m contour. Above this altitude the vegetation is quite different from the semiarid steppe and savanna woodland communities of the Rift Valley floor, and below 1800 m frosts are of infrequent occurrence and of negligible importance in determining the nature of the vegetation.

Figure 1. *Map of the Ethiopian Rift Valley showing units of the study area and 1000 m and 1800 m contours.*



The Rift Valley of Ethiopia, like its extension in East and central Africa, was formed by extensive downfaulting of the earth's crust at the end of the Tertiary and at the beginning of the Pleistocene period. It forms part of a series of fractures in the earth's crust extending from the Dead Sea in the north, via the Red Sea and the rifts of East and central Africa, to Mozambique in the south. In Ethiopia it has a general northeast to southwest trend and extends over approximately 750 km. South of Nazareth (lat. 8°20') it takes the form of a relatively narrow corridor (35–80 km wide) demarcated by faults at the edges of both the Ethiopian and the Somalian plateau.

Since the end of the Tertiary period the Ethiopian Rift Valley has been the scene of intense volcanic activity and further minor faulting. Consequently the geological formations are almost entirely volcanic in origin and include both alkaline (basalts) and acidic (rhyolites, ignimbrites, pumices and ash) rock types.

One consequence of the volcanic origin of the bedrock of the Rift Valley is the extensive and serious erosion in certain areas. This is particularly noticeable where the soils overlie ignimbrite—rock types deposited from incandescent volcanic clouds escaping from cracks in the crust, which opened after the formation of the rift. These young volcanic rocks are generally rich in base elements but in many cases are deficient in phosphorus.

Climate

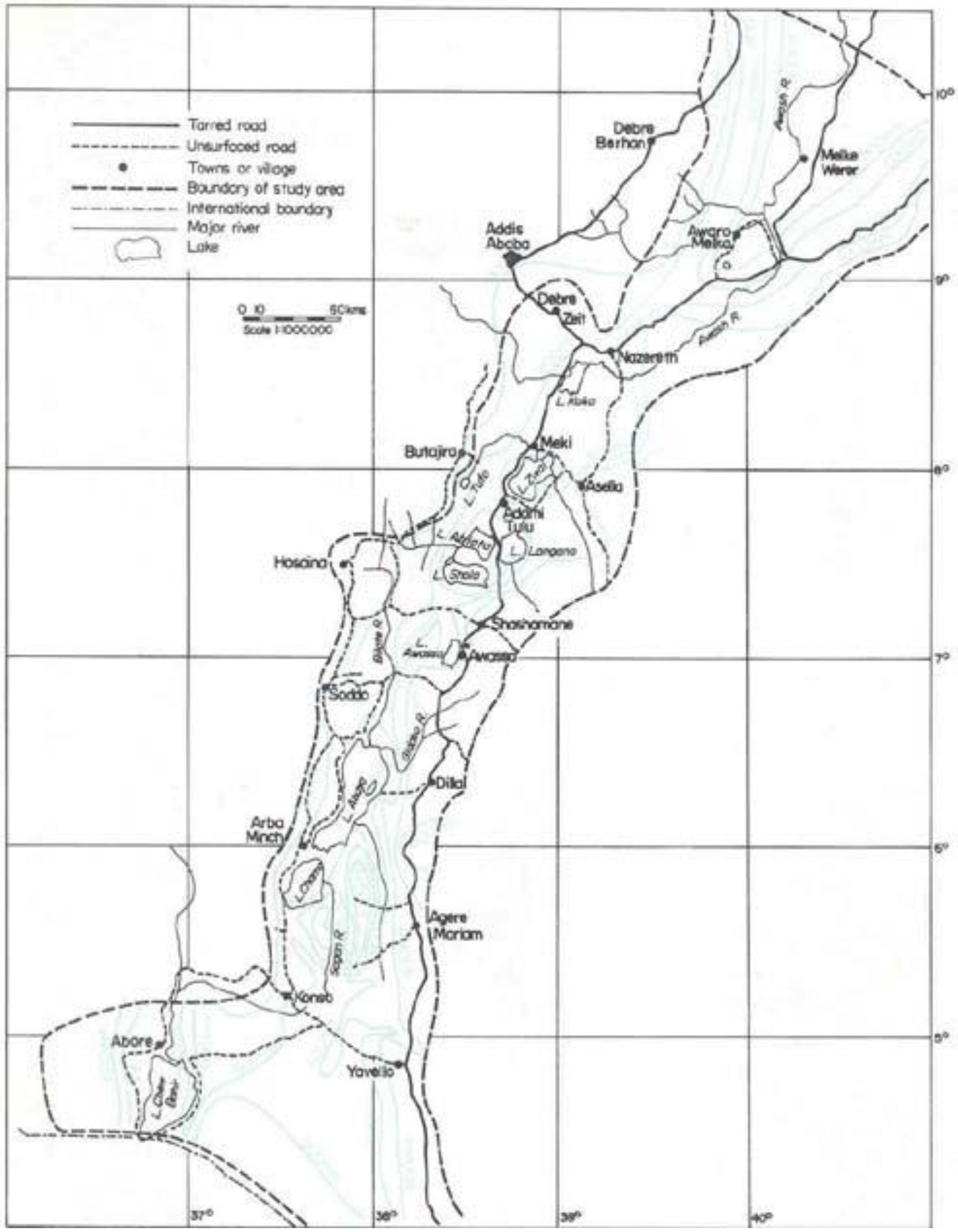
The climate of the Ethiopian Rift Valley

Rainfall

From November to February northeast winds prevail, giving settled dry weather throughout most of the valley. During this period there is little cloud, diurnal temperatures are high and relative humidities low. Between March and May more unsettled weather is experienced due to the convergence of moist southeast winds from the Indian Ocean with the northeast airstream. This brings heavy rains south of latitude 6°30' (Lake Abaya), but north of this latitude rainfall is normally light and very unreliable. From July to October the main rains come to the northern Rift Valley with the wet winds from the Indian and Atlantic oceans converging over the highlands. Intense rainfalls associated with convective thunderstorms are frequently experienced at the beginning of this period. In the southern part of the valley, however, there is little rainfall between June and August and a secondary peak in September and October. There are thus two rainfall regions within the valley.

