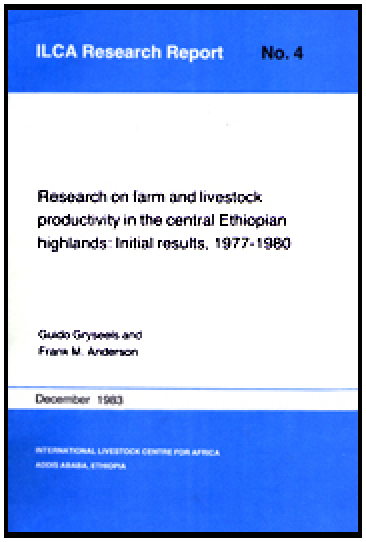
Research on farm and livestock productivity in the central Ethiopian highlands: Initial results, 1977-1980



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ILCA PUBLICATIONS

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ORIGINAL: ENGLISH

ABSTRACT

The Ethiopian highlands are briefly described and their potential for improved agricultural production is assessed. ILCA's studies on the traditional smallholder production system of the highlands are then reported in detail, and productivity aspects of the system's crop and livestock components are analysed. The results of research on innovations, including an improved forage/dairy cow package, improved animal traction and the cultivation of bottomland, are given. The approach to Farming Systems Research (FSR) with special reference to livestock is discussed together with the implications for adoption of the approach and its results by a national agency, some research experiences, and the outlook for future research.

KEY WORDS

/Ethiopia//highlands//small-scale farming//mixed farming//productivity//farming systems//research//food crops//feed crops//livestock//crossbreds//milk production//animal traction//bottomland soils//biogas/

RESUME

On trouvera dans le présent Rapport de recherche, une description succinte des hauts plateaux éthiopiens et une estimation des possibilités d'amélioration de la production agricole dans cet environnement.

Les travaux du CIPEA sur le système de production de la petite exploitation traditionnelle des hauts plateaux font ensuite l'objet d'une description détaillée et la productivité des composantes agriculture et élevage du système est analysée. Le Rapport présente en outre, les résultats de la recherche sur certaines innovations, notamment sur un programme d'amélioration intégrée fourrage/vaches laitières, sur la traction animale améliorée et sur l'exploitation agricole des bas-fonds.

L'approche à la recherche sur les systèmes d'exploitation agricole (RSA) est également analysée, en particulier en ce qui concerne la composante animale; pour terminer, le Rapport passe en revue les conséquences de l'adoption de la RSA et de ses résultats par un organisme public, ainsi que certaines expériences et perspectives en matière de recherche.

MOTS-CLES

/Ethiopie//haut plateau//petite exploitation agricole//exploitation mixte//productivité//système d'exploitation agricole//recherche/-/culture vivrière//culture fourragère//bétail//métis//production laitière//traction animale//sol de bas-fond//biogaz/

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Preface

The International Livestock Centre for Africa (ILCA) was established in 1974 and began activities in 1976. Its purpose is to carry out research, training and documentation activities "to assist national efforts which aim to effect a change in production and marketing systems in tropical Africa so as to increase the sustained yield and output of livestock products and improve the quality of life of the people of this region". ILCA undertakes research in the major ecological zones of sub-Saharan Africa, namely the arid and semi-arid, humid and subhumid, and highland zones.

This report focuses on ILCA's research in the highland zone. It describes the work carried out on and around ILCA's two research stations at Debre Zeit and Debre Berhan, in the central highlands of Ethiopia. The two stations were opened in 1977 and 1979 respectively.

Acknowledgments

The authors gratefully acknowledge the sustained contributions of ILCA field staff at Debre Zeit and Debre Berhan, without which this report would have not been possible. Particular thanks are due to Ephraim Bekele, Tadesse Tessema, Abate Tedla and Araya Selassie Bekele of the ILCA Debre Zeit research station, and to Woldeab Wolde Mariam, Berhanu Wolde Kidane and Taye Wolde Mariam of the ILCA Debre Berhan research station. Headquarters, staff in the Highlands Programme, namely Abiye Astatke, Getachew Asamenew, Amde Wondafrash and Joe Whalley also made important contributions. The data processing and statistical assistance of Robin Sayers warrants special comment. The authors also gratefully acknowledge the support and critical input of Cees de Haan.

Final thanks are due to Kelemework Asrat for typing the many drafts of this report and to Simon Chater for his careful editing.

THE AUTHORS

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1. Background

1.1. Introduction

This study summarizes the research of the ILCA Highlands Programme from its inception in 1976 to the end of 1980. In this chapter the background to the research is presented: the importance of the highland zone in sub-Saharan Africa is outlined in Section 1.2; Section 1.3 describes the Ethiopian highlands from an agricultural systems standpoint; previous experiences of research and development activities in the Ethiopian highlands are summarized in Section 1.4; and Section 1.5 provides an overview of the land tenure system in Ethiopia.

1.2. The highlands of sub-Saharan Africa and the Ethiopian highlands

The highlands of sub-Saharan Africa, defined as areas above 1500 m elevation or with mean daily temperatures of less than 20°C during the growing period, include approximately 1 million km² or some 4% of the land area of sub-Saharan Africa. About 75% of the highlands are located in eastern Africa. In Ethiopia, Kenya and Tanzania, they account for the great majority of the human and livestock populations. Rwanda, Burundi, Zaire, Chad, Somali, Cameroon, Angola, Malawi, Uganda, Zambia and Madagascar also have large highland areas. The distribution of highland areas in Africa is illustrated in Figure 1.1.

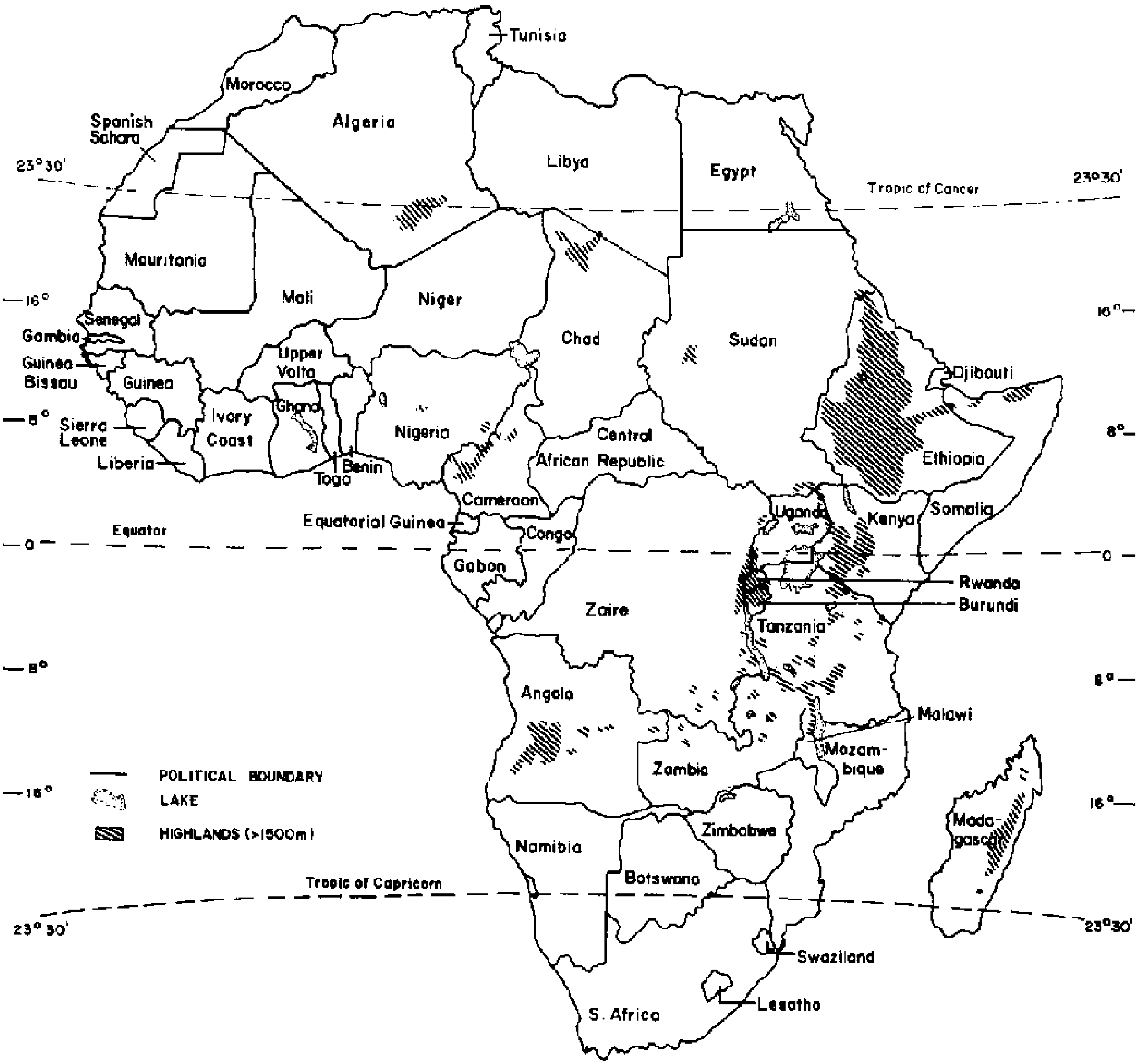
Although the highland zone is a small fraction of the land area of sub-Saharan Africa, it accounts for large human and livestock populations and has a considerable agricultural potential. Almost 20% of the rural human and ruminant livestock populations of sub-Saharan Africa are found in the highlands. The human population density of approximately 44 persons per km² is higher than in any other agroclimatic zone. The stocking density also is almost four times the average for sub-Saharan Africa as a whole. Table 1.1 summarizes the human and livestock population densities of the various zones in sub-Saharan Africa.

As indicated in the table, the highlands have a human population density more than double the average of sub-Saharan Africa as a whole. Several factors contribute to the concentration of people and their livestock in the highlands, including favourable climates and ecological conditions for smallholder mixed crop/livestock farming (good soils, moderate temperatures, ample radiation and rainfall), comparatively high levels of fodder production, and the absence of trypanosomiasis. While productivity levels of crops and livestock in the highlands are higher than at lower altitudes and in lower rainfall zones, the concentration of people and their crops and livestock over many centuries has resulted in substantial erosion problems and declining soil fertility in many areas.

Subsistence smallholder mixed farming prevails generally throughout the highlands, with crop and livestock husbandry typically practiced within the same management unit. Despite the zone's good agricultural potential, cropping is limited in large areas by harsh agroclimatic conditions, such as aridity or coldness (Jahnke, 1982). The highlands are a complex zone, characterized by wide diversities of climate, topography, development potential and land use. As a result, considerable differences in settlement and land-use density occur. For example, Rwanda and Burundi have extensive highland areas and national population densities of 160 to 185 persons per km². A detailed study on the agroclimatology of the highlands of eastern Africa is presented by Brown and Cochemé (1973).

Ethiopia has the largest highland area of the continent, covering 490 000 km², or around 40% of the country and almost half the total African highland area. It was therefore the initial focus of ILCA's highlands research, although the programme has a wider African perspective.

Figure 1.1. The highlands of sub-Saharan Africa.



Source: Adapted from Amare Getahun (1978a).

Ethiopia's highland topography is rugged and complex. The central part of the country is mostly high plateau, at least 1500 m above sea level with peaks rising to more than 4000 m, and is dissected by gorges and broad valleys. This plateau culminates in the east in a coastal plain spreading to the Red Sea, and in the west in the White Nile Valley plain on the Sudanese border. Most of these lowland plains are extensive rangelands inhabited by nomadic pastoralists.

Ethiopia's rugged terrain is a major constraint to economic development because of the inherent transport and communication problems. Half to three quarters of the population lives more than a day's round trip walk from an all-weather road.

The population of Ethiopia, estimated at 31 million in 1979, is growing at about 2.5% p.a. About 85% of the people live in the rural areas, and the highlands account for about 70% of national human and livestock populations. GNP in 1978 was estimated at US$ 3.5 billion, and overall per caput income is around US$ 110 p.a. Ethiopia is classified by the United Nations as one of the 25 least developed countries in the world. Almost one quarter of its children die before they are 4 years old. Only 6% of the population has access to safe water, the average daily calory supply is only 75% of requirements, and life expectancy at birth is 40 years (IBRD, 1981). In many rural areas, people are acutely vulnerable to drought and starvation. Furthermore, basic social services are seriously deficient. Until 1979, well over 90% of Ethiopia's population was illiterate, although many people have since benefitted from the national literacy campaign.

Table 1.1. ***Land area, human population and livestock densities by agroclimatic zone in sub-Saharan Africa.***

Zone	Area ('000 km²)	% of sub-Saharan Africa	Rural human population ('000)	% of sub-Saharan Africa	Rural population density (persons/km²)	LU[a] ('000)	% of sub-Saharan Africa	Stocking density (LU/km²)
Arid	8 327	37.3	12 000	5.3	1.7	41 697	30.4	5.0
Semi-arid	4 050	18.1	61 240	27.0	14.8	37 446	27.3	9.2
Humid	4 137	18.5	63 700	28.0	15.0	8 149	5.9	1.9
Subhumid	4 858	21.7	46 260	20.3	9.4	26 370	19.2	5.4
Highlands	990	4.4	44 000	19.4	44.2	23 646	17.2	23.9
	22 362	100.0	227 200	100.0	10.7	137 308	100.0	6.1

[a] One LU is equivalent to a ruminant animal of 250 kg liveweight.
Source: Adapted from Jahnke (1982).

The agricultural sector, since 1970 growing at only 0.4% p.a., contributes almost half of the country's GNP, and agricultural exports account for over 90% of total export earnings. Ethiopia has the largest livestock population in Africa, with approximately 26 million head of cattle, including around 6 million draught oxen, 24 million sheep, 18 million goats, 7 million equines, 1 million camels and 52 million poultry (de Montgolfier-Kouévi, 1976).

Livestock and livestock products contribute 35% of agricultural output and additionally supply the power to cultivate virtually all of Ethiopia's 6 million ha of land cropped annually. Livestock (mainly donkeys) also contribute substantially to rural transport needs. Exports of livestock products are presently limited to hides and skins, but a great potential exists for exports of beef, mutton and goat meat to the Middle East countries.

Less than 10% of the country is regularly used as cropland, 55% are grasslands or permanent pastures, 4% are swamps, 7% forests and the remaining 24% are barren, waste and other land.

The major crops grown are teff (*Eragrostis tef*), barley, horse beans, maize, sorghum, wheat and coffee. Since the mid-1970s, rural development has been organized within a socialist framework. However, collective farming through cooperatives and state farms accounts for less than 5% of the total area cultivated. Over 90% of agricultural output is still produced by individual subsistence smallholders who have "farming rights" over the land they till.

Agricultural conditions vary widely in the different ecological zones of Ethiopia, according to topography, climate, soils and natural vegetation. Climatologically, the country can be divided into six regions: the arid tropical, the dry equatorial, the semiarid equatorial, the humid equatorial, the highland equatorial and sub-equatorial regions. The last two regions constitute the target zone of the ILCA Highlands Programme.

1.3. The agricultural systems of the Ethiopian highlands

Several authors (among others, Huffnagel, 1961; Westphal, 1975; Amare Getahun, 1978a and b) have described the traditional agricultural systems of the Ethiopian highlands. On a technical basis, Westphal identified four distinct systems: seed-farming, *ensete* (false banana) planting, shifting cultivation and pastoralism. However, from an economic viewpoint the development potential and the resource base of the various highland regions is more important. In this regard Amare Getahun (1978a) differentiated the high-potential cereal/livestock zone, the low-potential cereal/livestock zone and the high-potential horticulture/livestock zone. The principal characteristics of these major agro-ecological zones are summarized in Table 1.2.

1.3.1 The high-potential cereal/livestock zone

The high-potential cereal/livestock zone is the most important in terms of human and livestock densities and the production of food crops. An adequate natural resource base exists for increased crop and livestock production, but social and economic infrastructures are poorly developed. The zone is also undergoing ecological degradation because of increasing human and livestock population pressures combined with the use of traditional agricultural technologies. Efforts to halt or reverse this trend are urgently needed. Throughout the zone, a simple, ox-drawn ard, known locally as a *maresha*, is the main agricultural tool.

This zone comprises the central highlands, the Arsi - Bale massifs, the Harar highlands, the northeastern highland valleys and the Lake Tana basin. The productivity of agriculture, which is based on cereals, oilcrops, pulses, *ensete* and livestock, could be improved considerably throughout the zone, but it is the central highlands area, the most important agricultural area of Ethiopia, which has the greatest potential. Here gains are expected to be easier to achieve in the livestock than in the crop component. Water-logging problems, a lack of response to inorganic fertilizer, and severe erosion are major impediments to achieving productivity increases in crops. On the other hand, the mild climate of the central highlands favours the introduction of higher-yielding crossbred animals and is suitable for the cultivation of forage crops, allowing productivity increases to be achieved through livestock. This central highlands area has therefore been the focus of ILCA's research.

In the Arsi - Bale massifs, covering approximately 34 400 km², livestock husbandry has traditionally dominated agricultural activities, but with the recent influx of Amhara farmers from the north crop cultivation has become more important, such that mixed farming now prevails. The area has benefitted substantially from an intensive rural development programme, which is discussed in more detail in Section 1.4.

Agriculture in the Harar highlands is dominated by sorghum and beef cattle production. This part of the high-potential cereal/livestock highlands is relatively well served with transport and marketing services.

The northeastern highlands and the Lake Tana basin are comparatively small and uniform areas of 6600 km² and 10 000 km² respectively. Both have a considerable potential for increases in crop and livestock productivity, but flood control, erosion and deforestation are important problems in the northeastern highlands. In the Lake Tana basin, the major obstacles to development are poor drainage, animal diseases and parasites. The incidence of malaria and bilharzia in the human population is high.

Table 1.2. *Characteristics of the major agro-ecological zones in the Ethiopian highlands.*

Characteristic	Zone		
	High-potential cereal/livestock	**Low-potential cereal/livestock**	**High-potential horticulture/livestock**
Area (km²)	140 300	162 920	186 300
Population density (persons per km²)	34	32	33
Livestock density (head per km²)	53	28	32
Climate	Humid/subhumid	Subhumid/semi-arid	Humid
Topography	Rolling plateaux	Mountains/escarpments/low plateaux	Dissected plateaux
Main crops	Cereals/pulses/livestock	Cereals/pulses/livestock	Tree crops/livestock

Source: Amare Getahun (1978a).

1.3.2 The low-potential cereal/livestock zone

The low-potential cereal/livestock zone consists of two regions, the degraded high-altitude highlands which are climatically part of the high-potential cereal/livestock zone, and the plateaux and escarpments lying between the lowlands and the more temperate highlands. Human and livestock pressures are high relative to the ressource base, but some out-migration is taking place to other highland systems. Crop yields are low and there is an acute shortage of arable land and productive pastures. Steep and rugged sites are cultivated, aggravating erosion. In many areas the problems of soil conservation are acute and new settlements should be discouraged and minimized. The existing agricultural resource base is deteriorating rapidly. Again, the *maresha* is the main agricultural tool.

1.3.3 The high-potential horticulture/livestock zone

The high-potential horticulture/livestock zone has high annual rainfall, an extended wet season and a moderate, warm climate. Social and economic infrastructures are poorly developed. Perennial crops such as coffee and tea are important, while *ensete*, root crops and maize are the principal food crops. Horticulture and chat (*Catha* *edulis*) production are also important. This zone is attracting government attention for potential resettlement programmes and commercial agricultural development. Quite high numbers of cattle are kept, but the number of small ruminants is low. The hoe is the main agricultural tool.

1.4 Previous agricultural research and development in Ethiopia

The first efforts by the Ethiopian Government to establish agricultural research and experimental facilities date from 1952. However, agricultural research in Ethiopia was not institutionalized until 1966, when the Institute of Agricultural Research (JAR) was set up. The IAR was given official responsibility for the sponsorship and coordination of all agricultural research, and now has eight research stations in the country.

Although the Ethiopian Ministry of Agriculture was established at the beginning of this century, it was not until the early 1950s that attempts were made to transform traditional peasant agriculture. Most of these attempts have used the "package" approach, although the initial focus was on the development of commercial farming. The major components of the package programmes have included fertilizers, improved seeds, farm credits, marketing facilities, better tools and implements, and improved storage facilities.

The basic aim in the package approach was to accelerate agricultural development by concentrating inputs and activities in geographically delimited regions (Stahl, 1973). A partial list of these intensive regional agricultural development projects is given in Amare Getahun (1977).

The first comprehensive package project established in Ethiopia was the Chilalo Agricultural Development Unit (CADU). This project began in 1967 and was financed jointly by the Ethiopian and Swedish Governments. It included research, extension, marketing aspects and credit and input supply schemes for smallholders. Its main impact was to show that significant increases in cereal yields were feasible through the use of fertilizer. Farmer extension services were an integral part of CADU's activities. Other similar projects were started in later years, but it was realized that implementing them throughout the whole country would not be feasible because of the high manpower needs and costs involved. Then, as now, Ethiopia had insufficient highly qualified staff to service adequately the needs of millions of farmers. These package programmes also fostered regional economic inequalities.

As a result of these disadvantages, the Minimum Package Programmes (MPPs) were initiated. In 1971 the Extension and Project Implementation Department (EPID) was established in the Ministry of Agriculture, with the general aim of increasing the production of peasant farmers by implementing the MPPs. The programmes were funded by the World Bank through a credit from the IDA (International Development Association). Most of the target farmers for these programmes were, however, located close to all-weather roads. Furthermore, the MPPs have concentrated on crop improvement, and to date the livestock component on farms has received comparatively little attention from researchers or developers despite its importance to the Ethiopian economy. Some research has been done on specific topics such as nutrition and breeding at the JAR, but little attention has been given to improving the overall farming system by developing the livestock component as an integral part of the farm.

