Chapter One

Economic Analysis of Crop-Livestock Integration: The Case Of the Ethiopian Highlands

This chapter introduces problems associated with persistent food production deficit and agricultural stagnation in sub-Saharan Africa. The research problem is identified as integrating crop and livestock production as a promising and feasible way of increasing food production and farm incomes in the rural sector. A case is made to investigate the role of livestock in alleviating the structural food deficit problem and improving farm incomes in the central Ethiopian highlands. The hypotheses to be tested and objectives of the study are outlined. An outline of the thesis concludes this chapter.

1.1 Background

Many countries in sub-Saharan Africa are experiencing rapid population growth, increasing degradation of the natural resource base, and declining per capita food production. With an average annual growth rate of 3.0 percent, the current population in the region of about 498 million will rise to 676 million by the year 2000 and to about 1294 million in the year 2025. Per capita annual food production is declining at an average rate of 1.1 percent. If production trends do not improve, projected production growth targets will not be met and imports will be necessary to avoid widespread food insecurity. Together with other essential imports such as energy, large food imports would deplete scarce foreign reserves and stifle prospects for socio-economic development in the region (World Bank 1989, 1992).

In Ethiopia, per capita food production (including milk in grain-equivalents) is estimated to be 141 kg, compared with 171 kg for other countries in sub-Saharan Africa. Per capita food production is declining at an annual average rate of 1.1 percent. Domestic production meets only between 63 percent and 75 percent of national food requirements. If production trends do not improve, food production in the year 2025 will be around 65 percent of the production target. Of the projected milk production, only 75 percent will be within projected targets (Negussie and Lemma 1992). Annual food imports either as humanitarian food aid or commercial imports have become and may remain necessary complements to domestic food production. Increased competition in the allocation of hard currency for various alternative imports and the widening food production shortfalls may render an increasing number of people more vulnerable to malnutrition and starvation, unless domestic production is improved (FAO 1992, E.I.U. 1990-1993).

The poor performance of Ethiopia's agricultural sector is symptomatic of inappropriate land use, lack of producer incentives, poor infrastructure, inappropriate technological and policy environments, and institutional and socio-economic bottlenecks (Lemma 1986, Belete et al., 1991). Compounding these problems is the increasing demand for food necessitated by population growth and scarcity of foreign currency reserves to commit to food imports. In the last two decades, the food deficit problem has been more acute in Ethiopia than in any other country in sub-Saharan Africa (Seavoy 1989, FAO 1992, pp. 1-2). Protracted droughts and man-made disasters such as human re-settlement and civil war have been major obstacles to improving agricultural performance. In recognition of these problems and challenges, there is increasing emphasis on strategies and mechanisms of institutional and policy reform aimed at improving agricultural production and overall resource management. Low and declining agricultural productivity in the face of population growth poses one of the greatest challenges in satisfying the increasing demand for food and creating exportable surpluses (Winrock International 1992, pp. viii-xii).

In parts of sub-Sahara Africa that are characterised by high population density, such as the Ethiopian highlands, there is increasing cropping and grazing pressure on scarce land resources. Soil erosion and declining soil fertility result from inadequate land-use practices and reduce the capacity of many households to satisfy their increasing demand for food (Aggrey-Mensah 1984, FAO 1984a). In Ethiopia, land degradation is assuming such magnitudes that farmers may not produce enough food even in periods of normal weather (Walsh 1984). To address the structural food deficit problem and environmental degradation, appropriate policies and technologies are needed that can simultaneously enhance food production, generate cash income and increase employment without significantly degrading the natural resource base (IAR 1989, ILCA 1993).

In the Ethiopian highlands, livestock is an integral component of the farming systems. A variety of biological and economic interactions between crop and livestock make crop-livestock integration appealing to farmers. Utilisation of animal traction improves the timeliness, effectiveness and scale of crop cultivation. As imported fertilisers are becoming more-and-more costly, manure is an important substitute for chemical fertiliser. Livestock can improve crop yields through production and use of animal manure (Gryseels and Anderson 1983). Cow dung is also an important source of fuel. Cow dung and crop residues provide more than half of the total national household energy needs in Ethiopia. During periods of feed scarcity, crop residues sustain livestock production which in turn broadens household food security. Improved household nutrition has important socio-economic dimensions in overall economic development of the country (Gryseels et al., 1989).

Cultivation of fodder and legumes often alleviates feed scarcity and improves soil fertility on mixed farms. Livestock provide opportunities for productive use of slack resources that may boost agricultural productivity. Integrated crop-livestock production is also a risk-diversification strategy whereby livestock provide an important investment opportunity for rural households and stabilise food availability by buffering risks associated with crop failure (Storck et al., 1991, Webb et al., 1992). Livestock contribute directly to the sustainability of farming systems by supporting farm households, especially, during periods of food shortage or financial stress. Crop production can stabilise farming systems that are heavily dependent on livestock (Mukhebi et al., 1991). In good rainfall years, crop production facilitates net investment in livestock. Livestock are often the largest component of farm capital stock in the absence of developed rural capital markets and act as the bank of last resort for most rural households (Gebreworld 1991, Ehui et al., 1994).

Different types of farmers face different resource, socio-economic and institutional constraints that necessitate different production decisions and practices, some of which may lead to efficiency losses to both the household and the society due to sub-optimal use of available resources. Small-scale farmers account for about 90 percent of total agricultural output and 84 percent of the marketed surplus in Ethiopia (FAO 1992). Therefore significant changes in the agricultural productivity in the small-scale farm sector will substantially affect national income and food security. Moreover, smallholder farmers constitute the bulk of the rural poor. Any change in agricultural performance of the small-scale farm sector may improve overall social welfare and minimise the need to divert public resources to direct welfare assistance programs (Belete et al., 1993). Improving crop-livestock integration will contribute to enhanced agricultural output considering the contribution of smallholder output in gross domestic product.

1.2 Research Problem

Where ecological, climatic, socio-economic and institutional factors permit, further crop-livestock integration offers opportunities for increasing food production, employment and farm income without degrading the environment. Opportunities for extensive land cultivation and off-farm employment are limited given the existing low levels of technology in Ethiopian agriculture (Sisay 1985). Intensification of land use appears a promising solution to increasing farm output and cash income. However, increased crop-livestock integration may involve higher input (e.g., labour) requirements, sophisticated management skills and may entail some environmental losses (e.g., soil erosion).

At the household level, crop-livestock integration and further agricultural intensification would involve trade-offs in alternative use(s) of land, labour, manure and crop residues. With limited opportunities for extensive agriculture and due to potential conflicts in the utilisation of scarce farm resources, decisions about livestock production may affect crop production and vice versa (Simpson and Evangelou 1984, Winrock International 1992). Considerable differentials exist between households in factor endowments and farming practices. This leads to complex household decisions on selection of enterprise combinations and production techniques. Such decisions have important implications for farm incomes and the sustainability of the farming system(s).

Few studies (e.g., McIntire et al., 1992, Ngambeki et al., 1992) have examined the effects of crop-livestock integration. To a considerable extent, these studies have provided useful insights into resource endowment, farming practices, constraints to and opportunities for agricultural intensification in highland farming systems. However, because of institutional considerations, these studies (e.g., Belete 1989) have not explored effects of factor rentals on farm production, enterprise mix and farm income.

Another major limitation of these studies has been sample selection. For example, Gryseels (1988) and Belete (1989) have randomly selected households that participated in the evaluation of mixed smallholder farming systems. Such sampling procedures may not adequately consider differences in resource endowments and farming practices by different types of households and may inadequately assess the role of livestock in mixed farming systems.

Third, other studies (e.g., McIntire et al., 1992) are across-country comparisons using simulation methods and may obscure location-specific features (e.g., animal traction) of mixed farming. Fourth, because of random sampling procedures, these studies do not indicate to which type of households and how mixed farming may be beneficial in comparison with crop farming alone. When ignored, this would bear considerable implications for policy design, implementation and evaluation of programs regarding improving agricultural performance in such farming systems that are experiencing increasing population pressure. Fifth, in the Ethiopian highlands, these studies have tended to be located within small geographical locations (within 5 kilometre radius) and relatively small sample size ($n \leq 50$). A small sample size within a small geographical location may obscure some generalisable and beneficial aspects of mixed farming.

With some of these limitations from previous studies and without empirical evaluation of the different effects of crop-livestock integration, debate about the role of livestock in sustainable agriculture will continue. This thesis explores economic outcomes from crop-livestock integration as one of the technically feasible means of improving agricultural output.

Compared with other studies in the Ethiopian highlands, this study has used a bigger sample (n = 94) and from a wider geographical radius (50 kilometres). Data collected from these sample units are used to investigate effects of crop-livestock integration for households with and those without livestock. This approach provides a systematic framework for conducting an empirical assessment (`tease out') of the quantifiable interactions between crop and livestock production. An economic evaluation of crop-livestock integration is necessary in order to make some suggestions that will contribute to informed debate about opportunities for agricultural intensification and its implications for farm incomes and agricultural resource management in the Ethiopian highlands and other highland farming systems (e.g., Kenya, Madagascar, Nepal, Rwanda, Zimbabwe).

1.3 Research Objectives

The general objective of this study is to describe the farming systems in Ethiopian highland agriculture and evaluate economic effects of integrating crop and livestock production. The specific objectives are to:

1. Determine the economic contribution of crop and livestock production to the farm household; and
2. Determine the economic effects of specific policy options of:

   (i) devoting scarce resources to sole crop production,

   (ii) combining crop and livestock production and thus devoting some farm resources to pasture and forage production.

1.4 Hypotheses to be Tested

Four hypotheses will be tested in this thesis and they are:

1. Integrated crop-livestock production provides more income than crop enterprises alone;
2. Employment of family labour is higher in integrated crop-livestock production systems than crop enterprises alone;
3. Improving livestock productivity is beneficial especially for farmers with limited resources especially the amount of arable land; and
4. Increasing forage production will lead to increased animal production, employment and income.

1.5 Outline of the Thesis

This thesis is organised in seven chapters. Chapter two presents an overview of effects of crop-livestock integration in highland farming systems. A conceptual framework for assessment of the effects of crop-livestock integration is proposed and discussed. The conceptual framework is cast around the conventional theory of the firm.

Methods that are used in the data collection are described in chapter three. It presents an account of the questionnaire design, sampling procedures, recruitment and training of field assistants, data collection and problems encountered during data collection.

Chapter four presents the results from statistical analyses that are descriptive of crop-livestock integration, household features, livestock ownership and husbandry practices, cropping practices and household income and expenditure. Details of the input-output coefficients and other parameter values that are used in the linear programming model are presented.

The analytical framework proposed for the analysis of crop-livestock integration is presented in chapter five. Aspects of modelling household resource allocation in the farm sector are discussed. In order to conduct an empirical analysis of the economic effects of crop-livestock integration, chapter five also presents the mathematical programming model that is applied in this study. Analytical scenarios to which the linear programming model is applied are also presented.

Chapter six presents outcomes of crop-livestock integration obtained from the linear programming model for the alternative analytical scenarios. These include timeliness of land preparation that is associated with oxen ownership and differences in land productivity. Opportunities for integrating crop and livestock farming are explored. Hypothesis testing is conducted and decisions are discussed.

Chapter seven discusses the main conclusions that are drawn from this study about crop-livestock integration and suggests some directions or areas of future research efforts in highland farming systems.

Chapter Two

Role of Livestock in Highland Agriculture

Without attempting to be exhaustive, this chapter describes some of the direct or implicit interactions between crops and livestock that make mixed farming appealing to resource-poor farmers. A conceptual framework, built around the theory of the firm, is proposed for evaluation of effects of crop-livestock integration. Application of some of these attributes in the analytical model is mentioned. Other indirect and less quantifiable functions of livestock in the process of agricultural intensification are highlighted.

2.1 Crop-Livestock Production Systems

Of the total livestock herd in Sub-Saharan Africa, smallholder farmers possess more than 75 percent, pastoralists own about 20 percent while ranches account for 5 percent. Crop-livestock production systems are prevalent in the highlands of eastern and southern Africa and in the Sahelian and Sudano-Sahelian zones of sub-Saharan Africa. Farming zones in sub-Saharan Africa are distinguished by their location in the (1) arid and semi-arid zone, (2) sub-humid or humid zone, and (3) highlands. Although the highlands constitute less than 5 percent of the total land area in Africa, they support more than 20 percent of the human population and about 17 percent of the livestock population. Ethiopia encompasses about 50 percent of the total highland area in tropical Africa (Gryseels 1988). These agro-climatic zones differ in land types, climatic and altitudinal features, length of period of growing (LPG), disease challenge, extent of crop-livestock interactions and average per capita incomes (Table 2.1).

The highlands are the most intensively cultivated areas and support the highest population densities and livestock stocking rates of any agro-ecological zone in sub-Saharan Africa. Population pressure has triggered the evolution and adoption of mixed crop-livestock production, replacing the former extensive grazing and bush fallow systems. Although the degree of crop-livestock integration may be less than optimal, integrated crop-livestock production has become an important feature in highland farming systems (Jahnke 1982, pp. 152-181). Due to variations in agro-ecological features, different farming zones can support varying types and combinations of agricultural enterprises. For example, more perennial crops can be grown in the highlands than in other agro-climatic zones.

Table 2.1 Major Farming Systems in sub-Saharan Africa

Feature	Agro-ecological Environment		
	Arid/Semi-Arid	Sub-Humid / Humid Zone	Highlands
Area (' 000 km^2)	11 588	8 971	934
Rainfall (cm/yr)	0 - 80	80 - 200	50 - 150
LPG (days/yr)	0 - 120	120 - 240	120 - 180
Population (persons/km^2)	0 - 80	10 - 140	40 - 200
Main Crops	Cereals, Pulses	Cereals, Pulses	Cereals, Perennials
Disease Challenge	Little or none	Moderate e.g., Trypanosomiasis	Little or none
Crop-livestock Interactions	Moderate	Little or none	none to high
Per capita GNP (1987)	309	410	208

Source: After Jahnke (1982) and McIntire et al., (1992) The agro-ecological zoning of the Ethiopia's highland agriculture is depicted as the (1) low potential cereal-livestock zone, (2) high potential cereal-livestock zone, and (3) high potential perennial crop-livestock zone (Sisaye 1980). These farming zones are differentiated by climate, soil types, land use, socio-economic and demographic factors, infrastructure and types of production technology (Getahun 1978 & 1980). The three highland zones have about the same land area and human population but differ in livestock population. Differences in livestock population are associated with differences in population density, cropping systems, resource endowments and potential for intensive farming (Table 2.2).

