ECONOMIC ANALYSIS OF LAND USE: THE CASE OF EAST HARARGHE ADMINISTRATIVE ZONE IN ETHIOPIA

BY

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Declaration

I declare that the thesis hereby submitted by me for the Philosophia Doctor (Ph.D.) degree at the University of The Free State is my own independent work and has not previously been submitted by me at another university/faculty. I furthermore cede copyright of the thesis in favour of the University of The Free State.

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ABBREVIATIONS

A.A.	Addis Ababa (the capital city of Ethiopia)
AU	Alemaya University
DA	Development Agent
EASTHAR	East Hararghe
E.C.	Ethiopian Calendar
EHAZ	East Hararghe Administrative Zone
FAO	Food and Agricultural Organization of the United Nations
FDRE	Federal Democratic Republic of Ethiopia
G.C.	Gregorian calendar
GDP	Gross Domestic Product
HH	Household
Kg	Kilogramme
MW	Mega watt
NGO	Non – Governmental Organizations
PAs	Peasant Associations
Ph. D.	Philosophia Doctor
SSA	Sub - Saharan Africa
TGE	Transitional Government of Ethiopia
UNESCO	United Nations Education, Science and Cultural Organization

DEFINITION OF TERMS

Birr Ethiopian currency (1 Birr equals 100 cents)

Cereals Include teff, barley, wheat, maize, sorghum, millet, oats, and rice (not grown in Ethiopia)

Pulses Comprise horse beans, chickpeas, haricot beans, field peas, lentils, vetch, soya beans

Oilseeds Include niger seed, linseeds(flax), fenugreek, rapeseed, sunflower, groundnuts, and sesame

Derg The Military regime that was formed in June 1974 and ruled Ethiopia until 1991.

East Hararghe Administrative Zone The study area where the research is conducted in Ethiopia.

Kebele The lowest level of urban administrative units in Ethiopia. A city and/or a town is divided into *Kebeles*

Land use systems Crop production systems and other land utilization systems practiced in the study area.

Land use types Crops grown by farmers and included in the study

LUSTs Specific combination of land, land use types (crops), and technologies with fixed input and output quantities

Merere Local name for heavy black clay soil

Oromia One of the administrative regions of Ethiopia in which the study area is located

Quintal Local unit of measurement for weight (1quintal equals 100 kilogrammes)

Timad Local unit of measurement for land (in EHAZ 8 timads equal 1 hectare)

Woreda Local Ethiopian name for district

ABSTRACT

This study aimed at developing and applying a methodology for land use analysis through looking for a form of land use that provides sufficient and rising incomes to the agricultural population of East Hararghe Administrative Zone, and at the same time maintains the productive capacity as well as other environmental services of the land resources of the zone.

The study starts with the elaboration of the problem statement, objectives, hypothesis and significance of the study. This is followed by the explanation of the approaches pursued in conducting the present study. The study area is also thoroughly described. The problem statement and the objectives of the study indicate that there exists a huge gap between zonal crop production and the population growth despite a substantial expansion of cropland in the zone. This implies the existence of numerous set backs in the land use system of the zone and necessitated a close investigation of the land use systems of the farming community of the study area in order to come up with an improved and efficient land use pattern that will overcome the acute land shortages as compared to the ever-increasing population of East Hararghe Administrative Zone.

The most important findings and results of this study are based on the literature study; the development of the research methodology; the description of the surveyed data that is obtained through questionnaire survey; and the analysis of the land use model of the study area. Land resource and land use was assessed from a global point of view. The problems that are associated with the use of the land resource in the developing countries were investigated. An extensive study was also carried out to introduce the agricultural sector of Ethiopia. The agricultural sector in Ethiopia is almost entirely dominated by small-scale, resource-poor farmers who produce 90 to 95 percent of all agricultural outputs. The role of economics within land use analysis is also reviewed. This role is elaborated through the discussion of a skeletal model of the agricultural sector; the concepts of regional agricultural planning, land evaluation and farming system analysis; the concepts of resource economics and land economics; and the issues of property rights and sustainable development.

A linear programming model for the economic appraisal of the land use in the study area was presented following the description of the conceptual framework of the model. The different parts of the zonal linear programming model were discussed under the headings of objectives, variables and constraints. This was followed by the general formulation of the land use model of the zone called EASTHAR. The matrix of the model includes three sub-matrices each representing a different farm type. The farm types are distinguished on the basis of agro-ecological classification of the surveyed districts and peasant associations. The EASTHAR model was analyzed by using the GAMS software after it was extensively written in the GAMS programming language.

Three land use scenarios are analysed to assess the effects of changes in factors that influence land use decisions and whether incomes of farms can increase through an

improved land use. The results of the base scenario indicated that the incomes of farms can increase with improved land use pattern as the value of the objective function, or the economic surplus, is positive for the entire zone and for the different farm types. The model showed, how land has to be assigned to the different crops at zonal level and at each farm types level for maximizing farm incomes under proper and improved resource use. The most important staple food crops of the population of the zone are all incorporated in the optimum land use and the potential for specialization that can exist among the different farm types of the zone has also been indicated.