1.5 Land tenure system

The pre-revolution land tenure system was very complex, differed regionally and was closely linked with the political power structures and social class organization existing at the time. Various authors, including Goericke (1979), have studied the pre-revolution system. Three main forms of land tenure could be identified: a form of communal tenure in the north of the country, individually owned land in the centre and south under a landlord/tenant system based mainly on sharecropping, and government- or church-owned land.

Since the political revolution in 1974, the Ethiopian Government has transformed the institutional and social basis of production in agriculture. The Land Reform Proclamation of 1975 dissolved all existing tenancy relationships and abolished private land ownership. All rural land became "the collective property of the Ethiopian people". The institutional vehicle to implement these reforms were the Peasant Associations (PAs) that were established by the same proclamation.

Each PA has 200 to 400 farm families with a total land area of around 800 ha. PAs are given wide administrative and judicial powers to redistribute the land, organize cooperatives and build rural institutions such as clinics and schools. By late 1980, over 25 000 PAs had been established with more than seven million members.

Government policy is to promote cooperative modes of production, but to date most land is still allocated individually. Farmers can therefore still be considered as individual smallholders, although most PAs also set aside a portion of their land as a cooperative farm. Individual farm units, comprising several plots, range from 1 to 5 ha depending on family size, local population density and the policies of the local PA. Distribution of land takes into account the different fertility levels of the soils within the land area of the PA. This policy, although fair in principle, has in practice contributed to the fragmentation of each farmer's cropping area.

2. Studies on the traditional agricultural system

ILCA concentrated its initial research efforts on the central Ethiopian highlands. This is a large zone with an estimated area of 73 000 km². Ethiopia's capital city, Addis Ababa, stands at its southeastern edge. Within this zone ILCA selected two study areas for its field research, each at a different altitude: the first area lay around Debre Zeit, 50 km south of Addis Ababa at an altitude of 1800 m, while the second lay around Debre Berhan, 120 km northeast of Addis Ababa at an altitude of 2800 m. Research stations were established in both areas.

This chapter reports on the results of ILCA's studies in the traditional agricultural systems of these areas. The research design is given in Section 2.1; the production environment is summarized in Section 2.2; this is followed by five sections presenting key results on land holdings and land productivity, livestock holdings and their productivity, the supply and allocation of labour, the subsistence food economy, and finally some details of agricultural product prices; Section 2.8 places these results in the context of a model of the smallholder production system.

2.1 Methods

ILCA's studies on traditional agricultural systems in the Ethiopian highlands started in 1976 with an intensive literature and data review. In some areas previous studies had been conducted by various government agencies, research institutes and universities[1].

> [1] Extensive bibliographies on these studies have been prepared by Alula Hidaru and Dessalegn Rahmato (1976), Ayele Gebre Mariam (1978) and Amare Getahun (1978b).

Most of this previous work, however, relates to the period before the 1975 land reform. ILCA therefore collected more up-to-date information through a series of field surveys, beginning with baseline surveys of the Ada Wereda around Debre Zeit and the Tegulet and Bulga Awraja around Debre Berhan[2].

> [2] Within each Ethiopian province the administrative subdivisions are *awrajas* and *weredas*. Several weredas comprise each awraja.

Such baseline surveys serve as a reference point in time for the future comparison of selected parameters. Their objective is to provide a basic understanding of the farming system, the availability and allocation of resources, and the constraints on their use. A baseline survey is also used to assess, in general terms, the potential for agricultural development of the area under investigation and the feasibility of certain development paths in relation to the existing economic and political framework.

In the collection of data, a combination of onetime interviews with individuals and panel or group discussions were used as a method of investigation. Group interviews proved particularly useful for obtaining information on the agricultural calendar, prevalent plant and animal diseases and pests, crop yields, seeding rates and dates, consumption patterns, cultural practices, sociological and religious customs; and general agricultural problems in the area.

For the survey in Ada Wereda, 151 households affiliated with 21 PAs were randomly selected and interviewed. In the Tegulet and Bulga Awraja, five weredas were surveyed and a total of 226 households belonging to 24 different PAs were randomly selected for interview. The enumerators used for the interviews were local twelfth grade graduates, mostly the sons of farmers. They worked under the close supervision of professionally qualified staff. The results of both these baseline surveys are given in Telahun Makonnen and Getachew Assamenew (1978) and Telahun Makonnen (1978).

Following the baseline surveys, routine data collection systems have been set up in each study area to gather further information on the traditional farming system. These ongoing surveys cover a smaller sample than the baseline survey, but provide updated and detailed information on certain parameters which identify the dynamics of the traditional system. They help ILCA identify new opportunities for development as well as any special problems and processes likely to occur with the adoption of innovations in a peasant economy. These sample farmers do not test ILCA's innovations themselves, but serve as a control group against which the innovations introduced elsewhere are evaluated.

Technical assistants with training in agricultural economics were assigned to each study area to supervise data collection by enumerators. The enumerators were secondary school graduates recruited through the local PA. These routine data collections were initiated at the same time as development of the respective research stations. The farms involved were randomly selected from three PAs around the Debre Zeit research station and from four PAs surrounding the Debre Berhan station. Initially, these control groups of 60 "outside" farmers at each location were visited at least weekly. The data collection programme was evaluated at the end of each year and progressively scaled down: the number of outside farmers visited, the frequency of visits and the items recorded have been gradually reduced.

The following information was collected for the period 1978 to 1980 for the Debre Zeit and Debre Berhan study areas:

- inventories of land holdings and plot sizes, stock holdings, tools and equipment, and demographic data;

- detailed input - output data on both crop and livestock production by labour category and farm operation.

In particular:

- basic agronomic data, including information on seeding, weeding and harvesting dates, crop diseases, and fertilizer response;

- market information from both Debre Zeit and Debre Berhan covering crops, livestock and livestock products;

- labour inputs by activity, and by age, sex and status of worker;

- draught animal usage;

- inputs to each crop enterprise by plot, including seed, fertilizer and insecticides;

- inputs to livestock enterprises, including feed concentrates, veterinary supplies and grazing;

- breeding and animal health records;

- outputs of grain, straw and residues from crop enterprises;

- outputs of work, manure, meat and milk from livestock enterprises;

- disposal of crop and livestock products through consumption, sale or gift;

- meteorological data;

- household economy information on consumption and expenditure patterns, use of cash income and energy use;

- sociological/demographic information on family size, task responsibilities, observance of religious holidays and fasting periods.

These routine data collections have been supplemented at times by special-purpose surveys on particular topics where information was lacking or not current, but considered essential to the research.

2.2 The production environment

The high-potential cereal/livestock zone is extremely diverse in its geology and soil formations. It is fragmented by valleys and rivers into many local land units, and consists of plateaux and tablelands surrounded by escarpments. The soils, shallow for the most part, are mainly alfisols, vertisols and inceptisols. They are red to light red-brown on the mountains and hillsides, red-brown on the intermediate slopes, brown to dark brown on the undulating plains, and black in the lower parts and bottomlands. The red-brown to dark brown soils are the most suitable for agriculture, particularly for grain crops. Stony mountain slopes and seasonally flooded bottomlands are used principally for grazing. The major soil-related problems are erosion on the slopes, poor drainage on the bottomlands and generally low levels of available phosphorus and nitrogen.

The rainfall regime over much of the highland area is typically bimodal, with the main rains, known as the *meher*, occurring from June through to September, and the short rains, known as the *belg*, occurring during February to May. Heavy storms and hail are common in much of the central highlands. The *belg* rains are not sufficiently reliable to permit crop planting each year, and when they do occur they can merge into the *meher*. The mean annual rainfall in the central highlands ranges from 500 to 1500 mm, depending on altitude. Some locations receive up to 2000 mm per year, but in spite of this, and because of excessive runoff, water shortage is a common problem for 5 or 6 months per year in many parts of the highlands. The *belg* rains are more reliable in the Debre Berhan area than at Debre Zeit.

Relative humidity is lowest in the year during the long dry period from November to March. Temperatures are generally moderate and uniform, although extreme diurnal variations can occur. Frosts occur above 2100 m between October and January.

Environmental conditions at the two sites selected by ILCA for its research work approximate to the upper and lower limits of the central highland plateau. They are representative of large areas of the Ethiopian highlands, so that the results of the research undertaken at either site will have broad applicability.

ILCA's initial field research in the Ethiopian highlands centred on a 160-ha site in the Ada Wereda of the Yerer Kereyu Awraja near Debre Zeit, 50 km south of Addis Ababa. The site was granted to ILCA by the Ethiopian Government in 1976.

The Ada Wereda covers an area of around 1750 km², with approximately 18 000 rural households belonging to 94 PAs. The total human population is about 130 000, of which approximately 45 000 live in Debre Zeit, the principal town. The average population density is 74 persons per km, with 0.8 ha per person of regularly cultivated farmland. Almost three quarters of the population are under 30 years old.

The area is well known for the quality of its teff, and is a net food exporter. Ada Wereda consists mainly of undulating plains with scattered crater hills, but can be divided into three altitude zones: an area of around 1000 km² or 57% of the land, at an altitude between 1800 and 2000 m; an area of approximately 600 km² or 34% of the land, at an altitude between 1500 and 1800 m; and the remainder, at altitudes of over 2000 m with peaks rising to 3100 m.

The ILCA research station is at 1850 m altitude. The annual mean temperature at the station is 16°C, ranging from a mean minimum of 10°C to a mean maximum of 22°C (1960-1974). Average annual rainfall is 845 mm, with 70% falling between June and September (1960-1974). Mean monthly rainfalls from October to February do not exceed 15 mm. From February to May the monthly average rainfall is approximately 40 mm, but is unreliable (Le Houérou, 1976). Normally there is only one cropping season.

An ILCA study of land-use patterns showed that 60% of the Ada Wereda is regularly cultivated, an additional 25% is seriously affected by ravine erosion and unsuitable for cultivation, and less than 15% is natural vegetation (Haywood et al, 1979). Half of this latter percentage is severely degraded owing to wood cutting and overgrazing. Of the total area, only 19% is high-potential farmland and a further 36% is medium-potential. The latter is on slopes subject to sheet and gully erosion. Low-potential cropland and degraded natural vegetation on steep slopes account for a further 16% of the wereda. Sheet and ravine erosion in these areas are widespread. Finally, 29% is forest, natural bush and grassland, urban areas and garden, a major part of which is also subject to sheet and ravine erosion.

On the ILCA station, soils vary from red sandy loams to clay and clay loams. Farmers in the area distinguish only between the light (red) and heavy (black) soils, located on hillsides and in valley bottoms respectively. Both types are slightly arid (pH 6.5 to 7) in the surface layers and neutral to alkaline in the deeper horizons. Soil fertility on the ILCA station is adequate with respect to phosphorus, at 35 to 70 ppm in the upper soil layers, while the potassium content is relatively high. Both the organic matter fraction at 1.52.5%, and nitrogen (0.1-0.2%), are low in the upper layers (Le Houérou, 1976).

In late 1978, three PAs provided a second site of 280 ha near Debre Berhan, 120 km north of Addis Ababa in the Tegulet and Bulga Awraja. This awraja covers 7844 km², with the rural population of around 530 000 organized in 761 PAs having a total farmer membership of 126 000. Its principal centre is Debre Berhan, which has a population of approximately 22 000. Seventy percent of the total population is under 30 years old. The awraja is divided into 12 weredas. The ILCA station is located in the Baso and Worena Wereda. The population of this wereda is organized in 100 PAs with a registered membership of just under 20 000 farm families.

The Baso and Worena Wereda is located around Debre Berhan and consists of undulating plains with hillocks and broad valley bottoms. This plateau area varies in altitude between 2600 and 3000 m. The ILCA station is at 2800 m altitude. The average annual rainfall is around 1150 mm, with 70% falling between July and September, which is the main cropping season. In some years cropping is also possible in the short rainy season from February to May. However, these short rains are unreliable, with adequate rainfall occurring only about one year in three[3]. Long-term data on temperatures in the Debre Berhan area are not available. Night frosts occur frequently from October to January, while hail is an important agricultural hazard and flooding on bottomland is a severe problem.

[3] Based on observations over 10 years only.

Section 2.3 gives details of the traditional classification of land types in the area by farmers. Soils on the ILCA station are poorly draining vertisols typical of the plains south of Debre Berhan. According to Murphy (1959), these soils generally have an organic matter content of above 3%, while nitrogen content is typically above 1%. Soils at the ILCA site have pH values between 5 and 6 and a nitrogen content below 1%. Available phosphorus is also low, at less than 7 ppm. The potassium content is generally less than 150 ppm.

Thus the two ILCA study areas are contrasting, but both are representative of large areas of the Ethiopian highlands, where land use is dominated by mixed smallholder rainfed agriculture producing cereals, pulses and livestock. Traditional agricultural tools (*maresha* cultivators[4], sickles and hoes) and paired oxen are used for producing a variety of crops such as teff, wheat, barley, sorghum, maize, horse beans, peas, lentils and a local type of hops. Annual crop yields average from 400 to 1000 kg per ha. Cereals are grown on about two thirds of the land cultivated each year, with the majority of the remainder sown to pulses. A widely practiced crop rotation is two consecutive cereal crops followed by a pulse crop, with a fallow period of variable length according to soil fertility and population pressures. Some control over crop diseases and weeds is also achieved by using this basic three-course rotation. Other rotations are also used, depending on the soil type and fertility. Land held in common and left uncultivated, as well as fallowed cropland, form a much higher fraction of the Baso and Worena Wereda than of the Ada Wereda.

[4] The *maresha* is constructed by the farmer from wood and has a metal tip for penetrating the soil. It does not turn a furrow like the conventional mouldboard plough, but only breaks and disturbs the soil. One to five cultivations are usually carried out with the *maresha* on each plot prior to planting. These cultivations are done in different directions and at different angles.

However, in both areas permanent pasture land is increasingly being cultivated, fallow periods are being reduced and pressures are increasing on the available arable land for subsistence crop production. This trend has substantially added to the erosion problem, and average farm sizes are reducing in both locations.

Overall soil fertility is declining in the highlands. The use of chemical fertilizers is limited. Manure is normally dried and used as fuel, only rarely as a fertilizer. In Ethiopia over the period 1970-1977, overall annual fertilizer consumption per ha of agricultural land averaged only 0.2 kg (Blodig, 1982). Fewer than 10% of farmers regularly use chemical fertilizers or improved seeds.

Manure is made into dung cakes by drying after mixing with grass and straw. Typical weekly consumption of dung cakes is given in Table 2.1, together with the use of firewood.

Table 2.1. *Typical weekly use of dung cakes and firewood by households in Ada and Baso and Worena Weredas*[a].

Fuel type	Consumption (kg/family/week)	
	Ada Wereda	Baso and Worena Wereda
Dung cakes[b]	41	48
Firewood	10	13

[a] From ILCA surveys in 1980 of 25 smallholder households near Debre Zeit and Debre Berhan.
[b] Based on sun-dried weight.

Firewood resources are not uniformly distributed throughout the highlands. Regions with high population densities tend to have limited forest cover. Since 1900, Ethiopia's forested area has been reduced from around 40% to only 4% of the land surface. The main species used for firewood are *Acacia* spp. and *Eucalyptus* spp.

Agricultural extension services are limited, and priority in the allocation of farm inputs is given to cooperatives.

Most farmers own livestock, and a typical inventory is two oxen, a cow, a few sheep, a donkey and some chickens. Cattle (Zebu type) are kept mainly as a source of draught power and manure production. Milk, meat and hides are relatively less important byproducts. Sheep and goats require minimal inputs and provide investment and security in times of need. Donkeys are used extensively to transport agricultural inputs and farm produce. FAO (1979) reported the donkey population of Ethiopia at 3.9 million head, as well as 1.4 million mules and 1.5 million horses.

Productivity is low for all livestock species. The seasonal shortage of feed for livestock is acute throughout much of the highlands. Grazing on communal lands and fallow plots constitutes the main source of feed. It is supplemented with straws, crop residues and stubble grazing. The food grain needs of the rising human population are resulting in a progressive extension of the area under cultivation and a consequent reduction of fallow areas, leading to increased use of the limited grazing resources that remain. Work oxen and cows in milk are supplemented with hay in the dry season and straw in the wet season. Valley bottoms and crop stubbles are grazed during the dry season from December to April. From about May to November, livestock are largely dependent for fodder on hillsides, field verges and roadsides. Systematic rotational grazing or the cultivation of special-purpose fodder crops is rarely practiced. PAs have well defined boundaries and control access to grazing within these boundaries. Differences in the endowments of crop and grazing lands between PAs comprise a new constraint to livestock production at the wereda level.

A typical farm of 2.5 ha, two thirds of which is sown to cereals and the remainder to pulses, together with an additional 0.75 ha of communal grazing land, produces a total of approximately 6 t of DM in a normal year. The average farm stock holding is around 3.67 LU[5].

[5] One LU equals 250 kg liveweight.

If the daily feed requirement is 2.5 kg of DM per 100 kg of liveweight, annual feed requirement is 8.4 t of DM. Thus, less than 75% of the feed required for optimal growth is available overall, although there are strong seasonal variations. Locally too, this percentage can be higher or lower, but generally speaking overall livestock feed resources are already inadequate and will become increasingly so unless current trends are reversed. Furthermore, most forages consumed by stock are of low digestibility, allowing only limited periods in the year when livestock can gain weight without supplementation with high-quality feeds.

These technical and environmental constraints are exacerbated by cultural, social, institutional and infrastructural problems. The cultural and social constraints include strict religious beliefs, which limit the amount of time farmers can work in their fields, a conservative attitude towards technical innovations, and low consumer demand for animal products during fasting periods. Institutionally, there is a lack of efficient veterinary and extension services. A major infrastructural problem is the inadequate road and transport system in most areas of the highlands.

2.3 Land holdings, use and productivity

Around the ILCA Debre Zeit station, the average farm size from 1978 to 1980 was approximately 2.5 ha, almost all of which was permanently cropped. The total area of fallow land was less than 5% of the total area regularly cultivated. Permanent pastures are often held in common and are overgrazed. Pasture areas on bottomland are seasonally flooded and during the rains grazing moves gradually onto the hillsides. Livestock must be herded only within the boundary of the PA of which the owner is a member.

In the vicinity of the ILCA Debre Berhan station, the average agricultural holding is 3.8 ha. This area is larger than at Debre Zeit, but only 50 to 60% of it - around 2.3 ha - is cultivated annually. Soil fertility levels are such that farmers keep the remainder as fallow or as pasture land to ensure long-term stability in crop yields. Most uncultivated land is in valley bottoms where, far more so than at Debre Zeit, cultivation is seriously constrained by seasonal flooding and frosts. Cropping intensity is highest on the hillsides.

Farmers around Debre Berhan, as throughout the highlands generally, distinguish three basic land classes: productive *aredda*, less productive *aredda*, and *yemeda*. Land is included in a particular class according to the natural environment, exposure to frost, fertility, and the type of crop grown.

Productive *aredda* land usually lies close to the homestead on the hillside. It is well drained, comparatively fertile, less exposed to frost and is usually cropped once a year during either the *belg* or *meher* seasons. Ash and manure are applied to this land class, and the fallow fraction is minimal. Horse beans, wheat and sometimes barley are grown, and the grain is used as seed for crops on all land classes. Average crop yields are highest on this land class, reflecting the factors mentioned above plus generally more intensive crop management. Grazing is actively restricted on productive *aredda* plots.

Land in the less productive *aredda* class is more exposed to frost and less well drained, with occasional waterlogging problems in the lower parts. *Gaye* or soil burning is sometimes practiced on this type of land[6]. Barley, horse beans, field peas, lentils and linseed are grown, again during either the *belg* or the *meher* seasons.

[6] Soil burning, *gaye*, is a traditional form of fertilization. After a plot has been fallow for some years, the surface vegetation is mounded together with dung, covered with earth and then ignited. After burning the mounded material is spread. Mounds are spaced at 2 to 3 m intervals over the plots. Although *gaye* increases post-fallow cereal yields, the long-term impact of this practice on soil structure and fertility is negative.

The *yemeda* land class consists of the seasonally flooded bottomland, and is most exposed to frost. It is usually used for cropping only during the *belg*, when flooding is not a severe problem and frost incidence is lowest. The use of *yemeda* land for cropping during the *meher* season is minimal. *Gaye* is widely practiced. Barley, which is early maturing and relatively water-tolerant, is almost the only crop grown on this land class.

In both the Debre Zeit and Debre Berhan study areas, the individual farmer's land holdings are highly fragmented in various parcels, subdivided into different plots. Fragmentation arises from the PA strategy of allocating the different land classes equally among its member farmers. The average plot size is 3500 m^2 at Debre Zeit, but only 2300 m^2 at Debre Berhan. Around Debre Zeit, plots are on average 650 m from the homestead, with some up to 3500 m distant. At Debre Berhan, they are on average 525 m from the homestead, with single plots up to 3000 m distant. Fragmentation makes effective grazing control difficult. Weed invasion from adjacent plots is also a problem. Plot fragmentation at both Debre Berhan and Debre Zeit may, however, help to lower overall production risks, especially at the former location where it minimizes the impact of frost on the plots of any one farmer.

In the Debre Zeit area, the main cereals grown are teff, maize, wheat and barley. Horse beans, chick peas and field peas are the principal pulses. Time series cropping pattern data for Ada Wereda are summarized in Table 2.2. Overall, the proportion of land cropped in the Wereda has increased in recent years. There has also been a steady increase in the cultivation of teff, as might be expected with the rapidly rising producer prices for this cereal. Teff has increased in price more than threefold since 1973 (see Section 2.7).

In the ILCA baseline survey of Tegulet and Bulga Awraja, a marked difference in land-use patterns was observed between the area south of Debre Berhan, and that to the north of the town. Population pressures are relatively greater and soils are seriously degraded in the northern area. Here, holdings average 1.8 ha, with 87% under crops and only 13% under natural grassland and fallow. By contrast, to the south holdings average 3.8 ha, with approximately equal land areas under crops and under natural grassland or fallow. Barley, wheat and pulses dominate cropping in both areas. Teff is not grown in the wereda as the altitude is over the 2200 m limit for this crop.