The average annual rainfall for all stations in the Rift Valley below the 1700 m altitude is 754 mm (n = 29). All such locations can be considered to be on the floor of the valley. This estimate is probably high due to the location of most stations in the highest rainfall areas. Figure 2 shows isohyets of mean annual rainfall for the Rift Valley. These suggest that a value between 600 and 700 mm annually is a reasonable average value for most of the floor of the valley.

Figure 2. *Isohyets of mean annual rainfall in the Ethiopian Rift Valley.*



Rainfall increases with altitude along the Rift Valley escarpment to an approximate annual average of 1600 mm at the 3000 m contour. However above about 1800 m the correlation of rainfall with altitude is particularly poor due to oreographic effects.

From the viewpoint of climatic classification the area of the Rift Valley includes four zones:

1. Arid zone: median annual rainfall less than 400 mm.

2. Semi-arid zone: median annual rainfall between 400 and 700 mm.

3. Subhumid zone: median annual rainfall between 700 and 1000 mm.

4. Humid zone: median annual rainfall above 1000 mm.

Approximate estimates for the overall areas of the semi-arid and subhumid zones within the Rift Valley are 35% and 55% respectively.

Temperature

Records for temperatures from stations in the Rift Valley are even fewer and more fragmentary than those for rainfall, and to date data have been obtained for only 13 stations. These data are summarised in Table 1. There is a reasonable correlation between temperature and altitude: on average mean annual temperatures decrease by approximately 1.55°C for every 100 m increase in altitude.

Table 1. *Mean annual temperatures for some stations in the Rift Valley*.

Station	Altitude (m)	No. of years	Ann. mean (Min.°C)	Ann. mean (Max.°C)	Ann. mean (°C)
Asela	1700	10	12.7	28.4	20.6
Alaba Colito	1800	10	11.5	26.4	18.9
Awassa	1680	12	11.5	26.8	19.1
Bekewle (Conso)	1380	6	16.9	27.3	22.1
Gato	1320	3	18.6	31.1	24.9
Mega	1700	6	14.2	23.1	18.6
Melka Guba	not known	3	18.6	32.0	25.3
Miereb Abaya	1290	4	17.1	31.2	24.1
Moyale	1200	2	19.1	29.8	24.5
Neghelli	1480	20	12.7	25.7	19.2
Tertele	1460	2	16.9	26.9	21.9
Wondo Chabicha	1800	11	11.3	26.3	18.9
Yavello	1740	13	13.1	25.2	19.1

Highest monthly temperatures are normally recorded in the dry season between November and March. Lowest monthly minimum temperatures are also recorded during the dry season when night skies are clear.

The incidence of low temperatures may influence the growth of plants at altitudes above 1400 m. It is known that many tropical legumes cease to grow at temperatures between 10 and 12°C (Fitzpatrick and Nix, 1970) and that some show considerable limitation in growth at around 15°C.

Length of growing season

The Ethiopian Mapping Agency has recently published a length-of-growing-season map for the whole of Ethiopia on a 1:2 000 000 scale (EMA,1983). The length of growing season is calculated in days for which rainfall exceeds 50% of the potential evapotranspiration calculated from Penman's formula. Very approximate estimates can be made for the proportion of the total area of the Rift Valley with different lengths of growing season as follows:

< 60 days 10%

60–75 days 5%

75–90 days 5%

90–120 days 10%

120–150 days 15%

150–80 days 25%

180–210 days 20%

210–240 days 10%

It is remarkable that, according to these estimates, over 50% of the area of the valley has a growing season in excess of 150 days. The shortest growing seasons (60 days) are found at the northern and southern extremities of the valley. The longest growing seasons (over 210 days) are found around the lakes Abaya and Chamo where the eastern and western escarpments of the Rift Valley most closely approach one another.

The climates of the Rift Valley and other areas of Africa

The important climatic zones in the Rift Valley are the semi-arid zone (400–700 mm rainfall) and the subhumid zone (700–1000 mm rainfall).

Since rainfall is of overriding importance in determining plant growth, the main basis of comparison has been the annual quantity and duration of rainfall. Seasonal distribution has also been taken into account. Temperatures have been considered, but only where extreme temperatures are likely to influence the distribution of tropical or subtropical plant species.

The Sahel

The Sabel comprises a vast area of semiarid and arid land. The climatic limits of the region are normally taken to lie between the 600 mm rainfall isohyet in the south and the 100 mm isohyet in the north. The most obvious feature of rainfall in the Sahel is its restriction to a period in summer of 2 to 4 months, with little or no rainfall during the rest of the year. The actual duration of the growing season varies from an average of 120 days at the southern edge of the region to about 45 days in the north (FAO,1978).

The areas of the Rift Valley which are likely to be most similar to the Sahel would therefore have a mean annual rainfall between 100 and 600 mm, with a unimodal distribution centred sharply on July and August and mean annual temperatures between 27.5 and 29.0°C. The most similar area is the extreme northern part of the Rift Valley in the Middle Awash valley. It is not argued that this area represents an exact climatic homologue to anywhere in the Sahel region— indeed the seasonal distribution of rainfall is broader than for most areas of the Sahel. However it does appear more similar than other areas of the valley, a conclusion supported by the data on vegetation.

The northern Sudanian savanna

The Sudanian savanna is a band of tree or shrub savannas stretching across West Africa between the Sahel to the north and the zone of dense tropical forest in the south. We are concerned here only with the northern portion of the region having an annual rainfall between 650 and 1000 mm and corresponding approximately with the subhumid zone as defined above. The dry season lasts for 6 to 8 months and mean annual temperatures vary between 26.0 and 29.5°C.

Although a large part of the Ethiopian Rift Valley has rainfall between 650 and 1000 mm annually, much of this area lies in the southern portion of the valley with a bimodal distribution pattern.