Most of the Ethiopian highlands lie between the 1500 and 3000 metres above sea-level. Vast areas of the highlands receive from 900 to 1 500 mm of rain for a variable period of between 6 and 8 months. The average daily temperature is about 20^{o}C. Soils in the highlands are derived mainly from Precambrian crystalline volcanic parent material. Alfisols, vertisols and inceptisols are predominant soil types. The soils are low in physical and chemical fertility, especially in phosphorus and sulphur (Cossins and Yemerou 1974, FAO 1992, pg. 22).

Due to agro-ecological conditions that are conducive to mixed farming, there is growing policy and research interests in addressing the various technical and policy constraints to livestock development in highland farming systems. The highlands are considered to possess the highest potential for agricultural development of any ecological zone in sub-Saharan Africa (Jahnke 1982, Winrock International 1992).

In integrated crop-livestock production systems, farmers practise crop and livestock production as a single management system. Effects of interactions between crops and livestock in separate crop and livestock production systems are discussed by, inter alia, McIntire and Gryseels (1986) and McIntire et al., (1992). There are various, often complex, physical, socio-economic and agro-biological attributes of crop-livestock integration. Some of these interactions include provision and use of animal traction, manure, food products, crop residues, improvement of farm cash income and accumulation of farm capital. On average, animal traction accounts for 40 percent of total livestock output, meat output accounts for 35 percent, milk accounts for about 20 percent and manure accounts for about 5 percent of total livestock output (McDowell and Hildebrand 1980, CTA 1989).

Table 2.2 Agro-Climatic Zones in the Ethiopian Highlands

Feature	Agro-ecological Environment		
	High potential cereal-livestock	Low Potential Cereal-livestock	High potential perennial stock
Area (' 000 km^2)	150	134	140
LPG (days/yr)	150 - 240	90 - 150	240 - 300
Population Density (persons/km^2)	73	72	74
Main Crops	Cereals, Pulses	Cereals, Pulses livestock	Cereals, tubers, Perennials,
Soil Types	volcanic	sedimentary, Metamorphic	volcanic
Climate	sub-humid/humid	sub-humid semi-arid	humid
livestock density (TLU/km^2)	55	30	27

Source: FAO (1992)

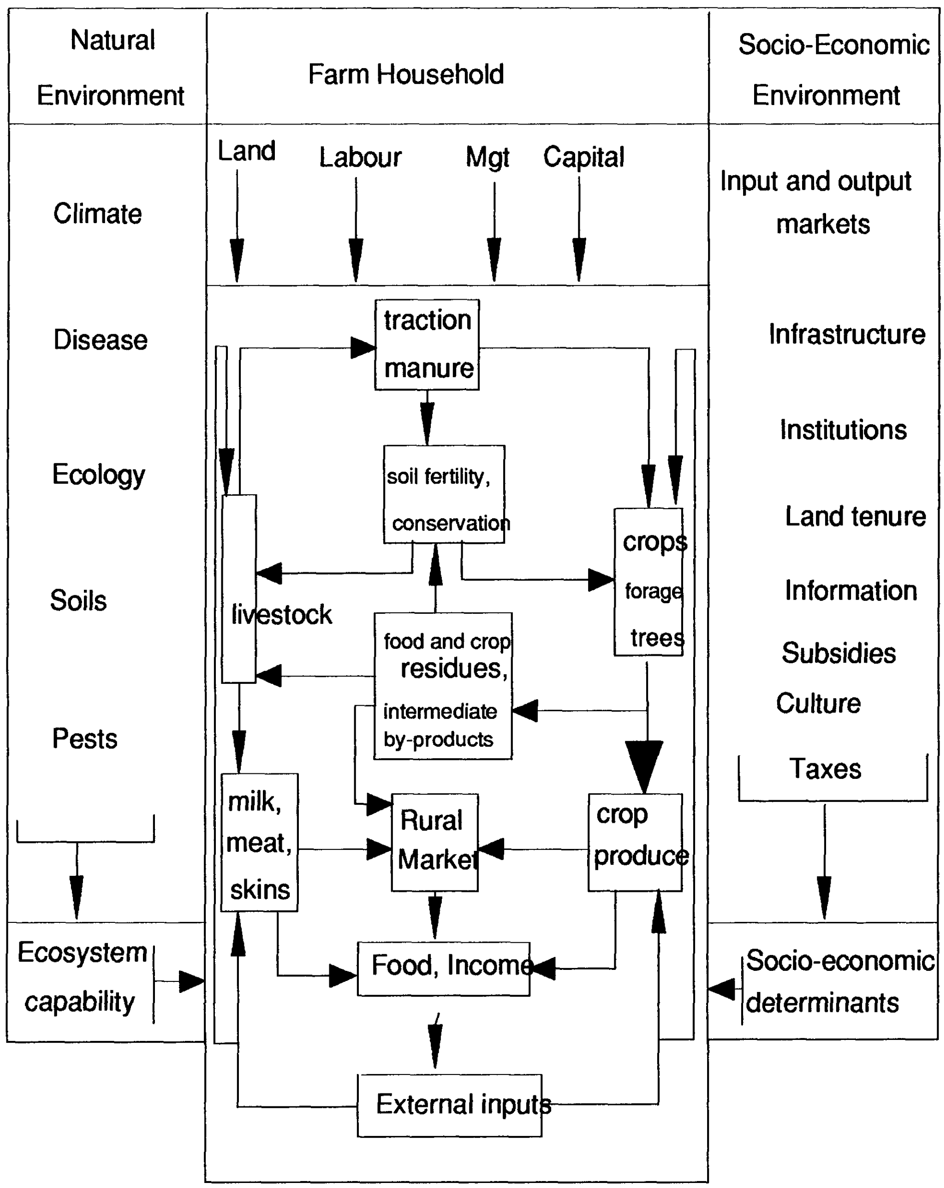
Animals also serve as a risk-absorption asset depending on, inter alia, weather, resource stocks, prices and infrastructure. These interactions are critical to the efficiency, stability and sustainability of the farming system. Any alteration in resource flow will lead to changes in the performance of either the crop or livestock sector (Bogahawatte 1984). Nutrient and energy recycling in the farming system play important functions for resource-limited farming. Socio-economic factors, demographic variables, infrastructure, farming practices, factor markets, technology and policy factors are among the important factors affecting crop-livestock integration and agricultural intensification in highland farming (Carter and Weibe 1990, Winrock International 1992, pp. 28-45).

The farm household is assumed to pursue welfare-enhancing objectives that include satisfying subsistence (e.g., food, shelter, health) goods, cash goods and utility of leisure (e.g., minimisation of drudgery involved in farm work). In allocating available resources to farm production, the household considers the various operating constraints including those due to the physical environment as well as external socio-economic constraints. Ecosystem and natural constraints generally delineate the ecosystem capability to support increasing livestock and human population. Social, political, economic and infrastructural constraints also influence degree of crop-livestock integration. The conceptual framework illustrating these interactions and constraints is schematised in the resource flow model in Figure 2.1.

2.2 Animal Traction in Highland Agriculture

Across the highland regions of the less developed world, the use of animal traction, a renewable source of energy, varies with different agro-climatic zones, resource endowments, socio-economic conditions and population density. Different draught animals are used for different specific or multi-purpose functions. Oxen are used mainly for ploughing and threshing of harvested crops, while donkeys and horses are used to transport both farm produce and people. Livestock are usually walked to the market for sale and slaughter, partly due to poor transport infrastructure in rural areas (McCown et al., 1979). The traction component includes land preparation (e.g., ploughing), land improvement (e.g., terracing), crop husbandry (e.g., seed covering), crop processing (e.g., threshing) and infrastructure (e.g., pumping water).

Figure 2.1 Conceptual Framework for Crop-Livestock Integration



Source : After McDowell and Hilderbrand 1980, Bogahawatte 1984

In 1975, the value of animal traction in sub-Saharan Africa was estimated at $2 billion, second only to meat production that was estimated at about $3 billion (Jahnke 1982, pp. 24-41). By 1988, livestock commodity output was valued at more than $ 11.8 billion constituting about 8 percent of gross domestic product (GDP) and about 25 percent of agricultural GDP (Winrock International 1992, pg. *x*). Often, official statistics underestimate or ignore the multipurpose role that livestock play in agricultural production and in the social life of rural households. If non-monetised livestock output (e.g., traction and manure) were valued and included, the value of livestock output would probably increase by about 50 percent to account for 35 percent of agricultural GDP (Sansoucy 1994).

Animal traction can influence farm production in many ways depending on the availability of complementary resources (e.g., feeds), farm size, cropping practices, type and efficacy of the traction equipment(s). It is often the case that farms using animal-drawn equipment are generally larger and can afford or obtain more credit to purchase animal equipment than farms using hand labour (McCown et al., 1979). About 52 percent of the cultivated area in developing countries is cultivated with the use of draught animals and 26 percent with hand-tools alone. However, about 15 percent of the arable land in sub-Saharan Africa is cultivated using animal traction, although this is less than the potential arable land (Sansoucy 1994). Absence of animal traction in some highland farming systems (e.g., in Rwanda) is, partly, due to small farm size, topography, presence of crops that do not permit use of animal traction and the low cost of hand cultivation (McIntire et al., 1992).

Availability of animal traction induces cropping patterns towards greater market-oriented crop choices. Farmers utilising animal draught power often plant more cash crops than food crops compared with farmers without livestock. Indeed, farmers with sufficient traction animals tend to cultivate more high-value crops which require more intensive land preparation than low-value crops. Animal traction is also associated with an increase in cultivated area. Area cultivated per family is usually about 25 percent greater where animal traction is used (Pingali et al., 1987). The effect of animal traction on crop yields is not easy to quantify because of difficulties in isolating the effects of other management practices such as the use of fertilisers, biocides and cultivation methods from the animal traction effects. While traction permits cultivation of more land, farmers often experience shortage of weeding labour which probably affects crop yields.

Within and between farming systems, there are variations in the number and ownership of draught animals and animal-drawn equipment. Low draught power availability per household often causes late or ineffective cultivation and often results in lower crop yields. Farmers make different arrangements to overcome or minimise the effects on crop yields arising from the lack of sufficient ownership or affordability of animal traction. These mechanisms include exchanging draught animals, lending out extra draught animals with/out payment, hiring draught animals, using cows and/or occasionally recourse to hand cultivation. Each of these arrangements has different effects on food production and income earning potential (Shapiro 1991). It has been observed that net crop income per peak labour hour of farmers employing animal draught can be 30 per cent more than those using hoe cultivation. However, net crop income for total labour hours is the same for both groups of farmers because the labour required to care for animals must be provided even when it is not required for crop production (Delgado 1989).

Availability of animal traction may increase farm incomes and labour productivity in the farming systems. However, there are several constraints to the increased and effective use of animal traction. Some of these factors include inappropriately designed implements and equipment, inadequate financial and veterinary services, low levels of capacity utilisation, long learning period for new farmers, low yield response to better land preparation, unfavourable opportunity costs of keeping and committing scarce resources to draught animals (Barrett et al., 1982, Jaeger and Matlon 1990, Ehui and Polson 1993).

There is some limited information on the impact of animal traction on agriculture in the Ethiopian highlands. Following the 1975 land reform proclamation, scarcity of draught animals became a serious constraint. Many farmers sold or slaughtered their draught oxen for fear of the nationalisation of livestock. In the 1980s, on average, 29 percent of farmers did not own any oxen, 34 percent owned a single ox, 32 percent kept two oxen, 3 percent had three oxen, while about 2 percent possessed four or more oxen (Belete 1989, Getachew et al., 1993).

On average, farmers without oxen cultivate about 1.6 ha of land and devote about 48 percent of the cultivated land to cereals. Farmers with two oxen cultivate, on average, between 30 and 50 percent more land (about 2.7

ha) than those with one ox or none and devote more than two thirds of the cultivated land to cereal production. Farmers with three or more oxen cultivate even more land (3.6 ha) and devote more than 90 percent of the cultivated land to cereal production. However, in farming systems engaged in production of perennial crops, there is a relatively smaller requirement for traction, and so land preparation may not necessarily be impeded by lack of oxen (IAR 1989, Gebrewold 1991).

Oxen ownership is also related to the nature of the distribution of land resources and/or the agrarian organisation in the rural economy. It is generally thought that farmers with more oxen possess more or better land. Shortage of traction may necessitate leaving land idle or cultivating smaller land area, or using a single-ox. Lack of sufficient draught animals is prompting a search for alternative means of enhancing agricultural productivity. Establishing rental draught oxen pools from lowland areas has also been suggested as a means of relieving the scarcity of oxen in the densely populated highlands (Belete 1989). However, there are constraints posed by feed scarcity and risk of disease transmission into the highlands which have to be overcome (ILCA 1993). In regions where there are markets for animal traction, farmers with surplus draught animals lease out oxen to households without adequate number of draught animals in exchange for some land or crop output.

The use of a single ox or crossbred cows for animal traction has been suggested to relieve problems of periodical shortage of draught power. The effects of ploughing using a single ox-plough, paired oxen and crossbred cows on farm income and risk portfolio have been compared by varying risk aversion parameters and herd sizes (Rodriguez and Anderson 1988). The results indicated that single ox-traction is more efficient than the traditional oxen-pair but will require some changes in livestock management and modification of ploughing equipment to suit the single ox and its draught output. Use of a single ox is not traditionally practised in the study area. Use of crossbred cows for animal traction can improve income earnings and nullify the necessity of keeping oxen for animal traction. However, use of cow traction may reduce milk yield and lower herd prolificacy (Winrock International 1985 &1992).

Another extension idea (yet to be developed and encouraged) is the use of equines for animal traction purposes. There is scope and potential to use the numerous donkeys, horses and mules for land preparation in addition to providing for transportation requirements (Simmonds 1985). Irrespective of the type of animal used to provide traction, there also will be a need to improve traction equipment in order to enhance food production (Panin 1989). Finally, on some farms, cropping pressure may necessitate reduction in livestock numbers leading to less manure production and less draught power availability which, in turn, may increase vulnerability of rural household to the vagaries of nature and may undermine rural food security (Collinson 1987).

2.3 Use of Manure

In highland farming systems, opportunities for maintaining soil fertility through shifting cultivation and rotational fallow are diminishing rapidly due to increasing population pressure. Continuous land cultivation depletes soil fertility in the absence of soil fertility amendment such as shifting cultivation or rotational fallow. Increasing land degradation through inadequate land use practices and declining soil fertility are major constraints to increased agricultural production. Manure improves soil fertility in various ways if available in sufficient quantities (Stonehouse and Narayanan 1984). The magnitude of crop response to application of manure depends on the type and quality of manure, time and frequency of manure application, soil properties and amount of manure applied per unit of land (Powell and Saleem 1987, Tandon 1992). One ton of cow dung contains about 8 kg nitrogen, 4 kg phosphorus and 16 kg of potassium. The chemical composition (and its value) of manure varies according to animal species and the type of the animal diet (Sansoucy 1994).