The area south of Debre Berhan was selected as the focus of ILCA's research because the most pressing problems to the north are related to soil erosion, which does not come directly under ILCA's mandate. Table 2.3 presents the average percentages of cropland sown to the different crops during the main cropping season, south of Debre Berhan. During the *belg* season from February to May, barley is almost always the only crop planted.

Farmers in the Debre Berhan area have had little or no exposure to improved agricultural technologies. During ILCA's baseline survey in the Tegulet and Bulga Awraja in 1978, only 5% of the farmers interviewed reported having used any improved technology during any of the previous 5 years.

Table 2.3. ***Percentages of cropland sown to different crops during the main cropping season in Baso and Worena Wereda south of Debre Berhan (average, 1979-1980)***[a]**.**

Crop	Percentage
Barley	72
Wheat	8
Horse beans	12
Field peas	6
Lentils and linseed	2

[a] From ILCA surveys.

Table 2.2. ***Cropping pattern in Ada Wereda (percentage of total area under crops).***

Crop	Crop year(s)

	1960-61[a]	1973[b]	1975[b]	1977[c]	1978[d]	1979[d]	1980[d]
Teff	37	37	44	41	49	56	50
Wheat	18	15	15	16	6	7	7
Other cereals	17	23	10	16	5	5	4
Pulses	28	24	30	25	37	31	36
Other	-	1	1	2	3	1	3

[a] From Borton et al (1969).
[b] From Vincent (1977).
[c] From Telahun Makonnen and Getachew Assamenew (1978).
[d] From ILCA surveys.

Table 2.4 presents comparative yields of the major crops grown using traditional farming practices in the two ILCA study areas. National average yields for these same crops are also tabulated. The table shows that relatively high teff yields are achieved in the Ada Wereda, but that pulses perform more favourably in the Baso and Worena Wereda.

2.4 Livestock holdings and productivity

The most important contribution of livestock to agricultural production in the Ethiopian highlands is the use of oxen as draught animals. Paired oxen are used for all but a small percentage of highland cultivation, and are also used for threshing. Milk, meat and hides from cattle are relatively less important byproducts, but manure is collected dried and used as the major household fuel. If he can, each farmer maintains one or two cows to produce the two oxen needed for draught. Entire males to be used as draught oxen are castrated at 4 to 5 years of age, when they are physically mature.

Cows are milked, with the milk being consumed mostly by young children. Domestic butter making is common. Livestock products are often sold to finance the purchase of basic household commodities such as coffee, tea, salt, cooking oil and sugar. Sheep and goats are kept mainly as a secondary investment and a source of cash in times of need. Only occasionally they are slaughtered for home consumption. Small ruminants are not milked. Riding horses are common, but seldom used as pack animals. Donkeys are widely used as transport animals. Poultry are widely kept, and are mainly used for egg production and home consumption. Livestock confer a certain degree of security in times of crop failure as they are a "near-cash" capital stock, important in areas where no institutional credit facilities exist.

Livestock productivity is low for all classes of animals, reflecting an underexploited resource and generally inadequate nutrition. Milk offtake from Zebu cows rarely exceeds 300 kg for a lactation period of less than 7 months. Calves consume some 100 kg of milk in their first 3 months of life. The annual calving rate for the indigenous Zebu types of cattle is just over 50%, which is adequate for maintenance of stock numbers but allows little opportunity for expanding offtake rates. Cows do not calve until approximately 4 years of age. Old cows and oxen and barren females account for almost all cattle sales. Cattle reach physical maturity at 4 to 5 years of age, with an average mature liveweight for cows of around 210 kg, while oxen average around 280 kg (Mukassa-Mugerwa, 1981).

Various factors contribute to the low lactation yields, extended calving intervals and relatively late ages at maturity of the indigenous cattle. Their overall genetic potential for production is considered to be low, but their low production also reflects an environment in which animals are subject to long periods of nutritional stress and heavy parasite burdens. The seasonal variability in the quality and quantity of feed on offer gives rise to an annual cyclical pattern of liveweight gains and losses. The pattern is also affected by energy demands for work.

Table 2.4. ***Average crop yields nationally and in Ada and Baso and Worena Weredas (kg/ha)[a].***

Crop	National average[b]	Ada Wereda[c]	Baso and Worena Wereda[d]
Teff	740	892	n.ap.[c]
Wheat	950	633	964
Barley	952	n.av.	846
Chick peas	628	486	n.av.
Field peas	606	n.av.	846
Horse beans	986	758	1 295

[a] Wereda-level data are based on ILCA surveys at Debre Zeit and Debre Berhan.
[b] Average 1974-1978, compiled from Ministry of Agriculture (1979).
[c] From ILCA surveys, 1977-1980.
[d] From ILCA surveys 1979-1980, *meher* season only.
[c] Teff is not grown in this area.

Liveweights of oxen owned by participating farmers (see Chapter 3), who have better feed resources than traditional farmers, averaged 312 kg in 1980 and ranged from a maximum monthly average of 328 kg in December to a minimum one of 293 kg in July. The monthly averages are given in Table 2.5. December is at the end of the harvesting season, when straws and crop residues are in plentiful supply, while July is at the height of the cultivation season.

Table 2.5. ***Average monthly liveweights of indigenous oxen owned by participating farmers in Ada Wereda*[a].**

Month	Liveweight (kg)
January	317
February	312
March	323
April	317
May	309
June	304
July	293
August	294
September	300
October	324
November	327
December	328

[a] From ILCA surveys, 1980.

Sheep are also relatively unproductive and, like the cattle, are subject to heavy endoparasitic burdens and long periods of nutritional stress. Available data suggest a lambing percentage of no more than 110% p.a., although local breeds lamb year-round. Morbidity and mortality are high - mortality rates of up to 30% p.a. have been reported - and liveweights at sale average 20 to 30 kg for typical sheep from the central highlands (Mukassa-Mugerwa, 1981).

Livestock graze in mixed sex groups, giving little opportunity for controlled mating or seasonal calving. Trypanosomiasis is not a problem in the highlands, but outbreaks of anthrax, pasteurellosis, blackquarter and foot-and-mouth disease occur sporadically. Ticks are common at the lower altitudes of the highlands, but endoparasites are responsible for the greatest production losses in livestock if morbidity and mortality are both taken into account. Liverfluke, lungworm and intestinal worm infection are important problems, principally due to extended periods of grazing on seasonally waterlogged bottomlands. More than 80% of cattle examined in a field survey at Debre Zeit had signs of liverfluke infestations as determined from faecal samples (Mukassa-Mugerwa, 1981).

Table 2.6 gives average holdings of livestock per farmer as determined in ILCA surveys in the Ada and Baso and Worena Weredas. The table highlights the regional differences in the relative importance of different livestock species. In particular, the average holdings of sheep and donkeys in Baso and Worena Wereda are substantially higher than in Ada Wereda. Observed minimum and maximum holdings of the different cattle classes are similar in both weredas.

An alternative compilation of the livestock inventory data is presented in Table 2.7, which gives the percentages of farmers in both weredas with holdings of various sets of livestock.

2.5 Labour supply and allocation

As in virtually all subsistence-oriented agricultural systems, the labour needed to operate family farms in the Ethiopian highlands is characterized by strong seasonality. Insofar as the family's work schedule is dictated by the agricultural calendar there are only limited opportunities for modifying it. An average rural family comprises five members, giving an annual labour supply in excess of aggregate labour needs for the farm operation. Nonetheless, non-family labour commonly has to be used by smallholders in the central Ethiopian highlands. Labour is both exchanged and hired to overcome labour bottlenecks. Hired labour is most important at harvest time, from October to December.

Table 2.6. ***Average livestock holdings per farmer in Ada and Baso and Worena Weredas*[a].**

Livestock type	Ada Wereda	Baso and Worena Wereda
Oxen	1.86 (2,0 - 4)[b]	1.02 (1,0 - 3)[b]
Cows	0.93 (0,0 - 4)	1.45 (1,0 - 4)
Heifers	0.33 (0,0 - 2)	0.88(1,0 - 3)
Bulls	0.48 (0,0 - 5)	0.69 (0,0 - 2)
Calves	0.64 (0,0 - 3)	0.98 (0,0 - 3)
Sheep	1.55 (0,0 - 4)	10.69 (5,0 - 32)
Goats	1.00 (0, 0 - 6)	0.12 (0,0 - 2)
Horses	0.05 (0,0 - 1)	1.12 (0,0 - 2)
Donkeys/mules	0.98 (0,0 - 3)	1.81 (1,0 - 5)

[a] From ILCA surveys on 42 farms in each area during 1980.
[b] Bracketed values are mean, modal value and range respectively.

Table 2.7. ***Percentages of farmers in Ada and Baso and Worena Weredas with holdings of different classes of livestock*[a].**

Holding	Ada Wereda	Baso and Worena Wereda
No ox	9	31
One ox	12	38
Two or more oxen	79	31
One or more cows	52	76
One or more bulls	7	55
Five or more sheep	12	69
Twenty or more sheep	0	14
One or more donkeys	55	74
One or more horses	5	50

[a] Compiled from ILCA surveys on 42 farms in each area during 1980.

All physically able members of the household assist in farm work. Tasks can be grouped as labour for crop production (seedbed preparation, planting, weeding, harvesting and transport of produce to the homestead, followed by threshing, winnowing and storing), livestock production (milking, feeding, herding, manure collection barn cleaning, butchering, etc), marketing, domestic chores, farm maintenance and communal farm work.

A typical farm of 2.5 ha of cropland, with two thirds sown to cereals and one third to pulses, requires approximately 1100 hours per year of labour, assuming no quality differences between the labour inputs of the different age and sex groups. This gives an average labour input of around 440 hours per ha per year. Of this total, around two thirds is typically supplied by the family, about one quarter is exchange labour, and less than 10% is hired. Most labour for cropping is supplied by adult males. Together, women and children (less than 15 years old) contribute up to one third of the total labour input for cropping enterprises.

Labour inputs by crop vary both yearly and according to location because of differences in rainfall, soil and land types, cultivation practices and crop yield. High yields can be due to more intensive weeding and better seedbed preparation, but in turn they require extra labour for harvesting and transport.

Teff (*Eragrostis tef*) is the most labour-intensive of all the food crops grown in the central high lands. It requires a clean seedbed, and plots have to be cultivated up to six times before planting. Substantial labour is required for weeding teff. Average labour inputs to the major crops grown around Debre Zeit and Debre Berhan are summarized in Table 2.8. The labour inputs from land preparation through to threshing are included.

Table 2.8. ***Average annual labour inputs by crop in Ada and Baso and Worena Weredas (hours/ha).***

Crop	Ada Wereda[a]	Baso and Worena Wereda[b]
Teff	550	n.ap.[c]
Wheat	480	425
Barley	n.av.[d]	395
Horse beans	320	415
Chick peas/field peas	295	255

[a] Average 1978 - 1980, for data collected on 42 farms.
[b] Average 1979 - 1980, for data collected on 42 farms.
[c] Teff is not grown in this area.
[d] Barley is grown in this area, but not by the farmers surveyed.

The labour inputs to each crop can be broken down according to activities. Labour allocation by activity for the major crop types is summarized in Table 2.9. The values are indicative and differences will occur locally, across years and between farmers. Adult men prepare the seedbed and plant, sometimes assisted by older children. The other crop labour activities are carried out mostly by men, but also by women and children.

In the two ILCA study areas, average crop labour inputs in 1980 were distributed over the year as shown in Table 2.10. Although in some years there are two cultivation seasons around Debre Berhan, the data tabulated are based on observations in 1980, when there was only one crop season.

Table 2.9. ***Average annual labour allocations in Ada and Baso and Worena Weredas for teff, other cereals and pulse crops by activity (percentage labour input)***[a]**.**

Activity	Teff	Other cereals	Pulses
Seedbed preparation and planting	30	30	35
Weeding	25	30	15
Harvesting and transport	30	25	35
Threshing, winnowing and storing	15	15	15
Total	100	100	100

[a] Compiled from ILCA surveys on 42 farms in each area during 1980.

Table 2.10. ***Average monthly labour inputs for all field operations in Ada and Baso and Worena Weredas (hours/farm)***[a]**.**

Month	Ada Wereda[b]	Baso and Worena Wereda[b]
January 1980[c]	2	21
February	5	39
March	27	54
April	29	44
May	31	45
June	53	73
July	125	36
August	112	33
September	138	46
October	136	89
November	207	182
December	160	150
January 1981[c]	129	83

[a] From ILCA surveys on 42 farms in each area during 1980.
[b] Labour inputs by all family members are given equal weights for addition purposes.
[c] The 1980 crop year began with land preparation in January 1980 and finished with threshing in

January 1981.

Land preparation for the main cropping season usually starts during March or April. Most crops are planted around July, after the onset of the main rains, and harvested in November and December. The latter two months are periods of peak labour demand and it is mainly then that labour is hired, at an average adult wage rate of approximately US$ 1 per 8-hour day. However, most non-family labour is on an exchange basis and does not involve cash payments.

Cultural factors limit the field work of Coptic Christian farmers, who observe between 150 and 200 religious holidays each year. However, given local differences in the observance of religious festivals, these totals are indicative only. For the Ethiopian calendar year ended August 1981, strict observance of religious festivals in the Debre Berhan area would have curtailed the farmers' field activities by 188 days in the year.

Labour inputs to livestock production, such as milking, barn cleaning, manure collection and handling, feeding and watering, are principally made by women and children. Herding is done mostly by the younger children and takes approximately 8 hours a day year-round. Young boys and girls herd the animals on their own from 7 years of age onwards. Girls help their mothers collect water and firewood, and assist with other household activities such as cooking and preparing dung cakes for fuel. At least once weekly the farmer, his wife or another member of the family attends the local market to sell farm produce and/or purchase household goods.

The amount of land cultivated cooperatively varies widely from one PA to another, but often seems to diminish from year to year as new farmers emerge within the PA and are allocated land. The output from cooperative land is used for social and political projects. Each farmer is required to supply labour to the collective enterprise with which he is affiliated. In many PAs this obligation is discharged on a fixed day each week. Additionally, farmers are expected to contribute their labour to assist aged or disabled farmers, and those families whose household head is away on government service. Seedbed preparation on the collective enterprise often has to be finished before the farmer can start on his individually assigned plots. These communal farm operations are mainly crop enterprises, and only limited numbers of dairy cooperatives have been established since the Land Reform Proclamation.

2.6 Subsistence food economy

Ethiopian farm families are heavily dependent on home production for their consumption. The staple food of most Amhara people - the dominant social group in the ILCA study areas - is *injera* and *wot*. *Injera* is a porous, sour pancake, a few millimetres thick and 40 to 50 cm in diameter. Although *injera* made from teff is generally preferred, it is also made from barley, wheat, maize and sorghum or even a mixture of these, depending on availability and price. The ingredients of *wot*, the highly spiced sauce which accompanies the *injera*, depend on what is available, fasting requirements and local tastes. Meat *wot* is preferred, but most farmers can afford it only on feast-days[7].

[7] Such as Easter, New Year, Christmas, Epiphany, the end of the short fast in August, Meskel (a religious festival) and weddings.

The fasting rules of the Christian Orthodox church prohibit the consumption of food containing animal protein (except fish) on Wednesdays and Fridays, and during long fasting periods, such as the 8 weeks before Easter and the second and third weeks of August. Most Christian families are thus confined to a vegetarian diet for 130 to 150 days per year. For those who also observe optional fasting days, the total can be as high as 220 days per year. On fasting days the *wot* is made of pulses (peas, beans, lentils) and spices.

Sheep account for most domestic meat consumption. Mutton and lamb consumption in rural areas is almost exclusively from home-produced sheep, while the beef consumed is usually purchased. Veal and pork are not traditionally consumed in Amhara areas. Pork is proscribed to followers of the Orthodox church.

A typical family farm in the central highlands produces sufficient cereals and pulses from its own cropped land to have a modest surplus over and above minimum family food needs in an average year. Table 2.11 presents indicative total production and its allocation for an "average" household of five people (two adults and three children) on an "average" farm of 2.5 ha in an "average" year.

Assuming average farm gate prices of US$ 35 per 100 kg for cereals and US$ 20 per 100 kg for pulses, the annual cash return from crops, after deducting seed and subsistence food needs from total yields, averages around US$ 90 per farm for the 155 kg of cereals and 175 kg of pulses sold. The value of home consumption, using the same prices, is US$ 400, giving a total value of crops produced less seed required for sowing of US$ 490.

Home consumption of animal products is limited by the low productivity of livestock and the need to use them as a principal source of cash for non-farm consumer items. On average a family will slaughter and eat a sheep three times a year. Beef is consumed only rarely: once a year a group of some eight to ten farmers may purchase an ox or cow jointly for slaughter and consumption. Total red meat consumption is approximately 10 kg per head per year. Average per caput consumption of dairy products is around 30 kg of milk equivalent per year. An annual consumption of one chicken and 20 eggs per head is also indicated by the limited data available on the productivity of indigenous poultry. On average, almost 50 kg of cattle dung cakes are consumed weekly for cooking, and sometimes a surplus is available for sale. Assuming prices of US$ 2 per kg of meat, US$ 0.30 per kg of milk and US$ 0.05 per kg of dung cakes, and an average family size of five, the value of consumed livestock products is US$ 288 per year.

Together then, the total gross annual value of crop and livestock products, using market prices for subsistence consumption, is US$ 490 plus US$ 288, or US$ 778 in all.

Cash returns on sales of livestock, livestock products (milk, butter, meat, eggs and dung) and traditional home-made alcoholic drinks total around US$ 50 annually, according to information collected in ILCA surveys. Off-farm income is low because labour is generally in abundant supply and opportunities for non-agricultural employment are very limited. It is usually about US$ 15 per family per year.

Together these sources of income give the "average" farm family a gross cash income in the region of US$ 155 per year - US$ 90 from the sale of crops, US$ 50 from livestock or livestock products and US$ 15 from other sources. This figure is only approximate and wide variations are encountered[8]. Nonetheless, this modest cash component within the system highlights the limited opportunity for internal financing of improvements. Cash is used to purchase agricultural inputs, to buy household goods, and to pay church dues and PA fees, taxes, medical and educational expenses and entertainment. Some money is also put aside for savings.

[8] A subsequent ILCA research report will analyse in detail the consumption and income patterns of smallholders surveyed in the Debre Zeit and Debre Berhan areas.

Table 2.11. *Indicative annual production and disposal of food crops on a typical 2.5-ha family farm in the central highlands.*

Crop type (area)	Total production[a] (kg)	Seed required for following crop[b] (kg)	Home consumption[c] (kg)	Available for sale (kg)
Cereals (1.65 ha)	1 320	165	1000	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] Seeding rates vary widely both yearly and according to location. ILCA has observed seeding rates from 50 kg to 250 kg/ha for the same crop. The values here 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.

The subsistence component of an Ethiopian smallholder can be analysed in terms of the food energy consumption on his farm. Using FAO/WHO standards (as reported in Agren and Gibson, 1968) the "average" farm family has an annual energy requirement of around 4.61 million cal, while the protein requirement is approximately 106 kg per year. Cereals produced in Ethiopia contain an average of 3360 cal and 100 g of protein per kg. Pulses have a higher nutritional value, at 3600 cal and 190 g of protein per kg. One kg of milk contains 760 cal and 34 g of protein, meat 1870 cal and 164 g of protein, eggs 4400 cal and 323 g of protein, and chickens 1200 cal and 155 g of protein (Agree and Gibson, 1968). Annual family consumption on the "average" farm can therefore be estimated as presented in Table 2.12, using the same data (for crops) as in Table 2.11.

The table shows that most of the food energy intake is from crops, and that the proportion of animal protein to total protein consumption is small. The calculations are approximate as they are based on average situations, and only take calories and protein into account. However, they show that in an average year a typical farm family consumed somewhat less than the subsistence food energy requirement in terms of calories, but well over the quantity of protein required. This may indicate that people use their excess protein for energy purposes. In good years, agricultural surpluses are used to build up the household food reserve and stock numbers. Teff in particular can be stored for several years with little loss. In the Debre Berhan study area, average sheep holdings doubled between 1979 and 1981 as a result of favourable crop harvests, which increased the amount of grain available for disposal.

Although in normal years sufficient is produced to satisfy the subsistence requirements of the farm family, there appears to be a chronic shortage of certain vitamins and minerals in the staple diet, such as vitamin A and riboflavin.

The food balance as discussed here is based on averages of "normal" years. Little is known on the probabilities of good and bad agricultural years, and a quantitative assessment of yield variances over time has not yet been undertaken. Nevertheless, Tables 2.11 and 2.12 show that if cereal crops were to fail and the net yield were half the normal amount, the farm family would face an energy shortage of almost 2 million cal. Farmers survive such years by consuming stored supplies and selling stock - sheep and goats initially, then oxen, and finally breeding cows at a later, more desperate stage.

2.7 Agricultural product prices

Land reform has resulted in a redistribution of assets and incomes toward former tenants and landless labourers. Detailed studies of the impact of this redistribution are not available. However, the farm gate prices of major staple crops such as teff have risen sharply. As a consequence, urban food prices have also risen substantially, due to both demand and supply factors.

Table 2.12. ***Annual food energy consumption and requirements for a typical highland smallholder family.***

Product		Quantity		Calories (x 10^6)	Protein (kg)
Crops[a]: Cereals		(1000 kg)		3.36	100.0
Pulses		(250 kg)		0.9	47.5
			Subtotal	4.26	147.5
Livestock[b]: Milk		(150 kg)		0.11	5.1
Mutton/beef		(50 kg)		0.09	8.2
Chicken and eggs		(3 kg) and (100)		0.02	1.2
			Subtotal	0.22	14.5
Total food energy available				4.48	162.0
Total food energy required				4.61	106.0
			Balance	-0.13	+56.0

[a] See Table 2.11 for consumption estimates.
[b] See text for consumption estimates.