Furthermore most of the areas with a subhumid climate lie at altitudes above 1300 m with average annual temperatures below 25°C and average minimum temperatures below 17.5°C. These areas are relatively cool compared to the northern Sudanian region of West Africa. However, much of the northern Rift Valley has mean temperatures for this period between 17.5 and 22.5°C. While these figures are 5 to 7°C lower than the corresponding values for the northern Sudanian zone, they are probably not limiting to the growth of many tropical legumes.

East Africa

The climate of East Africa is extremely complex. Griffiths (1972) describes 52 climatic regions for the area covering 30 different rainfall seasons. This complex pattern can be somewhat simplified by dividing the area into a part with unimodal rainfall and a part with bimodal rainfall. The region as a whole, and particularly Kenya, is also well known for the unreliability of its rainfall.

Stations in the Rift Valley of Kenya, like those in the southern Rift Valley of Ethiopia, have a bimodal rainfall distribution.

Although no temperature data are available for stations in Kenya, the relationship between temperature and altitude for the Kenyan Rift Valley should be similar to that for the Ethiopian Rift Valley. If this is the case there should be a reasonable similarity between areas at the same altitude in the Ethiopian and Kenyan portions of the Rift Valley. There are also other parts of the semi-arid and subhumid zones of East Africa, particularly in Tanzania, that may be climatically similar to the Rift Valley of Ethiopia.

Other areas

Although there are large areas of central and southern Africa that have semi-arid or subhumid climates, they differ from the Ethiopian Rift Valley in two important aspects:

1. South of approximately 7°S the rains fall between November and April, precisely the reverse of the case in Ethiopia.

2. Over much of this area low temperatures are experienced, at least for short periods, during the dry months when cold air penetrates the region from the south. Consequently night frosts can be experienced at this time of the year at altitudes as low as 1000 m.

Conclusions

The climate of much of the Ethiopian Rift Valley can be described as cool, semi-arid or subhumid with either bimodal or unimodal rainfall distribution. Only below an altitude of about 1100 m are hot conditions found. Much of the southern Ethiopian Rift Valley is climatically similar to the Rift Valley in Kenya and, possibly to that of Tanzania. There may be more general similarities between this part of the valley and other semi-arid and subhumid parts of East Africa as a whole. In the extreme north, below 1100 m, there is an area in the Middle Awash valley which shows some climatic similarities to the Sahel region of West Africa.

Soils

Soils of the Ethiopian Rift Valley

The information on soils was drawn from the maps in Makin et al (1975) and FAO (1965). Areas for major soil units within the southern Rift Valley were computed from King and Birchall (1975) and for the northern portion they were derived from planimetric measurements on the soils map of the Awash River basin in FAO (1965). The legend of the latter map was interpreted in terms of the approximate equivalent units in the FAO classification system. The FAO system of classification was used (and adapted) because it permits comparisons between the Rift Valley and other parts of Africa, based on the FAO/UNESCO Soil Map of Africa (1977).

Major soil types

Thirteen major units and a further six subunits in the FAO/UNESCO soil classification are of importance in the Rift Valley.

Table 2 shows the estimated extent of each of the major soil units within the Rift Valley and the proportion of the total area occupied by these units. For our purposes, histosols and gleysols can be ignored as being permanently flooded or waterlogged. Saline soils (solonchaks and solonetz), while used for grazing to some extent, are of sufficiently small area to be of little importance overall. The most important groupings in terms of total area covered are thus: vertisols (19.2%), cambisols (17.9%), fluvisols (16.2%), regosols (15.8%), lithosols (9.5%), andosols (7.1%) and acrisols (6.1%). All remaining soil units taken together account for less than 10% of the total area.

Table 2. *Estimated extent of FAO soil units within the Ethiopian Rift Valley and the proportion of the whole area covered by each unit.*

FAO soil unit	Total area (km²)	% of whole area
Ferric acrisols	3 367	6.1
Chromic cambisols	3 671	6.7
Eutric cambisols	6166	11.2
Eutric fluvisols	8 529	15.2
Calcaricfluvisols	391	0.7
Histosols	200	0.4
Eutric gleysols	262	0.5
Eutric nitosols	436	0.8
Vitric andosols	3 888	7.1
Pellic vertisols	6 229	11.3
Chromic vertisols	4 330	7.9
Eutric regosols	8 669	15.8
Lithosols	5 210	9.5
Luvic xerosols	1780	3.2
Haplic xerosols	940	1.7
Orthic solonchaks	647	1.2
Orthic solonetz	253	0.4
Total	54 968	

Source: FAO (1977).

The soils of the Rift Valley and other areas of Africa

The soils of the Rift Valley of Ethiopia are quite diverse. Seventeen out of 106 FAO suborders are important in the region, a reasonable proportion for a small area in African terms. However, there are certain peculiar features of the Rift Valley soils that distinguish the valley from many other areas of the continent. Firstly, the soils are for the most part derived from young rocks of volcanic origin. The result is that many of the soils are of good nutrient status since leaching has not proceeded to a very marked degree. Approximate estimates based on the figures in Table 2 would suggest that 46% of the area has soils of excellent base status, 31 % of the area has a moderate base status while only 23% of the area has soils of poor base status. Such a high proportion of `good' soils must be relatively unusual for other African regions. Overall the most frequent limitation to plant growth in the Rift Valley is likely to be availability of water rather than soil fertility.

The other important feature of the soils of the area is the absence of certain major soil units (e.g. arenosols, luvisols and ferrasols) which are of widespread occurrence in other areas of Africa.

The total area and proportion of sub-Saharan Africa occupied by various soil units is shown in Table 3. This reveals some interesting features of these units as regards their importance in tropical Africa as a whole. Firstly, the 17 units listed together only account for 27% of the total area of tropical Africa. Secondly, if one divides the soil units into those of `high', `medium' and `low' base status one finds that `high' base status units account for 6.6% of the total area of tropical Africa, `medium' for 7.3% and `low' for 12.9% of the total area. This is exactly the reverse order to that for the Ethiopian Rift Valley. Thirdly, 11 of the 17 soil units are proportionally better represented in the Rift Valley than in sub-Saharan Africa as a whole.