The relative efficiency of chemical fertiliser, manure and crop mulches in improving soil fertility and crop yields is not clearly quantified under rainfed mixed farming conditions. Application of manure with some inorganic fertiliser improves soil fertility more than the use of crop residues as mulch alone. A light application of chemical fertiliser with manure is superior to heavy fertiliser application without manure. Organic fertilisers are complements and not substitutes for inorganic fertilisers. Manure is a slow-release organic fertiliser that adds to land productivity and reduces costs associated with subsequent fertiliser purchases. Farmers manage livestock in various ways to improve or maintain crop yields through such techniques as concentrating manure on specific crop fields (Jahnke 1982, Powell et al., 1993).

Manuring practices differ in different regions depending on, inter alia, the nature of crop rotations, crop types, field location, cattle ownership and resource endowment especially labour. Where manure transport costs are high, manuring is performed by paddocking or corralling animals on fields near homesteads (Cornick and Kirkby 1981). In circumstances where paddocking is expensive and the cost of transportation is low, intensive application of manure is commonly practised. Farmers practising high cultivation intensities generally apply more manure on their fields compared with farmers practising low cultivation intensities (McCown et al., 1979). Application of manure, in the highlands, is easily done because of cheap labour (due to high population density) relative to other resources and field plots are nearer the homesteads. Sometimes field plots receive manure without direct farmer effort as animals are grazed from one part of the farm to another grazing field.

Where applied, manure is simply thrown in heaps on the field and then incorporated into the soil during land preparation and sowing. Depending on the cropping practices, sometimes farmers concentrate manure on specific spots in the field to benefit the crops that are to be grown in such spots (e.g., tree crops). In other cases, manure is scattered in the fields in heaps as dictated by the mode of transportation (e.g., basketfuls or ox-carts). Similar methods of manure application are reported and discussed by Bonkian (1987) and Gavian (1992) for semi-arid environments in sub-Saharan Africa.

Though manure is widely used as organic fertiliser, research on crop yield response to manuring often appears to indicate exaggerated results that would not provide useful extension advice to farmers seeking to practise crop-livestock integration (McIntire et al., 1992, pp 86-87). Where inorganic fertilisers are unavailable or expensive, manure serves as a major source of replenishing plant nutrients, maintaining soil structure and soil fertility. The influence of manure on crop yields is not significantly different from that of industrial fertilisers if and when applied at similar concentrations using similar cropping practices (McIntire et al., 1992). However, to obtain the same concentration of nutrients, substantially greater amounts of manure are required. Large quantities of manure are scarce on most farms (Gryseels and Anderson 1985). Nonetheless, manure will also become increasingly important because of the constricting or disappearing fallow and other soil fertility maintenance practices. Manure will remain an affordable input for low-input sustainable and productive farming (ILCA 1993).

Choosing between fertiliser and manure depends on many factors including the availability of inorganic fertilisers, transportation and labour costs, short-run versus long-run effects of manure compared with inorganic fertilisers, stocking rates and the comparative advantage in either animal or crop production. Studies in Asia indicate that falling fertiliser prices and rising labour wages have eliminated manuring of rice in Japan, making manure less profitable than inorganic fertilisers (IRRI 1988).

Supply-side constraints are major impediments to expanding the use of inorganic fertilisers on a sustained basis in most of sub-Saharan Africa. Alternative sources of organic fertilisers (e.g., urban garbage, sawdust) are often poor in nutrients. Moreover, time and effort are required to remove non-biodegradable materials such as glass and plastics from the garbage. It is not uncommon to find glass pieces and injection needles in the garbage that pose problems to farmers apart from risk of injury and health hazards (Tandon 1992). The role of manure as an organic fertiliser will become more and more important as many countries phase out subsidies on chemical fertilisers under structural adjustment programs. By providing manure, animals make an important contribution to intensification and sustainability of the agricultural sector (McIntire et al., 1992).

Many households use cow dung as domestic energy (fuel) for cooking and heating purposes in many areas of rural Ethiopia. The use of cow dung as fuel implies that farmers value manure more as fuel than as fertiliser under their prevailing social and economic circumstances. This could be due to low prices of agricultural commodities relative to energy. Diverting cow dung to fuel reduces household expenditure on firewood or fossil fuels. Unless compensated by use of inorganic fertilisers, diverting animal dung to fuel is a loss to crop production. However, by diverting animal dung to fuel, the farm household saves on labour that would be devoted to collecting firewood or on the cost of alternative fuels. The time saved (from collecting firewood) could be allocated to more intensive crop cultivation to compensate for the effects of decreased application of manure on crop yields (Kumar and Hotchkiss 1988). Although not practised, encouraging biogas production would be a potential viable compromise for the use of cow dung as energy and fertiliser (Winrock International 1992, Sansoucy 1994).

Between 60 and 90 percent of the cow dung produced in the Ethiopian highlands is used for fuel. More cow dung is used as fuel where there is serious deforestation and scarcity of firewood. Using crop-response functions, the incremental grain production that would result from using the cow dung as organic fertiliser can be estimated. Estimating the nutrient value of cow dung at the price of imported fertilisers could also indicate the opportunity cost of household use of cow dung (Pearce and Turner 1990). Another valuation approach is to estimate the actual market value of cow dung employing prices that cow dung cakes are sold at in local markets. Ethiopian households use at least 7.9 million tonnes of cow dung annually. Using an average grain-response value of US $ 76 per tonne of cow dung, the foregone agricultural output by diverting cow dung to fuel is estimated at more than US $ 600 million each year (Newcombe 1984).

2.4 Crop Residues and Fodder Crops

In highland agriculture in less developed countries, the role of crop residues and fodder crops in enhancing livestock productivity depends on, inter alia, stocking rates, feeding regimes, resource use arrangements and institutions pertaining to communal pasture resources. In the use of communal and public grazing land in low intensity systems, animals freely graze with minimal labour and capital (e.g., fencing) inputs. At higher levels of cropping and grazing pressure, the labour input increases and forages may be grown, especially for dry-season grazing. In such systems, farmers adapt to seasonal feed shortages through various herd and pasture management strategies. Controlling reproduction and culling rates are common herd structure management strategies. Moreover, pasture management becomes critical. It involves various practices to minimise feed scarcity such as rotational grazing, fodder production and storage of crop residues.

Sown fodder crops, especially forage legumes, provide superior feed quality compared with ordinary feed resources and serve as important adjuncts to crop residues and natural pastures in filling gaps in the seasonality of feed availability. The ability of ruminant animals to convert poor quality, or otherwise unusable, grass and crop residues into high-value livestock products (e.g., meat) has special appeal for crop-livestock integration. Animals provide a direct and beneficial means of utilising any damaged grains, root crops, non-marketed or failed crops. Other than serving as amendments to soil fertility, these by-products would be virtually lost without crop-livestock integration. The loss of such biomass would reduce the biophysical and economic viability of resource-challenged farming. While increased food crop production will require more land, this will be offset by more crop residues being produced and fed to animal and thus increasing livestock production (Grove 1991).

Crop residues and fodder crops also protect agricultural land from water and wind erosion, improve the soil water holding capacity and thus serve the long-term goal of maintaining land productivity. Results from agronomic trials, in USA, indicate that cereal yields would increase considerably (85 kg/ha for wheat) due to mulching with crop residues. Using crop residues as organic fertiliser would also spare some manure to be used as fuel or other alternative uses. Although mulching with crop residues can increase crop yields, complementary efforts in soil conservation could be required to sustain any increase in crop yields (Sandford 1989).

Forage legumes can be grown as pure stands, incorporated into natural pastures, intercropped or cultivated in fodder banks. However, production of fodder crops may involve competition in the use of farm resources especially land and labour. The opportunity cost of committing scarce resources to fodder production can impede widespread cultivation of fodder crops depending on the relative profitability of livestock production. Leguminous fodder can improve the nutritive quality of livestock feed and hence improve livestock production. Legumes reduce both the rate of deterioration of soil fertility through nitrogen-fixation and the length of soil fertility-regenerating fallow period (Tothill 1986). The residual carry-over nutrients influence crop yields and may save the farmer some fertiliser expenses in subsequent seasons (Kennedy et al., 1973).

Farmers have adapted to grow crops that have high food or income effects while producing substantial amounts of crop residues that serve as animal feed. This satisfices household food requirements without compromising input use and livestock production (McDowell 1978). In some cases, farmers sow at a higher seeding rate in order to obtain crop thinnings to feed animals during the crop growing season. Lower crop leaves are also stripped to serve as animal feed during the crop growing period when feed scarcity is often a serious constraint.

There is a trade-off between using crop thinnings/clippings as mulch versus feed. In some instances, farmers ignore intensive weeding of palatable weeds that are instead cut and fed to animals or are grazed during the post-harvest period (Nordblom 1983). There is a trade-off between the yield-decreasing effects of sub-optimal weeding of palatable weeds and their contribution to livestock feedstuffs.

There are trade-offs between devoting scarce land and labour resources to forage production instead of food crops, trade-offs in using crop residues for as livestock feed instead of being used as mulch or fuel or as a source of farm income, and trade-offs in feeding different animals serving different purposes on the farm (Shapiro 1991, Griffith and Zepeda 1994). Other than serving as livestock feed, crop residues are also used as packaging material, thatching material for houses, building walls for rural homes or burnt as cooking fuel (Tandon 1992).

Various forms of exchange and trade in feed resources are commonly observed in crop-livestock farming systems. Inasmuch as both stover and other crop residues are highly valued as livestock feed, the desire to commit land to forage production is daunting to many resource-poor farmers. As an example, in the eastern Ethiopian Hararghe highlands, the price of stover and other valued crop residues per camel load increased six-fold during the drought periods of the 1970s and 1980s (Emana and Storck 1992).

Availability of crop residues and communal grazing reduces the demand of forages. Continued intensification of peri-urban market-oriented dairy production presents a potentially profitable opportunity for income-oriented forage production in peripheral areas of the urban areas (ILCA 1993). However, any effort to promote fodder production will need to consider the different location-specific constraints and opportunities to livestock production in the farming system (Braveman and Stiglitz 1982, Gryseels and Anderson 1983).

Efforts to improve fodder production hold limited success unless accompanied by lower fodder production costs, profitable market outlets for livestock products and removal of various infrastructural, socio-economic and institutional constraints to crop-livestock integration in the farm sector (Winrock International 1992, pp. 57-58). The conspicuous absence of sown forage crops in the central Ethiopian highlands is, perhaps, a testimony to the conflicts between fodder, crop and livestock production in the use of scarce farm resources. When there are severe labour bottlenecks during crop sowing and weeding, cultivation and weeding of fodder crops receives low priority in household labour allocation especially under rainfed conditions (McIntire and Siegfried 1987).

2.5 Cushioning Rural Food Security

The use of various livestock food products varies between cultures and households, and with the level and seasonality of production, infrastructure and markets. The contribution of livestock towards improving the dominantly protein-deficient diets is especially significant for the large and malnourished child population of sub-Saharan Africa. Consumption of animal products corrects nutritional deficiencies and would enhance labour productivity especially in malnourished and undernourished populations. In many developing countries, an enormous number of poor people cannot afford consumption of animal products in their diets. Various agricultural policies recognise the role that livestock production would play in meeting food production targets and human nutritional standards (Diaz-Briquets et al., 1990, FAO 1992, pp. 8-16).

Livestock play a crucial role in fending off seasonal threats to household food security. Livestock sales provide income to purchase grains, permitting households to stabilise their nutritional balance. The pre-harvest periods are often the most critical in nutritional requirements as stored grain stocks are almost exhausted and grain prices in local markets tend to be high and rising. Such periods are the most difficult in terms of financial stress especially for the rural poor. However, meat can be processed in different ways (e.g, smoking, salting, sun-drying) to be consumed during moments when sources of alternative food are exhausted. Incidentally, at the same time livestock prices tend to be rising in many areas (ILCA 1993). Households without livestock benefit from the price-stabilising effects of livestock trade on the availability and prices of food grains in rural markets. Therefore livestock plays an important role in food security of rural households if shortages of grains are neither widespread nor protracted (Berg and Whitaker 1986, Coppock et al., 1986).

Given the importance of livestock production to human nutrition, expanded livestock production will be necessary in order that nutritional and welfare standards are not compromised in future. One of the most pressing challenges confronting policy makers is the elimination of famine and rural poverty which has resulted, in part, from inappropriate agricultural development policies. To meet the food production requirements, agricultural output will have to grow at more than 4 percent annually. Though ambitious, such growth is achievable but will involve the use of improved technologies, increased use of modern inputs and creation of an enabling (economic and institutional) environment with favourable agricultural development and support policies (FAO 1993, pg. 3; E.I.U. 1990-1993).

2.6 Diversifying Income Earnings

On average, agriculture as a whole accounts for about 35 percent of gross domestic product (GDP) of most of the countries in sub-Sahara Africa. Livestock generates about 11 percent of GDP (Winrock International 1992, pg. *x*). Livestock contribute about 40 percent of agricultural GDP in Ethiopia (FAO 1992, pg. 1). These estimates are based upon both subsistence and marketed production. Nonetheless, the share of livestock is often underestimated because of the exclusion of the value of animal traction, manure and capital appreciation of the livestock inventory. Other than the contribution to agricultural intensification, the supply of proteinous food products (e.g., milk) makes an enormous contribution to economic growth and farm income in the region (Gollin 1991).

Supply and demand forces will probably generate greater demand of animal products if accompanied by favourable pricing and institutional policies. Livestock account for a significant share of farm incomes through direct sale of livestock products (milk, eggs, honey) or irregular sales (live animals, hides and skins) or from provision of productive services such as fees for draught power or breeding fees. Income earned from livestock enterprises facilitate the purchase and utilisation of improved technologies (e.g., fertiliser). Improvement in farm cash income creates or improves the opportunity to adopt new technologies and also improve farming practices (World Bank 1989, Sansoucy 1994).