Under the tenancy system existing before the land reform, tenant farmers had to give a portion of their output to the landlord, who channelled a large part of this to the urban market. This portion usually ranged from 30 to 50% of total yield, differing according to local tenancy customs. Farmers appear to have responded to land reform by increasing on-farm consumption and maintaining higher on-farm stocks. In both ILCA study areas, most farmers reported consuming more than before the land reform.

Other factors, such as marketing and transport problems, might be contributing to the reduction in marketed surplus, but it will be some years before the causal mechanisms become both apparent and stable.

On the demand side, purchasing power in rural areas has increased substantially, and there is also better distribution of food in towns through shops run by the Urban Dwellers' Associations (*kebeles*).

In 1975 the government introduced fixed purchase prices for most crops. Table 2.13 presents official government wholesale prices and free market prices for a range of crops for 1973, 1979 and 1980 at a selection of markets. The data show the substantial differences between the two prices, and provide evidence of the more favourable terms of trade for farmers compared with urban dwellers resulting from the land reform.

Crop prices fluctuate seasonally, with a peak in the rainy season around July when crops are being planted.

The lowest prices occur at harvesting and threshing time from November to January, when market supplies are most abundant. Although food crops such as teff are easily stored, few farmers keep their surpluses until prices rise. Domestic cash needs are usually such that most of the output available for sale must be sold immediately after threshing. The seasonality in prices of selected crops is illustrated in Table 2.14, where the average monthly market prices of the major crop produced in the area are tabulated for both Debre Zeit and Debre Berhan. At Debre Zeit in 1980, the peak mean monthly price for white teff of US$ 100 per kg in July was 43% higher than the minimum mean monthly price of US$ 35 per kg in January. At Debre Berhan in 1980, the minimum and maximum mean prices for barley occurred in the same months, with the July price 50% higher than the January one.

Table 2.14. ***Average monthly prices in 1980 at the Debre Zeit and Debre Berhan markets for the main cereal crop (US$/100 kg)***[a]**.**

Month	Debre Zeit	Debre Berhan
	White teff	Barley
January	35	22
February	40	22
March	39	23
April	42	24
May	45	27
June	46	30
July	50	33
August	47	31
September	45	30
October	46	29
November	42	26
December	40	25

[a] From weekly ILCA market surveys.

Table 2.13. ***Official government and average market prices for selected crops in 1973, 1979 and 1980 (US$/100 kg).***

	Market prices			Official price (1980)	Market prices		
	1973	1979			1980		
	Nazareth[a]	Debre Zeit[b]	Debre Berhan[b]		Debre Zeit[b]	Debre Berhan[b]	Addis Ababa[c]
White teff	12	41	43	23	43	46	45
Red teff	12	35	38	17	37	42	37
Wheat	11	41	37	15	41	44	40
Barley	8	22	22	13	27	26	29
Sorghum	8	28	26	14	22	25	27
Chick peas	11	25	23	15	28	29	26
Field peas	n.av.	25	20	16	31	25	28
Horse beans	9	17	17	15	19	20	20
Maize	8	17	23	10	19	23	15

[a] Central Statistical Office (1975). Nazareth is approximately 45 km south of Debre Zeit.
[b] Compiled from weekly ILCA market surveys.
[c] From data collected by the Agricultural Marketing Corporation.

Farm input costs have risen rapidly in recent years. Seed costs have increased directly in line with escalating output prices. Fertilizer prices have tripled over the last 10 years, as shown in Table 2.15. Access to institutional credit is limited, and only available for short-term loans, usually for the cropping season only.

Table 2.15. ***Fertilizer prices, 1971-1981 (US$/100 kg)***[a]**.**

Year	DAP[b]	Urea[c]

1971-1973	19	16
1974	22	20
1975	25	25
1976	24	20
1977	24	20
1978	27.50	27.50
1979	32.50	32.50
1980	42.50 (37.50)[d]	42.50 (37.50)[d]
1981	58 (42.50)[d]	41 (35)[d]

[a] Farm gate price.
[b] DAP: 18-46-0
[c] Urea: 46-0-0.
[d] Beginning in 1980, prices to individual farmers were higher than to cooperatives and PAs. Prices to PAs are given in parentheses.

Most cattle sold by smallholders are old oxen or old/barren cows. Seasonality in cattle prices is minimal, particularly at the point of sale by farmers. Cattle intended for sale are usually given preferential feeding by farmers for up to 3 weeks before sale. Prices of smallstock are more variable than for cattle and fluctuate over the year according to the timing of fasting periods, feasts and other celebrations. They are highest immediately before Easter and Christmas.

Table 2.16 presents typical values of various classes of livestock held by farmers. The values tabulated are based on averages observed during weekly ILCA market surveys at Debre Zeit and Debre Berhan during 1979 and 1980[9]. Application of these approximate values to the average holdings of the farmers surveyed by ILCA in 1980 (see Table 2.6) gives average livestock inventory values of US$ 578 in Ada Wereda and of US$ 793 in Baso and Worena Wereda[10].

[9] Local differences not reflected in the table do occur: sheep, for instance, have higher average values in the Debre Berhan than in the Debre Zeit area.

[10] Sheep and goats of mixed ages are valued at US$ 20 per head. Horses are excluded because they do not contribute directly to smallholder production.

Table 2.16. ***Typical values of livestock held by farmers in the central highlands (US$/head)[a].***

Livestock type class[b]	Value (US$/head)
Oxen	150
Bulls	120
Cows	110
Heifers	100
Calves (mixed sex)	40
Adult sheep	25
Lambs	12
Adult goats	25
Kids	10
Donkeys/mules (mixed sex)	30

[a] Based on weekly ILCA market survey data, 1979-1980.
[b] All stock are of indigenous breeds.

The marketing of fluid milk is organized by the Dairy Development Enterprise (DDE)[11], which operates a-milk factory in Addis Ababa. This enterprise pays farmers US$ 0.22 per litre of milk. Milk is collected up to 120 km from Addis Ababa along four major routes radiating from the city. Individual farmers deliver milk to local collection centres, whence it is brought by DDE vehicles to the factory. After standardization to 2.7% butterfat, pasteurized milk is sold by DDE to consumers at US$ 0.30 per litre. This official milk channel is not able to satisfy the demand for milk in Addis Ababa, and urban and pert-urban milk producers selling on the open market receive almost twice the official price. Nonetheless, urban dairies are important sources of milk in most large communities in Ethiopia[12].

[11] Previously known as the Dairy Development Agency (DDA) and founded in 1971 with funds provided by IBRD.

[12] A study of the milk market in Debre Berhan was initiated by ILCA in 1981 and will be reported separately. The study is relevant to a significant number of Ethiopian country towns.

The supply of milk from rural smallholders varies seasonally according to the quantity and quality of the feed on offer to the cows. All but a small percentage of the cows owned by smallholders are of indigenous breeds, and are seldom provided with special-purpose feed supplements to boost milk production.

Butter prices are higher than liquid milk prices on a per litre of milk equivalent basis. The majority of farmers do not have access to a fresh milk market, and they commonly market butter and consume the residual of the conversion process in the home, either as cottage cheese and whey, or else as sour milk. The traditional practice of converting milk into other products largely overcomes the marketing problems associated with fresh milk.

2.8 Model of the traditional system

Figure 2.1 is a representation of the main factors influencing the enterprise choice and productivity of an Ethiopian smallholder. The principal purpose of this schematic model is to illustrate the complexity of the agricultural system from the point of view of the smallholder. Even so, it necessarily simplifies the processes and factors involved. The model distinguishes between factors which can be considered as essentially under the control of the smallholder, and those factors over which he has little or no control. A further distinction is made between subject areas being researched by ILCA, and those which are not. The model does not explicitly recognize the time delays involved between inputs and outputs, nor the time sequencing of inputs or outputs.

Not all the linkages in the model can be discussed here. Instead, only those which concern the relationship between a smallholder and the PA of which he is a member are discussed; since they have particular implications for national development of the highland smallholder system.

Membership in a PA implies access to land for communal and individual cultivation, with the size of the individual holding determined mainly by the size of the smallholder's family and the total land area and mix of land qualities available to the PA. Plots allocated to a smallholder in one year are not necessarily allocated to him again in subsequent years.

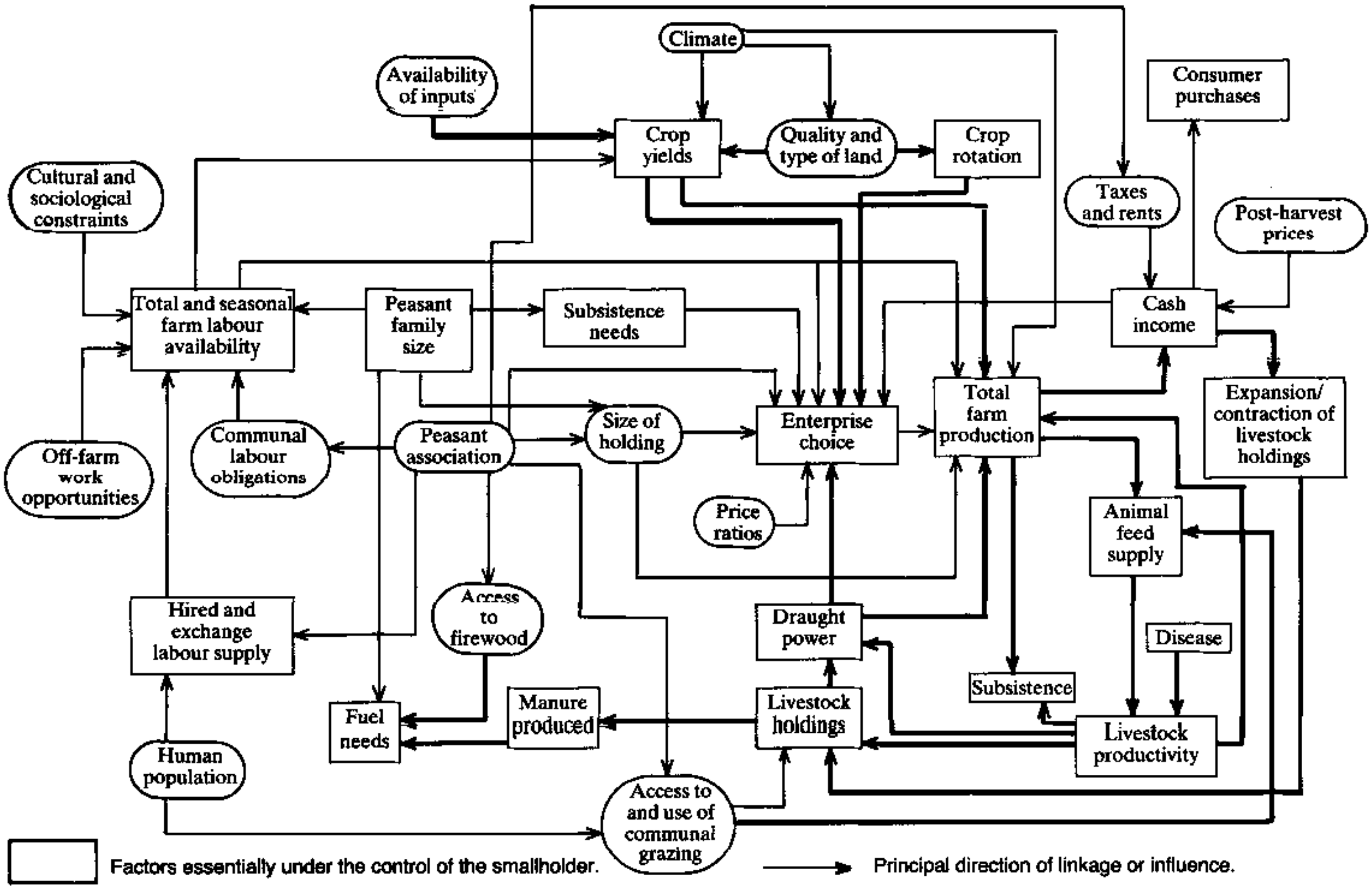
At present individual stock holdings are not restricted by the PAs, but steady increases in the area cropped within each PA will occur as a consequence of growth in the human population, and it is therefore conceivable that such controls will be introduced in the future. However, PAs do control access to communal grazing lands, and via this mechanism some indirect regulation of individual livestock holdings may be achievable.

As already noted, it is common practice for the communal farm area to be cultivated before the individual farmer's plots. Timeliness of cultivation is a major determinant of crop yields. In this regard the potential competition for labour and ox power between communal and individual plots is an important practical consideration in formulating strategies to achieve the most productive use of a PA's total land resources.

Forested areas are diminishing rapidly over much of the central highlands. The remaining timbered areas are under the direct control of the PA. As noted previously, farmers are now heavily dependent on dung cakes instead of firewood for household fuel. Expansion of the forested area will be a key long-run determinant of the stability of the smallholder family system, as trees not only produce wood for fuel but can also contribute to soil stability by reducing erosion and water runoff. In the more exposed areas, they can additionally be used to reduce crop damage and soil dessication due to strong winds, which are common in the highlands. The government has an active national reafforestation programme. The PA also taxes its members to finance local forestry and other development ventures.

PAs with the authority to implement local development are appropriate vehicles for the introduction of innovations into the livestock component of the smallholder system. With limited trained manpower available, the Ethiopian Government must necessarily concentrate its inputs to development at the PA level. It does not have the resources to service individual farmers. Any technology developments for use by individuals will come to them mainly via their PA.

Figure 2.1. Main factors influencing enterprise choice and productivity of an Ethiopian smallholder.



Legend:

Factors essentially under the control of the smallholder.

Factors essentially beyond the control of the smallholder.

Principal direction of linkage or influence.

Subject areas of ILCA's research.

3. Research on innovations for the smallholder agricultural system

3.1 Research background

As indicated in Chapter 1, agricultural research and extension in the Ethiopian highlands has concentrated in the past on the crop component, and particularly on improvements in crop husbandry and marketing. Although livestock production is important in Ethiopian agricultural systems, comparatively little research has been done on improving overall farming systems via the development of animal production at the farm level[1].

> [1] ILCA has conducted some surveys on a number of small farms that had been previously supplied with crossbred cows by EPID and DDA. The surveys showed that farmers encountered substantial problems in ensuring adequate fodder supplies, that veterinary services were inadequate, and that in many cases the overall management of the animals was poor, resulting in high calf mortalities and extended calving intervals.

In 1977 the ILCA Programme Committee authorized the initiation of an ILCA Highlands Research Programme with the objective of "bringing together available technologies in a range of farming systems that will increase animal productivity and profitability in the highlands" (ILCA, 1978). The research programme was to be guided by the following assumptions (adapted from ILCA, 1978):

- smallholder farming for the production of subsistence crops will be the prevailing system for the foreseeable future in the East African highlands;

- there is an urgent need to maintain and build up soil fertility;

- animal draught will remain an integral part of the Ethiopian highland farming system;

- improved forage production and better genetic capabilities are the basis for improving livestock output;

- improved forage production on arable land is possible only when basic subsistence requirements are fulfilled; because of the extreme scarcity of land this generally means that yields per unit area of subsistence crops have to be increased in order to make room for the planting of forage crops;

- there is a growing demand for dairy products and increasing interest among smallholders in starting up a dairy enterprise;

- sheep are an important feature in the highlands of Ethiopia, and there is considerable scope for increased output; again, only if fodder production and genetic potential can be improved;

- at present there is a certain amount of underutilization of labour in most Ethiopian farming communities at certain times of the year.

The basic hypothesis of the research was that substantial gains in farm productivity could be achieved by applying technologies which were, for the most part, already proven. At current human population growth rates of 2.5% p.a, it is essential that such gains be realized by the farming population at large, or there will be a severe food crisis in the Ethiopian highlands by the year 2000.

In the initial years of the research, ILCA concentrated on acquiring knowledge about the role and potential of smallholder dairy development in the central highlands of Ethiopia. Experience elsewhere in the world, for example in India and Kenya, has shown that introducing smallholder dairy production based on crossbred cattle is a powerful means of raising net farm incomes and farmer welfare. In the longer term, a much expanded smallholder dairy sector in Ethiopia would also be a major employer of labour.

The results of ILCA's research since 1977 have indicated that the basic assumptions underlying the programme are still most relevant. Although the programme has not so far dealt with all the topics arising from these assumptions, substantial progress has been made in terms of both systems and component research. The following sections of this chapter present details of the research results from 1977 to 1980 at ILCA's Debre Zeit and Debre Berhan research stations. The former became operational in 1977, 2 years before the latter, and the details presented reflect the longer duration of research at Debre Zeit.

3.2 The research approach

Prevailing prices and price ratios, favourable climatic and environmental conditions, the orientation of small farms towards mixed agriculture, and accessibility to urban markets all suggested a substantial potential for an expansion of smallholder dairy production in both the ILCA study areas. Debre Zeit and Debre Berhan are both included in the milk collection network of the government-owned dairy processing plant at Shola near Addis Ababa[2]. Research results acquired at both stations would thus be directly applicable to other smallholders with good market access for their livestock and dairy products.

[2] An ILCA survey of the Addis Ababa dairy market indicated that the market is able to absorb a substantial increase in supply without a significant reduction in price.

However, an estimated 50 to 75% of Ethiopian farmers are more than half a day's walk from an all-weather road. These off-road producers will continue to have milk marketing problems until the national road network and general infrastructure are much expanded. On the other hand, if smallholder-oriented dairy processing technologies were to be made available to them they too would benefit from ILCA's research. During the early years of the Highlands Programme research was directed primarily towards solving the basic problems of establishing an improved dairy enterprise, but even at this early stage it was envisaged that research on processing technologies would become an integral part of the programme's future activities.

The approaches to research at Debre Zeit and Debre Berhan are presented in Sections 3.2.1 and 3.2.2.

3.2.1 Debre Zeit

The general scarcity of land in Ada Wereda has been described in Section 2.3. It has also been noted that, even with current stock numbers, the quality and quantity of forage available from natural pastures, fallow and crop stovers, are seasonally variable, well below the optimum for livestock production, and occasionally barely sufficient even for maintenance needs. Furthermore, indigenous breeds have a limited milk yield potential even with improved feeding, as reported by IAR (1976). Significant increases in the production of milk in smallholder dairy enterprises will only be achieved by using higher-yielding breeds or crossbreeds of cattle. The use of Friesian sires for crossbreeding, in accordance with the upgrading programme already long since undertaken by the Ethiopian Government, results in crossbred progeny that are substantially larger than local indigenous breeds. To realize economic milk production from locally available crossbred cows therefore requires a high plane of nutrition not generally available in the existing smallholder production setting.

Combined with the land scarcity problem, the need for this high nutritional plane indicated that a farming system with forages grown as an integral part of the cereal - pulse rotation would be necessary. However, Ethiopian farmers do not traditionally grow forage crops, so in this sense forage production would be a new enterprise. Furthermore, the primary goal of subsistence farmers is to satisfy family food requirements through grain crop production, implying that diversification into a new enterprise would only be acceptable if the latter were not put at risk.

ILCA's hypothesis was that subsistence farmers would grow forage crops only if the yields per ha of human food crops could be increased sufficiently to allow some land in the cereal phase of the rotation to be sown to them, and if the net income from the livestock enterprise using the forage were significantly greater than the value of the cereal crop that could have been grown instead. If either of these conditions could not be satisfied, then there would be no basis for expecting farmers to reallocate their limited land, labour and capital resources to the specialist dairy enterprise.

Income from the dairy enterprise is realized only after the conversion of the forage into livestock products via the animal. The delays inherent in this process and local unfamiliarity with the improved forage/dairy cow enterprise created production risks which would need to be overcome by the attractions of a substantially higher gross margin and a regular cash flow.

A multidisciplinary ILCA team discussed the feasibility of introducing a higher-yielding cow along with forage production into the smallholder system as a means of raising income levels in areas such as Ada Wereda. The "package" approach to testing innovations in the traditional system was selected as the most appropriate.

A package based on the best available knowledge and experience would be introduced to a number of farmers in the area. The functioning and performance of the package as adopted by the farmers, called by ILCA "participating" farmers, would be closely monitored. Parallel research on the package would be conducted by ILCA on research farms under ILCA management. Selected components of the production system would also be studied on-station. The results from the monitoring of the participating farms would be used as an input to the design and operation of both the research farms and the component research.

The package was designed taking into account the results of research by institutions such as the JAR, the Debre Zeit Agricultural Research Station of the University of Addis Ababa, EPID, DDE and CADU[3].

[3] The Arsi Rural Development Unit (ARDU) is now responsible for all the former activities of CADU. Chilalo Awraja is part of Arsi Province.

It comprised the following elements:

- the use of improved cereal seeds and chemical fertilizer based on IAR recommendations;

- the use of recommended seeding rates and sowing dates on the different crops;

- the incorporation of forage crops as a regular part of the rotation;

- the provision of initial advisory services through a weekly visit by an extension officer;

- the introduction of an F_1 crossbred (Boran x Friesian) heifer and rearing of its female calves to their first calving; male calves were to be sold or slaughtered as soon as practicable after birth[4];

- the provision of initial credits according to government guidelines at an interest rate of 12% p.a., to allow farmers to establish their enterprise.

[4] The Boran is an indigenous Zebu cattle breed. Only Friesian sires have been used for crossbreeding on any scale in Ethiopia. As a consequence only Friesian x Boran crossbred cows are available in sufficient numbers for research purposes. Management and health problems at the smallholder level favour the use of F_1 crossbred cows rather than purebred Friesians or even cows with ¾ or more of Friesian blood.

For the most part the separate elements of this package were considered to be well understood. However, it was necessary to conduct research on the package as a whole, as well as on certain aspects of it, to assess its relevance and robustness in the wider context of the Ethiopian highlands. The original objectives of the research can be stated as follows:

- to test the effect of the package under smallholder conditions;

- to quantify the inputs required for and the outputs resulting from the operation of the modified farming system;

- to identify other constraints on the improvement of livestock production and on the further integration of livestock production with the cropping system;

- to evaluate the approach and the results as regards their transferability to other sites and production situations.