Table 3. *Total area in km' and proportion of sub-Saharan Africa occupied by some soil units of importance in the Rift Valley of Ethiopia.*

FAO soil unit	Total area (km^2)	% of sub-Saharan Africa
Ferric acrisols	589 290	2.7
Chromic cambisols	226 370	1.0
Eutric cambisols	245 920	1.1
Eutric fluvisols	332 270	1.5
Calcaric fluvisols	85 790	0.4
Histosols	17 450	0.08
Eutric gleysols	237 380	1.1
Eutric nitosols	404 290	1.9
Vitric andosols	1 440	0.006
Pellic vertisols	344 810	1.6
Chromic vertisols	597 080	2.8
Eutric regosols	524 590	2.4
Lithosols	1 646 310	7.6
Luvic xerosols	17 630	0.08
Haplic xerosols	398 330	1.8
Orthic solonchaks	72 950	0.3
Orthic solonetz	93 190	0.4

Source: FAO *(1977).*

Vegetation

Vegetation of the Ethiopian Rift Valley

No complete vegetation survey exists for the Rift Valley as a whole and general descriptions are vague and concentrate almost entirely on woody vegetation. The following general description of the vegetation of the region must thus be regarded as provisional. The diversity of vegetation types in the area is however apparent.

General description

Makin et al (1975) divide the southern Rift Valley into the following four ecoclimatic zones:

Zone 1: Humid to dry-humid lands, now mostly under coffee or other intensive agricultural use; formerly forest or montane grassland.

Zone 2: Dry subhumid or semi-arid lands characterised by evergreen shrubs, Combretum or allied vegetation.

Zone 3: Semi-arid lands with relatively low or erratic rainfall, characterised by dryland acacias with some broad-leaved trees and shrubs.

Zone 4: Arid lands, mostly dry thorn bushland unsuitable for rainfed agriculture.

Zone 1 lies almost entirely above 1800 m altitude and therefore is not considered in this study. Zones 2 to 4 correspond in a very general way to the subhumid, semiarid and arid climatic zones defined above, but the exact limits of each zone in tenors of rainfall are not clearly defined.

Table 4 shows the approximate area and proportion of the southern Rift Valley occupied by each ecoclimatic zone and also the relationship of these zones to those defined by Pratt et al (1966) for East Africa.

Table 4. *Areas for the major ecoclimatic zones of the southern Rift Valley and corresponding zones in Pratt et al (1966)'s classification.*

Eco-climatic zone	Total area (km^2)	%	Pratt[a] zonal equivalent
2	11 200	34	III
3	13 760	41	IV
4	8 220	25	V & VI

[a]From Pratt et al (1966).

Zone 2 or the subhumid zone has a tree cover characterised by the presence of broad-leaved *Combretum* and *Terminalia* species. Important species include *Acacia hockii, A. abyssinica, Albizia gummifera, A. schimperiana, Combretum aculeatum, C. molle, Croton macrostachyus, Cordia abyssinica, Erythrina abyssinica, Ficus sycamores, Heeria reticulata, Terminalia brownii, T. schweinfurthii* and *Vernonia abyssinica.* At lower altitudes (1300 to 1500 m) evergreen thicket is common and is dominated by *Carissa edulis, Dodonaea viscosa, Euclea schimperi, Rhus natalensis*and *Olea africana.* The dominant grasses include *Eragrostis superba, Heteropogon contortus, Hyparrhenia hirta, H. rufa, Themeda triandra* and *Andropogon* spp*.*

Zone 3 or the semi-arid zone is characterised by the presence of acacias as the dominant species of the tree and shrub layers. Physiognomically there are vegetation types ranging from closed acacia woodland to scattered and open acacia bushland. The most common *Acacia* species are *A. brevispica, A. mellifera, A. nilotica, A. nubica, A. reficiens, A. seyal* and *A. tortilis.* They are accompanied by many broad-leaved trees and semi-evergreen shrubs such as *Acokanthera brownii, Balanites aegyptium, Cadaba farinosa, Capparis tomentosa, Commiphora africana, Croton macrostachyus, Dichrostachys cinerea, Euphorbia tirucalli, E. candelabra, Harrisonia abyssinica, Sclerocaryea birrea* and *Terminalia brownii.* Dominant grasses include *Aristida kenyensis, Chloris pycnothrix, Hyparrhenia anthistirioides, Panicum atrosanguineum* and *Pennisetum schimperi.*

Zone 4 or the arid zone, with less than 450 mm annual rainfall, is characterised by dry thorn bnshland. The common shrub species include *Acacia etbaica, A. horrida, A. mellifera, A. nilotica, A. nubica, A. reficiens, A. senegal, A. seyal,* and *A. tortilis.* Trees and shrubs commonly associated with these include *Boscia coriacea, Cadaba farinosa, C. rotundifolia, Commiphora* spp.*, Dobera glabra, Grewia* spp.*, Sansevieria ehrenbergii, Salvadora persica* and *Sterculia africana.*

The grass cover is discontinuous, with up to 60% bare ground in very dry or heavily grazed areas. In all areas other than those that are seasonally waterlogged or saline, *Chrysopogon plumulosus* is the dominant grass accounting for up to 65% of the herbaceous cover. Ephemeral annual grasses are abundant, particularly species of the genera *Aristida* and *Eragrostis.*

Vegetation of the Rift Valley and other areas of Africa

Phytogeographic relationships

According to Ibrahim (1978), Ethiopia lies within the Sudano-Zambezian phytogeographic region of Africa which comprises the largest formation of the continent and can be characterised as tropical, with an annual dry season of 4 to 9 months, annual rainfall between 300 and 1500 mm and vegetation which includes steppe, savanna and dry to subhumid woodland and forest. More specifically it comes within the Sudanian subregion with a dry tropical climate and rainfall up to 1000 mm. The highlands of Ethiopia are, of course, excluded, forming part of the Afro-montane region. At a third level of organisation Ibrahim includes Ethiopia in the Afro-Oriental domain which covers the lowlands of Tanzania, Kenya, Somalia and Ethiopia. Vegetation ranges from steppe to thorn woodland. Ibrahim sets an attitudinal limit of 1100 m for this domain but it probably extends considerably higher than this in the Ethiopian Rift Valley.