A comparison of the results of the base scenario with the results of an opportunity cost scenario represented an important outcome of the model. The zonal economic surplus in the opportunity cost scenario is 33% lower than the base scenario. The valuation of the on-farm household labour thus has a negative effect on the incomes of the farm households. However, land use as well as labour, current input and draft power uses did not change from that of the base scenario. This shows that the mere valuation of the on-farm household labour will not automatically disturb land use decisions.

An interesting outcome was observed when comparing the results of the base scenario with the results of a scenario of an assumed drought condition. The drought case scenario analyzes the consequences for land use in case drought occurs in the study area. Drought is a recurring problem of Ethiopians especially the rural population. The results of the analysis indicated that almost every land use defining variable was subject to change when drought occurs. According to these results, in a subsistence agriculture which is solely rain fed, a decline in the annual rainfall will undoubtedly lead to large reductions in the income of the farming population.

Based on the results of the study important policy recommendations were outlined. The implementation of the envisaged improved land use patterns can have important impact in altering the poor income earning capacity of the farm households in the zone and have a better environmental impact. For farmers to produce the amount of grains required for home consumption and ensure their food security, there is a need to subsidize them to the amount of their lost gross margins during drought periods. Farmers must also be encouraged to save and have financial reserves for unforeseen adverse production conditions through the establishment of appropriate saving institutions to limit the subsidy. It may also be necessary for the government to approach donors to contribute to the subsidy, as this contribution will hopefully be lower than the cost of food aid in monetary terms. However, the dependence on food aid cannot be a preferable alternative and to supply enough food to the growing population of the region more food needs to be produced by the zone itself. This is because although other zones can produce food cheaply, for subsistence farmers who are producing crops mainly for home consumption (and not for the market) it is extremely hard (if not impossible) to engage in trade and rely on outputs produced in other zones.

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CHAPTER 1. THE RESEARCH PROBLEM

1.1 Introduction

Ethiopia remains one of the least developed countries in the world. The economy of Ethiopia is predominantly agriculture. Agriculture accounts for more than half of the GDP, 90% of exports, and 80% of total employment (http:/www.Africa.8m.net/cgi-bin/b/726/64/dXN1cmJhbm51cg. December, 2002).

Ethiopia's major staple crops include a variety of cereals, pulses, oilseeds, and coffee. Grains are the most important field crops and the chief element in the diet of most Ethiopians. The principal grains are teff, wheat, barley, maize, sorghum, and millet. The first three are primarily cool-weather crops cultivated at altitudes generally between 1,500 and 3,500 meters above see level. Sorghum, millet, and maize are cultivated mostly in warmer areas at lower altitudes along the country's western, southwestern, and eastern peripheries. Sorghum and millet, which are drought resistant, grow well at low elevations where rainfall is less reliable. Maize is grown chiefly between elevations of 1,500 and 2,200 meters above sea level and requires large amounts of rainfall to ensure good harvests (http:/www.1upinf.com/country-guide-study/ethiopia/ethiopia98.html. December, 2002).

Pulses are the second most important element in the national diet and a principal protein source. Pulses, grown widely at all altitudes from sea level to about 3,000 meters above sea level, are more prevalent in the northern and central highlands. Oilseed cultivation is also an important agricultural activity. The most important oilseeds such as the indigenous niger seed (neug), flaxseed, sesame and other oilseeds of lesser significance are grown at elevations ranging from 1,500 to 2,500 meters above sea level. The consumption of vegetables and fruits is relatively limited, largely because of their high cost. Common vegetables include onions, potatoes, tomatoes, peppers, and cabbage (http:/www.1upinf.com/country-guide-study/ethiopia/ethiopia98.html. December, 2002).

Similar to the country as a whole, in East Hararghe Administrative Zone, the study area, different types of crops are grown of which cereals occupy the largest proportion of the cultivated area. According to the information obtained from the East Hararghe Agricultural Development Department report (2000), the total area under major crops (cereals, pulses and oilseeds) was 363,504 hectares, of which cereal crops accounted for 280,392 hectares, pulses 68,427 hectares and oilseeds 14,685 hectares. The larger percentage of the cropped land of the zone was occupied by sorghum, maize, wheat and barley.

As agriculture is the main stay of the population of East Hararghe Administrative Zone, the land resource in the zone is by no means abundant as compared to the total requirement of the population. There is keen competition, though not perceptible in the short run, for land between crop production and livestock rearing activities. The urgent needs arising out of the increased demand for food for a growing population would bring more land under cultivation. The consequent squeeze on grazing resources, resulting from a decline in grazing land and an increase in livestock population, is likely to exacerbate the land degradation problem as well. This is because in subsistence farming conditions it is improbable that grain and crop stover (used as fuel wood) will be fed to animals. The practice in the zone is that farmers tend to raise livestock and also want to expand arable land simultaneously. Under this situation there is a lot of pressure on the land and this exacerbates the land degradation problem.