Thirty-four families were originally resident on the land granted to ILCA at Debre Zeit. Some of the household heads were part-time farmers with outside employment. Eighteen of the full-time farmers subsequently became participating farmers who adopted the ILCA package. Originally it was planned to have over 30 participating farmers, but this target was not achieved because insufficient crossbred cows were available to establish the enterprises. In return for agreeing to participate in the research programme, 18 farmers received long-term credits for the purchase each of an in-calf crossbred heifer and a pair of local oxen, and the construction of a cow shed. Short-term credits were given for the annual cropping programme[5]. The maximum credit provided to any farmer was US$ 750. As the farmers had no prior experience with forage crops, ILCA agreed to compensate them for any losses in the first year arising directly from ILCA's advice[6]. This guarantee was offered because in this part of Ethiopia oats - one of the forage crops to be used - are usually regarded as a weed.

[5] Long-term credits have to be repaid within 5 years, while short-term credits

cover a single cropping season.

[6] In the first year only one farmer was compensated for losses.

The land holding of each participating farmer was fixed according to the rules of the local PA, the available land and the family size. Bachelors were allocated 1 ha of cropland, married couples 2 ha, and families with children 2.5 ha. Each farmer had separate plots on the different soil types. The typical rotation in the Debre Zeit area is a 3-year cereal - cereal - pulse rotation. The crop rotation under the improved system was planned in accordance with soil type, but the basic rotation recommended was cereal forage pulse. In addition to their individual land holdings and garden plots, the 18 participating farmers also had access to a 30-ha communal pasture area.

In order to evaluate the package, a comprehensive data collection system was set up covering all aspects of the production and household system of the participating farmers. The information collected closely paralleled the data collected from "outside" farmers (i.e. those in the traditional system), the details of which were provided in Section 2.1.

Research parallel to that undertaken with participating farmers was carried out on research farms at the station which were managed and operated by ILCA employees on a fixed salary plus an annual bonus as part of an incentive scheme. In addition to providing a direct means of assessing the technical and biological feasibility of a range of alternative enterprise combinations, the research farms served as a clearing house for more innovative enterprises which might later be introduced to the farming community. If the best available technologies are tested on research farms, these indicate the upper limits of the productivity increases feasible off the station.

A range of different systems is being assessed on the six research farms which have been in operation at Debre Zeit since 1978. Two farms with 2.5 ha of cropland are variants of the traditional farming system, testing the same package as participating farms but with a modified traction component. Three operate on a somewhat larger scale, holding 4 ha of cropland and 1.5 ha of natural grazing, and examine the potential of more intensive dairy enterprises. The last farm is a specialist goat enterprise on 1.5 ha of light soil, of which two thirds is arable.

The basis for examining this last system is that a larger number of goats than cows can be kept on a given area, while lactation yields per doe can be as high as in local cows, implying less production risk. Goat farming appears, *prima facie*, appropriate in those areas where demand for milk is high but land is scarce and not well suited to permanent cultivation.

The station at Debre Zeit is also used for component research. The major activities are screening and production trials on a wide range of annual and perennial forage crops; a comparative study on different, low-cost surface-water drainage methods; cultivation trials with different breeds of oxen and, finally, a small-scale project on biogas production using cattle dung.

Forage agronomy studies have accounted for the major part of the overall component research. They have been particularly important as a technical complement both to the package in use by participating farmers and to the research farms managed by ILCA. The forage research programme at Debre Zeit and Debre Berhan is described in Section 3.4.1, together with selected results.

ILCA's drainage research addresses the problems and potentials of making routine use of the fertile but seasonally waterlogged bottomlands by the construction and maintenance of low-cost surface-water drainage works. The use of animal rather than tractor power for the engineering works indicates the importance ILCA attaches to developing the renewable farm-based energy resources on which smallholder agricultural systems will depend in the long term. Key results on this topic are also reported in Section 3.4.1.

ILCA is conducting research at both Debre Zeit and Debre Berhan on the efficiency of various cultivation schemes using different breeds of oxen. Innovative research has also been initiated on the use of cows for both milk production and traction. Cows are not used for traction in the traditional agricultural system in Ethiopia, nor, with rare exceptions, anywhere else in sub-Saharan Africa. The initial results of this work at both stations are given in Section 3.4.2.

The stress ILCA places on the role of renewable energy resources in the agricultural small-holding has already been noted. ILCA's experience with methane digesters has been limited, but although modest in scale this activity has attracted substantial interest on the part of farmers in the area. Details of this aspect of ILCA's research are presented in Section 3.4.3.

3.2.2 Debre Berhan

Research at the ILCA Debre Berhan station has followed a more phased approach than at Debre Zeit. Little information was available on the nature of the technologies which would be applicable under the prevailing conditions of the traditional farming system. It would therefore have been premature to formulate and introduce packages with traditional farmers for testing at their own risk. Accordingly, it was proposed to evaluate a number of farming systems under ILCA's own control on the research station. Once various enterprise combinations had been appraised, innovation packages would then be designed and specific recommendations made to farmers in the area. Research on specific components of the agricultural system, such as forages and pastures, early maturing crop varieties, animal traction and low-cost surface-water drainage methods, would also be undertaken.

The Debre Berhan station is located on *yemeda* class land (see Section 2.3). The agricultural hazards - frosts and waterlogging - to which such land is subject added significantly to the research task. However, if the research was successful it would have wide applicability over large parts of the highlands where cultivation is limited by these constraints. In particular it would allow the arable area of the highlands to be expanded significantly, providing for greater national food security.

During the first 2 years of operations at Debre Berhan the emphasis was on developing the station infrastructure. Research was conducted both on and off the station as the site was being built. As a follow-up to the baseline survey conducted in the first year, data collections continued in the traditional agricultural system, to provide information on particular production constraints and to allow year-to-year dynamics in the system to be quantified. Together these data would allow formulation of improvement packages that could be tested with farmers in the area. The routine data collection system has been discussed in Section 2.1.

The on-station systems research was to focus on the evaluation of different farming systems with an improved livestock component. Studies on the station with Friesian x Boran crossbred cows complemented the work at Debre Zeit. Sheep were also to be included in the research. The systems were to be evaluated by using ILCA-managed research farms, as at Debre Zeit. Initially 12 farms, each of 5 ha, were established with an additional 4 farms being added in 1980. Eight different combinations of livestock with forage or subsistence cropping enterprises were tried, each replicated twice.

Crops were extensively damaged by frost in both 1979 and 1980. Early growth of crops was very favourable, but the frosts occurred at the maturing stage and seed yields were severely reduced. Barley yields on the research farms in 1979 averaged 1010 kg per ha. Average wheat yields were 488 and 810 kg per ha in 1979 and 1980 respectively. Forage crop yields based on a combination of oats and vetch ranged between 2 t and 4 t of DM per ha. Cows on the research farms calved first at the end of 1979. Average annual milk yield, adjusted for calving interval, was over 1700 kg ± 510 in the first lactation, with a range of 900 to 3000 kg.

In early 1981, the eight different systems were consolidated into four replicates of four innovative enterprise combinations considered applicable in the larger agricultural zone of which the Debre Berhan station is a part. The main distinguishing features of the new systems are summarized below.

The first system is an intensive dairying option in which cows are used for both traction and milk production. Four Friesian x Boran crossbred cows are kept on each replicate. The system is suitable for farms where milk marketing is not a problem, such as those near towns and along major roads where collection is feasible.

The second system is a combination relevant to small farms away from major roads with no ready access to crop inputs or market outlets. It is a farm heavily dependent on sheep production. Besides approximately 30 ewes plus followers, one crossbred cow plus female followers is kept. The animal draught power is provided from off the farm. According to the design a Jersey x Boran cow is required, but to date these have not been available. A Friesian x Boran cow is used until the former become available[7].

> [7] Although a Jersey type cow yields less than a Friesian type its milk has a higher butterfat content. Furthermore, its total feed requirements for maintenance and production are lower than those of the larger Friesian type cows.

The third system is suitable for both on-road and off-road smallholders, and is a mixture of the above systems. It has one Friesian x Boran crossbred cow plus followers and one Friesian x Boran crossbred ox. Together these two adult animals provide the traction power for farm cultivation needs[8]. Approximately 15 sheep are also being kept during the first year of implementation, with more or less to be kept in later years according to the capacity of the farm to carry them.

> [8] Preliminary work at ILCA has shown that the crossbred ox is capable of cultivating as a single animal, so that pairing for cultivation is not an absolute necessity. This line of research is being pursued further.

The fourth system is expected to produce the highest human food surplus of all four systems under test. It is a combination of forage crops for use by crossbred cows and potato growing for human consumption. It is well suited to producers with good road and market access so that farm products can be sold readily. Each replicate of this set of enterprises has three Friesian x Boran crossbred cows providing both milk and traction power. No oxen are used. Approximately 1 ha of potatoes are grown each year. Indications are that potato yields of over 15 t per ha are feasible under smallholder management.

All 16 farms grow 1.5 ha of subsistence crops as well as 1 ha of annual forage crops out of their total allocation of 5 ha. Feed concentrates are used only when difficulties are encountered in animal feed supplies during the establishment phase. Modifications to these systems will be made in response to results obtained and as further possibilities for improvement are identified.

3.3 Results of systems research at Debre Zeit

3.3.1 Participating farmers

This section summarizes results and experiences from 1977 to 1980 with the package of innovations adopted by the participating farmers at Debre Zeit. Generally, this part of the programme has been successful in showing that the proposed improved system is feasible at farm level, and that crop and livestock enterprises can be profitably integrated, giving rapid and substantial increases in farmers' incomes.

Throughout this section the term "outside" farmers is used to refer to those farmers outside the research station who have been studied in ILCA's surveys of the traditional agricultural system (see Chapter 2). These outside farmers have a similar resource base to that of participating farmers, with about 2.5 ha of cropland each, and at the start of the programme also had similar inventories and asset positions.

An underlying assumption of the ILCA package was that yields per ha of traditional crops could be increased significantly through the use of improved seeds and cultivation practices, and the strategic application of chemical fertilizer[9]. Table 3.1 gives the average yields of participating and outside farmers for subsistence crops traditionally grown in Ada Wereda. Yields on the plots of participating farmers were 45% and 43% higher than on outside farmers' plots for teff and wheat respectively. Pulse yields, on the other hand, were comparable: yield improvements in pulse crops were not included in the ILCA package.

[9] Fifty kg per ha of DAP on teff and bread wheat.

The higher yields shown for participating farmers in Table 3.1 are due to the fertilizer effect and to improved crop husbandry, including better seedbed preparation and weed control. Participating farmers had a higher proportion of seasonally waterlogged vertisols, in which teff grows particularly well, and this may also have contributed to their higher average yields. Wheat yields were below expectations and, with the exception of 1978, have been disappointing. Average yields were highest in 1978 due to favourable climatic conditions: total rainfall in 1978 was 980 mm, compared with 673 mm in 1979 and 766 mm in 1980. In 1979, approximately half the participating farmers did not use fertilizers, but their yields were still substantially higher than those achieved by outside farmers, who also did not use fertilizers. These higher yields reflected previous fertilizer use and more careful weeding of crops.

Although the package showed that average cereal yields could be increased significantly, farmers did not reduce the areas sown to cereals as anticipated. Prices of cereals more than doubled over a 2-year period, and farmers responded to this price incentive by allocating larger areas to teff. Among participating farmers, the average proportion of land under teff went up from 32% in 1978 to 49% in 1979. Among outside farmers, it increased from 49% in 1978 to 56% in 1979. Teff prices stabilized in 1980, and the proportion of land under teff in that year was 48% for participating farmers and 50% for outside farmers. This finding indicates that Ethiopian smallholders are price-responsive and willing to modify their production mix to increase total farm gross margins. Average cropping patterns from 1977 to 1980 of participating and outside farmers are summarized in Table 3.2.

Table 3.1. ***Average crop yields for participating and outside farmers at Debre Zeit, 1977-1980 (kg/ha).***

Crop	Participating farmers[a]					Outside farmers				
	1977	1978	1979	1980	Average	1977	1978	1979	1980	Average
Teff[b]	1 154	1 524	1 289	1 191	1 290	722	984	932	879	892
Wheat	627	1 209	766	1 011	903	470	850	407	804	633

Horse beans	970	874	938	817	900	790	878	769	597	758
Chick peas	650	304	182	n.ap.	379	620	585	420	317	486

[a] Using 50 kg per ha of DAP on teff and wheat.

[b] Yield differences of teff crops between participating and outside farmers for corresponding years were significant at the 1% level.

Table 3.2. ***Average cropping patterns of participating and outside farmers at Debre Zeit, 1977-1980 (percentage of total area under crops).***

Year and farmer type		Cereals	Pulses	Forage	Fallow
1977	Participating	40	30	30	-
	Outside[a]	n.av	n.av.	n.av.	n.av.
1978	Participating	43	30	27	-
	Outside	60	37	-	3
1979	Participating	60	10	30	-
	Outside	68	31	-	1
1980	Participating	53	9	37	1
	Outside	61	36	-	3

[a] The ILCA survey of outside farmers began in the 1978 crop year.

Average gross margins per ha (value of production minus cash costs) are summarized in Table 3.3. Teff is a profitable crop principally because of its grain price, but the amount of teff that can be cultivated on a farm is limited by seasonal labour constraints, the timely availability of draught oxen power, and rotation restrictions. As indicated in Table 2.8, teff requires more labour per ha than any other crop. Pulses are much less profitable than teff because of their low yields, low output prices and high seeding rates. They are rich in protein, however, which makes them an essential part of the diet, especially during the long fasting periods. In the long run pulses must be included in the crop rotation to maintain soil fertility, especially as inorganic fertilizers are expensive for farmers to use.

Participating farmers had consistently higher gross margins per ha than outside farmers. Taking the average gross margin per ha for all food crops (as in Table 3.3), the increase was 31% in 1977, 27% in 1978, 43% in 1979 and 22% in 1980. Over the 4-year period, participating farmers had an average gross margin 31% higher than outside farmers. The higher gross margins for cereal food crops are due to the effects of fertilizer, the use of genetically superior seed, and higher labour inputs for land preparation and weeding. Much of this extra labour was hired. Participating farmers also followed ILCA's advice on early seedbed preparation, and used recommended sowing dates.

In 1977, fodder oats and maize were grown, but harvests were poor because of late sowing, a low seeding rate and the reluctance of farmers to accept and manage the forage crops as a necessary part of a farming system to support a high-yielding cow. Maize produced only 2 t of DM per ha in that year. The maize and some forage oats were ensiled, but labour for this operation was required while teff was being weeded, and a substantial capital investment was also necessary for transport and machinery. Unless silage making technologies suited to the ressources of the Ethiopian smallholder become available, the prospects for using this alternative for producing high-quality forage appear bleak.

Only pure stands of oats were planted by participating farmers in 1978. They were used as green feed in cut-and-carry systems, and for hay making. Oats were grown on three plots on each farm, one each for green feed, hay making and seed production. Hay yields averaged 5.9 t of DM per ha with a 10% CP content. Average seed grain yields were 550 kg per ha.

Table 3.3. ***Average gross margins on food crops for participating and outside farmers at Debre Zeit, 1977-1980 (US$/ha).***

Crop	Participating farmers					Outside farmers				
	1977	1978	1979	1980	Average	1977	1978	1979	1980	Average
Teff	435	657	511	346	487	307	443	363	362	369
Wheat	66	549	189	246	263	75	379	113	299	217
Horse beans	75	146	181	116	130	44	107	106	84	85
Chick peas	91	61	23	n.ap.	58	80	144	81	75	95
Weighted average	216	404	371	305	324	165	317	259	250	248

Beginning in 1979 a mixture of oats and vetch (*Vicia dasycarpa*) was recommended to participating farmers, on account of its favourable yield and its high protein content[10]. Some practical problems arose because farmers had limited experience with forage crops and particularly with crop mixtures. Sample yields in 1980 were promising, but late rains delayed the harvest of the hay crop and farmers left their forages in the fields until after the food crops had been harvested. As a result field losses were substantial, as much of the crop was eaten by grazing animals. Usually, the harvesting of forage crops does not compete with teff harvesting, hay making taking place a few weeks earlier. Farmers in 1979 and 1980 harvested on average only 3 t of DM per ha from their forages.

> [10] Difficulties with the supply of vetch seed have been encountered since the start of the programme. To alleviate the problem ILCA contracted with a government farm to grow vetch seed beginning in 1980.

When forage crops fail, the farmers must supplement their animals with purchased concentrates, usually middlings, wheat bran and oilseed cake, to maintain milk yields. These concentrates are not expensive, at US$ 0.08 per kg, but the supply is irregular and transporting them from the town to the farms has proved to be a practical problem.

In December 1977, each farmer purchased one in-calf Friesian x Boran crossbred heifer for US$ 190. The animals were bred on the government ranch at Abernossa. They calved between 1 and 3 months after distribution. Purchase was on standard Ethiopian Government credit terms of 12% with a 5-year repayment period, including insurance for 1 year which guaranteed replacement of the animal in the event of death or a milk production of less than 800 kg in the first lactation. Loan repayment was through a levy of US$ 0.05 per litre on milk sold. The price paid to farmers for milk sold to the DDE is US$ 0.22 per litre.

For breeding purposes ILCA relied initially on the AI service of the government, which proved unsatisfactory. Delays in servicing cows resulted in extended calving intervals and dry periods between first and second carvings. The average calving interval between first and second calving was around 18 months. In May 1978 a purebred Friesian bull was purchased for the station, and since then all matings have been by natural service.

The overall mean birth weight of the crossbred (¾ Friesian) calves was 29.7 kg. Male calves' weight was on average 30.3 kg at birth, 8.6% higher than the birth weight of female calves. However, the growth rates of the females were faster, and average weight after 3 months was 56 kg for male calves as against 63.7 kg for females. After 8 months, male calves weighed 101 kg, compared with 112 kg for females. The farmers fed and managed female animals better than males. Rearing male calves is unprofitable, they are often sold at an early age.

For the first 60 days after birth an average of 180 kg of whole milk was fed to all calves. This increased to 246.8 kg over the first 90 days after birth. The average milk intake of calves over 120 days amounted to 273 kg per head.

Adjusted annual milk yields from the crossbred cows averaged 1769 litres per cow during the first lactation, ranging from 1197 to 2809 litres with a standard deviation of 412 litres[11]. Milk production increased substantially in the second lactation, with an adjusted annual yield of 2347 litres (range 1141 to 3929 litres, standard deviation of 581 litres). The interval between second and third carvings averaged 12 months. These cows had liveweights between 400 and 500 kg.

The average length of the first lactation was 439 days, falling to 304 days for the second lactation. Table 3.4 summarizes the production and disposal of milk from the cows of participating farmers. Cows first calved in 1978 and the resulting lactation extended into 1979. Second lactations began in 1979 and extended into 1980.

As stressed previously, acceptability of the composite forage/dairy cow enterprise will depend on its being substantially more profitable than the grain cropping alternatives. Table 3.5 presents the costs and returns of an improved cow enterprise at Debre Zeit. The values tabulated are based directly on the results of ILCA's own data collection, but are modified to give the budget expected if the enterprises mature and steady-state production is achieved. This modification was necessary to overcome the procedural and interpretational difficulties of determining profitability in developing enterprises. Full details of the assumptions made in preparing Table 3.5 are given as notes to the table. The impact on profitability of alternative production assumptions can be readily determined. The budget is presented on a per cow basis, and assumes that all milk sold is in liquid form.

[11] $\text{Adjusted annual milk yield} = \frac{\text{total lactation yield in days}}{\text{calving interval}} \times 365$

Table 3.4. ***Average annual milk yields and uses for participating farmers at Debre Zeit, 1978-1980 (litres/farm)***[a]**.**

Parameter	1978	1979	1980	Average 1978-1980
Total production	2 185	1 805	2 139	2 043
Sales	1 821	1 375	1 650	1 615
Home consumption	133	172	322	209
Calf consumption	231	258	167	219

[a] Each farmer has one cow; values tabulated are the yearly averages for the 18 participating farmers.

The budget indicates an expected return, from an enterprise consisting of a single improved cow plus followers utilizing 1 ha of forage land, of US$ 437 per year. However, the enterprise must be evaluated in the context of the whole farm, because arable land is used to grow forage. Table 3.6 presents average returns per ha for food and forage crops for the period 1978 to 1980 for the participating farmers at Debre Zeit. In this way the profitability of the dairy enterprise can be directly linked to the land resource. Table 3.6 is based on the actual costs and returns, with the values adjusted to a per ha basis, while average gross margins actually recorded per farm from the two enterprises are given in Table 3.7.

Table 3.6 indicates that the average gross margins for all food crops combined are slightly below those for forage crops. Gross margins for teff (see Table 3.3) are higher than for forage, but rotational restrictions limit continuous teff cropping as a means of increasing incomes. These results satisfy the precondition for adoption of improved dairy production in the area - namely that the per ha profitability must be substantially higher than the traditional arable land alternatives available to the smallholder. This conclusion is reached despite the fact that the market price for teff has increased markedly over the study period, while prices paid for milk have not increased. Any increase in milk prices will directly favour the relative and absolute profitability of the specialist dairy enterprise. Profitability of the dairy enterprise would also increase if the milk were converted into products such as butter or cheese, using surplus family labour and traditional processing technologies.

Table 3.5. ***Expected annual costs and returns of a mature crossbred dairy enterprise on 1 ha in the Debre Zeit area (US$/cow)***[a].

Costs[b]		Returns[c]	
Item	**Amount**	**Item**	**Amount**
1. Forage	120	1. Milk production	471
2. Feed concentrates	50	2. Dung cakes	60
3. Veterinary/health care	10	3. Male calves	6
4. Housing and tools	20	4. Surplus females	85
5. Breeding	10	5. Residual value of cow	50
6. Hired labour	25	Total returns	672
Total costs	235		

[a] The enterprise consists of one cow plus followers to time of sale.