In plant geographic terms the lowlands of Ethiopia belong with the rest of East Africa, with most of Uganda excluded. However, they have more general connections throughout the Sudano-Zambezian region. In particular White (1965) suggests that the Sahel region, which can be characterised as wooded steppe with *Acacia* and *Commiphora* spp., represents a floristically impoverished western extension of the rich Afro-Oriental domain.

Of the tree species found in the Ethiopian Rift Valley, *Acacia nilotica, A. seyal, A. senegal,* and *A. sieberiana* occur throughout much of the Sudanian subregion, including the Sahel, while *A. nubica*and *A. mellifera* have an Afro-Oriental and eastern Sudanian distribution. The grass *Schoenfeldia gracilis* is a more strictly Sahelian species but is also known from the lowlands of Ethiopia (Froman and Persson, 1974). Other important grass species from the

Ethiopian Rift Valley which have a general Sudano-Zambezian distribution pattern include, *Andropogon gayanus, Aristida* spp*., Bothriochloa insculpta, Cenchrus ciliaris, Chloris gayana, C. pycnothrix, Cymbopogon giganteus, Eragrostis cylindrifiora, Hyparrhenia filipendula, H. rufa, Imperata cylindrica, Panicum maximum, Pennisetum ramosum, Setarui sphacelata, Sporobolus pyramidalis* and many others (Wickens, 1976).

Application of Hartley's agrostological index

Hartley (1963) has devised a technique for comparing grass floras on the basis of the proportion of different tribes of grasses in the flora of a given area. Using a previous analysis of the climatic relationships of some of the more important tribes of tropical grasses, he was able to show that the proportions of these tribes within the flora of a given area provided a reasonable indication of the prevailing environmental conditions.

The first step in using this analysis to compare Ethiopian and other grass floras was to try to quantify the relationship between the proportion of different grass tribes in the floras considered with climatic factors. This was possible for annual rainfall even though in some cases the figures used were taken from rather vague references or, in the cases of some of the larger areas, were the mean figure from a wide range.

Figures 3 and 4 show the relationship between mean annual rainfall and the proportion of different grass tribes in the floras of 15 localities in West Africa, Sudan and Ethiopia. It can be seen that there is a good positive correlation ($r = 0.88$) between annual rainfall and percent Andropogoneae in a grass flora, while Aristideae show a good negative correlation ($r = –0.81$) with rainfall. The proportion of Eragrostideae is negatively correlated with rainfall but the correlation is poor ($r = –0.64$), while the proportion of Paniceae does not appear to be correlated with rainfall at all. It should be noted that the majority of observations were from the semi-arid and arid zones and that the relationships determined here do not necessarily extend to wetter climatic zones.

Figure 3. *Relationship between rainfall and proportion of (A)* Andropogoneae *and (B)* Aristideae *in different grass floras.*