In Ethiopia food production declined consistently throughout the 1980s. During the 1990s, the performance of the crop sub-sector experienced an improvement compared to the 1980s. The increase in production during this period was mainly due to the advent of good weather; appropriate policies and strategies of government; and increased use of agricultural inputs such as fertilizer, improved seeds, chemicals, and herbicides (Tadesse Kuma, 2002). However, Ethiopia's demand for grain continued to increase because of population pressures, while supply remained short, largely because of drought and government agricultural policies, which adversely affect crop production. Population pressure is also a major cause of land fragmentation and decline of agricultural productivity in the highlands of the country (TGE, 1993; McCann, 1990).

The study area, East Hararghe Administrative Zone, is no exception to the above problems of Ethiopian agriculture. According to the 1994 Population and Housing Census report, this zone has an annual population growth rate of 2.23% for the rural and 4.11% for the urban areas. On the other hand the annual grain production growth rate in the zone is only 1.1% per year despite the expansion of the area of grain farms by 15.7% each year (Department of Planning and Economic Development, 1994), indicating an overwhelming food grain deficit in the zone.

1.2 Problem statement

East Hararghe Administrative Zone is said to be better in agricultural potential and natural resource endowment (see chapter three) as compared to other areas of the Oromia region. Nevertheless, the closure of the gap between the zonal crop production growth and the population growth was far from attainable despite a substantial expansion of cropland in the zone as indicated above. This clearly indicates that there are numerous set backs in the land use system of the zone for attaining food crops self-sufficiency in conformity with the needs of the ever-increasing population of the zone.

On the other hand, as shown in FAO (1992), land use has to change to meet new demands. This change brings new conflicts between competing uses of the land, and between the interests of individual land users and the common good. Land taken for towns and industry is no longer available for farming; likewise the development of new farmland competes with forestry, water supplies and wildlife.

In an effort to address the above situation there will be a need to focus on the efficient utilization of zonal potential resources, especially land. As it is well known, land is one of the most important resources in boosting agricultural production. In some areas of the zone, inaccessibility, water shortages, and infestation of disease-causing insects, mainly mosquitoes, etc. have prevented the use of large parcels of potentially productive land. In the lowland parts of the zone, for example, the presence of malaria has kept farmers from settling in many areas. Moreover, most agricultural producers of the zone are subsistence farmers with smallholdings, often divided into several plots. Most of these farmers are squeezed and live on the highlands, mainly at elevations of 1,500 to 3,000 meters above see level.

Therefore, there is an urgent need to closely investigate the land use systems of the farming community of the study area in order to come up with an improved and efficient land use system that will overcome the acute land shortages as compared to the ever-increasing population.

1.3 Objectives of the study

In light of the above, the study pursues the following major objective:

To develop and apply a methodology for land use analysis which aims at a land use system that provides sufficient and higher income to the agricultural population of East Hararghe Administrative Zone, and at the same time maintains the productive capacity of the land.

Moreover, in this study the specific objectives are to:

1. Build a farm and a sub-regional level linear programming model in land use analysis, for East Hararghe Administrative Zone, which can also be applied at the national level
2. Classify farms into different farm types according to their farming systems (operations) and on the basis of their agro-ecological zones
3. Determine whether the current land use system makes the best use of the limited resources through the application of an optimization technique so as to come up with an optimal land use system and cropping pattern in view of accepted objectives, and of environmental and societal opportunities and constraints.
4. Make policy recommendations that can help to move from the existing situation to

the optimal and sustainable land use system.

1.4 Research hypothesis

In line with the objectives pursued in this study the following research hypothesis will guide the investigation: -

The current land use system of the farming community in East Hararghe Administrative Zone does not allow optimal and best use of the limited zonal resources. Through the development and application of a research methodology for land use analysis that utilizes optimization techniques, it is possible to assess the current levels, manner and combinations in which the land as well as other resources in the zone are used and come up with an improved land use system and cropping pattern in view of accepted objectives, and of environmental and societal opportunities and constraints.

1.5 Importance of the research

Most of the agricultural economics research activities in Ethiopia are seen to be focused and being conducted in a very narrow geographical location (usually in a single district or woreda). This approach may lack the ability to indicate what is needed for an improvement in community development. It may also not be suitable for policy formulation at regional, national and country level and could be unable to show sub-regional potentialities.

Consequently, this study was initiated to address the above issues by focusing on a wider research domain with quite broader, tangible and primary data based research, and with the aim of developing a land use methodology and model at a sub-regional level, which is launched from the farm or the district level. Moreover, as it was observed during the literature study, no agricultural economics and / or agricultural resource economics research activity is so far conducted in such a wider research domain including fourteen districts (woredas) or more in the country. Therefore, this research is the first of its kind.

To this effect, the study is hoped to provide contributions in widening the research outlook of agricultural economics researchers in the nation, and thereby enhancing national agricultural development.

In line with this, the methodology developed in this study will provide valuable information to researchers through which they can become familiar with this methodology and be able to extend it to the national level for more comprehensive national agricultural actions. The methodology and the outcome of the study will also play important roles in formulating sub-regional, regional or national agricultural policies and thereby helping policy makers in overcoming fragmented action plans to upgrade the living standard of the rural community.