[b] Assumptions as follows:

1. Cash costs for the forage are seed (100 kg of oats at US$ 15/100 kg; 20 kg of vetch at US$ 250/100 kg) and fertilizer (100 kg DAP at US$ 55/100 kg). Ploughing is assumed to be done by the farmers' own oxen at no cash cost. 2. 1000 kg of feed concentrates at US$ 0.05/kg. 3. Indicative cost for veterinary/health care. 4. Housing is fully depreciated over 5 years with no residual value. 5. Breeding cost per effective insemination based on estimated AI cost in Addis Ababa. 6. A total of 25 worker-days of hired labour used per year at US$ 1 per day.

[c] Assumptions as follows:

1. Milk production is 2500 litres/lactation or 2143 litres/year, assuming an average calving interval of 14 months. This yield is the amount available for sale and home consumption after allowing for milk consumed by the calf. Milk is valued at the official purchase price of US$ 0.22/litre. 2. Dung cakes are valued at US$ 0.05/kg. Annual production of dung cakes from a cow plus followers is 1200 kg. 3. Male calves are sold at US$ 15 per head and do not consume milk. Mortality rate to time of sale is 10%. 4. Cows rear their own replacements. Each cow produces an average of five calves over a 6-year productive life. One of the female calves is kept as a replacement, allowing for the sale of 1.5 heifers in 6 years, less allowance of 15% for mortality to time of sale. Surplus heifers are sold at 15 months of age at US$ 400 per head. 5. No data available; rough estimate only.

Table 3.6. ***Average gross margins from food and forage crops for participating farmers at Debre Zeit, 1978-1980 (US$/ha).***

Crop group	Year			Average
	1978	1979	1980	1978-1980
Food crops[a]	404	371	305	360
Forage crops[b]	496	411	319	409

[a] Cereals plus pulses.

[b] Assuming all returns on the dairy enterprise to be directly attributable to the forage crop.

As already indicated, participating and outside farmers have similar resource bases. Nonetheless, individual holdings of participating farmers, at 2.5 ha, were somewhat smaller than the average holding of an outside farmer, which was almost 2.8 ha in 1978 but declined to an average of 2.5 ha in 1980. This decline is due to increasing population pressures and resettlement programmes. Both participating and outside farmer families have an average of 5.5 members, consisting of two adults, and two or three children under 15 years old. The families of outside farmers were thus working slightly larger areas than those of participating farmers, a factor which partially explains their higher labour inputs. Overall labour inputs (family, hired and exchange) for crop-related activities by both groups of farmers at Debre Zeit were as shown in Table 3.8.

Table 3.7. ***Average gross margins per farm of participating farmers at Debre Zeit, 1978-1980*** **(US$).**

Enterprise	Year		
	1978	1979	1980
Dairying (including forage)[a]	372	308	293
Food crops	721	631	454
Total	1 093	939	747
Average farm gross margin/ha[b]	434	403	299

[a] Including interest charges, but excluding cow replacement charge.

[b] The area cultivated varied slightly from year to year.

Table 3.8. ***Average labour inputs per year for crop-related activities by participating and outside farmers at Debre Zeit, 1978-1980 (hours/farm)***[a]**.**

Farmer type	Year		
	1978	1979	1980
Participating[b]	1 377	1 193	1 082
Outside	1 513	1 124	1 183

[a] Includes land cultivation, weeding, harvesting, transport, threshing and storing of the produce.

[b] Includes forage crops.

The decline in labour inputs reflects the lower crop yields of 1979 and 1980 and, for outside farmers, the smaller land area cultivated. Most of these labour inputs are provided by the family, although participating farmers used substantially more hired labour than outside farmers, as illustrated in Table 3.9.

Table 3.9. ***Average annual cash expenditure on hired labour by participating and outside farmers at Debre Zeit, 1978-1980 (US$/farm)*[a].**

Farmer type	Year		
	1978	1979	1980
Participating	30	48	54
Outside	25	11	13

[a] Average wage rates are around US$ 1 per day. Expenditure occasionally also includes rent of one or two oxen.

The inputs of family, exchange and hired labour in 1980 were as summarized in Table 3.10. The table indicates that participating farmers substituted a substantial part of their exchange labour for hired labour, and that their own family labour input for field activities was somewhat reduced, allowing labour resources to be allocated to the dairy enterprise.

The improved dairy enterprise adds around 1 hour daily to labour requirements, for milking, calf care, barn cleaning, marketing of the milk and extra hand feeding of the cow and her followers. Herding is done jointly with other traditional livestock, and is therefore not taken into account. Although herding activities take an average of 8 hours per day, they are performed by the younger children who would otherwise have little input into farm operations. Thus the opportunity cost of the labour input for herding is close to zero. If the additional 1 hour per day or 365 hours per year is added to the existing labour inputs of participating farmers (Table 3.8), then their overall labour input into the combined crop and dairy enterprises was 1742 hours in 1978, 1558 in 1979 and 1447 in 1980.

Table 3.10. ***Distribution of family, exchange and hired labour inputs by participating and outside farmers at Debre Zeit, 1980 (hours/farm)*[a].**

Farmer type	Family labour	Exchange labour	Hired labour
Participating	653	119	310
Outside	763	330	90

[a] Assuming no quality differences between labour inputs of different age and sex groups.

A comparison of average gross margins per ha of participating farmers with those realized by outside farmers is given in Table 3.11, which shows an increase in the average value of production per ha attributable to the innovation package of 37% in 1978, 56% in 1979 and 20% in 1980. Statistical tests showed this difference to be significant at the 5% level. This comparison only takes into account returns from cropland, whether it is used for food crops or forage crops. It excludes the returns from traditional livestock production, which are approximately the same for both participating and outside farmers, estimated at around US$ 50 per annum.

Table 3.11. ***Average overall gross farm margins of participating and outside farmers at Debre Zeit, 1978-1980 (US$/ha).***

Farmer type	Year		
	1978	1979	1980
Participating	434	403	299

Outside	317	259	250

Average returns to labour are summarized in Table 3.12. Values tabulated are calculated by dividing overall farm gross margin by the sum of family plus exchange labour. Participating farmers had a consistently higher return to labour than outside farmers.

Table 3.12. ***Average annual returns to labour for participating and outside farmers at Debre Zeit, 1978-1980 (US cents/hour)***[a]**.**

Farmer type	Year		
	1978	**1979**	**1980**
Participating	71	77	66
Outside	66	62	57

[a] Calculated as the overall gross farm margin divided by the sum of family and exchange labour.

Including specialist dairy enterprises in farm operations thus led to a rapid increase in cash incomes. As shown in Table 3.13, the gross cash incomes of participating farmers were over two and a half times those of outside farmers in 1979. This ratio rose to nearly 4 to 1 in 1980.

Table 3.13. ***Average gross cash incomes of participating and outside farmers at Debre Zeit, 1979-1980 (US$/farm).***

Farmer type	Year	
	1979	**1980**
Participating	575	830
Outside	212	218

This extra income enters the household as a regular cash flow, as the DDE pays for milk deliveries bimonthly. A part of this higher cash income of participating farmers is used to repay the loans for establishment of the dairy enterprise, and also to pay for the extra inputs (seeds, fertilizer, hired labour) for the crop enterprise.

Initially, participating farmers used the higher income to improve their own family welfare. A substantial amount was spent on better clothes for the family, children-were kept at school to complete more advanced grades than usual, and most participating farmers constructed a new and better house, or started buying the necessary construction materials to do so.

It is anticipated that once basic social needs have been met a substantial part of the extra cash generated through the dairy enterprise will flow back into the farming system to increase the productivity of the crop component still further. This trend will illustrate not only the close interaction of crop and livestock production in mixed agricultural systems, but also the advantages of using the livestock component as a mechanism for benefitting the farming system as a whole.

The initial results of the ILCA package at Debre Zeit confirm that a farmer can satisfy his subsistence cereal requirements from a substantially reduced area: average teff yields per ha of participating farmers were 45% higher than those achieved by outside farmers. Although it was initially assumed that the land made available by growing subsistence grain crops on a smaller area would be used for forage production, in order to grow their fodder crops the farmers reduced instead the area sown to pulses. In this regard farmers were more responsive to prices than initially expected.

Average annual milk yields more than 10 times those from local breeds are obtainable from improved crossbred dairy cows under smallholder conditions. Dairy production with improved cows is a profitable enterprise even at the milk price now paid to farmers. It is a most efficient means for generating rapid productivity increases in the smallholder farming system, and leads in the short run to a substantial increase of both the gross cash and the net farm income.

Rearing and selling female heifers is also a profitable aspect of the improved dairy enterprise as now operated. So far however, only a few of the participating farmers have reached the stage of selling offspring.

Finally, the increased home consumption of dairy products is making a valuable contribution to overall nutritional levels in participating farmers' families.

The ILCA research experience at Debre Zeit differed from that of other institutions in that the expected beneficiaries of the results, the traditional farmers, were represented from the outset in the research process. This approach gave rise to a greater degree of insight into the problems and opportunities associated with the introduction of a markedly different kind of livestock enterprise into a traditional agricultural system.

The impact of the innovations on the social and economic circumstances of the participating farmers cannot yet be fully assessed. Nevertheless, there are strong indications that the basic package would be adopted and maintained by a wider population of farmers if it were made available to them.

At present supplies of suitable cattle to provide the foundation stock for the enterprise are generally limited. The supply of forage seeds is also a constraint on the wider application of the package. For both these reasons, the ILCA research experience with participating farmers can be considered only as a preliminary step towards development. The research results provide the Ethiopian Government with sound information to guide the future development of smallholder dairy production in the central highlands, assuming that the basis for planning such development is that solutions are first found to these two problems.

3.3.2 Research farms

Of the two research farms at Debre Zeit which are variants of the existing system, one is on light soil and the other on heavy vertisols. In addition to the 2.5 ha of arable land available for food and forage crop cultivation, each farm has 1.5 ha of non-arable land for grazing. Both have one Friesian x Boran crossbred dairy cow rearing its own replacements. Some improved crop varieties with different fertilizer treatments are also being evaluated on each farm.

The adjusted annual milk yields over the first two lactations were 1591 and 1998 litres on the two farms. Both farms have 0.9 ha of forage, of which approximately half is used for green feeding and half for hay making. A mixture of *Sorghum almum* and *Dolichos lablab* is grown for green feeding, while hay is made from a mixture of oats and vetch. DM yields over the 3-year period 1978 to 1980 averaged approximately 6 t per ha. Since 1980 the farm on light soil has been allocated two additional crossbred cows for ploughing, thereby taking advantage of the ability of cows to cultivate light soils. The yields of crops grown on these two research farms are summarized in Table 3.14.

The third research farm produces teff and forages and uses three crossbred cows for both dairy production and ploughing. It has 5.5 ha of heavy soils, of which 4 ha is arable land sown to teff and forage crops and 1.5 ha is non-arable swampy bottomland used for grazing and hay making. With fertilizer applications of 100 kg of DAP and 100 kg of urea per year, teff yields for 1979-1980 averaged 1665 kg per ha. Adjusted annual milk yields for the cows on this farm averaged 1388 kg for the first lactation and 1629 kg for the second. A mixture of

Rhodes grass (*Chloris gayana*) and lucerne (*Medicago sativa*) was sown for cut-and-carry forage production. This mixture has produced an annual average of over 3 t of DM per ha over the 3 years it has been established.

The fourth and fifth research farms are specialist dairy operations on 5.5 ha each of heavy vertisols. As for the third research farm, 4 ha is arable land and 1.5 ha is bottomland used for grazing and hay making. Both farms produce perennial and annual forages and have three crossbred cows. One farm rears female calves as cow replacements; the other does not. The cows on these farms had adjusted annual milk yields averaging 1652 kg in the first lactation and 1889 kg in the second. Both farms initially used perennial forages such as Rhodes grass/lucerne mixtures and Napier grass (*Pennisetum purpureum*)/*Desmodium uncinatum* for cut-and-carry feeding. In 1980, a mixture of oats and vetch was added for green feeding and hay making.

Table 3.14. ***Crop yields on two research farms at Debre Zeit, 1978-1980 (kg/ha)***[a]**.**

Crop	Light soil farm			Heavy soil farm		
	1978	1979	1980	1978	1979	1980
Cereals[b]						
White teff	1 550	1 467	1 569	1 555	1 324	1 469
Bread wheat	1 739	1 672	2 164	806	1 232	796
Horse beans	932	1 475	1 661	416	1 105	897
Field peas	1 056	1 235	1 010	n.ap.	1 617	184
Forages[c]						
Oats/vetch	6 900	6 100	5 800	6 300	3 500	4 700
Sorghum almum/Dolichos lablab	4 500	3 400[d]	5 500	2 600	2 000[d]	4 200

[a] The farms had enterprises very similar to the package used by participating farmers.

[b] Seed yield (kg/ha).

[c] DM yield (kg/ha).

[d] *Sorghum almum* and field peas mixture.

On the sixth research farm - the specialist goat dairy enterprise - Toggenburg she-goats were first used, but were of poor quality and subsequently replaced by six Saanens. The latter were delivered in late 1979. Milk yields to date have been discouraging. A contributing factor to the poor performance of this system has been the limited experience of both the staff and the farm operator in handling goats. There is no tradition of specialist goat production or of goat milk consumption in the Ethiopian highlands. Individual lactation yields have not exceeded 100 litres over a 5-month lactation. The full potential of this enterprise has thus not yet been realized. Perennial forages, including lucerne, Rhodes grass and *Panicum coloratum*, have been sown on the farm's 1 ha of arable land. Shrubs, including *Leucaena leucocephala*, have been established on the non-arable 0.5 ha of hilly land.

Although the research farms at Debre Zeit are not replicated, results have been obtained and constraints identified which would not have been discovered so readily in a different research setting. Teff yields have on average been 23% higher than those achieved by participating farmers and 67% higher than on outside farms. Wheat yields on the research farms were 55% and 221% higher than on the plots of participating and outside farmers respectively. For pulses the yield margin of research farms over participating and outside farms was around 66%. Forage yields were twice those of participating farmers, and perennial species performed well under farmer conditions. More testing is needed in the smallholder context but it seems that there is a role for a cut-and-carry feeding system in the central highlands. The use of crossbred oxen and cows for traction has also given favourable results, offering the prospect of wider use of such innovative traction systems in a practical smallholder setting.

3.3.3 Cooperative farms

In 1979, ILCA established a 20-ha cooperative farm adjoining the station. It was managed jointly by 10 farmers nominated by the nearby Dembi PA. This extension of ILCA's activities was a response to government policy encouraging cooperative production. In the research context it may provide indications of the strength of any economies of scale.

A production package similar to the one for participating farmers was introduced. It included a dairy enterprise based on 12 Arsi x Friesian crossbred dairy cows, fertilizers and improved seeds. Cultivation implements and four each of local and crossbred oxen together with an animal shed were provided on credit. ILCA has made routine data collections to allow comparison of the performance of this cooperative with that of three outside ones. The three outside cooperatives belong to the PAs of Dembi, Godetti and Babogaya, three villages which surround the ILCA station. Individual outside farmers also belong to one of these three PAs, so that part of their labour is necessarily devoted to the three cooperatives. In 1979, the average amount of land cultivated cooperatively was 63 ha for each of the three PAs, but this fell to 14 ha in 1980.

These outside cooperatives are using fertilizer supplied to them more cheaply than to individual farmers (see Table 2.15). For the participating cooperative farm, the average labour input per ha in 1980 for field activities was 352 hours, compared with 740 hours for outside cooperatives and 440 hours for individual participating farms. Crop yields in 1979 were encouraging, but damage by floods and insects was substantial in 1980. Table 3.15 summarizes the average crop yields of participating and outside cooperatives for 1979 and 1980.

Table 3.15. ***Crop yields on participating and outside cooperative farms at Debre Zeit, 1979-1980 (kg/ha).***

Crop	Participating cooperative		Outside cooperatives[a]	
	1979	1980	1979	1980
Teff	1 170	660	762	903
Wheat	1 170	711	184	n.ap.[b]
Horse beans	1 410	572	733	581

[a] Average for three cooperatives.

[b] Not grown in 1980.

The production of the participating cooperative is distributed to its members according to their individual labour inputs. These inputs included labour for both the crop and the livestock enterprise, and averaged 1406 ±121 hours per member in 1979, and 1895 ± 142 hours in 1980.

The participating cooperative farm is on black vertisols. Nineteen hectares out of the 20 are cultivated, half for food crops and half for forage crops. *Sorghum almum* with field peas is grown for green feed, while a mixture of oats and vetch is grown for hay making. In both 1979 and 1980 the forage yields were less than 3 t of DM per ha, due mainly to farmers' lack of experience in growing and managing fodder crops. The Arsi x Friesian cows originally supplied to the cooperative were poor milk producers, and in 1980 were replaced by eight Boran x

Friesian crossbreds. To date the cows have produced an average of 4 litres of milk per head per day. The lack of previous dairying experience of these farmers is a serious handicap. It may take time before this venture will show convincing results, and as yet little can be said on the potential of cooperative dairy production.

3.4 Results of component research at Debre Zeit and Debre Berman

3.4.1 Pasture and agronomy research

The design of the pasture and agronomy research begun in 1978 has taken into account the various constraints of the existing agricultural system. Species selection and agronomic work were to be guided by the following considerations:

- land is generally scarce in the Ethiopian highlands, and forage species must be sufficiently high yielding to provide returns per ha comparable with food crops. On the basis of initial projections (ILCA, 1978) the target production level for the lower elevations in the highlands was set at 5 t of DM per ha, with 12% protein and using only moderate applications of phosphorus (P) (50 kg P_2O_5 per ha per year). The target production level at higher altitudes was 4 t of DM per ha, with the same protein content and fertilizer regime;

- the medium and high elevations of the Ethiopian highlands would be the target areas for the forage research. Separate work should be conducted on the three main soil types found, namely the black vertisols of the bottomlands, the red soils of the lower slopes and the thin, poorer soils of the upper slopes;

- special-purpose forage production must be tailored to a subsistence-oriented farming system. Forage crops must combine with existing crop rotations. Annual forages are therefore more likely to be accepted by farmers than perennial forage crops. The initial research effort would therefore focus on annual forages;

- declining soil fertility, caused by continuous cropping and the export of nutrients, makes it necessary to concentrate on nitrogen-fixing legumes;

- peak labour demands at harvesting time and inadequate small-scale technologies limit the opportunities for silage making. Species should therefore be screened and evaluated for their use in cut-and-carry and hay making systems.

Table 3.16. ***Number of forage grass and legume accessions screened at Debre Zeit, 1978-1980.***

Year	Total accessions	Accessions selected for further study
1978	137	60
1979	235	155
1980	131	97

Screening and evaluation of species takes place as follows. Accessions are planted in rows 8 m long for screening. Grasses receive a basal dressing of 50 kg of P_2O_5 per ha, and are split into low-level nitrogen (N) (50 kg of N per ha) and high-level N (200 kg of N per ha) treatments. N is not applied to the legumes, which receive 25 kg of P_2O_5 per ha and 100 kg of P_2O_5 per ha respectively as low- and high-level fertilizer treatments. Promising species from this screening work are then evaluated in terms of their yield and nutritive value on production plots of 60 m² each in four replicates. At the evaluation stage the legumes receive standard phosphate fertilization of 50 kg of P_2O_5 per ha, while the annual grasses are tested at zero and 100 kg of N per ha. The most promising species or species combinations are then introduced on the research farms. Table 3.16 gives the number of accessions screened at Debre Zeit station in the period 1978-1980.

Table 3.17. ***Average annual performance of the most promising forages and mixtures for hay making at Debre Zeit, 1978-1980***[a]**.**

Species	DM yield (kg/ha)	CP (%)
Avena sativa cv Lampton	4 550	7.8
Avena sativa cv Grey Algier	4 850	8.2
Sorghum almum	6 500	6.0
Avena sativa/Vicia dasycarpa	3 950	14.4
Sorghum almum/Lathyrus purpureus	6 700	10.2

The most promising grass species belong to the *Avena, Sorghum* and *Lolium* genera. Among the legumes, *Vicia, Dolichos, Lathyrus, Trifolium* and *Medicago* spp. are the most promising. Productivity results over the 3-year period indicate yield levels of between 4 and 6 t of DM per ha when the forage is used for hay making. Table 3.17 summarizes the results. The beneficial effect of legumes on the protein content of hay is amply shown. Although *Sorghum almum* alone or in mixture outyields the *Avena* cultivars, it is unsuitable for hay making.

Regrowth characteristics are important when forages are grown for green feeding. Increased protein yields per ha and higher average digestibility levels can be expected through a combination of early and late cutting for green feed. Table 3.18 gives the performance of different forages and mixtures for the purposes of green feeding. The table shows the higher persistency of *Sorghum almum*, indicated by its higher yield on the second cut, and hence its usefulness for green feeding. However, because of its low average feeding value, it should normally be used in a mixture with a legume.

Within species there were consistent differences in productivity on different soil types, as can be seen in Table 3.19. Yields were consistently lower on the heavy bottomland soils, although these are higher in soil fertility. They were depressed by the effects of excess surface water, persistent for most of the wet season, highlighting the potential contribution to productivity of improved drainage in these areas.

Table 3.18. ***Average annual performance of different forages and mixtures for green feeding at Debre Zeit, 1978-1980***[a]

Species	Early cut		Late cut		Total	
	DM yield (kg/ha)	CP (%)	DM yield (kg/ha)	CP (%)	DM yield (kg/ha)	CP (%)
Avena sativa cv Lampton	2 100	12.1	950	11.1	3 050	11.8
Avena sativa cv Grey Algier	2 100	11.7	1 200	10.8	3 300	10.1
Sorghum almum	1 350	9.0	1 950	6.3	3 300	7.4
Avena sativa/Vicia dasycarpa	1 600	15.9	1 550	12.0	3 150	14.0

Sorghum almum/Lathyrus purpureus	1 650	14.4	2 350	9.5	4 000	11.5

[a] Unfertilized.