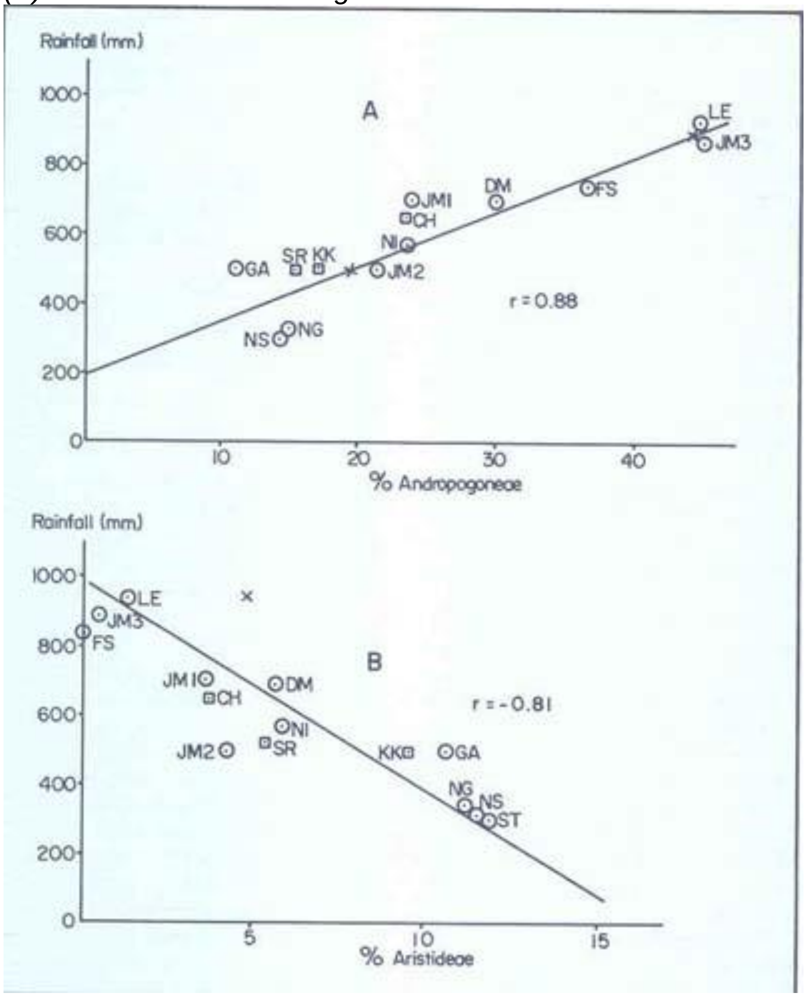
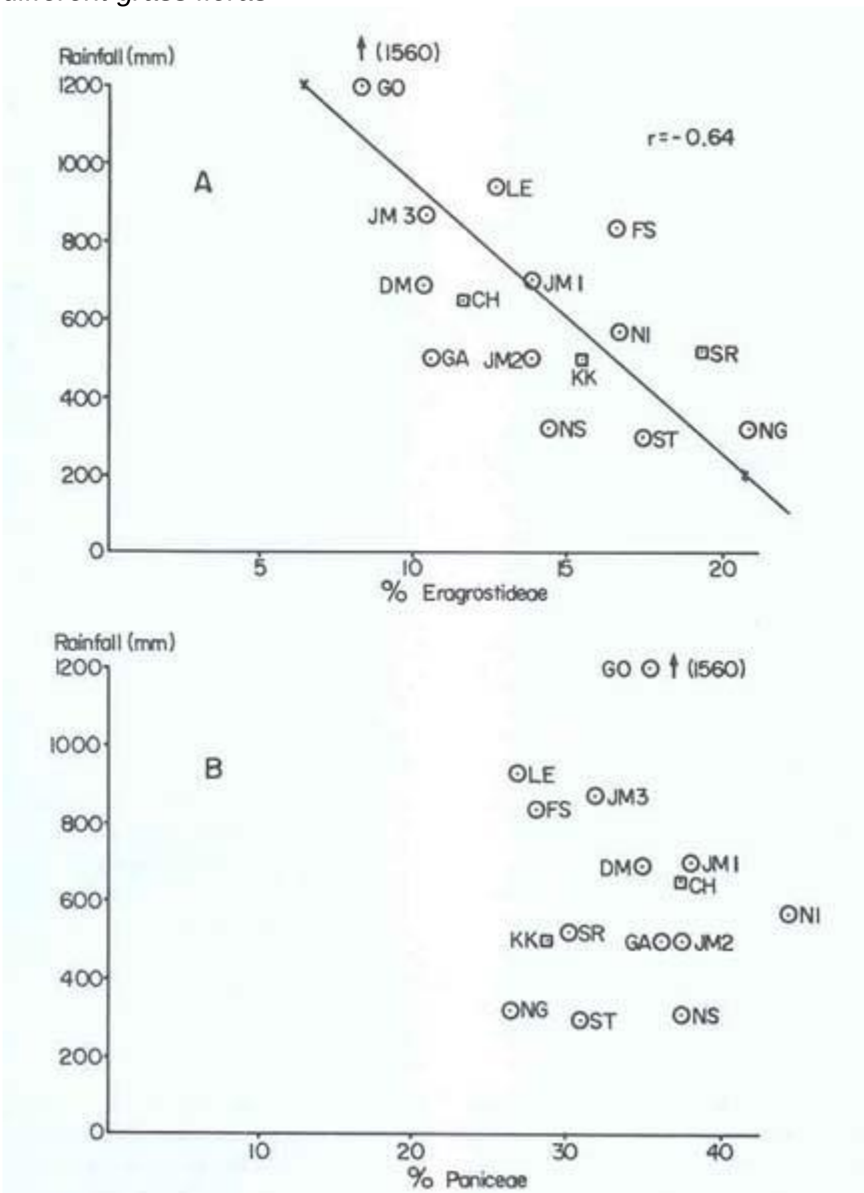


Figure 4. *Relationship between rainfall and proportion of (A)* Eragrostideae *and (B)* Paniceae *in different grass floras*



Key to abbreviations used in Figures 3 and 4.

CH	Chilalo, Ethiopia
DM	Dalliol-Maouri, Niger
FS	Ferlo-Sud, Senegal
GA	Gallayel, Senegal
GO	Gomoko, Central African Republic
JM 1	Jebel-Marra 1, Sudan
JM 2	Jebel-Marra 2, Sudan
JM 3	Jebel-Marra 3, Sudan
KK	Kessem Kabana, Ethiopia

LE	Leo, Upper Volta
NG	Nord-Gouré, Niger
NI	Niono, Mali
NS	Nord-Sanam, Niger
SR	Southern Rangelands, Ethiopia
ST	Sud-Tamesna, Niger

The data on tribal composition of the 20 grass floras considered in this study are shown in Table 5. Only the proportion of the larger tribes is included, together with annual rainfall (where known) and the approximate latitude for each site. The method used in classifying these grass floras was cluster analysis. In this method clusters of observations are formed based on the Euclidean distance (i.e. the square root of the sum of squares of differences between values of observations for two sites). The Euclidean distance between 2 sets of clusters (j and 1) is:

$$d_j l = \left[\sum_i \left(x_{ij} - x_{il}\right)^2\right]^{\frac{1}{2}}$$

Table 5. *Proportion of major tribes in the grass floras of 20 African locations together with rainfall and latitude (where known).*

Tribes location		Andropo-goneae	Eragros-tideae	Paniceae	Aristideae	Others	Total species	Rainfall (mm)	Latitude
1	Gallayel Senegal	10.6	17.0	36.2	10.6	25.6	47.0	500	15040
2	Ferlo-Sud Senegal	7.2	16.7	28.2	0.0	17.9	48.0	835	13°40
3	Niono, Mali	23.8	16.7	41.7	11.9	11.9	84.0	570	14°20
4	Leo Upper Volta	42.3	12.8	26.9	1.4	16.6	78.0	930	11°20
5	Nord-Sanam Niger	14.5	14.5	37.7	11.6	21.7	69.0	310	15°25
6	Sud-Tamesna Niger	19.3	17.4	31.1	11.9	20.3	100.0	300	16°00
7	Dalliol-Maouri Niger	30.1	10.4	34.9	5.7	18.9	106.0	690	13°00
8	Nord-Goure Niger	15.2	20.9	26.7	1.4	25.8	105.0	320	15°00
9	Gomoko R.C.A	35.5	9.2	35.5	0.0	19.8	76.0	1560	4°50
10	Jebel-Marra 1 Sudan	24.1	13.9	37.9	3.7	20.4	108.0	700	12°30
11	Jebel-Marra 2 Sudan	21.5	14.0	37.6	4.3	22.6	93.0	500	12°30
12	Jebel-Marra 3 Sudan	42.6	10.6	31.9	0.0	14.9	94.0	870	12°30
13	Kessem-Kabana Ethiopia	17.3	15.4	28.8	9.6	28.9	52.0	590	9°15
14	Chilalo Ethiopia	23.5	11.8	37.3	3.9	23.5	51.0	650	8°00
15	S. Rangelands Ethiopia	15.5	19.4	30.2	5.4	29.5	124.0	520	4°30
16	Themeda Kenya	19.1	12.8	31.9	4.3	31.9	47.0	–	–