Livestock and crops influence household investment and survival strategies across periods of variable climatic conditions. In periods of bumper harvests, grain sales provide income that is often used to purchase livestock and vice versa during grain deficit periods. In the absence of well developed rural capital markets, purchase of livestock is an interest-earning investment and a hedge against inflation in a world characterised by risk and uncertainty. Large animals (e.g., cattle) serve as equity investment accounts while small stock (e.g., sheep) serve as a cash-deposit account that can easily be drawn upon when farm families experience financial stress. Small ruminants (especially sheep) reduce variations in total farm income to cushion farm enterprises against unpredictable weather and unstable commodity prices. Since infrastructural constraints limit sale of perishable crop produce, livestock are a better source of income since animals are transported or walked to markets alive (McDowell and Hildebrand 1980, CTA 1989).

Livestock (e.g., poultry) production systems provide employment and income-earning opportunities especially for the poorer sections of society. Low-income groups spend proportionately more of their income on food. Improvement in the employment and income potential of the poor should bear multiplier effects in the economy through increased food consumption, enhanced labour productivity, increased comparative advantage in labour-intensive activities and exportable surpluses. As favourable and equitable development pursuits gather ground, improved farm incomes will prompt greater demand for low-carbohydrate and high-protein diets. Increased livestock production will be necessary to keep such livestock products available and affordable while reducing the volume of food imports (Mellor and Adams 1986, Shapiro 1991).

2.7 Enhancing Factor Productivity

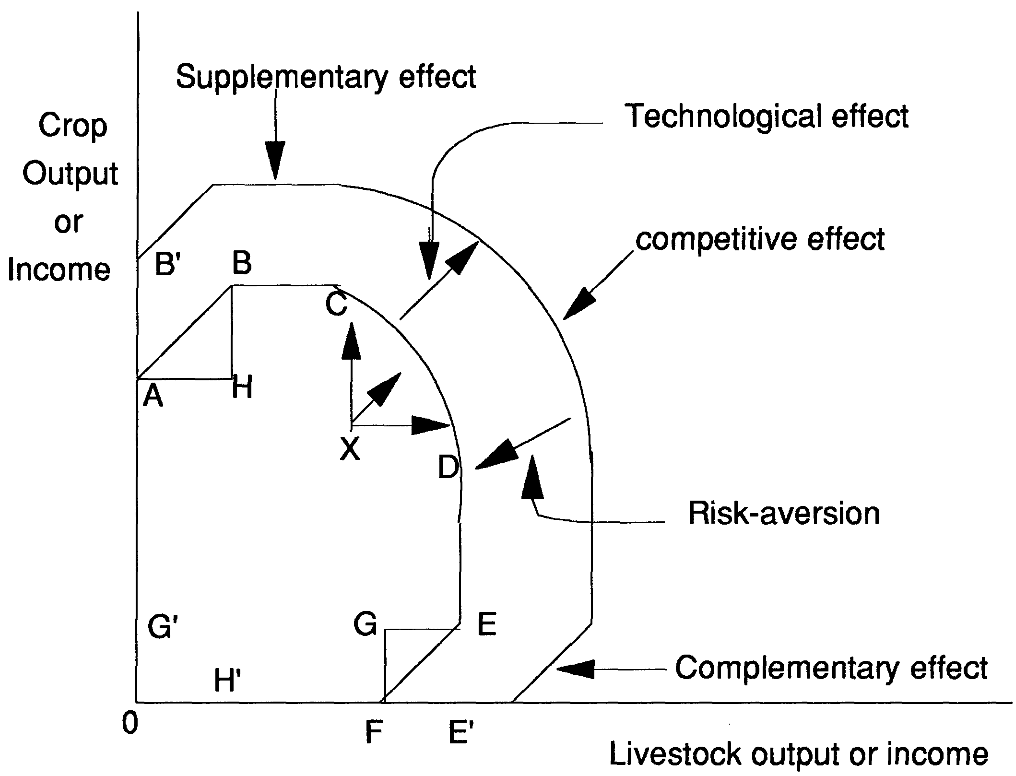
Crop-livestock integration can increase household welfare through more productive use of slack resources and exploitation of the synergies inherent in crop-livestock integration. Crop-livestock interactions can be supplementary, complementary or competitive. Supplementary relationships exist whereby some attribute(s) of either crop or livestock production enhance(s) farm production (without affecting the other subsector) through the use of slack farm resources (Sherphard 1970, Doll and Orazem 1984). Idle post-harvest labour may be used to herd animals for longer periods. The same case would stand for use of crop residues for post-harvest livestock feeding. Such crop residues would otherwise be wasted in the absence of farm animals. Farm output can also be increased through complementary relationships such as nitrogen fixation by leguminous crops (Simon 1979, Sandford 1989), due to improved soil fertility arising from animal manure and urine.

Increased income and farm liquidity either through supplementary or complementary effects bears positive welfare effects on farm households. However, with further crop-livestock integration, situations would arise whereby increased output in either sub-sector is not possible without reduction in the relative contribution of the other sub-sector to total farm output. Beyond this level, attaining higher levels of agricultural performance will require new technology or use of external inputs (Powell et al., 1993).

Conceptually, households can engage in either crop or livestock production or both. The value of farm production may be expressed either as physical output or monetary income. Employing production economics tools that are espoused in the theory of the profit-maximising firm and using the illustration in Figure 2.2, the maximum attainable crop output (or income) is at level OA with existing technology without the integration component. Without integration with crops, the corresponding maximum attainable performance level for livestock farmers would be at point OF with existing technology, socio-economic and institutional circumstances. Where there are opportunities for crop-livestock integration, total farm output or income could be increased through exploitation of complementary and supplementary relationships between crops and livestock. Specialisation in either subsector could be influenced by many factors including overcoming technical impediments to crop-livestock integration such as livestock diseases, extreme land scarcity or the relative crop-livestock price ratios (which affect comparative advantage of either sector) and population pressure.

For crop farmers, the curvilinear complementary range is depicted by line AB. By introducing livestock activities (from zero to OH'), total crop output is increased from level OA to OB' and total farm output by the magnitude of the area covered by ABH. Similarly for livestock farmers, introduction of crops (by the size shown as (OG'), total livestock production increases from OF to OE' and the incremental income is shown by the area covered by EFG. Between the range shown as BC and DE, the effects of crop-livestock integration are supplementary, an increase in either crop or livestock activity will lead to increased farm performance without negatively affecting either enterprise. This is achieved through utilisation of slack resources such as farm labour in performing such activities as harvesting grass hay, collecting manure from communal grazing lands, etc. Both the complementary and supplementary effects are welfare-enhancing since there is increase in farm income from either type of farming activity (Swason 1955, Ritson 1977, Ngambeki et al., 1992).

Figure 2.2 Crop-Livestock Integration and Farm Production Levels



ABCDEF is the Production Possibiliy Frontier (PPF)

Source: After Dillon and Anderson (1977), Doll and Orazem (1984)

The area depicted as CD is the competitive range between crop and livestock in the use of farm resources. Theoretically, the optimum level of crop-livestock integration will fall along CD at the point where the marginal rate of production transformation between crop and livestock output is equal to their inverse price ratio, irrespective of the level of technology.

Assuming constant returns to scale, any increase in crop output will lead to decrease in livestock output and vice versa. However, farmers under rainfed agricultural conditions face different problems (e.g., infrastructural, institutional, risk) that necessitate engaging in production activities that are inside the production possibility frontier (PPF) i.e. ABCDEF. This leads to existence of ***X***-inefficiency (i.e. operating within the PPF) due to sub-optimal use of available resources, or inefficient organisation of farm operations, or imperfect knowledge, or risk-aversion (Anderson et al., 1977, Barry 1984, Alston et al., 1994). Under such circumstances, the production choices that farmers may elect to pursue would be based on perfectly rational decisions. However, a farmer at point OX can improve farm output by increasing either crop or livestock production or both, but this would involve incurring more risk.

Improving agricultural output will initially involve utilisation of slack resource or better farm re-organisation without necessarily introducing new inputs or techniques. Elimination of ***X***-inefficiency will be a prerequisite to improved resource use. These strategies will include better land use, intensification of labour use, increased use of animal traction, development of infrastructure and rural factor and commodity markets. There will also be a need for farmer training and provision of technical and extension services to reduce inefficient farm organisation of production processes (Keulen and Wolf 1986, Dejene 1987, Korvier and Arendonk 1988).

Once farm production has improved to reach the PPF, alternatives can be sought that will increase farm output to a new production possibility frontier depending on the relative profitability of crops to livestock and vice versa. The key to enhancing crop-livestock integration lies on the impact of mixed farming on farm resource use and the different factors that influence the relative opportunity costs of available resources. Technological change or policy reform (or both) will be crucial to enhancing the productivity of mixed farming. Relative output rations and prices of crop and livestock enterprises will determine the relative shares of either enterprise in farm overall performance (Ghatak and Ingersent 1984, Winrock International 1992).

Most farms in the highlands are small and grazing land is limited. Because of heavy dependence on crop production, livestock production systems rely heavily on farm feeds, crop residues and other by-product feeds. Backyard livestock production (e.g., poultry, rabbits, sheep) provides part-time gainful employment opportunities, especially for the peri-urban poor or landless people. Crop and livestock production need not be viewed as necessarily mutually exclusive or competitive farming activities. If food production is to be produced with minimal negative environmental impact, integrated crop-livestock production is perhaps the cheapest, most efficient and sustainable means of increasing food production (Winrock International 1992, pp. 8-13).

2.8 Social Functions of Livestock

The social role of livestock is often overlooked in attempting to understand the complex socio-cultural relationships in rural communities in developing countries such as Ethiopia. Livestock are often a source of social ties through exchange of gifts and services (Scoones 1992). For example, farmers with oxen often plough fields of other farmers (without ox) without any formalised mode of direct payments. The benefits of social prestige and a feeling of `being good to others' may be enough payment, or there may be a later in-kind payment as a gift exchange. Livestock play an important social role in marriage contracts and ceremonial festivities in many societies that is neither tangible nor quantifiable (Barrett 1992).

Animals are often viewed as a repository of wealth, risk insurance scheme (against market and policy failures), symbol of social esteem and a way of life. In some societies, livestock play important religious functions such as cleansing homesteads, funeral services and christening ceremonies. Other intangible benefits of livestock include provision of sports and entertainment (e.g., bull-fights, cockerel-fights), medicinal value and sentimental (e.g., pet) value (Amir and Knipscheer 1989, Omiti 1994b).

Sociological constraints may partially explain the reluctance of many households to adopt innovations that would improve herd productivity such as regular culling of old stock and replacement with young animals or crossbred animals. It is often the case that peasant farmers consider the productivity of livestock to be a function of number of animals rather than the output per animal unit. Apart from attitudes towards various forms of risk, farmers keep large herds for long-term breed selection of superior performing animals. The farmer's preference for a large herd of animals may be summarised as:

> `The more animals you keep, the more manure you collect. Two thin oxen can be traditionally paired for ploughing while one fat ox is useless. Two small donkeys carry almost twice as much cargo as one big one. The farmer who owns two small sheep can sell one in times of financial strife and is still left with one unlike the farmer with only one big sheep' (Gryseels 1988, p.147).

Livestock provide satisfaction both in their numerical numbers and in their monetary value. The monetary cash value that is accumulated in the livestock herd is important in meeting contemporaneous consumption needs. The numerical herd size influences other long-term needs such as insurance against crop-failure, prestige and social status. In some cases, livestock (especially large ruminants like cattle and horses) are acquired as a repository of wealth as an end in itself and not a means of generating additional income. Arguments forcing farmers into holding large herds, irrespective of livestock productivity, would proceed as follows:

> (i) if animals must be sold to meet specific financial obligations, then a minimum number will be sold, (ii) factors or circumstances that increase the value of livestock will enable the farmer to sell fewer animals (thus remain with a relatively big herd than without the influence of those factors), (iii) farmers will seek the highest priced markets such that they sell fewer animals and thereby maximise relative wealth, (iv) when the risk of loss of livestock increases during such periods as those occasioned by droughts, farmers will be willing to sell more animals, and (v) livestock sales will tend to increase during periods of low rainfall or less pasture to compensate for crop failure and reduce risk of total disaster (adapted from Doran et al., 1979, pp. 42-43).

Claims of the potential benefits of crop-livestock integration can under-emphasise practical realities in rural farming systems. It may appear inefficient to divert intermediate inputs (such as manure) away from maintenance of soil productivity to alternative uses (fuel or income-earning), especially against a background of diminishing fallow or shifting cultivation. However, perhaps farmers ignore the slow degradation of land resources because of the alternative resource scarcity values attached to survival goals in the face of worsening poverty and technological stagnation.

Without increased use of modern technologies, persistence of semi-subsistence production may continue into the future (Powell et al., 1993). Subsistence production in the Ethiopian highlands is characterised by cultivation of small non-contiguous plots, use of traditional tools, limited monetisation of farm production, persistent labour under-utilisation and unemployment. Persistence of subsistence-oriented production is one of the greatest challenges in transforming the rainfed agricultural systems in rural Ethiopia (Belete 1989, Pausewang et al., 1990).

2.9 Crop Damage, Weeds and Pests

In sedentary mixed crop-livestock farming, livestock and wild animals break fences or stray into crop fields causing crop and tree damage. Destruction of capital invested in trees, fences and soil conservation structures negates the acclaimed benefits of crop-livestock integration. During post-harvest grazing, livestock are good agents for dispersal of seed. While this attribute is potentially useful in the long-term quest for bio-diversity, some weeds eventually involve increased labour requirements for weeding and lead to lower crop yields. Moreover, the effects of post-harvest grazing of crop-residues on soil compaction and exposing the farm land to soil erosion could be debatable and site-specific (Grove 1991).

In Ethiopia, large-scale meat production is practised in the lowlands that are sandwiched between desert-like conditions and the intensively cultivated highlands. Conflicts between pastoralists and sedentary agriculturalists often occur in the temporal and spatial use of pasture and water resources. Due to population growth, pastoralists will often be pushed (i.e. marginalised) to the least productive lands. Their dry season drive into sedentary agricultural areas will often cause social conflicts between pastoralists and agriculturalists in the use of pasture and water resources. This has also been observed in northern Cameroon, northern Nigeria and southern Kenya. Moreover, livestock and wild herbivores cause considerable crop damage. Estimates of forage lost on cultivated land as a result of wildlife are neither available nor compensated (McCown et al., 1979, Ellis 1991, Ngambeki et al., 1992).