Moreover, the study would benefit the study area by providing a workable methodology of land use analysis which aims at a land use system that provides sufficient (and increased) incomes to the agricultural population of the zone and at the same time maintains the productive capacity of land. The contribution focuses in particular on the role of economic analysis. Furthermore, the study will help to show the production, resource and market potentialities of the sub-region with respect to the region as well as the nation, and encourages specialization and low cost inter-regional product exchange.

On the other hand the classification of the farms in East Hararghe Administrative Zone into farm types will assist researchers in recognizing the important farming types in the zone for subsequent research undertakings. This will also help the policy makers of the country to understand common sub-regional farm problems in the zone and alleviate these problems jointly thereby reducing costs of uncoordinated actions.

1.6 Scope of the study

East Hararghe Administrative Zone, the study area, consists of fifteen districts. However, this study covers only fourteen districts. The 15^{th} district, known as Golaoda, was not used during the primary data collection owing to remoteness and the lack of security in the district at the time of the survey. Moreover, according to the information obtained from the zonal agricultural office and European Union food aid experts, through personal communication during the survey, the district contributes the least in terms of the sub-regional total production (only 1.21% of the total zonal production) consisting of a small number of rather insignificant peasant associations, and it largely depends on food aid rather than engaging in productive activity.

To materialize the concept of sustainability in this study, it was planned to collect data on soil nutrient depletion and biocide use during the survey. In the case of biocide use, it was found that from the 210 farmers included in the survey only 11 of them applied pesticides and 6 of them used herbicides on only few crops. Hence there was no need to constrain the analysis by biocide use, as this very insignificant application was not regarded very detrimental to the environment. In the case of nutrient depletion, there was a need to obtain nutrient balances in the sub-region. As these data were not available during the survey, owing to the lack of documentation in the area, it was also not possible to include constraints on the use of nutrients in the analysis.

Farms in the study area were classified based on agro-ecological zones, as significant soil and land to labor ratio differences among farmers were not observed in the survey. Most farmers possess land plots of all major soil types in the study area. In addition to this only 8 major food crops were included in the study and the other minor (secondary) crops were accounted through the land area they occupy which means that the area occupied by these minor crops was deducted from the total available land used in the optimization model.

1.7 Arrangement of thesis

The thesis comprises of 8 chapters. After introducing the reader with the auxiliary parts of the thesis such as abstract, acknowledgements, table of contents, list of tables and list of figures, Chapter 1 presents and discusses the problem statement, objectives of the study and the research hypothesis.

Chapter 2 discusses the research approach utilized in conducting the study. In this chapter the sequences of the tasks performed in conducting the research work is introduced to the reader. These tasks start with an introduction which discusses the three phases that the whole research activity consisted of. This is followed by an explanation of the identification process of the research problem, the selection of the research area, the conducting of a literature study and the determination of the model to apply in this study. The chapter concludes with an illustration of the data collection and the data analysis processes of the study.

In Chapter 3 the study area is discussed. The most relevant information concerning East Hararghe Administrative Zone is presented in this chapter. Information with regard to climatic conditions, natural resources, soils, demographic profile of farm households, enterprise composition of farms, etc. is addressed.

The literatures reviewed in the study are presented in Chapter 4. In this part of the thesis an extensive discussion of the research performed on similar topics are presented. Important elements of resource economics, land economics, theories of resource use and property rights are discussed. Land as an economic resource is defined and related concepts of sustainable development are assessed. This is followed by discussion on methods and models in land use analysis. Moreover, the linear programming approach in land use analysis is investigated in depth.

The overall research model, utilized in the thesis, is presented in Chapter 5. In this chapter the use of linear programming models for land use analysis at both the farm and sub-regional levels are outlined. This formulation of land use activities with fixed input and output coefficients is similar to the common ways of thinking of many farmers about crop cultivation and livestock rearing. Furthermore, the three central components of linear programming; objective function, variables, and constraints, connect well with the basic idea of land use, i.e. the allocation of land for different land use types aiming at the best land use. Hence, the setting and the formulation of the zonal linear programming model, called EASTHAR, is the major task in this chapter.

In Chapter 6 a description of the surveyed data and the classification of the farms in the study area into farm types is presented. In here, various tables are employed in order to present summary statistics of information with regard to the extent, availability, and intensity of the use of land, material inputs, human labour, animal traction, outputs of crops, prices of inputs and outputs, and levels of costs and incomes. In addition to this, information on the relative importance of the major crops in each district, household demographic features and the farming problems of farmers are discussed. Moreover, in this chapter, the farms in the study area are grouped into farm types. This helps to distinguish between the farm and the sub-regional levels of analysis, and lays the foundation for the latter analysis in Chapter 7. Furthermore, distinguishing farm types provides an understanding of the difference that exist among farm types with regard to land use and income distribution aspects.

Chapter 7 deals with the analysis and the discussion of the results of the sub-regional model of land use for the entire zone. Through the incorporation and the study of possible scenarios, the effect of changing land use determinants or different policies regarding land use and farm incomes, at sub-regional level, is assessed in this chapter.

The study ends with Chapter 8 by providing summary, conclusions and recommendations regarding the proposed approach for land use analysis on the basis of the results of the study.

CHAPTER 2. RESEARCH APPROACH

2.1 Introduction

In this chapter an overview of the research approach, which is applied in the study, is given.