17	Hyparrhenia Uganda	26.5	20.4	24.5	2.1	26.5	49.0	–	–
18	Acacia Uganda	12.8	19.1	25.5	8.5	34.1	47.0	–	–
19	Acacia/Combretum Uganda	27.3	14.8	28.4	2.3	27.2	88.0	–	–
20	Themeda Uganda	25.0	15.9	25.0	4.5	29.6	44:0	–	–

Source: 1. Mosnier(1967)
2. Diallo (1968)
3. Boudet and Leclercq (1970)
4. Toutain (1974)
5. Peyre de FabrBgues(1963)
6. Peyre de Fabregues(1970)
7. Boudet(1969)
8. Peyre de Fabregues(1965)
9. Audru and Boudet (1964)
10. Wickens (1976)
11. Wickens (1976)
12. Wickens (1976)
13. Corra(1981)
14. Mengistu (1974)
15. Agrotech/CRG/SEDES (1974)
16. Lind and Morrison (1974)
17 Langdale-Brown et al (1964)
18. Langdale-Brown et al (1964)
19. Langdale-Brown et al (1964)
20. Langdale-Brown et al (1964)

Initially each site is considered to be in a cluster of its own. At each step the two clusters with the shortest Euclidean distance between them are amalgamated and treated as one cluster. This process of combining clusters continues until all sites are combined into one cluster. This algorithm is known as the average distance or average linkage. A tree diagram of the clusters is then constructed to describe the sequence of clusters formed. This is shown in Figure 5.

Figure 5. *Dendrogram derived from cluster analysis of sites listed in Table 5.*

* Estimated from regressions in Figure 3.

A particularly interesting feature of the classification is that the Kessem-Kabana and southern rangelands of the Ethiopian Rift Valley are closer in tribal composition to a number of localities in the Sahel of West Africa than to the Chilalo area of the Rift Valley or to most East African sites. By contrast the Chilalo area of the Rift Valley is closest to two of the Jebel-Marra sites in Sudan and also quite close to the *Themeda* grasslands of Kenya. Given the inadequacy of some of the floristic data and the problems of estimation of rainfall, the classification correlates reasonably with climatic conditions.

Comparison by shared species

A second method of comparing vegetation of different areas is to use shared species to group related, areas. For this purpose a very simple index, Soroensen's quotient of similarity, was adopted:

$$Q = \frac{2_j}{a + b}$$

where
j = species shared between two areas;
a = total number of species in area a; and
b = total number of species in area b.

In this index, shared species are weighted by a factor of 2 to stress their importance. When the quotient is calculated for all combinations of the areas considered, they can be arranged in the form of a Trellis diagram where individual sites are ranked in an order that brings together those with close quotients of similarity. The areas can then be divided on a subjective basis into `communities' with similar indices.

Because computation of shared species by hand is highly time-consuming, only 12 of the 20 sites listed in Table 5 have been included in the analysis. These have been selected to include the full range of geographic locations and of annual rainfall covered by all the sites. They also include all three locations from the Ethiopian Rift Valley.

The Trellis diagram for the sites analysed is shown in Figure 6. The shading in the upper quadrant has been added to assist interpretation and shows values for the index between 0.00 and 0.20, 0.21 and 0.40, 0.41 and 0.60 respectively. Firstly, the values are generally low with only 4 out of 66 exceeding 0.40. Secondly, it is clear that there is a group of West African sites (Gallayel, Niono; Sud-Tamesna and Leo) with a high proportion of shared species.

Figure 6. *Trellis diagram showing relationships between 12 grass floras from Africa using Soroensen's index of similarity to group floras according to shared species.*

	Rainfall (mm)	Gallayel, Senegal	Niono, Mali	Sud-Tamesna, Niger	Leo, Upper Volta	Gomoko, R.C.A.	Jebel-Marra, Sudan	Kessem-Kabana, Ethiopia	Chilalo, Ethiopia	S. Rangelands, Ethiopia	*Themeda*, Kenya	*Acacia*, Uganda	*Hyparrhenia*, Uganda
Gallayel, Senegal	500												
Niono, Mali	570	0.46											
Sud-Tamesna, Niger	300	0.49	0.59										
Leo, Upper Volta	430	0.16	0.41	0.34									
Gomoko, R.C.A.	1560	0.13	0.19	0.15	0.32								
Jebel-Marra, Sudan	500	0.36	0.36	0.28	0.34	0.25							
Kessem-Kabana, Ethiopia	500	0.16	0.10	0.11	0.03	0.05	0.29						
Chilalo, Ethiopia	650	0.06	0.04	0.09	0.03	0.05	0.18	0.33					
S. Rangelands, Ethiopia	520	0.14	0.18	0.24	0.09	0.05	0.32	0.34	0.28				
Themeda, Kenya	(580)	0.17	0.11	0.12	0.05	0.08	0.26	0.22	0.33	0.26			
Acacia, Uganda	(420)	0.19	0.12	0.23	0.06	0.10	0.24	0.28	0.24	0.29	0.36		
Hyparrhenia, Uganda	(400)	0.12	0.12	0.13	0.14	0.13	0.32	0.18	0.14	0.21	0.31	0.29	

Index value: 0.00 – 0.20   0.21 – 0.40   0.41 – 0.60

A major grouping of sites includes those in the Ethiopian Rift Valley with those from East Africa. Here the value of the index is lower (0.21–0.40), with the highest values occurring within the subregions, i.e. the East African sites are most similar to each other as are the Ethiopian sites.