2.10 Communal Grazing and Land Degradation

Accompanied by constricting or disappearing fallow periods, overstocking against a background of increasing cropping pressure is virtually unsustainable. Livestock depend on crop residues as a major source of dry season feed. Animals graze also on waterlogged valley bottoms, degraded hill sides and along the road sides. For most of the time, the animals are almost on a `starvation diet' that can ill-afford other production requirements such as the provision of draught power. Most grazing lands are common pool (*res communis*) or open access (*res publica*) grazing areas in the highlands (Hardin 1968, Constable 1984). Regulation of the use of these grazing lands lie outside the mechanism of the market framework. It has been difficult to institutionalise and enforce efficient and stewardly use of communal pasture resources (Dasgupta and Heal 1979, Runge 1984). Lack of secure ownership or inappropriate land use may lead to exploitative current-period utilisation with little regard for inter-temporal and inter-spatial welfare objectives (Yapp 1989, Sinden 1984).

Critical policy issues relating the role of livestock and wildlife in relation to land degradation include the role of livestock in land degradation, deforestation and de-vegetation, extensive cultivation of marginal land and the potential contribution of livestock to sustainable agriculture. The role of livestock in land degradation is debatable and transcends many disciplines, often, with divergent views (Crosson and Miranowski 1982, Randall 1985, Blaikie 1989).

Animals increase the spatial heterogeneity of nitrogen and soil fertility under shrubs while in search of pasture and water. Subsequent establishment of woody vegetation especially near watering points is a positive ecological attribute. Isolating grazing effects from weather effects on vegetation development and soil erosion is difficult. It is also difficult to isolate short-term from long-term effects, and temporary from permanent effects (Dodd 1991). Nonetheless, livestock will continue to play an important role in the evolution and development of sustainable farming systems through the intensification process of farming systems that will be necessitated by either population pressure or beneficial market opportunities (Roberts 1963, Nuru 1984, Cohen 1987, Ellis 1993).

Opportunities for extensive cultivation of less-and-less productive land are fading rapidly, concomitant with reduction in grazing lands. Outward expansion of agricultural land has serious implications upon the extent of livestock farming and its overall output, even though, increased land use conflicts may trigger some beneficial crop-livestock integration or specialised production systems. Because of decreased availability of land and the drive into more marginal areas, both livestock and crop farmers face increased incidence of crop failure and livestock mortality, especially during protracted dry or drought periods. Since most grazing lands are regarded or held as communal or open access resources, farmers usually increase their livestock numbers to maximise the individual use of available pastures. Overstocking depletes range land resources, increases the risk of soil erosion and de-vegetation. This may lead to slow death of some plant and animal species through habitat destruction or the impairment of the nutritional base of the endangered species (Bajracharya 1983, King 1983, Hodge 1984, IAR 1989).

While the costs of overgrazing are often collective and societal, the benefits accrue to individual herdsmen. Game theoretic modelling approaches have been applied to evaluate such resource management problems embracing such models as the `prisoner's dilemma' or `assurance problem' approaches. The theoretical foundations of such game theoretics hinges on maximisation of individual welfare and the mistrust regarding the intentions of other resource users. This would explain why rational individuals would opt for Pareto-inferior outcomes (e.g., overgrazing) while they could achieve a preferable and socially desirable levels of resource use (Dasgupta and Heal 1979, Chambers 1983).

From the standpoint of social justice, communal and public lands not only support agriculture but assist especially the rural poor to meet their basic requirements of fodder, fuel and food. By providing for fodder, food, other agricultural inputs (e.g., fencing poles), such lands raise agricultural output and reduce threats of overgrazing on pasture lands. Extensification of agriculture into communal and public lands beyond a certain point, without considerable societal structural change, would render agriculture unsustainable and worsen rural inequality. Any poorly instigated public interventions (in the form of take-over and replanting trees) would deprive the rural poor of their use of `public' lands and undermine efforts to sustainable resource management (Jahnke 1982, Nadkarni and Pasha 1991).

2.11 Summary

The preceding sections have emphasised the multiplicity of livestock functions in highland farming systems. These multiple roles are likely to vary from one place to another and over time. The relative importance of the various functions of livestock in the farming systems will also vary with agro-ecological factors, socio-economic circumstances and household demographic features. Some of the direct functions of livestock such as provision of draught power, manure, milk and meat are amenable to economic evaluation using various quantification techniques. Other functions are less direct and difficult to quantify such as the role of livestock as a risk-insurance strategy against crop failure, or sealing marriage contracts or symbolising of social status. Although not amenable to direct quantitative estimation, such social roles should not be ignored in evaluating the role of livestock in low-input agricultural systems (Barrett 1992, Scoones 1992).

The literature that is generally available for sub-Saharan Africa, and Ethiopia in particular, has certain deficiencies preventing substantive statements about the importance of crop-livestock systems. These deficiencies stem from uneven distribution of livestock between and within countries. There is also considerable variation among research objectives of various studies on crop-livestock systems preventing systematic analyses and specific comparisons (Mortimore 1991, pg 61). The importance of different types and levels of crop-livestock integration to the economies of rural households remains obscure and, at best, is judgemental and location-specific. The existence of alternative valuations of crop-livestock integration in different regions is a source of considerable uncertainty in qualifying the economic benefits of crop-livestock integration (Winrock International 1992, pg. 62).

Notwithstanding such difficulties and ambiguities, this study will consider and apply the quantifiable attributes of livestock in the analytical model. The analytical framework proposed for this study is cast around the theory of the firm. Estimated quantity (per herd unit) of manure output, animal draught power availability, milk output, consumption of crop residues and other livestock feeds are used in the analytical model. Methods used in data collection are discussed in chapter three.

Chapter Three

Methods of Data Collection

This chapter discusses the methods employed to obtain the data that were required to describe crop and livestock interactions in the Ethiopian highlands. The data were also used to confront questions raised in the study through application of linear programming. Questionnaire design, sampling procedures, recruitment and training of field assistants, questionnaire administration and problems encountered during data collection are discussed.

3.1 Background on Ethiopian Highland Agriculture

More than 88 percent of Ethiopia's 53 million people live in the highlands and are engaged in agriculture. The highlands are defined as elevations in excess of 1500 metres above sea-level and constitute approximately 44 percent (49 million ha) of the total land area in Ethiopia. Most of the central highlands are found in the Shewa administrative region in central Ethiopia. Some of the basic background information about Ethiopia are provided in Appendix 1.

Crop cultivation and grazing land each account for about 40 percent of total land use in the central highlands compared with a national average of 15 percent and 51 percent, respectively. There is thus more intensive cultivation and cropping pressure in the central highlands than elsewhere in Ethiopia. The average population density in the Ethiopian highlands is estimated to be about 85 persons per square kilometre. However, the mean population density in the central Ethiopian highlands is estimated at 100 persons per square kilometre (Mamo et al., 1993).

Agriculture in Ethiopia is characterised largely by low-input semi-subsistence mixed farming. Households employ traditional production techniques. Associated with chances of drought or dry periods, there is limited use of high yielding crop varieties and improved inputs. Without assurance of alternative sources of cash income such as seasonal wage employment, farmers strive to satisfy household food requirements before contemplating surplus production. Yields are low and marketed production is estimated to average between 13 and 25 percent of gross farm output.

Agricultural implements used in the study area have low efficacy in performing attendant activities. Land preparation (ploughing and harrowing) is performed using the age-less wooden plough with a short metallic tine (*maresha)* plough. Because of exclusive reliance on the *maresha* plough, the fields have to be ploughed a number of times (depending on the crop and availability of oxen) before planting. This delays timely planting and may expose households to greater vulnerability of food insecurity.

Most of the households are members of the Coptic orthodox church. They customarily work an average of 15 days per month on crop production activities, mainly, due to restrictions imposed by religious holidays. Fencing and other livestock husbandry activities can be performed on religious holidays, the remaining days can be used on crop activities and routine livestock activities (e.g., herding). Declining per caput agricultural output has generated considerable policy debate about alternative technical and policy interventions that may improve sectoral performance.

3.2 Exploratory Field Surveys

Agricultural and resource management problems pose important policy challenges for meeting food production objectives in Ethiopia and other countries in sub-Saharan Africa. Exploratory field surveys involved visiting potential study sites to both observe and conduct brief interviews to learn about the local situation in greater detail for effective problem identification. A major challenge conducting research in rural areas of many developing countries lies in the lack of reliable and efficient communication networks and scanty and sparsely distributed background information (often outdated).

With limited financial and personnel resources, collection and authentication of data through conventional surveys is also time-consuming and expensive. There is often a tendency to visit potential research areas that are along major all-weather roads and contact rural people that are likely to be more privileged than other sections of the local community. This has been labelled `development tourism'. As a departure from development tourism, this study employed exploratory surveys to select study sites (Ghirotti 1991, Webber and Ison 1995).

Rapid rural appraisals were conducted in the central Ethiopian highlands to underscore existing farming, general resource management practices and gain some familiarity with the area. The rapid rural appraisals involved interviews and group discussions with Ministry of Agriculture extension agents (Development Agents (DAs)), individual farmers, small groups of farmers, local village leaders, officials of various non-governmental organisations working in the area and ILCA field research staff. Given the focus of this study, other visits involved observing what farm produce is available in the local markets in order to get a glimpse of local farming features. Attempts were made to visit local flour mills to see what food grains were being processed as an indication of local food preferences and type of crop farming.

From these exploratory surveys, a two-stage data collection process was adopted. First, a one-page questionnaire was administered in 1993/94 on 892 households in 23 villages in four peasant associations in the Baso and Worana Woreda[1]. The second phase involved intensive data collection from a sub-sample of the surveyed population of 892 households. During the initial (census survey) period, we were only able to meet with 900 households of whom 8 provided unreliable responses and were omitted from the sample. This population figure is likely to change over time due to continuing immigration and outmigration in the peasant associations, subdivision of land among household members, deaths and non-contiguous land holdings.

3.3 Selection of Study Sites

After the exploratory surveys, six peasant associations were selected in Baso and Worana Woreda. A peasant association is composed of approximately 250 households and covers about 800 hectares of both cultivated and pasture land. The six peasant associations are Kormargefia, Tabasse, Faji (120 kilometres north west of the Ethiopia's capital city - Addis Ababa), Ametsegnar Agher, Bakelo and Dimbaro (150 kilometres north west of Addis Ababa). The approximate geographical location of these peasant associations is illustrated in Figure 3.1. Two of the peasant associations presented difficulties for the study and were later omitted from further research.

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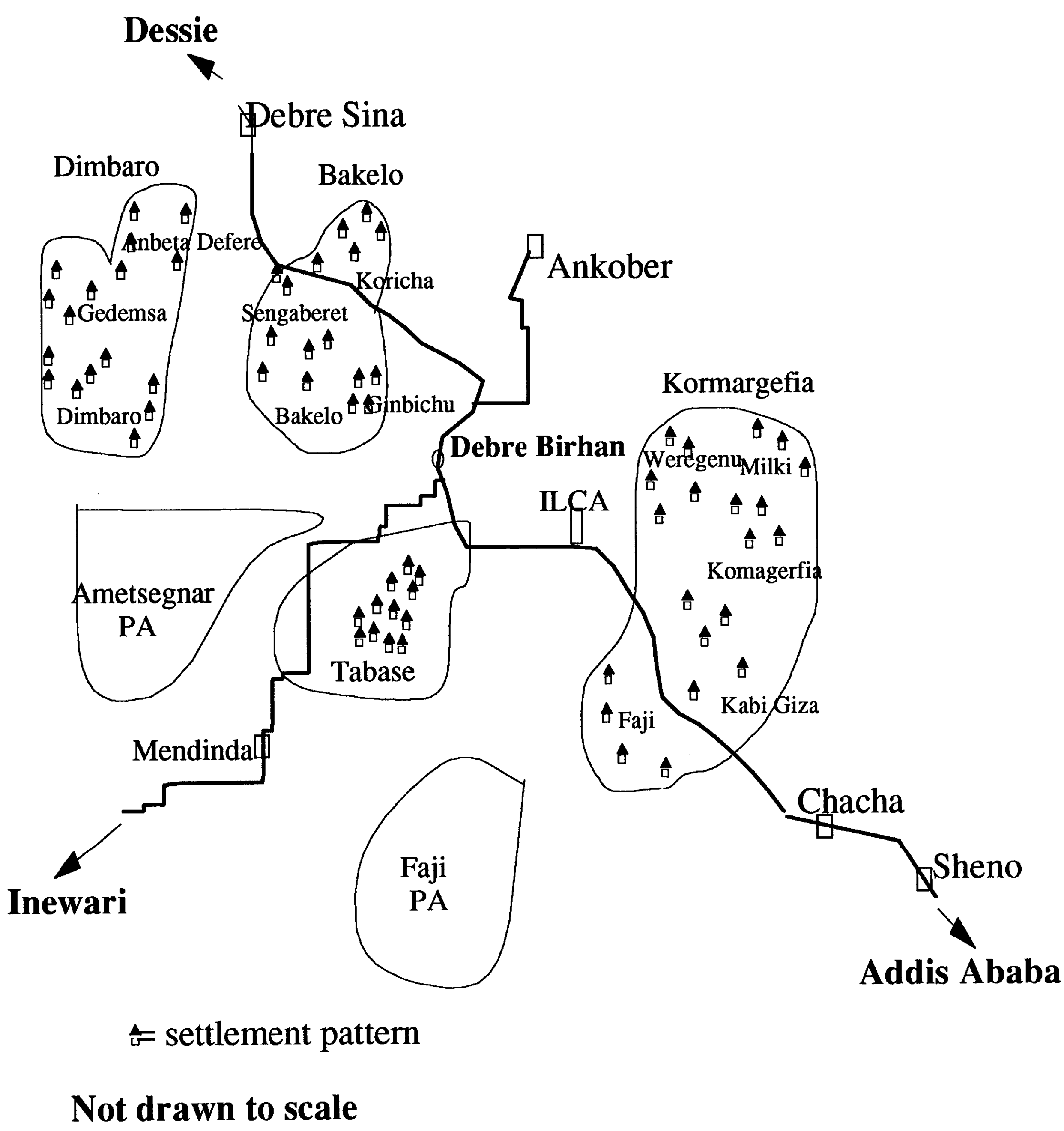
[1] In 1994, the Baso and Worana Woreda was split into two Woredas (sub-districts) of Debre Birhan Woreda and Bakelo Woreda.

Figure 3.1 General Location of Study Sites



Farmers are scattered in sparse individual settlements making intensive and continuous data collection rather cost-ineffective for the objectives of this study. They were Faji and Ametsegnar Agher. Bakelo and Dimbaro were selected in preference to Ametsegnar Agher because of their larger human population and greater heterogeneity in farming practices such as gravitational irrigation. The four remaining peasant associations provided contrasts in the nature of human settlement, distance from the all-weather road, socio-economic conditions and farm management practices in relation to crop-livestock farming.