Table 3.19. ***Average annual yields of the main forage crops on light and heavy soils at Debre Zeit, 1978-1980 (kg/DM/ha)***[a].

Species	Soil type	
	Light	Heavy
Avena sativa cv Grey Algier	7 050	3 410
Sorghum almum	8 500	4 650
Avena sativa cv Grey Algier/*Vicia dasycarpa* *Sorghum almum/Lathyrus purpureus*	8 600	5 600

[a] Unfertilized, single cut.

Application of N increased forage yields in most cases. The average yield increment was higher on the heavy bottomland soils, at 20 to 30 kg of DM per kg of N, than from the light soils on the arable slopes, where recorded returns were zero to 20 kg of DM per kg of N. The shortage of other nutrients in the light soils may have inhibited full response to N.

Work has also been carried out on improving the natural vegetation of eroded slopes through N and P fertilization of pastures oversown with legumes. The results of 3 years' experimentation indicate a poor response to N - less than 10 kg of DM per kg of N and no apparent effect of the legume on total productivity and quality. Cultivation of fodder shrubs and trees is an alternative use of these slopes which may allow these areas to contribute to the productivity of the farming system. This avenue is being researched and species including *Leucaena leucocephala* have been planted and are being evaluated.

Table 3.20. ***Average annual performance of perennial forage species at Debre Zeit, 1978-1980***[a].

Species	DM yields (kg/ha)	CP (%)
Pennisetum purpureum	4 800	8.3
Panicum coloratum	4 000	7.1
Chloris gayana	3 550	5.4
Pennisetum purpureum x P. typhoides	3 100	5.0
Pennisetum purpureum/Desmodium intortum	4 250	7.9

[a] Annual fertilizer application of 100 kg P_2O_5/ha.

Perennial grasses which have shown some promise are *Chloris gayana, Panicum coloratum*, and *Pennisetum purpureum x P. typhoides* (Banagrass). Average performances over the period 1978 to 1980 are provided in Table 3.20.

Establishing adequate stands of both perennial and annual forages on heavy bottomland soil proved difficult owing to the lack of surface drainage. For this reason different drainage treatments have been evaluated for these areas. The effects of the different treatments on various crops are summarized in Table 3.21. Natural vegetation without drainage served as the control for these trials, and yielded an average of 2 t of DM per ha over the period 1979-1980. As the table shows, crop yields on drained bottomland were considerably higher than on regularly cultivated arable plots on the lighter soils. If low-cost techniques can be used to develop and crop these more fertile bottomlands, they could contribute significantly to farm production. Both drainage works and cultivation in these areas require more draught power than can be provided by local oxen, so the use of larger, more powerful crossbred oxen is being evaluated as a farm-level means of allowing these areas to be brought into production.

At higher altitudes such as Debre Berhan, agricultural conditions are considerably harsher than at Debre Zeit. Little prior information was available regarding suitable forage species for these higher altitudes, with the result that ILCA strongly emphasized the screening work at Debre Berhan. At the same time, collection of the numerous ecotypes of local legumes found at these altitudes was initiated. These accessions are being screened at Debre Berhan. With regard to introduced species, the emphasis was on temperate varieties, with screening for productivity in both the *meher* and *belg* seasons. In addition to forage species, accessions evaluated in 1979 and 1980 included potato varieties from the International Potato Centre (CIP), and triticale and wheat varieties from the International Maize and Wheat Improvement Centre (CIMMYT). The total numbers of forage accessions tested are summarized in Table 3.22.

The research period has been too short to allow definitive selection of species suitable for the higher altitudes. The promising genera seem to be *Avena* and *Lolium* among the grasses and *Vicia, Pisum* and *Lathyrus* among the legumes. To date, DM yields of 2000 to 6000 kg per ha have been achieved, with *Avena sativa* var. 8237 as the highest yielding forage crop.

Table 3.21. ***Average annual yields of food and forage crops on bottomland under different drainage treatments at Debre Zeit, 1979-1980 (kg/ha).***

Crop	Drainage treatment		
	Ridge and furrow	Ditch and dyke	Ridge and furrow plus ditch and dyke
Wheat[a]	1 150	1 200	1 750
Teff[a]	1 150	1 500	1 350
Chick peas	400	500	500
Horse beans[b]	1 000	2 150	2 650
Avena sativa cv Lampton[c]	2 900	6 300	5 500
Sorghum almum[c]	2 250	7 800	7 800

[a] Grain yield (kg/ha). Fertilizer application of 50 kg/ha DAP applied to all plots in both years.

[b] 1980 Only.

[c] DM yield (kg/ha).

3.4.2 Animal traction research

The traditional agricultural system in the Ethiopian highlands depends heavily on animals for draught power to cultivate and transport agricultural produce. ILCA surveys in 1980 around Debre Zeit and Debre Berhan estimated that animal power used for crop activities on outside farms averaged 1050 animal hours per farm. Most of this power was supplied by oxen, but other classes of cattle were sometimes used for threshing. Some 50 to 80 hours were also contributed by donkeys transporting the produce from the field to the homestead[12]. Some 60 to 70% of the total animal power input was for seedbed preparation and planting: approximately 350 oxen-pair hours were used for these purposes.

[12] Donkeys are again used to transport produce from the homestead to the

market, but no data are yet available on this activity.

Research on various aspects of animal traction has been an important component of the ILCA Highlands Programme. Cultivation throughout most of the Ethiopian highlands is by the *maresha*, drawn by a pair of indigenous oxen each weighing from 250 to 350 kg (see Chapter 2). The number of animal-drawn metal implements in Ethiopia is insignificant. Few such implements have been introduced and tested in Ethiopia. Furthermore, the draught power developed by oxen of indigenous breeds is insufficient to operate heavy metal implements efficiently.

Table 3.22. *Number of forage grass and legume accessions screened at Debre Berhan, 1979-1980.*

Year	Season	Total accessions	Accessions selected for further study
1979	*Belg*	101	60
	Meher	337	139
1980	*Belg*	111	76
	Meher	186	96

Oxen are commonly worked for 4 to 9 hours per day. Oxen in the Debre Zeit area are worked throughout the day with few breaks. By contrast, farmers in the Debre Berhan area normally work oxen in two periods each day, and the animals are watered and fed in between these two sessions. The availability of draught power has important effects on area cultivated and crops sown. These effects are being investigated.

Oxen drawing the *maresha* have been observed working at an average speed of 2 km per hour and ploughing at an average depth of 13 cm in light soils with an average moisture content of 22% (by weight). In such conditions a pair of oxen produce an average power output of 0.68 kW per hour. The gross energetic efficiency of oxen, defined as the energy in the form of work accomplished as a percentage of energy consumed for maintenance and work on working days, ranges between 11% and 15%. These values highlight the relevance of making efficiency gains in the draught animal component of farming systems where forages are in short supply.

It was against this background that in June 1979 ILCA began comparative investigations into the use of crossbred oxen, which weigh more than the local breeds and produce more draught power. The use of crossbred oxen is linked with the prospect of the more widespread introduction of dairy enterprises using crossbred cows. Currently, the few thousand crossbred males produced annually in Ethiopia, mostly on state-owned dairy farms and ranches, are slaughtered soon after birth rather than reared and used for traction purposes. The routine use of crossbred males as draught oxen should allow cultivation of lands not tillable by oxen of indigenous breeds - and particularly the bottomlands with their heavier soils. Additionally, crossbred oxen can contribute to agricultural production on lands now tilled, because they cultivate faster and thereby allow more timely planting, and because they can draw a range of implements giving improved seedbed preparation and weed control, resulting in higher average crop yields.

The paragraphs which follow summarize the most important results of the animal traction research from June 1979 to the end of 1980. Work in progress includes the evaluation of different cultivation systems using oxen of local and crossbreeds, the technical and economic efficiency of using crossbred cows for draught purposes as well as milk production, and the use of oxen worked as singles rather than as the traditional pair. Different harnesses and yokes are also being developed.

Trials are being conducted over a 3-year period, 1980-1982, to compare cultivation systems based on improved implements with the traditional cultivation system. The systems will be compared in terms of cultivation and weeding times, power requirements of the different implements, and crop yields[13]. The cultivation trials are conducted at three sites: one each on the two soil types at the Debre Zeit station - clay loams - and the third at Debre Berhan, on the clay loams there.

> [13] Longer-term effects on soil structure are expected to arise from the use of deeper ploughing implements, but it will be some years before these effects (if any) become evident.

For the traditional system which acts as the experimental control, all seedbed preparation and seed covering is done with the *maresha*. For the first of the two new systems being evaluated, a mouldboard plough is used in the first pass, while secondary cultivation is done by zig-zag or chain harrow, according to the crop. In the second new system primary cultivation is by a spring tine cultivator, again followed by the use of zigzag or chain harrow according to the crop. A pair of crossbred oxen is used for drawing all improved implements, while a pair of local Zebu oxen pull the *maresha*. Details of the 1980 results are available in Abiye Astatke and Matthews (1981). Table 3.23 summarizes their results in terms of cultivation rates and energy costs of cultivation, while Table 3.24 gives the crop yields per ha for the various treatments on each soil type.

Table 3.23. ***Cultivation rates and total energy cost of three systems of cultivation on three soil types at Debre Zeit and Debre Berhan, 1980.***

Soil type - Location/crop	**Cultivation system[a]**					
	1		**2**		**3**	
	hours/ha	**(kWh/ha)**	**hours/ha**	**(kWh/ha)**	**hours/ha**	**(kWh/ha)**
Clay - Debre Zeit:						
Teff	157	(80)	58	(50)	49	(48)
Wheat	141	(80)	55	(47)	49	(38)
Horse beans	125	(62)	49	(39)	41	(30)
Clay loam - Debre Zeit:						
Teff	158	(108)	73	(70)	76	(76)
Wheat	161	(120)	66	(63)	79	(80)
Field peas	138	(104)	54	(50)	64	(63)
Clay loam - Debre Berhan:						
Wheat	95	(74)	40	(34)	31	(34)
Barley	90	(73)	40	(34)	30	(33)
Horse beans	92	(60)	43	(39)	32	(42)

> [a] System 1: all passes with the *maresha*.
> System 2: primary pass with mouldboard plough, followed by zig-zag harrow or chain harrow.
> System 3: primary pass with spring tine cultivator, followed by zig-zag harrow or chain harrow.

Table 3.24. ***Average crop yields for three systems of cultivation on three soil types at Debre Zeit and Debre Berhan, 1980 (kg/ha).***

Soil type-Location/crop	**a**

	Cultivation system		
	1	2	3
Clay - Debre Zeit:			
Teff	915	950	1 047
Wheat	774	932	839
Horse beans	1 992	1 764	1 147
Clay loam - Debre Zeit:			
Teff	1 707	1 680	1 553
Wheat	2 254	2 250	2 138
Field peas	843	905	802
Clay loam - Debre Berhan:			
Wheat	687	941	829
Barley	1 022	774	842
Horse beans[b]	n.av.	n.av.	n.av.

[a] See Table 3.23 for details.

[b] Horse bean crops failed due to frost.

Cultivation hours per ha needed on the clay loam soils at Debre Berhan were significantly less than on either soil type at Debre Zeit. Overall, the system using the spring tine cultivator appears the most efficient as regards total hours spent per ha. Statistical tests showed no significant crop yield differences between systems. The results for 1980 only, as reported here, indicate that the total draught power required on the clay soils at Debre Zeit is 25 to 50% lower than that required on nearby clay loam soils. The clay loam soils at Debre Berhan require approximately the same draught power as the clay soils at Debre Zeit.

In addition to these trials, ILCA has initiated research on the use of cows as both milk producers and draught animals. A total of 32 cows are involved in the experimental research, with 16 each in a working and a non-working group. The cows were installed in late 1980. The trial is scheduled to continue until the end of the third lactations of the cows tested, when the effects on lifetime productivity can be estimated. If results show that cows can work without significant penalty to either reproduction rates or lactation yields, then peasant smallholders in the Ethiopian highlands will have available a development option which does away with the need to keep breeding stock in order to produce oxen which are worked only some 300 to 500 pair hours per year[14]. The testing of avenues such as these in order to achieve significant improvements in the overall efficiency of farming systems is a principal goal of ILCA's systems research in the Highlands Programme.

[14] Preliminary results indicate that crossbred cows can be worked 4 or 5 hours a day with virtually no reduction in milk yield if they are fed a supplement to allow for the energy cost of field work.

3.4.3 Alternative energy sources for smallholders

Alternative sources of energy for household use are being explored by ILCA to permit cattle manure, which is now burned as domestic fuel, to be returned to the soil to maintain fertility. A range of tree species has been planted to identify high wood-yielding species. A manure-fuelled methane digester has been installed at Debre Zeit and is being used on an experimental basis. The digester is an Indian type with a metal gas collector of 2.83 m^3 capacity. Using the manure from three stalled adult cattle, it produces enough methane for the cooking and lighting needs of a family of five. The sludge residue of the digestion process can be returned to the fields as fertilizer. Trials are being conducted to assess the value of sludge as fertilizer and to establish a practical *modus operandi* for the entire process.

A major constraint on the use of methane digesters is their capital cost. The plant at Debre Zeit costs approximately US$ 700, and a substantially lower capital cost will be necessary if the technology is to be applicable to smallholders with limited cash incomes. A secondary constraint on the use of digesters is the need to add approximately 1 litre of water with each kg of manure used. Domestic water supplies over much of the highlands are already limited, and this additional requirement may prove impossible to meet unless alternative water sources are developped.

To a large extent the capital cost problem may be overcome by constructing the below-ground Chinese type of digester instead of the Indian model. The Chinese digester uses a minimum of purchased materials and is also less prone to variable rates of methane production due to changes in ambient temperatures - a considerable advantage when average daily temperatures fall below 20°C. Tests with a Chinese type methane digester will be initiated during 1982.

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4. The highlands programme in the context of FSR

4.1 The FSR approach

The basic objective of the Highlands Programme's research is to study ways of improving the overall productivity of mixed smallholder farms by increasing the technical and economic efficiency of livestock enterprises. Particular emphasis is given to enhancing the complementarily of the livestock and crop components. The research experience and its results in Ethiopia will, in many cases, have direct relevance to other highland smallholder situations in sub-Saharan Africa, where the same urgent need exists to increase agricultural production.

Past experience has shown, both in Africa and elsewhere, that enhancing the complementarity and reducing the competitive aspects of crop and livestock enterprises in the smallholder setting will substantially increase the overall efficiency of resource use on the farm. In many situations crop and livestock enterprises are already linked, but at the same time many opportunities remain for substantially increasing returns to land, labour and capital.

Crop and livestock enterprises interact in the smallholder mixed farm setting as follows:

- use of animal power for transport and crop production. Crops produce straws, stubbles and residues which in turn are utilized by livestock. These feedstuffs are otherwise of little use;

- use of animal manure to improve soil fertility;

- reduction in overall production risk by combining crop and livestock enterprises;

- improvement of crop productivity through the inclusion of improved legume-based pastures or forage crops in the crop rotation to increase yields per unit area and/or allow a higher fraction of arable land to be sown annually to food crops;

- consumption of milk and meat by smallholders, adding significantly to human nutrition;

- sale of livestock products such as milk, improving farm cash flows and stabilizing farm incomes;

- use of livestock as a "near-cash" capital stock, which is important in areas where no institutional credit facilities exist. Livestock can be sold at any time, thereby providing valuable support to subsistence farmers, whose crop inputs must often be purchased at planting time many months after the previous harvest;

- use of hides and skins for storage and transport of crop products.

Research must contribute to more efficient exploitation of these linkages. Past research and development efforts have often stressed technical innovations without fully understanding the impact of such interventions on the overall farm resource allocation. For this reason, the Highlands Programme has adopted the Farming Systems Research (FSR) approach, in which all the key components of the production and marketing system are considered together - implying a balanced emphasis on both crops and livestock in the mixed farming system. On-farm testing, whereby improved technologies are evaluated on a whole-farm basis, is an essential part of this approach.

FSR is an important activity in most of the research centres sponsored by the Consultative Group on International Agricultural Research (CGIAR). However, it has been conducted mainly by the crop research institutes, and is accordingly more advanced for crop than for livestock subsystems.

Gilbert et al (1980) note specifically that the livestock subsystem has received little attention in the context of FSR, at least from a theoretical standpoint. Critical reviews of experiences with FSR in the international centres can be found in CGIAR (1978) and Gilbert et al (1980).

ILCA's basic methodological approach has been summarized elsewhere (ILCA, 1980). The remainder of this section summarizes the principal features of the approach to FSR taken by the Highlands Programme. This approach is considered generally applicable to the many different mixed farming systems in sub-Saharan Africa in which crop and livestock production are closely linked.

The approach is presented in the context of FSR conducted in a target area representative of a relatively large, homogenous agricultural production zone. It is assumed that this area has not previously been the target of specific research, but has been identified by the national government as a priority development area. Agricultural production in the area is assumed to be dominated by subsistence-oriented mixed crop/livestock smallholdings.

4.1.1 Diagnostic stage

In the diagnostic stage of FSR, the environmental, technical, economic and sociological contexts within which the farming system operates are determined and assessed. The literature review and systematic collection and analysis of existing data done at this time are usually supplemented with a separate, problem-oriented baseline survey of the target area. The latter provides a basic understanding of the farming system and the availability, allocation and productivity of the resources available at the farm level. If conducted in a "normal" year, the results of the survey may serve as a reference point for the later comparison of selected production parameters. Combinations of single interviews with individual farmers and panel or group discussions are typically used to acquire the data. Group interviews are particularly useful for obtaining information on the overall role of livestock in the farming system, the agricultural calendar, crop and grazing management practices, prevalent plant and animal diseases, crop yields, livestock productivity, consumption patterns, sociological and religious factors as they influence farm production, and general agricultural problems in the area.

The results of the diagnostic phase permit an initial assessment of the agricultural development potential of the area and the feasibility of different development avenues in relation to the existing economic and political framework. Component research priorities can be defined at this stage, although they may be revised later as the research proceeds. The diagnostic phase should also include an appraisal of future prospects for the area if there are no development interventions, the so-called "zero option".

Finally, it is during the diagnostic phase that the area is divided into different recommendation domains, each of which will require the formulation and testing of different production recommendations. Stratification into a manageable number of recommendation domains is based on the spatial and production characteristics of the cropping and animal production system. In many areas, for example, it may be both convenient and appropriate to define these domains on the basis of the principal soil types present. More complex definitions may include soil type, intensity of land use, market access, etc.

4.1.2 Design and testing stage

A principal research site may then be selected within the study area. Ideally, it should be representative of a large part of the target area, so that results from station research are directly applicable and location specificity is minimized.

Once the station has been established component research can be initiated, in which new sets of farming practices are evaluated. Component research should be tailored to the needs of the area, but typically includes topics such as the screening of crops for their response to seeding and fertilizer rates, the evaluation of techniques to improve animal health, and the productivity responses of livestock to improved nutrition. If appropriate, some of the station research may complement parallel component research at another site or sites so as to test the robustness of results in different production environments. This research is basically biotechnical, but is conducted with an awareness of price relationships and the intention, if the results are favourable, of making the technologies available to farmers. In other words, new technologies must be both profitable and practicable at the farm level.

Concurrently with station development and the setting up of component research, routine data collections subsequent to the baseline survey are initiated in the traditional farming areas beyond the research station boundary. These data collections complement and supplement the baseline survey, and allow for the in-depth study of topics where seasonality is important (such as labour data, cash flows, or time allocation of the various family members), or topics not addressed satisfactorily in the initial survey. They also permit an improved understanding and specification of the dynamics of the agricultural system not obtainable from the analysis of cross-sectional data. Specifically, these data collections will reveal the seasonal profile of livestock feed resources available (by quality and quantity) from both individually farmed and communally held areas. This information will allow the marginal value of improved feed supplies in the different seasons to be estimated, which in turn helps focus forage research and facilitates prior appraisal of likely opportunities and problems associated with the introduction of new or modified livestock enterprises.

A limited number of innovative enterprise combinations may then be tested in a whole-farm context at the station. As these synthetic systems will often involve additional production risks vis-à-vis traditional enterprise combinations, and as practical (or even unexpected) difficulties will usually be encountered in their operation, these research farms should be operated under the close supervision of research staff. In this way management problems and resource conflicts can be resolved before farmers are encouraged to adopt the new systems. However, such conditions remove many of the production risks faced by practicing farmers. Hence it will often prove difficult to transfer results from research farms to the real world setting. In principle, research farms demonstrate the upper limits of the potential for improved agricultural productivity at the farm level, and to this extent they can be used to set production targets for farmers when the latter come to test the new technologies by themselves.

Data collections on research farms will be at least as intensive as those made on outside farms in the traditional system. The outside farms serve as a control group against which the productivity gains or losses achieved on the research farms are measured.

Whether or not new component technologies are tested on research farms at the station, it is proper to gain further experience with them under farmer-managed trials before they are promoted in the farming community at large. A wide range of component technologies can be tested in farmer-managed trials, including a crossbred cow enterprise based on home-produced forage crops, animal health packages, alternative calf rearing systems, new or modified uses of draught animal power and improved dry-season feeding strategies (such as new ways of using crop byproducts) to supplement working oxen or cows in milk. These examples show how innovations can range from simple changes to existing enterprises through to packages of changes creating completely new enterprises. Such a wide spectrum of livestock production alternatives is applicable in almost all smallholder mixed farming situations. It mirrors on-farm tests in the crop production sector, which may include new varieties of traditional crops, new crops, new crop protection methods, fertilizer response trials, new crop rotations, etc.