This Ph.D. study, which started in 2000, was sub-divided into three phases. The first phase consisted of undertaking course work and developing a research proposal while staying at the University of the Free State, in the department of Agricultural Economics. Consequently, in 2000 a research proposal was developed and endorsed by the department of Agricultural Economics after a seminar was given on the proposal. A questionnaire was developed as part of the proposal.

The second phase of the research consisted of conducting a field survey in Ethiopia, as the research was to be conducted on 'sandwich' basis. This was carried out from January 2001 to July 2002.

The third phase comprised of analyzing the collected field and secondary data as well as the write up of the thesis. This was scheduled to be undertaken at the University of The Free State, South Africa and was done starting from August 2002 and was concluded in the year 2003.

With the above introductory remarks regarding the different phases in which the research was conducted, the research approach as applied in this study is described below. This research approach basically consists of doing the under-mentioned tasks:

- Identifying research problem
- Selecting a research area and stratification
- Conducting literature review
- Determining the model to apply

- Data collection
    - Developing questionnaire
    - Sample drawing
    - Conducting fieldwork
- Data analysis

Each of the above activities of the research methodology is elaborated on below.

2.2 Identifying research problem

The research problem was the starting point of the study, which is described in detail in chapter one.

The identification of the research problem was conceived after observing the ever-increasing recent concerns for land use around the globe as well as in Ethiopia. Some of these concerns include: Are the land (and water) resources able to supply sufficient products (food and other) to sustain a growing population and provide the agricultural population with increasing incomes? Will land and water resources be able to maintain their productive capacity over time, and provide sufficient living space and environmental amenities? The answers to these kinds of questions range from pessimistic to optimistic. The pessimistic answer is mainly based on extrapolating present trends of population growth, and of agricultural production and productivity, while the optimistic one is based on comparing population trends with what could potentially be produced by land and water resources in different regions of the earth (Schipper, 1996).

As also expressed by Miranowski and Cochran (1993), agriculture is an activity that modifies the natural environment for the purpose of enhancing the flow of goods and services from natural resources. Accompanying these environmental modifications are the consequences that may impair the long-run potential of the land to sustain production of agricultural goods and services and impair the flow of other goods and services from the land, air, and water.

In Ethiopia, where the study area is located, there is a continuous redistribution and reallocation of individually cultivated land among members of the rural farming community for the purpose of ensuring that the would-be-farmers or the newly-formed households could get land (Tekie, 2000). This automatically leads to extreme fragmentation of land, which could actually reach a point of no economic significance in terms of agricultural production. This has been clearly pointed out as well by Bedassa (1998) when he indicated that there is a shortage of cultivated area in many parts of Ethiopia, particularly in the highlands, of which East Hararghe is one. This must be seen against the fact that there is no significant rental market for land in the zone since the land does not belong to the farmers.

In view of all the above arguments, it was decided that there is an urgent need to closely investigate the land use system of the farming community in the study area in order to deal with the acute land shortages as compared to the ever-increasing population of the area as well as the country. Hence, the researcher was convinced of pursuing an economic analysis of land use in the study area for which the detailed problem statement is given in section 1.2 of Chapter 1.

2.3 Selecting a research area and stratification

The study area, East Hararghe Administrative Zone, is one of the twelve administrative zones of the Oromia region in Ethiopia. It is located in the eastern part of the region as its name indicates. In terms of area coverage, East Hararghe Administrative Zone is the 5th largest zone, in Oromia region, with a total area of 22,623 Km^2 (6.2% of the total area of Oromia region). According to the 1994 National Population and Housing Census of Ethiopia, the total population of the zone in 1999 is projected to be 2,054,496 (9.4% of the total population of the Oromia region). A detailed description of the study area is presented in chapter three.

The selection of this area as a research site was based on the following arguments and reasons:

(1) First and foremost, the study was planned to be conducted on a wider geographical area, such as a sub-region, for the very reasons that are explained in chapter one. Such a wider research perspective has got its own relevance, particularly when it comes to land use analysis and agricultural economics research activity, and the reader is referred to Chapter 1 for a better understanding of the importance thereof. As a result, in comparing different sub-regions for the purpose of selecting a study area, East Hararghe Administrative Zone was found to possess the advantage of being close to the vicinity of the work place of the researcher, Alemaya University. Consequently, it was found convenient in terms of arranging transport facilities, obtaining skilled enumerators and for other logistical purposes.

(2) Second, all the three prominent agro-ecological zones of Ethiopia (which are elaborated on in chapter three) are also found in East Hararghe Administrative Zone. This will make the zone to be a typical representation of the country, as far as agro-ecological zones are concerned, and enable the stratification of farms into separate farming systems based on agro-ecological zones and analyze the land use accordingly. Moreover, the results of the study could be applicable countrywide as it is based on data collected from all the prominent agro-ecological zones of the nation.