The socialist-villagised mode of human settlement is still intact in Tabasse (three villages) while homesteads were scattered in Bakelo, Dimbaro and Kormargefia in twenty villages. The names of some of the large villages are inserted in Figure 3.1. However, the semi-socialist settlement mode is disintegrating in many villages either due to civil conflict or farmers quitting membership of producer co-operatives. Households desire to live as independent homesteads to minimise the social costs of living together. In their view, living as independent homesteads would also improve livestock husbandry especially during the wet season.

The distance between the farthest two peasant associations (Kormargefia and Dimbaro) is about 50 kilometres. This provides room to obtain substantial variations amongst households. A wider distance range would have been possible were it not for constraints imposed by the budget, time and other logistical considerations.

Despite the presence of a few asphalt (i.e., all-weather) roads, most of the roads in the peasant associations were virtually impassable during the wet season except by using horses and mules for transport. Given a fixed budget outlay, a bigger distance would have involved either employing more enumerators or covering fewer households. There is a greater possibility of either missing detail on crop-livestock production activities (observational errors) or enumerators concocting data to avoid walking long distances (measurement or response errors).

The selected study sites are considered appropriate for this study for a number of reasons. First, most of the production techniques, enterprise combinations, climatic cycles and infrastructure in the central highlands are representative of Ethiopian highland agriculture. Second, most of the salient agricultural, demographic, socio-economic, institutional and ecological features prevalent in the Ethiopian highlands are found in the central highlands (Belete 1989).

Third, the region is especially typical of the cereal-livestock agro-ecological zone (between 1800 and 3400 metre contour). Fourth, since smallholder production dominates the country's agricultural output, and smallholder farming predominates in the Ethiopian highlands, any change in agricultural production in the highlands will probably modify the face of agriculture in Ethiopia. Fifth, a number of socio-economic studies have been conducted in Baso and Worana Woreda (within the central highlands) and its periphery (e.g., Gryseels 1988, Belete 1989, Wolde-Mariam 1991, McIntire et al., 1992) and provided insights into the major agricultural practices and socio-economic conditions in the region.

Sixth, the international livestock centre for Africa (ILCA) has been and is conducting a wide range of livestock and crop-related research in the study area that is complementary to this research. Seventh, and from a logistical point of view, ILCA Debre Birhan station is located in Baso and Worana Woreda and provided accommodation, security of equipment (e.g., vehicles) and easy retrieval of vehicles when bogged down in the rugged terrain.

3.4 The Sample Unit

The sampling unit was the farm household. Despite definitional difficulties, a household is viewed as a family unit composed of the household head (usually a male), the spouse(s), children and other relatives who normally resided in a hut, eat and work together. Female-headed households (e.g., elderly widows, polygamous homes) are considered independent household units.

3.5 Selection of Sample Households

Basic household information (e.g., names and age of household heads, livestock numbers, farm size) was obtained from the local Ministry of Agriculture and the regional Inland Tax offices. These lists are prepared for different purposes. The Inland Tax office attempts to keep the most recent list of all persons required to pay tax while the Ministry of Agriculture office tries to maintain a list of all households for its extension services. As a result, therefore, different lists would generally contain gaps in some entries. A number of farmers shared names, had non-contiguous farms or were non-resident in the villages. These records were prepared during the socialist period of public administration and would have been inaccurate in one way or another.

One major motivation to conceal actual number of households living in a particular area was to avoid the government re-settling more people into such peasant association(s). This permitted households have access to greater size of communal grazing land as well as avoid land re-distribution. From the preliminary statistical analysis of the data that were collected from the 892 households, there is considerable variation amongst households in resource endowment (e.g., farm and herd size) which prompted the need to categorise households into relatively homogenous clusters.

3.5.1 Rationale for categorising households

Within any farming system, households differ in family size and resource endowments and they often face different constraints and welfare-enhancing opportunities. Households with a similar family structure, similar scale and mix of enterprise combinations may be assumed to experience similar socio-economic and institutional constraints and bear similar development needs. Since agricultural production and farm resource use issues present important challenges, investigation of agricultural practices among different households would provide a basis for technical and policy interventions. Information about the differences between households would enable allocation of research and extension resources through co-ordinated interventions according to household groups, technology and policy packages (Parton 1992, Fujisaka 1994).

Resource allocation studies can, and often, do improve technical knowledge about the performance of farming systems and overall resource management. In a structuralist approach, categorising rural households can be useful as long as the identified cluster attributes are sufficiently generalisable to permit their use in inductive and mission-oriented research (e.g., on-farm fertiliser trials) or extension work. Such research would assist in describing unique features of each farming system to elaborate on alternatives that are technically compatible, economically attractive and socially acceptable. Without proper categorisation of households and prioritisation of farmer problems, valuable resources may be wasted on developing short-term solutions to problems of unidentified clientele (Fitzhugh et al., 1992, Smith 1994).

Clustering of rural households into relatively homogenous groups is thus important in many ways. It facilitates defining appropriate policy and technology interventions and assists in identifying groups of households that are faced with specific social, financial or economic difficulties arising from implementation of specific or economy-wide (economic) policies. Grouping households in this way can also help identify and target specific policies and increasingly scarce resources to groups of households that are more likely to adopt promising agricultural and resource management innovations. Indeed, classification of households can help agricultural research and extension practitioners to focus particular attention on identified socio-economic or technical problems that particular groups of households face (Shaner et al., 1982, Mettrick 1993).

Agriculture in Ethiopia is characterised by slow rate of agricultural development. The objective of the classification scheme was to identify factors that would facilitate clustering households as crop farmers, livestock farmers or crop-livestock farmers. Variables describing households' resource endowment, resource exchange mechanisms and farming practices were used to categorise households and to indicate some suggestions about potential for technology adoption and response to policy intervention(s).

3.5.2 Defining classification variables

Defining and selecting variables for categorising rural households depends on the purpose of the classification scheme and cost of obtaining data regarding the different components of each variable. The objective of any classification scheme influences the selection, number and type of variables used. The cost of obtaining data imposes restrictions on the number of study units in the classification process. There has to be an intuitive trade-off between the number of study units and the number of variables. Using many variables is costly in terms of the time and effort required to generate the required information while recruiting few study units may not reveal the basic distribution of the values of each variable in the population, regardless of the sampling procedure.

A compromise strategy in empirical research is to select variables with high discriminating power and to omit highly correlated variables as suggested by literature review, purpose of the research and the researcher(s)' intuition. It is important that selected variables are empirically meaningful in affecting the nature and direction of change that may be occurring in the system. As an example, changes in both household and farm size and structure over time affect the nature of structural changes occurring in the agrarian sector over time (Anderberg 1973, SAS 1987).

In developed country agriculture, classification schemes have commonly used variables that circumscribe the structural transformation of agriculture and the nature of agrarian structure. Some of these variables include whether farms are corporate or family-owned, the relative share of off-farm income, whether farm operators are full-time or part time, and the relative contribution of hired labour to total farm labour (Gebauer 1977, Schmitt 1989). In developing countries, categorisation of farming households has employed rather different variables because of the dominance of agriculture in gross domestic product (GDP) and these classification schemes are influenced by socio-economic, institutional and infrastructural attributes in the farming systems. For example, production and marketing variables have been applied to categorise households in Niger (Williams 1994).

In this study, the variables that were selected included household size; size of individual crop land, irrigated land and pasture land; number of work oxen, cows, sheep and donkeys and distance from the road. Dichotomous (Yes/No) data included whether households hire and/or exchange land, labour and work oxen; use manure as organic fertiliser and as fuel; leave land fallow (*idari*), engage in soil burning (*guie*) and use chemical fertilisers. The sample units were expected to show variation in a number of these features including household size, ownership and access to productive resources, disease and pest challenges, subsistence needs, cropping practices and extent of crop-livestock integration.

3.5.3 Stratified sampling and cluster analysis

The cross-sectional data were analysed using principal components analysis (PCA) to indicate the magnitude of variation between households that is explained by each variable or combination of variables. Principal component analysis generates a smaller set of variables derived from linear relations of the original quantitative variables without losing information contained in the initial variables. From these relationships, variables with the maximum variance are sequentially selected to characterise the study units. This approach has be used in other studies in farming systems research such as in Mexico (ICRA 1985, 1988) and Niger (Williams 1994).

From the PCA results (discussed in next section), all the households were serialised according to the principal component factors. Equidistant strata of households were constituted, from within which households were selected using a stratified within-stratum random sampling procedure. The proportion (n_i) of households selected from each peasant association (i) depended on the number of households (N_i) and the standard deviation of each major variable (j) in each peasant association (σ_{ij}) using the following relationship. If only one variable is important to distinguishing between households:

$$n_i = \frac{N_i \, \sigma_{ij}}{\sum_{i=1}^{n} N_i \, \sigma_{ij}} , \quad j = 1$$

If more than one variable is important in distinguishing rural households for the purpose of the classification scheme, the proportion of households will be drawn using the following relationship:

$$n_{ij} = \frac{N_{ij} \, \sigma_{ij}}{\sum_{i}^{n} \sum_{j}^{p} N_{ij} \sigma_{ij}} , \quad j > 1$$

After preliminary analysis of the data obtained in the first stage, a sub-sample representing just over 10 percent (94 households) of the original sample was selected for an intensive study. Uncooperative or unavailable farmers were replaced through a stratified random (equal probability) selection process from the sub-sample. This two-stage data collection exercise permitted collection of more reliable responses on sensitive household matters such as size of individual farm land and sources and uses of farm income than during the first phase. Apart from statistical and budgetary considerations, the selection of 94 households was determined also by availability of accommodation in the peasant associations and number of households each field assistant could effectively work with.

Multivariate clustering was conducted to classify the 94 households using a combination of household characteristics, resource endowment, physical factors and farming practices using the Fastclus clustering procedure (*SAS* 1987). The purpose of the clustering approach was to constitute groups of households with relatively similar features within the clusters and quite dissimilar characteristics between clusters (Kshirsagar 1972).

The Fastclus clustering approach is non-hierarchical[2] and does not permit chained membership of any of the clusters. Due to the advantage of discrete cluster membership, the cluster means and variance of declared variables were analysed to determine similarities and differences within and between the identified clusters (ICRA 1988, Hair et al., 1992).

3.5.4 Household categories

Results from principal components analysis indicate that the total number of livestock (LIVESTOCK), amount of crop land (CROP LAND), household size (HHD SIZE) and distance from the main all-weather road (DISTANCE ROAD) explain most of the variation between households (Table 3.1). Out of a total of twenty quantitative and continuous variables, the eigen values of the covariance matrix indicate that livestock herd size, crop land, household size and distance from the road, respectively, account for 75.3, 9.9, 6.1 and 2.8 percent of the standardised variance between households.

The first principal component (PRIN1) has high positive loading (0.73) on livestock herd size with reasonable loading (0.51) on the number of sheep per farm. The second principal component has high positive loading (0.75) on crop land with some positive loading (0.32) on total farm size. Similarly, the third and fourth components have a positive loading (0.54) on household size and (0.71) on distance from the main road, respectively.

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2 There are various hierarchical clustering methods (e.g., Maximum Likelihood or Ward's Method) that permit chained membership of constituted clusters. The Fastclus clustering method is considered sufficient for the purposes of this classification scheme.

Table 3.1 Results from Principal Components Analysis

Total Variance = 176.68726724

Eigen values of the Covariance Matrix

	Eigenvalue	Difference	Proportion	Cumulative
PRIN1	132.960	115.542	0.752515	0.752515
PRIN2	17.417	6.569	0.098578	0.851093
PRIN3	10.849	5.838	0.061400	0.912493
PRIN4	5.011	1.059	0.028359	0.940852

Eigenvectors

	PRIN1	PRIN2	PRIN3	PRIN4
ADULT MALE	0.036247	0.018491	0.093477	0.071372
YNG MALE	0.024492	0.015165	0.132803	0.170027
ADULTFEM	0.017936	0.013409	0.102517	0.009155
YNG FEM	0.021445	0.014687	0.220162	0.021830
CROP LAND	**0.217746**	**0.756650**	**-.347126**	**0.258849**
PASTURE LAND	0.058930	0.155846	-.034567	-.167134
OXEN	0.067478	0.060822	0.141906	-.060076
COWS	0.082294	0.118685	0.113732	-.163868
DONKEY	0.065925	0.047770	0.103791	-.092931
MULE	0.002966	0.002859	0.011835	-.009269
SHEEP	0.514360	-.388254	-.340467	0.237135
IRRIG LAND	-.008595	-.038474	0.108586	0.058617
DISTANCE ROAD	**-.018209**	**0.025384**	**0.091877**	**0.718602**
HHD SIZE	**0.100119**	**0.061752**	**0.548959**	**0.272384**
ADULTS	0.077151	0.046826	0.372477	0.176456
TOTAL LAND	0.105730	0.321449	-.058169	-.098475
CATTLE	0.149772	0.179507	0.255637	-.223944
LIVESTOCK	**0.733023**	**-.158118**	**0.030796**	**-.089008**

YNG = Young, IRRIG = Irrigated, FEM = Female

Religion and animal grain sales were not important features. All respondents were members of the same religious faith (Coptic orthodox church). Animal and grain sales are conducted through a piece-meal staggered selling strategy to serve immediate and periodic household needs, especially with risk-averse farmers under rainfed agricultural systems. Similarity in both religion and marketing strategies imply considerable similarity in the mode of life, cultural habits and that farmers tend to do things in the same way. There is thus potential for wide applicability of conclusions that drawn from this study about crop-livestock farming in the Ethiopian highlands.

There is wide variation between households in family size, farm size and livestock ownership (see Tables 3.2, 4.1, 4.3 and 4.5). The wide range in household differences in these features is interpreted to indicate substantial rural diversity among households. The data indicates that there is substantial inter-household social differentiation that has important socio-economic implications for agricultural development interventions, especially regarding livestock and functioning of rental markets for land and animal traction.

Moreover, such differentiation may be indicative of rural inequity. This is in accord with the observation that some landless households survive on the brink of destitution and that they increasingly encroach on communal and public lands for either arable land or source(s) of income (e.g., sale of gathered firewood, honey).

The mean and standard deviation of the various physical and socio-economic variables of the households from the 23 villages are shown in Table 3.2. A critical relationship between principal components analysis and the results in Table 3.2 is the preponderance of variables with high variance over those with low variance. This arises out of the wide statistical range between the lowest and highest numerical values of the factors considered. However, except for distance and household size, all other variables have a lower bound of zero value.