An important design element of FSR with livestock is the splitting of outside farmers into two groups, one of which voluntarily adopts one or a combination of the new technologies to be appraised, while the other continues unaltered and functions as a control group. The test farmers, i.e. those adopting the new technologies, accept these at their own expense and risk, and are responsible for their own management decisions. To this extent they can accept or reject any of the component technologies on offer[1]. Test farmers may be introduced as early as the second year of the research programme, and even at a new location if robust technologies are already available from relevant work elsewhere. However, major new technologies will usually only be available for on-farm testing after component research on the station has verified their relevance to local circumstances. For this reason, firm schedules for on-farm testing can seldom be established.

> [1] Financial credits for development may be made available to farmers from the usual sources and on the usual conditions. In situations where appropriate credit institutions do not exist credit may have to be provided from the research project. However, this is undesirable, as it can lead to the formation of an elite group of farmers who become unrepresentatively dependent on the research programme and its staff.

It will usually be an advantage to have several different technologies available for on-farm testing, so that farmers can select those they consider to be most suited to their needs. The FSR approach used by ILCA explicitly recognizes that farmers themselves are the only final arbitors of the usefulness of a particular change to their farming system. Giving them a choice of technologies can accelerate the process of technology appraisal by farmers, allowing earlier feedback to researchers on the acceptability and productivity characteristics of the technologies on offer.

Because the farmers themselves choose what to do, statistical rigour must often be sacrificed to some degree in on-farm testing. In this regard, livestock enterprises are intrinsically more difficult to appraise than crop enterprises, since they exhibit more variability than the latter. Furthermore, as in the case of dairy production, outputs (milk) can occur continuously and at variable rates over the year, in contrast with the usual single-harvest situation for most crop enterprises. To the extent that the most important aspect of on-farm testing is the acceptability of the new technology to farmers, statistical rigour as regards sample size and homogeneity is not an absolute requirement.

The above approach allows new technologies to be evaluated from several standpoints; firstly, through comparison of the performance of the test farmers before and after adoption; secondly, through contemporary comparison (within any year or other relevant time period) of the performance of the test farmers with those of the control group; and thirdly through direct comparison of the performances of both the test farmers and the control group with that of the research farms under researcher management. Some of these research farms may continue to be used to evaluate the improvement packages adopted by test farmers. Meanwhile, others may be used to evaluate further new systems or improved technologies.

The several stages of the FSR approach are iterative. It is therefore routine to review and revise ongoing research regularly. Major reviews of all research should be made at least yearly.

The data collected from outside farmers and the results from test farmers, research farms and component research should be combined and synthesised into farm-level planning models to allow testing of alternative enterprise combinations, as well as the gains, problems and opportunities presented by technology changes. Models can be used at an early stage in the research to foster a common understanding of the functioning of the target system. Simple enterprise models will often suffice, with more complex models being developed as required and as permitted by available data. In the longer term, the essential role of such models is to provide improved advice in the determination of research priorities, and to enable field results obtained in one production system to be used to greatest advantage in other similar systems.

Particular attention in the evaluation of mixed farming systems will be given to the competition for farm resources between the crop and the livestock enterprise over the year. It is also important to focus on the input - output relationship between enterprises. The evaluation of improved mixed farming systems must also take into account the multiple objectives of farmers. Certain activities have an intermediate role in farm production (such as draught animal power), while others generate end products that can be either sold, or consumed at home.

This combination of systems research, component research and modelling is efficient. It provides a basis for the development and transfer of improved technologies to the farmer population in the target area.

4.1.3 Adoption of the research approach and its results by a national agency

National agricultural research agencies in Africa often have very limited funds and professional staff available to carry out their task. Any new research approach must take these constraints into account if it is to have practical impact. The approach to FSR presented here can be implemented by national agencies and is seen as an efficient way of identifying and testing opportunities to produce productivity gains at the smallholder level. Implicit in the selection of the FSR approach is the idea that smallholders should be the main target group of African agricultural research - a conviction borne out by their primary importance to food production in Africa.

The FSR approach also implies the decentralization of national research activities and responsibilities. In the short run there may be institutional impediments to the implementation of the approach because manpower shortages have resulted in a centralized structure in most African research agencies. Centralization leads to operational inflexibility, with severe practical disadvantages for the overall efficiency of FSR type operations.

The approach to FSR suggested here has important implications for experimental design and data collection and analysis, especially as regards on-farm testing. For these reasons it is essential that statistical and analytical considerations be addressed during the planning of the FSR programme. For example, the minimal control possible over test farmers' activities, and indeed their selection, implies the need to have large numbers of test farmers in order to derive statistically rigorous results. However, in most instances this will prove impractical for logistical and cost reasons, and researchers will have to depend to a great extent on their familiarity with the target area to gauge the comparative merit of the research they are undertaking. Thus it is essential for the researchers to interact regularly with extension agents assigned to the area, so that both groups are kept fully aware of all aspects of the farming system and of the new technologies under test. This interaction encourages extension of the technologies throughout the community with a minimum of difficulty once they have been found suitable on the basis of the results of the on-farm tests. Regular formal and informal meetings with farmers are also essential, so that farmers are made aware of the work in progress and, equally importantly, researchers can be given candid appraisals of their work by farmers.

Other important issues in the conduct of FSR include the role and organization of control groups, the phasing of research activities, team composition and organization, the role and relevance of principal and secondary research sites, the transferability of FSR results, and training in the FSR approach. There are no clear-cut guidelines for these topics, and local circumstances will to a large extent dictate what choices and actions are made and taken. Regular interaction with other FSR workers addressing similar problems will prove advantageous. This will be especially important if several FSR groups are active in different areas of any one country.

4.2 Research experiences and outlook

The central tasks of ILCA's Highlands Programme are to provide methods and results which would, if applied on a wider scale, improve the productivity of mixed smallholder farms in the Ethiopian and African highlands. For this reason it is important to illustrate the linkages between the research and the real system under study, so that the relevance of the research can be assessed. These linkages are summarized in Figure 4.1.

Several important issues have arisen during ILCA's research which have influenced the selection and implementation of particular research topics. This situation is hardly exceptional - all FSR projects will be subject to such influences - but these issues merit note here because many of them will have their counterparts in other situations.

Several cattle breeds and crossbreeds are appropriate for use in improved highland production systems in Africa. Many countries have depended primarily on the Friesian breed to develop higher-yielding dairy cattle populations. This has been the case in Ethiopia. However, other breeds such as the Jersey have higher butterfat yields per unit of metabolic body weight than Friesians and are well adapted to tropical conditions. Furthermore, crosses with breeds such as the Jersey could play a productive role in areas with poor road and market access, where whole milk production and marketing is at a disadvantage compared with the production of cheese or butter.

As noted earlier, only Friesian x Boran cross-breds were available in sufficient numbers for ILCA's research, and even the supply of these was not adequate to ensure the desired level of statistical rigour. Also, ILCA had intended to make regular use of the Ethiopian AI service. This proved unworkable in practice, and the programme was obliged to acquire sires for use by natural service. Thus animal resources available limited the scope of the programme and have highlighted the need for Ethiopia to expand the supply of different animal types, at least to permit appraisal of alternative breed crosses so as to be certain that development plans are based upon the best potential results.

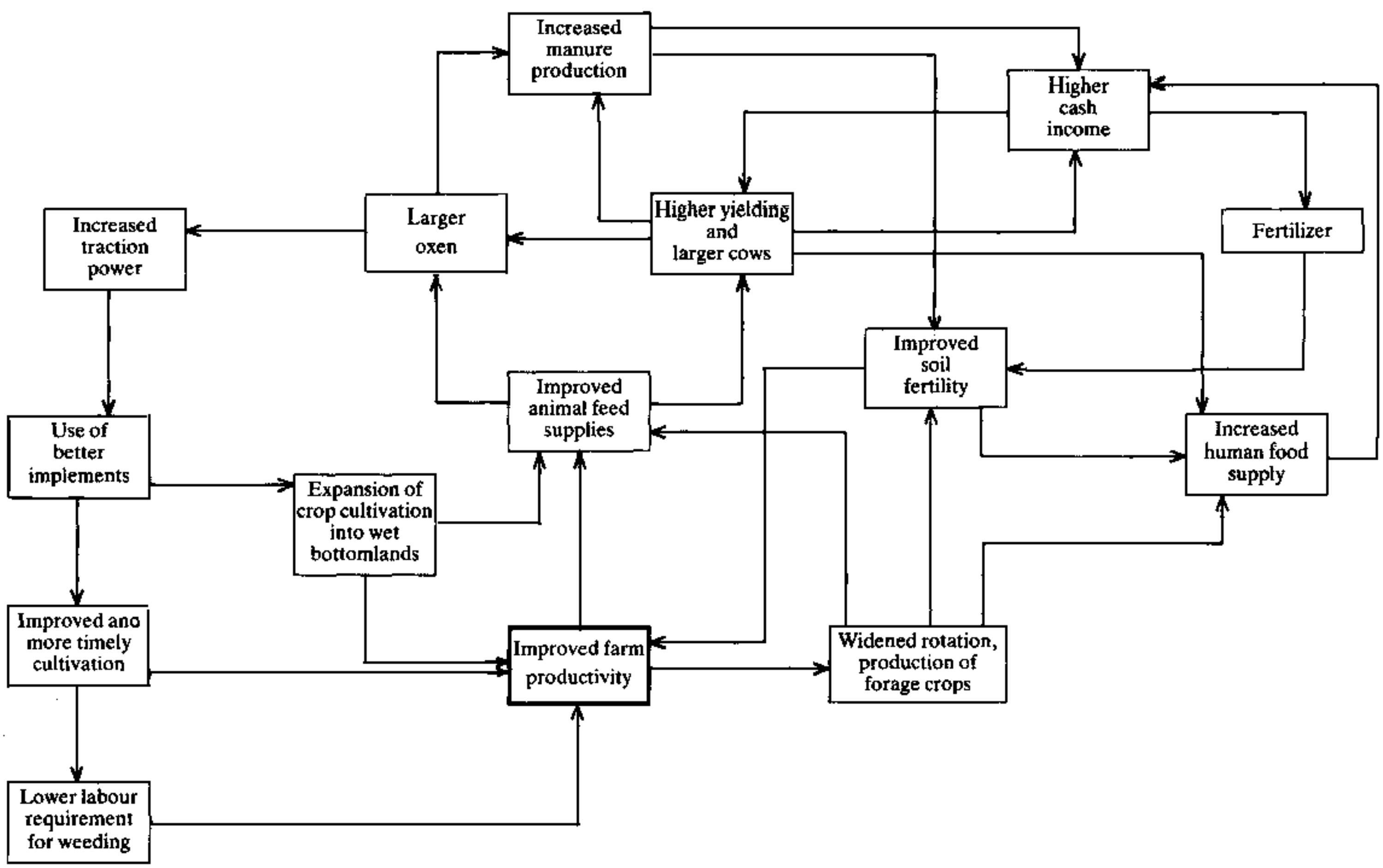
ILCA's research has confirmed that the crossbred cow enterprise would be a profitable addition to the enterprise mix for many Ethiopian farmers. If this enterprise is to be adopted on a large scale it will require a substantial increase in the supply of suitable crossbred cows. As in many other situations where dairy development has been promoted, the most suitable means of providing these cows has not been adequately researched. The problem in Ethiopia is especially difficult because of the poor road network, the difficulties of providing an effective AI service, and the small herd sizes of farmers.

Limited supplies of suitable forage seeds also impeded the research. ILCA's results have identified a number of forage species, including legumes for use in mixtures, which are currently available in quantities sufficient only for research purposes. Any wider-scale policy of encouraging smallholders to grow forages will need to be supported by adequate seed supplies. Forage seed production in Ethiopia is in its infancy, and only recently has the government addressed the issue from either a research or a large-scale production standpoint.

While the introduction of new cattle breeds and the expansion of the supply of forage seeds are both key development issues to be addressed by government, there were also site-specific issues which arose during the research. The price paid per litre by the DDE to milk producers did not increase during the period 1977 to 1980[2]. Over this same period the farm gate price of cereals more than doubled. This adverse change in the milk/cereal price ratio made it more difficult the improved forage/dairy cow enterprise to compete with cereals for arable land. Although participating farmers did grow forages as recommended in the package, they tended to grow them as a substitute for pulses rather than for cereals. This producer-level response was rational, but cannot be sustained in the longer term because of the likely depletion of soil fertility caused by removal of the major part of the legume component of the rotation. The producer response might have been as recommended if the relative prices of milk and cereals which prevailed at the start of the research had continued throughout the period.

[2] As yet it has still not increased in 1982.

Figure 4.1. Linkages among the principal components being researched by the ILCA Highlands Programme.



Fertilizer prices also doubled over the same 4-year period. Both this increased fertilizer price and changes in the milk/cereal price ratio have mitigated against acceptance of the improved forage/dairy cow enterprise in the Ada Wereda situation. Despite these market forces, the participating farmers have maintained their interest in the enterprise.

The research at Debre Berhan station in Baso and Worena Wereda has not yet reached the stage at which "new" packages have been tested adequately for them to be regarded as acceptable for use by farmers. Frost is an important agricultural hazard in the Debre Berhan area: as the success of a package depends directly on the success of its component parts, this hazard must be circumvented by identifying suitable cereal varieties able to mature before frost damage can occur.

Some changes in current operations are anticipated following the planned review of progress to date[3]. The research farms at Debre Zeit, which are unreplicated and quite different from one another, will probably be phased out. The land currently allocated to these farms will be used to strengthen the component research and forage seed production trials.

[3] During 1982.

The implementation of FSR at Debre Zeit would have been more effective if a larger group of participating farmers had been involved, and if they had been more distant from the research facility, so as to minimize the easy dependence on ILCA which proximity encouraged. The possibilities for expanding the number of participating or test farmers are now being explored. The problem of proximity is being tackled by reducing ILCA's day-to-day involvement in the activities of these farmers. ILCA's involvement will in future be limited to the observation and recording of selected farm activities. These data will allow continued comparative studies of the performance of participating and outside farmers, including low-intensity studies with the same control group of outside farmers as has been cooperating with ILCA since 1977.

The cooperative farm established with ILCA assistance, and other cooperatives in the area, will also continue to be observed. Special emphasis will be placed on the role of dairy production in cooperatives, as such cooperatives are receiving strong encouragement from the government as part of its overall development programme.

The systems-level research at Debre Berhan to date comprises only research farms on station and studies in the traditional system with a control group of outside farmers. Until the technical and economic performance characteristics of the packages being tested on the research farms have been evaluated, it is considered inappropriate to establish participating farmers there. Two more years of study of the research farms are probably necessary. Participating farmers can be identified during this time but will not be brought into the research before the 1982 crop year.

Component research on forages will continue at both stations, with an increased emphasis on low-input systems[4]. This emphasis will be consistent with results to date at Debre Zeit, which have indicated that forages have a positive contribution to make towards improving farm productivity, but that farmers tend to allocate their resources in favour of cereal crops. Competition for labour at cultivation time, for example, means that less attention is given to seedbed preparation for forages than for cereals. This factor is illustrated in Table 4.1.

[4] Low-input systems use a minimum of fertilizer and labour for seedbed preparation. Improved cultivation methods will additionally reduce the labour requirement for weeding. In this way the traction research is directly linked to "easy-care" systems.

Table 4.1. ***Labour inputs for different activities by participating farmers for forages and cereals at Debre Zeit, 1980 (hours/ha).***

Activity	Forages[a]	Cereals[b]
Soil preparation and planting	89	171
Weeding	24	115
Harvesting and transport	134	194

[a] An oats and vetch mixture.

[b] Wheat and teff grown as separate crops.

One conclusion which can be drawn from the experience to date is that it will take many years for farmers to accept new enterprise alternatives which use land now normally allocated to subsistence crops. Studies on the risk attributes of forage crops are planned, with the intention of developing more guidelines on the likely acceptability of changes to traditional systems. Different forage crop species will continue to be evaluated, but the work will be consolidated and will concentrate on the more promising species. While the Ethiopian Government agency concerned with seed production recognizes the need to expand production of suitable forage seeds, its priority mandate is to work with human crops. Arguments for strengthening the forage component of its operations will depend on the continued demonstration of successful dairy enterprises, backed up by research results which clearly prove the superiority of the latter over other production alternatives for at least an important fraction of farmers in the highlands.

The collection and evaluation of indigenous legumes, particularly *Trifolium* species, is an important programme activity. The resources allocated to this work will increase. The Ethiopian highlands have not been systematically explored for legumes, and the identification of outstanding legume material is expected to be of direct benefit elsewhere in the African highlands as well as to temperate pasture zones in other parts of the world.

Studies on various aspects of the animal draught power component of highland farming systems are already well advanced at both research stations. Substantial data will have been acquired by the end of the 1982 crop year on the comparative efficiencies of oxen of local breeds and Friesian crossbred oxen. A multilocation study involving four sites and three institutions in Ethiopia is planned to begin in 1983, covering the three main soil types and the main breeds and breed crosses of oxen now available in Ethiopia[5].

[5] The experimental sites will be Debre Zeit and Debre Berhan (ILCA), Asella (ARDU) AND Holetta (IAR).

A byproduct of this research will be better information on the extent to which animal draught power is a determinant of farm production. Additionally, the research will help elaborate the options available to smallholders accustomed to using draught power but who will in the future be increasingly unable to keep the numbers of stock held in the past because of the feed shortages caused by reduced farm sizes and competition between crops and livestock for land. Draught animal power is a topic of paramount importance in many smallholder situations in sub-Saharan Africa.

Brief mention only has been made of farm energy studies. This aspect of the work will continue, as it is recognized that the domestic energy needs of low-income smallholders must be satisfied in the long term from local sources. Through its conversion to biogas, animal manure is one means[6] of providing energy for basic household cooking and lighting. Furthermore, the sludge produced after digestion in the converter is a valuable organic fertilizer. ILCA's research in this area will concentrate on the development of practicable and capital-efficient ways of converting manure to gas and then distributing the gas to households and the residue to the fields.

[6] Nurseries have been established on the ILCA stations to evaluate different species of fodder trees and shrubs as fuelwood and feed resources.

Assisting national research institutes is an important and expanding role of ILCA's Highlands Programme. ILCA has already assisted national agencies on topics as diverse as the analysis of animal production and farm management data, the design of animal-drawn implements, and the provision of laboratory analysis.

Finally, the Highlands Programme is planning an increased involvement in training in FSR with special emphasis on livestock enterprises. Such training is seen as an efficient means of providing national research agencies with the skills to conduct their own systems research - a goal of considerable importance if, as ILCA believes, it is relevant studies on whole systems rather than on isolated components that will identify and facilitate the greatest possible production gains to be achieved in the livestock sector of the African economy.

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Acronyms, abbreviations, signs and units

The following acronyms, abbreviations, signs and units of measure are used in this report:

AI	Artificial insemination
ARDU	Arsi Rural Development Unit (Ethiopia)
°C	Degrees centigrade
CADU	Chilalo Agricultural Development Unit (Ethiopia)
cal	Calories
CGIAR	Consultative Group on International Agricultural Research (Washington, D.C.)
CIMMYT	International Maize and Wheat Improvement Centre (Mexico)
CIP	International Potato Centre (Peru)
CP	Crude protein
cv	Cultivar
DAP	Di-ammonium phosphate
DDA	Dairy Development Agency (Ethiopia)
DDE	Dairy Development Enterprise (Ethiopia)
DM	Dry matter
EPID	Extension and Project Implementation Department (Ethiopia)
F_1	First generation crossbred
FAO	Food and Agriculture Organization (United Nations)
FSR	Farming Systems Research
g	Grams
GNP	Gross National Product
ha	Hectare
IAR	Institute of Agricultural Research (Ethiopia)
IBRD	International Bank for Reconstruction and Development (World Bank)
IDA	International Development Association (World Bank)
ILCA	International Livestock Centre for Africa (Ethiopia)
kg	Kilogrammes
km	Kilometers
km^2	Square kilometers
kWh/ha	Kilowatt-hour per hectare
LU	Livestock unit
m	Metres
m^2	Square metres
m^3	Cubic metres
mm	Millimetres
MPP	Minimum Package Programme (Ethiopia)
N	Nitrogen
n.av.	Not available

n.ap.	Not applicable
P	Phosphorus
PA	Peasant Association
p.a.	Per annum
pH	Measure of acidity (<7)/alkalinity (>7)
ppm	Parts per million
spp.	Species
t	Metric tonnes
TAC	Technical Advisory Committee (CGIAR)
US$	United States dollars
var	Variety
WHO	World Health Organization
%	Per cent
'000	Thousand

The Consultative Group on International Agricultural Research

The consultative group on international agricultural research

The International Livestock Centre for Africa (ILCA) is one of the 13 international agricultural research centres funded by the Consultative Group on International Agricultural Research (CGIAR). The 13 centres, located mostly within the tropics, have been set up by the CGIAR over the last decade to provide long-term support for agricultural development in the Third World. Their names, locations and research responsibilities are as follows:

> Centro Internacional de Agricultura Tropical (CIAT), Colombia: cassava, field beans, rice and tropical pastures.
>
> Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Mexico: maize and wheat.
>
> Centro Internacional de la Papa (CIP), Peru: potato.
>
> International Centre for Agricultural Research in the Dry Areas (ICARDA), Lebanon: farming systems, cereals, food legumes (broad bean, lentil, chickpea), and forage crops.

International Board for Plant Genetic Resources (IBPGR), Italy.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India: chickpea, pigeon pea, pearl milks, sorghum, groundnut, and farming systems.

International Livestock Centre for Africa (ILCA), Ethiopia: African livestock production

International Rice Research Institute (IRRI), the Philippine: rice.

International Institute of Tropical Agriculture (IITA), Nigeria: farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), and food legumes (cowpea, lima bean, soybean).

International Laboratory for Research on Animal Disease (ILRAD), Kenya: trypanosomiasis and theileriosis of cattle.

West Africa Rice Development Association (WARDA), Liberia: rice.

International Service for National Agricultural Research (ISNAR), the Netherlands.

International Food Policy Research Institute (IFPRI), USA: analysis of world food problems

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