(3) Last but not least is that, as indicated above, East Hararghe Administrative Zone is one of the most populous administrative zones of the Oromia region. It accounts for 9.4% of the regional population and is the fourth most populous following West Shewa, Arsi and Jima zones (Central Statistical Authority, 1996). Moreover, in terms of agricultural production it is the leading zone in crop production consisting of large areas of cropped land (elaborated in chapter three). This places East Hararghe Administrative Zone in a position, which makes it suitable for land use study owing to the large number of the population living in rural areas that solely depend on the land (through farming) in obtaining its

livelihood. According to the Central Statistical Authority (1996) 94.2% of the total population of the zone are rural residents.

2.4 Conducting literature study

An extensive literature study is conducted in Chapter 4 by referring to a wide variety of books, journal articles, dissertations and other relevant documents, in order to determine a research model to be used in the study, to obtain a theoretical framework for questionnaire development, and to substantiate the present theme of land use analysis with previous similar research activities.

Consequently, the land resource and land use is assessed from a global point of view. A thorough investigation is made on the problems that are associated with the use of the land resource amid the ever-increasing population of the developing countries. Moreover, an extensive study is carried out to assess the agricultural sector, the land resource and the land use practice in Ethiopia.

An in depth literature study is also conducted to cover some economic theories that facilitate the understanding of the concept of land use and land use analysis. In addition to other resources, the use of land, and especially the limitations of land in relation to population growth, is studied as one of the concerns of resource economics. It was noted that land economics, as a branch of resource economics, is concerned with the allocation and use of scarce resources, mainly the land resource. As institutional factors are important factors that can influence sustainable agricultural production (Bedassa, 1998), institutional aspects of land use, particularly that of property rights is also investigated. As noted by Van Zyl, *et al* (1996) past property right regimes that allowed almost unrestricted use of natural resources by favoured groups in society poses the most serious environmental threat in low-income developing economies and should therefore be confronted through improved access to land in order to protect the environment. The concept of sustainable development in relation to land use and agricultural production is assessed in depth.

An investigation of some methods used in land use analysis and planning is a component of the literature review. The other important part of the literature study consisted of an assessment of the applications and the importance of linear programming models in land use analysis. It was explained that, in recent years, mathematical programming, of which linear programming is one example, has become an important and widely used tool for economic analysis in agriculture.

2.5 Determining the model to apply

Based on the literature study, a model of land use analysis was developed as shown in Chapter 5. According to the literature studied, the linear programming optimization model was selected as a particularly suitable one for this study (Hazell and Norton, 1986). This is because farmers, agronomists, and other agricultural specialists share a common way of thinking about agricultural inputs and outputs in terms of the annual crop cycle, and about input-output coefficients per acre or hectare or other unit of land. Yields are conceived of in tons or bushels per land unit, and fertilizer applications in kilograms per hectare or like units. In farm-level cost of production studies, input costs are typically disaggregated into labour, machinery services, draft animal services, fertilizer costs, other chemical costs, etc., per land unit. This way of visualizing agricultural production in numbers is a short step to forming the column vectors of inputs and outputs that constitute the backbone of the programming model (Hazell and Norton, 1986).

Similarly, agriculturalists often pose their problems in terms of inequality constraints, such as upper bounds on seasonal resource availability. And they are accustomed to the existence of slack resources in some seasons while the same resources are fully utilized in other seasons. This kind of thinking fits naturally into an analysis via programming models (Hazell and Norton, 1986).

Furthermore, as described by Schipper (1996), linear programming, as a method of analysis, is best suited to questions of allocation of resources at the farm and sub-regional level (which is one of the aims of the present research) for a given set of market conditions. He indicates that econometric methods are better suited to analyze product and factor markets at higher levels of aggregation while linear programming is more justified at the farm or sub-regional level than at the regional, sectoral or national level, because of the assumption of fixed prices[1].

On the other hand, looking for optimal land use is analogous to the principle of linear programming or other optimization models, in which an objective function is maximized by selecting from alternative activities, subject to constraints. Linear programming can thus be of help in the search for the best land use.

Therefore, in this study, a linear programming model is utilized as a tool for land use analysis at farm and sub-regional (zonal) levels. Linear programming models used at these levels are also potentially useful for policy formulation with regard to land use and related sustainable agricultural development as described by Schipper (1996). Consequently, the precise formulation of the linear programming model used for the economic appraisal of the land use in the study area is given in Chapter 5.

2.6 Data collection

2.6.1 Developing questionnaire

In order to determine the optimality of resource use, information on the extent, availability, and intensity of the use of land, material inputs, human and animal power; outputs of crops and levels of costs and incomes are required. Prices of inputs and outputs are another set of information required to quantify the productivity of resources. In this regard the study primarily focuses on the major agricultural crops of cereals, pulses, oilseeds and vegetables.

In this study both primary and secondary data are employed. The primary data were collected from the study area through a farm survey, which was done to establish

[1] See Chapter 4 for clarification

relationships between land, land use types, input and factor use, outputs, and economic returns. The survey was conducted by utilizing structured questionnaires. Structured questionnaires were used as the influence of the interviewer is not required and the recording of the responses is usually straightforward (Bless and Higson-Smith, 2000). The questionnaire is intended to obtain primary information concerning present land use such as farm size, crop types, farm labour, etc. and current farm problems in the study area.