Table 3.2 Some Household Characteristics (Mean, Standard Deviation)

Variable	`Census'data 23 villages	Peasant (farmer) Associations				Sample farmers
		Kormargefia	Tabasse	Bakelo	Dimbaro	
	n = 892	n = 228	n = 62	n = 392	n = 210	n = 94
Farm size (ha)	2.60 ± 1.70	4.50 ± 1.85	3.63 ± 1.38	1.55 ± 0.65	2.15 ± 0.88	3.32 ± 1.98
Sheep flock	5.8 ± 5.9	8.0 ± 7.5	7.8 ± 5.9	4.6 ± 4.3	5.5 ± 5.8	7.0 ± 6.3
Family size	4.9 ± 2.4	4.9 ± 2.4	6.0 ± 2.7	4.9 ± 2.2	4.7 ± 2.4	5.0 ± 2.4
Distance (km)	3.1 ± 2.3	3.2 ± 2.1	1.4 ± 0.4	3.0 ± 2.8	3.8 ± 1.3	2.7 ± 2.1
Cattle	2.9 ± 2.0	4.2 ± 2.4	3.7 ± 2.0	2.2 ± 1.4	2.6 ± 1.7	3.3 ± 2.2
Work oxen	1.5 ± 1.1	2.0 ± 1.3	1.8 ± 1.0	1.3 ± 0.9	1.4 ± 0.9	1.7 ± 1.1
Cropland (ha)	1.83 ± 0.90	2.48 ± 1.08	1.98 ± 1.48	1.43 ± 0.58	1.80 ± 0.70	2.10 ± 0.97
Pasture land (ha)	0.98 ± 0.70	1.95 ± 1.03	1.60 ± 0.75	0.13 ± 0.18	0.28 ± 0.23	1.16 ± 1.20
Irrigated land (ha)	0.26 ± 0.35	0.08 ± 0.20	NONE	0.20 ± 0.28	0.63 ± 0.38	0.22 ± 0.31

Source : Author 's (1993-94) survey results

3.5.5 A tabulation of the results of cluster analysis

The 94 sample households were classified into non-hierarchical categories using the first four derived principal components. Using the derived principal components had two basic advantages over raw variables. First, situations arise whereby it is impossible to discriminate the relative importance of one variable over another when the eigen vector of one principal component has almost equal absolute loading with another variable. Second, even if it were possible to select the key variables from the eigen vectors of a principal component, using derived variables adds more weight to the would-be-selected dominating variable and thus improves the validity and stability of the identified clusters (Hair et al., 1992).

The households were grouped into three clusters containing 34, 37 and 23 members. By varying the number of either principal components or raw variables, the number and membership of identified clusters varied. Generally, few (four or five) principal components generated better cluster stability than a larger number (seven or eight) of principal components or declared quantitative variables. The derived clusters contained smaller root mean squared standard deviations and shorter distances from the initial seeds to the individual observations.

Cluster one (CROP FARMS) has 34 members[3]. These households have small family sizes and few or no livestock on their farms. Households in this cluster have, on average, the smallest farms and they often rent and exchange arable land. Although land per household does not differ significantly between the clusters, few households in this cluster leave their land under fallow. Perhaps because they own few animals, this group of households least apply, if any, manure on their farms to resuscitate soil fertility. The small land size and lack of work oxen aggravates the problem of proper and timely cultivation of their fields. Members of this cluster are relatively young households or new farmers (e.g., former soldiers or civil servants) who possess few livestock and supplement their dependence on

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[3] Details of cluster differences are described and discussed in chapter four (sections 4.1, 4.2 and 4.3), with emphasis on crop farms (cluster one) and crop-livestock farms (cluster three). Cluster two (semi-mixed farms) is a transitional cluster between clusters one and three, and its discussion is ignored for purposes of brevity.

crop production with non-farm sources of income such as sale of local brew or firewood (often gathered from communal lands).

Cluster two (SEMI-MIXED FARMS) has 37 members and is dominated by male-headed households. They have the largest family size and modest farm size. They have modest livestock herd sizes with their sheep flock ranging from three to fifteen, one work ox and one cow. Compared with cluster one members, they hire seasonal farm labour more frequently. Proportionately more households in cluster two leave their land under fallow than those in cluster one. Not many members of this cluster rent or exchange agricultural land. Because they own more livestock than cluster one households, cluster two members often sell cow dung fuel cakes. Because of supplementary grazing on fallow land, farm plots of cluster two members receive some manure.

Cluster three (CROP-LIVESTOCK FARMS) has 23 respondents who, on average, have the largest farm size and modest family size. They have the largest livestock herd. They have large sheep flocks and one to three draught oxen. They are generally male-headed households and hardly ever rent or exchange arable land. These households always sell cow dung cakes because they possess the most livestock and they also lease or exchange oxen. Most of the cluster members often leave part of their land under fallow and because of supplementary grazing on fallow land, their farm plots receive more manure compared with fields of households in the other two clusters. Households in this cluster are relatively wealthier because of relatively diverse sources of income and employment.

Assuming that the classification variables are normally and independently distributed in the population, *t*-tests were used to test if the distribution of the variables is significantly different between any two clusters. In all cases, crop-livestock farmers (CLUSTER THREE) have bigger farm size (both crop and pasture land) and more livestock (oxen, cows and sheep) than crop farmers (CLUSTER ONE) ($t = 6.4844$, *d.f.* = 55). Crop-livestock farmers (CLUSTER THREE) have larger farms and more cows than semi-mixed farms (CLUSTER TWO) ($t = 2.3639$ *d.f.* = 58). Members of clusters two and three have approximately equal numbers of sheep and equines. Crop farmers, have less crop land, fewer livestock and smaller family size than semi-mixed farmers. These results are consistent across the identified clusters and would be potentially useful in directing alternative technical and policy interventions that would appreciate the different constraints, farming strategies and opportunities that confront different categories of households.

Although ownership of livestock improves the asset-equity position of mixed farmers relative to those without livestock, it is not intended to be a policy criterion to discriminate between households on the basis of wealth (or other indicators of socio-economic wellbeing). Farming systems are usually undergoing change over time. For example, households grouped as crop-livestock farmers can lose their livestock (e.g., through mortalities caused by drought or disease) and thus join the group of crop farmers. After drought years, individual herds recover and households can be identified as either crop or crop-livestock farmers. The identified cluster of households can be assumed to remain stable over time although their membership may change, from time to time. This clustering approach permitted the research to elicit the different constraints, investment opportunities and potential interventions that are applicable to different clusters of households (some of these aspects are discussed in chapters four and seven).

Ownership of livestock plays various important, often complex, roles in the economies of rural households in the developing world (chapter two and section 5.2). These roles often depend on the level and complexity of crop-livestock integration and what aspects characterise the nature of crop-livestock integration (Mortimore 1991) to indicate sources of (or pressure for) crop-livestock integration (e.g., population growth or market-driven intensification). Using the rationale behind the categorisation scheme (section 3.5.1), various technical or policy interventions can be instituted to affect the direction and pace of agricultural development in rural areas by targeting specific clusters of households. Such interventions may include agricultural credit schemes, rural poverty-alleviation and employment programmes or agricultural extension services for specific household clusters.

Membership of each of the three clusters represents categories of households in different stages in the path to intensification of agricultural production and resource management. Cluster one members are mainly crop farmers and do not possess many livestock except poultry and some sheep. Cluster two members possess relatively more livestock (more sheep and some cattle) and appear to represent households that are intensifying agricultural production through crop-livestock integration. Cluster three members possess even more livestock, especially cattle and crossbred dairy animals.

3.6 Designing and Pre-Testing Questionnaires

Three sets of questionnaires have been used to obtain data used in this study. The first (one-page) questionnaire was designed to verify household characteristics on a single-visit basis. Another questionnaire was prepared and presented to the local Ministry of Agriculture officials to validate some farming practices (e.g., soil burning, irrigation, use of fertilisers, extent of land rentals) in the study area. The third questionnaire was the formal questionnaire administered to individual households to obtain various data on household characteristics and crop-livestock farming during the survey period.

3.6.1 Pre-testing the questionnaire

Before its full-scale administration, the formal questionnaire was designed and pre-tested on 27 households to gauge the length and suitability of the questionnaire in eliciting farmer responses. Questions that appeared vague or to attract multiple responses were duly adjusted. Questions that seemed unduly sensitive (e.g., number of livestock or farm size) were both toned down and interspersed through the questionnaire. The questionnaire appeared too long for effective farmer co-operation and was thus split into four sections that were administered separately.

3.6.2 The structured questionnaire

The first part of the structured questionnaire (Appendix 2) involved interviews about household resource inventory. The land area of each household was estimated in terms of crop area, pasture area, wasteland, etc. Farm size was also estimated according to the geographical location of each field plot from the homestead. Incidence of hiring, renting or exchanging of land and related repayment modes were elicited and observed. Households were interviewed on the constraints experienced in the rural land market (leasing/renting).

Households also provided their household size (age-sex structure), labour-use profiles in different farming and livestock husbandry activities, livestock inventory (species, sex and age) and use of work oxen in different farming activities. Other data collected included: tree inventory, farming goals and strategies in good/bad seasons. This questionnaire took an average of three visits each taking up to one hour to complete. Farmers were willing to spend more time to respond especially on days that farming operations were not being done.

The second part of the formal questionnaire (Appendix 3) involved multiple single-visit interviews of farmers concerning farming practices. Data collected included: frequency and reasons for different fallow and soil burning practices, extent and reasons for use (or non-use) of commercial fertilisers, manure and crop residues, extent and attitudes towards soil conservation, extent and reasons for crop rotation, seasonality of livestock feed production and feeding management strategies, sources, type and uses of money on investment in farm production and farming information. This questionnaire took an average of three visits each consuming up to 100 minutes to complete.

The third piece of the structured questionnaire (Appendix 4) involved several single-visit interviews about resource scarcity. Data collected included: extent of and perceived solutions to scarcity of crop land, farm labour and work oxen, hiring/exchanging of labour and work oxen and associated repayment arrangements, constraints to hiring and exchanging of labour, crop farming and livestock husbandry problems (weather, diseases, pests and market prices), sources, types and frequency of household income, major household expenses and the constraints to access and use of improved inputs. This part of the questionnaire took an average of four visits each taking up to 1.5 hours.

The last part of the formal questionnaire (Appendix 5) involved weekly visits to households to collect whole-day activity data by both observation and short interviews (when the farmer was free) about labour use in crop production (ploughing, weeding, harvesting, etc.) and livestock husbandry (herding, feeding, milking, barn cleaning, watering, etc.). Other data collected included: milk production, household food consumption, sales/purchase and storage of crop products (grain and crop residues), livestock (and their products) and farm inputs (fertiliser, seed, biocides). Information on prices of different crop products, different livestock and livestock products, and various inputs (e.g., fertiliser) was collected, through informal interviews, from farmers, private traders and other participants in the local markets. The main weekly market days were Thursdays and Saturdays.

3.7 Procedures in Primary Data Collection

The data collection exercise involved a number of procedures to ensure its success. These include aspects of selecting and training enumerators, acquiring field equipment and maintaining rapport with local leaders and sample farmers.

3.7.1 Maintaining rapport with farmers

Considerable efforts were made to gain the acceptance of the local administration and population, to facilitate the purpose of the study without having to give gifts to households to elicit their co-operation in the study. The wisdom of giving sample households gifts to elicit their co-operation can be questioned since it may create problems of obtaining data from the same or nearby households (or their relatives) in subsequent studies. Neither is such remuneration necessary if the research effort is well planned.

However, in some unique cases, small gifts may be offered at the end of the study as a sign of appreciation but not on a promissory basis. Some of these concerns about gifts are also expressed by Norman (1973) especially for organisations with a thin budget or personnel resources. Cultural, religious and interpersonal considerations were sorted out early in the survey and any misunderstandings were minimised. For example, substitution of enumerators appeased household heads who had objected to being interviewed by an enumerator of particular gender.

In many instances and when there was reasonable urge to, the author and the field assistants shared meals with sample farmers, participated in various community and social functions with farmers such as attending funeral and cultural occasions. The research team was fairly integrated in the local community and such an approach helped to avoid farmers' suspicion. The author made deliberate and frequent efforts to greet and discuss informal issues with the chairman of each peasant association as a social and informal gesture to maintain the rapport with the village community system, even if the chairman was not one of the sample households.

3.7.2 Timing of data collection

Timing of data collection periods proved important for obtaining reliable data because the data collection exercise coincided with the performance of farming activities within the local cropping calendar/schedule. Many households are either illiterate or do not keep written records of their activities, so fitting the data collection schedule within the farm production calendar schedules eliminated the necessity to depend of the farmer's memory recall on detailed specifics of farming (Amir and Knipscheer 1989, Poate and Daplyn 1993) or other farm business activities performed.

3.7.3 Recruitment of field assistants

Recruitment of field enumerators was time-consuming but finally proved rewarding. Forty prospective enumerators were interviewed through both oral and written examinations. Twenty-seven of them were selected and screened for their effectiveness under field conditions. Effort was made to select enumerators with a minimum education level of ordinary school certificate (pre-university level), pleasant personality and indigenous to the study area but not known to individual households that they were to interview.

Care was taken to include enumerators of both gender. The rationalisation of including female enumerators was to meet the requirements of some household heads (or their household members) who objected being interviewed by enumerators of opposite gender. Moreover, female enumerators became very useful in gathering data about household food consumption and other delicate issues pertaining to gender-sensitive variables.

The enumerators were further screened on the basis of their performance in recording field note-books, filling questionnaires, communication ability (simplicity in *Amharic* language), conversational approach to households and commitment[4] to the data collection exercise.

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4 To boost their morale, enumerators were supplied with kerosene pressure lamps, insecticide sprays, rain coats, gum boots, spotlight torches, rainproof leather bags (for carrying questionnaires and other field work gear), water containers and watches (for keeping time-records).

Sixteen enumerators were selected for intensive training about the research work and mechanics of interviewing farmers and filling the questionnaire. The assistance and name of each enumerator has been (and is) gratefully acknowledged. Many of them had substantial previous exposure to data collection and had spent most of their time in the rural areas. These enumerator attributes enhanced quick adjustment into whichever areas they were allocated to work and easily garnered congenial relationships with farmers in the study sites.

3.7.4 Enumerator training

A conceptual understanding of the research project was deemed necessary for the enumerators to adhere to the methods of data gathering considered in the study. For a period of six to eight weeks, enumerators were trained on various aspects of data collection including questionnaire administration, interviewing techniques, discussion techniques, maintaining confidentiality of information obtained, taking field notes, alternative meaning of questions and potential responses (contained in the questionnaire).