The two types of analysis of the grass floras carried out here clearly provide different types of information concerning the similarity ,of the areas studied. Hartley's agrostological index tells us about the general environmental conditions, and more particularly about the degree of aridity or otherwise of an area. Analyses based on shared species provide information on present-day pathways of dispersal of species and on the phytogeographic history of the areas concerned.

Conclusions

Climatically much of the Ethiopian Rift Valley is very similar to the Rift Valley of Kenya, and possibly to parts of Tanzania. However the region is clearly diverse, with climates ranging from hot and arid to cool (subtropical) and humid. Both temperatures and rainfall vary with altitudes, although in the latter case the relationship is only approximate due to oreographic effects. While frosts are probably of little importance within the Rift Valley as defined above, it is concluded that low temperatures may well affect the growth and distribution of tropical legumes at altitudes above 1400 m. In the extreme north of the Rift Valley there is an area of hot, lowlying country with unimodal rainfall centred on July and August, which has some similarities to the climate of the Sahel region of West Africa. The climatic comparisons have been limited by lack of suitable data for other areas of Africa.

The soils of the Rift Valley, mainly derived from young volcanic rocks, are generally of good base status. In this they differ markedly from soils of many other areas of Africa, where a combination of poor parent materials and intensive weathering has produced soils impoverished in mineral nutrients. Constraints to forage or crop production in the Rift Valley relate to the low phosphorus status of many soils, micronutrient imbalances and, in the case of vertisols and saline soils, difficult physical conditions. It is possible that for the purposes of screening forage species in the Rift Valley, soil types (e.g. acrisols and nitosols) of low fertility can be located that have a range of constraints for plant growth similar to the highly weathered arenosols and luvisols characteristic of many other parts of Africa. The importance attached to locating such impoverished soils will depend on the relative weight given to screening for climatic or edaphic adaptation of forage species.

In phytogeographic terms the Rift Valley belongs to the Sudano-Zambezian region of Africa, with rainfall between 300 and 1500 mm annually and 4 to 9 months of annual dry season. In areas with annual rainfall between 300 and 700 mm the dominant woody species are acacias, but above 700 mm broad-leaned trees and shrubs are dominant. Many of the common acacia species are very widely distributed and are also dominant in the Sahelian domain of West Africa which is extremely similar, in physiognomic terms, to many areas of the Rift Valley of East Africa and Ethiopia, although floristically impoverished.

The use of Hartley's agrostological index also suggests that there is a clear relationship between some of the lower-lying areas of the Ethiopian Rift Valley and the Sahel region of West Africa, while the areas at higher altitudes appear more similar to other areas in East Africa.

The other method of floristic comparison used here, based on the proportion of shared species in different grass floras, is probably of less value for establishing agronomically similar areas. It is probably influenced by historical factors in the evolution of the floras concerned, and certainly by the ease of dispersal of species between different areas. Many of the shared species between two or more sites will have either pantropical or palaeotropical distribution patterns which contribute little relative information about the areas concerned.

Attempting to use soils as a means of comparing areas has many drawbacks. Soils are normally of secondary importance to climate (in particular rainfall) in determining where plant species will grow. Also the soil units used for mapping purposes often do not reflect the problems faced by the plant in growing in those soil types. Many of the major soil, units are of such widespread distribution that they are of little use for the purposes of classifying different areas.

The use of climatic information for comparing different areas avoids many of these drawbacks and has been tried with some success in the past (e.g. Russell and Moore, 1970). However Williams and Burt (1982) highlight two difficulties with this approach. The first is the theoretical one that plants respond to more than just climate. The second is the difficulty in obtaining reliable and comparable climatic data for many areas in the tropics.

On theoretical grounds plants themselves should act as the best indicators of all the factors that influence their ability to survive in a particular area. For the grass floras examined in this study there does seem to be a reasonable correlation between the proportion of certain families and rainfall at least in the semi-arid and subhumid areas of Africa.

In screening forage species, the range of adaptability of species already in use, especially those in commercial production, is of particular importance. In Table 6 the adaptability of some of the important tropical genera is shown with respect to water stress, temperature stress and poor soils.

Table 6. *Adaptability[a] of some genera of tropical forage legumes in commercial use to water stress, heat stress and poor soil.*

Genus	Water stress	Thermal stress	Poor soils
Stylosanthes	+++	+	+++
Gentrosena	–	–	++
Desmodiurm	–	+	++
Macroptilium	++	++	+++
Neonotonia	+	++	–
Lotononis	–	+++	++
Leucaena	++	+	++
Acacia	+++	+++	+++

Sources: Humphreys (1980), Skerman (1977) and Summerfield and Bunting (1978).
[a] – low adaptability
+ moderate adaptability
++ good adaptability
+++ very good adaptability

The widest range of adaptability is shown by *Acacia* spp. This genus of some 800 species of trees and shrubs has worldwide distribution and in Africa alone is found at altitudes from sea level to almost 3000 m and on a wide variety of soils. The much smaller genus *Macroptilium* also has reasonable adaptability to these conditions.

Adaptation to temperature stress, particularly low temperatures, appears more widespread than adaptation to water stress amongst these genera.

Adaptation to poor soils is widespread among all but one of the genera considered.

If these genera are representative both of those in commercial use and those likely to come into commercial use, it suggests that the most critical parameter in the screening process is water stress. In other words so long as it is possible to locate areas with a range of different rainfall regimes in which to carry out screening, soils and temperature regimes are of secondary importance. The conclusions drawn from the table are in fact supported by the screening currently taking place with new lines of existing commercial species both in Australia and South America. This work suggests that there is a much greater range of genetic adaptability available in these species than is currently being exploited in commercially available cultivars (B. Grof, pers. comm.).

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