On the other hand, the secondary data which includes information on the climatic conditions, natural resources, development status and aspects of human and livestock population are vital and are gathered from secondary sources such as administration offices at the district levels, at zonal levels and special institutions which foster development. Additional sources of secondary data were mainly published materials from libraries and organizations (such as scientific reports, publications, theses and dissertations), and zonal and district unpublished materials.

2.6.2 Sample drawing

In order to conduct the survey in the zone it was necessary to identify the number of districts and peasant associations in the zone. There was also a need to identify the number of farm households, total population and total land use at each district level. This preliminary information was obtained from the zonal agricultural head office and respective district agricultural offices.

The study area, eastern Hararghe administrative zone, comprises 15 districts, which are subdivided into 417 Peasant Associations (PAs) and 17 urban kebeles. The study covers 14 of these districts. The investigation excludes the district called Golaoda due to its remoteness and security problems, which made virtually impossible the collection of data from the district.

Based on this information, 15 sample farmers were randomly selected from a randomly chosen peasant association in each of the fourteen surveyed districts in the zone and the total sample farmers are 210 for the entire zone (sub-region).

In addition to this survey, information obtained from group discussions with experts consisting leader farmers, extension officers and other researchers were also utilized to enrich the primary data.

2.6.3 Conducting fieldwork

The fieldwork started with the activity of pretesting the questionnaire, which was developed for collecting the primary data. This was successfully conducted and some relevant modifications were incorporated into the final questionnaire based on the information grasped through the pretesting activity.

In launching the actual survey two enumerators were employed for each peasant association in order to assist the researcher in conducting interviews with the sample farmers. The selection of the enumerators was based on the criteria that they had to have completed high school (grade 12), know how to read, write and communicate in English as well as in the local languages of the farmers, got training as a development agent for at least 6 months and work as an extension or development agent (DA) with farmers for a minimum of one year. The enumerators, who were employed on the basis of the above criteria, were then trained by the researcher for two weeks in order to teach and familiarize them with the content of the questionnaire and the basic theme of the research work. The above task has been accomplished successfully and the fieldwork was conducted in the year 2001/2002.

2.7 Data analysis

As a preliminary step of the data analysis, a descriptive analysis of the surveyed data was done which is presented in Chapter 6. Various tables, charts, figures and graphs are employed in order to present summary statistics of information with regard to the extent, availability, and intensity of the use of land, material inputs, human labour, animal traction, outputs of crops, prices of inputs and outputs, and levels of costs and incomes. In addition to this, information on the relative importance of the major crops in each district, the climatic conditions, natural resources, development status, and aspects of human and livestock population, etc. are presented and discussed in detail.

As a major part of the data analysis, in this study, the data collected are analysed using a linear programming model. The model can be referred to as a sub-regional land use model, which is based on data obtained from 14 districts in East Hararghe Administrative Zone. The model can be classified as being an agricultural sector model as it is formulated for the agricultural sector of the study area. It can also be classified as being a fixed price model as all the prices, both the input and the output prices, are exogenously determined.

The land use analysis, which is based on the linear programming model, aims at deriving relevant land use options by balancing economic criteria for agricultural production with ecological criteria. Three levels of analysis (farm, farming system and sub-region) are incorporated into the methodology of land use analysis. At each level of analysis different decisions are made. In East Hararghe Administrative Zone, as a sub-region of the Oromia region in Ethiopia, land use decisions are made at the farm level, influenced by policy decisions at sub-regional, regional, and national levels. And in the linear programming model two levels of decision-making are incorporated: land use decisions at the farm level and policy decisions at the sub-regional level. The latter thus including decision-making at levels higher than the farm level.

Because of aggregation issues[1], modeling land use is complicated. The first aggregation issue, decision-making both at the farm as well as the sub-regional level, is approached by using a reasonable objective function for farm households namely, maximization of the difference between the value and the cost of production, including household and hired labor, plus off-farm earnings. This objective function, which maximizes economic surplus, is calculated as the farm household income minus a valuation of on-farm

[1] The reader is referred to Chapter 4 for detailed discussion of aggregation issues

household labor. In this way the effects of policies at the sub-regional level on land use decisions can be studied. The second aggregation issue, aggregation bias, is diminished by incorporating three farm types in the sub-regional model, each with specific resource availabilities with regard to land and household labor. The third aggregation issue, exogenous variables becoming endogenous, is sidestepped by supposing that the sub-region is sufficiently small in relation to the country and that the supply from the sub-region is too small to influence prices of products. On the other hand, a restricted sub-regional labor supply forms part of the model: all farms together cannot hire more labor than is available within the sub-region. However, the price of hired labor is fixed.

Land use activities (LUSTs) are the main component of the model. LUSTs are defined as a combination of land use type and a specified technology. At present, the model of this study contains eight land use types: sorghum, maize, wheat, barley, horse beans, groundnuts, potatoes, and green pepper.

For each land use system different technologies are specified. Each LUST is described quantitatively as a sequence of operations and summarized in input and output coefficients (quantities or values per hectare) for use in the linear programming model: land requirements, labor requirements, costs of variable inputs, input quantities, prices, labor costs, production specified per product, etc.