Enumerators were divided into working groups to share their training and field experience. Training of field enumerators was completed well in advance of the proper start of data gathering. Enumerators made mistakes early in the research but suitable timing permitted omission of data collected early in the study and effective subsequent supervision of data collection.

On some occasions, when time was a serious constraint, part of the sample of farmers were temporarily left out of the intensive data collection and were later incorporated through use of memory recall. This data collection arrangement arose when either a sample farmer or an enumerator was bereaved and data collection was thus constrained. When using memory recall, efforts were made to give farmers good time to remember or consult household members. The research team offered some memory aids (as reference to occasions or measurement units) to minimise errors and potential distortions.

The reliability of memory recall tended to be associated with the nature of activity (e.g., regular or irregular weeding) or time that has elapsed since the last occurrence of the event (monthly or weekly sales), the nature of the reference aid (e.g., daily or weekly milk churning) and the characteristics of the event (e.g., routine or unique such as fencing). Other useful tips of minimising memory bias are discussed by IFPRI (1993) and Spencer (1993).

3.7.5 Supervision of data collection

The geographical location of each parcel of land of each sample household within the peasant association was sketched through visits by the author to each homestead. This helped supervision of data collection and guarded against leaving distant fields or isolated households out of the study especially in the highly dissected rural hilly areas. The geographical location of each homestead and field plots has been examined to evaluate alternative sampling procedures (e.g., adaptive sampling) for technology assessment, especially for technologies that involves high transportation costs or difficulties in sample selection (Nokoe et al., 1994, Omiti et al., 1994c & 1994d).

Each enumerator was allocated six farmers. Each household was interviewed and observed for a whole day each week. Arrangements were made to obtain accommodation for field assistants in the villages. Arrangements were also made to ensure that the enumerator was acceptable to the farmer through informal introduction and discussions when the farmer was not engaged in farm work. Frequent checking of questionnaires and appropriate assistance to enumerators boosted their morale and invigorated their continued interest in the study. Such close and frequent supervision, often at irregular intervals, ensured that enumerators did not concoct information without visiting the allotted sample household.

During the entire data collection exercise, the author cross-checked all questionnaires and dubious data entries were cross-checked with individual households employing a different enumerator. In some cases, the author re-interviewed the household with the assistance of ILCA field research staff.

3.7.6 Ranking of farming problems and priorities

Eliciting farmers' goals, aspirations, constraints and priorities can give insights into which technology and policy interventions are likely to be easily accepted by them. As such problems and goals are not measurable but perceived impediments to agricultural performance, considerable effort was made to design and evaluate responses to various specific questions to minimise observational as well as response errors.

Care was taken to sequence and intersperse sensitive questions in the questionnaire. It has been assumed that most of the relevant questions and potential responses were included during the phase of pre-testing of the questionnaire. Households were first asked to mention their farming goals, problems in crop and livestock farming, solutions to those problems and preferred uses of money in various farming activities. This approach permitted the study to obtain a matrix of the most important farming goals, problems and potential solutions.

During the next phase, the farmer was asked whether other goals, problems, etc listed in the questionnaire (and not mentioned by the farmer) were important. Finally the farmer was asked to mention the three most important goals, problems (in crop and livestock farming) and solutions (coping strategies) to various problems. Ranking and/or prioritisation of farmers' goals, problems and adaptations to various agricultural problems have been analysed using statistical procedures such as principal components analysis and frequency analysis.

3.7.7 Duration of data collection

Data were obtained through direct measurements, group and individual interviews, field observations, administration of a structured questionnaire and from secondary sources. Farmers were interviewed and observed for one year, starting April 1993 until March 1994 (i.e., entire *meher* cropping season). Farmers were co-operative and often enthusiastic about the research. During the period of data collection, farmers gained confidence in the field work and provided information that they hitherto did not provide accurately or freely.

After completing data collection, 20 per cent of the sample households were selected and interviewed using the initial one-page questionnaire to cross-check and validate any doubtful responses. There were minimal discrepancies between the data obtained in the initial and latter stage. As an illustration, a farmer could have sold or purchased one or two animals during the one year interval. There were minimal discrepancies between the first and latter run of the one-page questionnaire which provides some confirmation of the reliability in the data obtained.

3.8 Nature and Sources of Secondary Data

In addition to primary data collection, data regarding the input-output coefficients and other parameters that are used in the linear programming model were collected from various secondary sources. Such data included grain and straw yields of different crops, labour and traction requirements, milk yields, livestock nutritional requirements, minimum subsistence requirements and prices.

These secondary data were useful for validating the estimates derived from field surveys. These data were also useful in specifying the nutritional requirements of indigenous and crossbred cattle, sheep and work oxen. Derivation of technical parameters of livestock nutritional requirements is outlined in Appendix 6. Sources of these secondary data included published statistics from the Ministry of Agriculture (MoA 1987-1993, MoA 1989), International Livestock Centre for Africa (Soller et al., 1986, Gebrehiwot 1988, Anindo et al., 1994), academic theses (Giglietti and Stevan 1986, Gryseels 1988, Assefa 1989, Belete 1989) and journal publications (Rodriguez and Anderson 1988, Emana and Storck 1992).

3.9 Difficulties Encountered During Data Collection

During the survey period, a number of difficulties were encountered that would have a bearing on the data quality and are relevant to subsequent discussions on the nature of crop and livestock farming in the study area. These problems are briefly outlined.

3.9.1 Sample selection and farmer cooperation

The fieldwork was conducted during a transitional period from a semi-collectivist agrarian structure and protracted (30-year) civil war to a partially liberalised market economy. There were government restrictions on conducting rural surveys for security reasons. This was overcome by obtaining a formal letter of approval from the administrative (*Woreda*) authorities. The author and the field assistants carried a copy of this research permit letter (from the *Woreda* chairman) throughout the survey period.

During the pre-testing of the questionnaire, some farmers questioned the criteria used in selecting them. Coupled with indications of large variations in farmer responses during the pre-testing phase, a one-page questionnaire was designed and administered to all households in the study area. Using the cushion of this `census' survey, there were few objections raised by selected households during the subsequent formal surveys. The purpose of the farm-level research study was explained to the sample farmers, as was the idea that they represented other farmers in the study area who were not selected. The research team explained to the farmers the need to understand their various constraints as an important policy concern and the need to work with rural households in participatory agricultural research.

Nonetheless, some farmers refused to participate in the formal survey. Some had participated in previous rural surveys and did not want to participate in another. Other non-participatory farmers were former soldiers who appeared suspicious of the motives of the research or wanted regular cash inducements to participate in the study. Some farmers were actually not uncooperative but were very old (e.g., blind). In such cases, information was obtained from the dependants (wife or children) who operated the land.

Farmers were often cheerful and provided incisive ideas about highland farming with considerable honesty and humour. Sometimes, however, some peasant responses were very complicated. Farmers would pause to think about each question before responding to disclose certain issues or divert discussions to other issues. Some minimum knowledge of the *Amharic* language is critical to conducting rural surveys in the central Ethiopian highlands. At times, the translation by the field assistants was inadequate or incorrect in obtaining in-depth farmer responses, and some questions had to be repeated.

The case study approach that is followed in this study (through multiple visit interviews) permitted both respondent and enumerator bias to be minimised through regular cross-checking and learning-by-doing. In any case, it is important to appreciate that inaccurate responses may arise from inadequate questionnaire design, or the respondent's ability or willingness to provide the proper information sought without soliciting or giving material incentives.

Inaccessibility, especially during the rainy season, of some villages was a serious challenge in reaching sample households before farm operations for the day had begun. However, because many activities are performed later in the day during the wet season, not much production data were missed. Recourse to rental use of horses and mules helped in many ways. All field assistants were settled in the respective peasant associations to both save on walking time and develop rapport with farmers.

Other farmers were itinerant retailers who spent little time in their homes. Due to poor transport infrastructure, household heads who were itinerant or retail traders tended to stay back in the urban areas until all their marketed items were sold. In the initial phase, such `absenteeism' of household heads tended to delay completion of the single-visit questionnaires (Appendices 2-4).

Religious, social or natural events constrained data collection. During the survey period, some members of either the sample households or some of the field enumerators died. In cases where the household head passed away, very few field activities are performed and may affect some of the statistical results presented in this thesis. Similarly, problems of illnesses would affect labour-utilisation statistics too. However, since religious holidays are observed by all households, data about crop and livestock activities are not likely to be affected or biased by this.

3.9.2 Measurement problems

Measurement of anything in rural Ethiopia presents onerous challenges. Many farmers base their transactions on visual observations and appraisal, not on weighing scales, kilograms, or measuring tapes. Authenticating farm size was difficult because farmers concealed the actual number of their many, non-contiguous field plots, partly due to insecurity of tenure. Some tended to report their own plots as hired in order to mystify their farm size. Farmers use traditional units of measurements that vary quite significantly. Similar measurement problems are also reported by Wolde-Mariam (1991).

For example, one *timad*[5] of fertile (*areda*) land is differently expressed, in area, with respect to one *timad* of less fertile (*yemeda*) land due to farmer

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[5]One timad is the land area that one pair of oxen can plough in one day and is estimated to be, on average, about 0.25 ha. However, the definition and size of one timad varies with bullock capacity and nutritional frame, topography, soil and weather conditions and the efficacy of the ploughing implements.

estimation of relative productivity. In the initial phase, farmers were asked their farm size in local units. Some responses were difficult to validate with such answers as `five or six timads'. In trying to obtain accurate estimates, many farmers did understate their true farm holdings. Some judgement was needed in cleaning the data of such measurement inconsistencies.

Moreover, it was difficult to quantify the amount of communal grazing land that is available to individual households. Communal land tended to vary in pasture productivity and its land size from place to place. In some cases, individual households tended to understate the size of communal grazing land to foreclose upon any potential immigrants who might lay claim on communal grazing for purposes of making use of it as cropland. Within on-going farmer relocation to individuated land ownership (following the collapse of `villagised' settlement), the future of communal grazing land is uncertain and its continued availability is in question. Therefore communal land is excluded from the linear programming model in chapter five.

Despite such efforts, statistical results of some continuous variables (e.g., size of irrigated land, pasture land) may indicate standard deviations in excess of the average value of the variable (e.g., Tables 4.1, 4.3 and 4.5). Such results serve to indicate the wide statistical range of the distribution of the variable in the sampled population of respondents. This is due to the highly variable responses from farmers regarding land ownership. Due to the gravitational type of irrigation in the rather hilly terrain, some farmers may have access to considerable irrigation water while some have no access to the river for irrigation purposes, hence yielding such analytical results.

Estimation of labour use in different crop and livestock husbandry activities was not painless. Different members of the household performed multiple activities in non-contiguous holdings or in the farm labour markets, thus making it difficult to follow all members of the household in their productive engagements throughout the day. It is thus not easy to make estimates of leisure preferences. Again, following farmers in their afternoon activities was cumbersome. Some were engaged in social discussions and social activities such as drinking local brew or coffee. For social reasons, it was not possible to consistently follow what chores women and children performed on a regular basis. It is thus not possible to have a gender division of labour in the linear programming model.

Estimating crop yields and quantities of processed livestock output (e.g., butter) presented interesting challenges. Ideally the total yield from the whole field or one animal should have been weighed. However, this is only possible with non-food monocrops on small fields and harvested at one time (not sequential harvesting on perennial crops such as hay). This study resorted to taking diagonal samples from each crop field. Instead of 10*10 metre quadrant samples, five 1*1 metre samples were taken and were manually threshed. The 10*10 metre yield samples from farmers' fields were too small to thresh using animals yet too much for hand threshing. These 10*10 metre samples were too light to transport using animals yet too heavy for manual transportation to the threshing ground (usually near the homestead). Each respective farmer was given the grain and straw from the sample that was taken from his/her farm. Although the representativeness of yields obtained from the quadrant samples for total yield estimates from the farmers' fields may be queried, substantial effort has been made to compare the yields with other recent studies in the study area.

3.9.3 Data and enumerator bias

Although they performed quite well under difficulty circumstances, enumerators had difficulty in following instructions properly. While substantial effort was made to cross-check questionnaires on a regular basis, some errors were difficult to eliminate especially in data about household expenditure and sources of cash income. In some cases, farmers did not provide accurate information about some of the questions about household expenditure and income or other sensitive aspects espousing crop-livestock farming. Efforts were made to give farmers good time to remember or consult household members. The research team offered some memory aids (as reference to occasions or measurement units) to minimise errors and potential distortions.

Some response and measurement errors are difficult to detect or correct *a priori*. Substantial efforts were made to reduce such distortions through rigorous enumerator training, questionnaire pre-testing and cross-checking and comparing doubtful data with secondary sources.

Accuracy of any data set depends on several factors including the sensitivity of the data required; method(s) used to collect the data; rapport between the researcher, enumerator and the farmer; frequency of interview and supervision, level of enumerator education and training; the type and effects of incentives for data collection and the overall duration of data collection (which affects `enumerator fatigue'). As long as data inaccuracies are accidental and void of systematic influences, it is assumed that such measurement and response errors eliminate each other through statistical averages.

3.10 Summary

Methods of obtaining data needed to evaluate the contribution of crop-livestock integration to the household economy have been discussed. Both primary and secondary sources of data were sought and involved use of formal questionnaires, group discussions and published secondary data. These data were analysed[6] using descriptive statistics (i.e., means and standard deviations). Substantial effort was made to obtain reliable and the most recent information.

Rural households possess different characteristics depending on their resource endowment, geo-physical location, farming practices and welfare-enhancing opportunities. Identifying the similarities and differences between groups of farmers is an essential step in trying to identify their constraints and in designing interventions that take consideration of their homogeneity in the discriminating variables.

There are wide disparities in household resource endowment that have important bearings on the way rural families interact despite the skewed resource endowment and array of opportunities and constraints. Principal components analysis, multivariate clustering and other statistical analysis of data provide a sound and systematic methodology.

Realising the difficulties encountered during data correction, it is possible that some aspects mixed farming may not be covered in depth or broadly as could have been otherwise possible. There may be no perfect solution to these problems, particularly in rural areas of the developing countries. Working with few farmers per enumerator through frequent

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[6] The data have been cleaned, massaged and analysed using various statistical softwares including dBase, SAS and MicroSoft Excel.

interviews and field observations for the whole cropping season reduced measurement errors.

Other common problems associated with data quality include sampling errors, sampling bias, inadequate enumerator training and supervision, non-response or incomplete surveys, response and observational errors, processing and interpretational errors. We have tried to reduce errors through intensive data cleaning, cross-checking and authentication. Notwithstanding these limitations, the results describing the farming systems with particular emphasis on crop-livestock integration in the central Ethiopian highlands are discussed in chapter four.