In the sub-regional linear programming model, a number of variables are included per farm type: LUSTs and the use of farm household and hired labor. All labor variables are specified per month.

In addition to variables, a number of constraints are stipulated per farm type as well: the availability of land, and the availability of household labor, both specified per month. The latter is also specified per year.

After this introduction of a possible set-up of a linear programming model in land use analysis, the precise formulation of the model in East Hararghe Administrative Zone is presented in Chapter 5.

CHAPTER 3. RESEARCH AREA[1]

3.1 Introduction

Ethiopia, the home country of the study area, East Hararghe Administrative Zone, is one of the largest tropical African countries located in east Africa.

Ethiopia is bordered by Eritrea in the north, Djibouti and Somalia in the east, Sudan in the west and Kenya in the south. Ethiopia is a land-locked country. Although there are a number of seismic areas in the country, there are no active volcanoes. The main mountain ranges are in the northern part of the country, the Semien Mountains, with Ras Dashen about 4550 meters above sea level. The central highlands are the second range of mountains, with Mountains Batu and Karra rising more than 4300 meters above sea level. The Rift Valley almost cuts the country into two starting from northeast and extending across the center to the southwest. There are a number of lakes in the Rift Valley area, mostly in the south and southwest. The Blue Nile, known as Abay in Ethiopia, runs for about 800 kilometers inside Ethiopia cutting across the northwestern part of the country. The two longest rivers in the country are the Awash and Wabishebele rivers, both flowing from the highlands to the lowlands in the southeastern direction. There are many other rivers in the country, making it, potentially, capable of producing about 2 billion MW of hydropower per year (http://www.tradepartners.gov.uk/, December 2002).

According to a census report by the Central Statistical Authority in July 2002, Ethiopia has 67.2 million people. Approximately 88% of the population lives in the rural areas. The national literacy level is roughly 24%; urban literacy stands at 69%; average age is 25 years; average life expectancy is 48 years. The Ethiopian Orthodox Church is the main church in Ethiopia, with Christians making up approximately 40% of the population. There is also a large Muslim community, (40 - 45%), made up mostly of Arabs, Somalis

[1] Unless mentioned otherwise, most of the information in this chapter is taken from Zonal Atlas of East Hararghe (2001).

and Oromos. The remainders are Animists and others (http://www.tradepartners.gov.uk/, December 2002).

Ethiopia has a temperate climate in the highlands where the average temperature is about 20 degrees Celsius. The lowland areas are hot with temperatures averaging 35 degrees Celsius. There are two rainy seasons, the light rains from February to March, and the summer rains from mid June to mid September (http://www.tradepartners.gov.uk/, December 2002).

3.2 Location and administrative sub-divisions of EHAZ

The study area, East Hararghe, is one of the twelve administrative zones of the Regional State of Oromia, according to the 1991 administrative divisions of Ethiopia. As its name manifests, it is located in the eastern part of the Oromia region. The geographical location of the zone is $7^{0}32'$ N – $9^{0}44'$ N latitude and $41^{0}12'$ E – $42^{0}53'$ E longitude (Planning and Economic Development Office for East Hararghe, 2001).

East Hararghe Administrative Zone has 824 km borderlines with Somali Regional State in the east, southeast, north and northeast, Dire Dawa administrative council in the north, West Hararghe administrative zone in the west and Bale administrative zone in the south. Harari Regional State is enclosed within the zone. East Hararghe Administrative Zone has the longest borderline of 466 km with the Somali Regional State, which accounts for 56.6 % of the total border length of the zone. It shares the least borderline with Dire Dawa administrative council. Harar, located in the eastern part of the zone, is the capital city of East Hararghe Administrative Zone and is 525 km from Addis Ababa (the capital city of Ethiopia).

East Hararghe Administrative Zone is divided into 15 districts, which are again sub-divided into 417 peasant associations and 17 urban kebeles. The largest district is Girawa with an area of 5,966 km^2 (26.4% of the zonal area), while Kurfachele is the smallest with an area of 302 km^2 (1.3% of the zonal area).

The administrative sub-divisions of East Hararghe Administrative Zone are shown in Figure 3.1 and Table 3.1 shows the area coverage, the capitals, and the number of peasant associations of the districts in East Hararghe Administrative Zone.

Table 3.1 Area, capital, and number of peasant associations of the districts in EHAZ

No.	District	Number of peasant associations	Area In Km^2	Percent of zonal area	Capital town
1	Babile	14	3022	13.4	Babile
2	Bedeno	38	974	4.3	Bedeno
3	Deder	33	878	3.9	Deder
4	Fedis	23	2194	9.7	Boko
5	Golaoda	22	3849	17.0	Burka
6	Gorogutu	27	531	2.3	Karamille
7	Girawa	46	5966	26.4	Girawa
8	Gursum	36	967	4.3	Fugnenbira
9	Alemaya	33	522	2.3	Alemaya
10	Jarso	18	488	2.2	Ejersa-goro
11	Kombolcha	14	554	2.4	Melka rafu
12	Kurfachele	14	302	1.3	Kurfachele
13	Melkabelo	23	1147	5.1	Jaja
14	Metta	41	684	3.0	Chalenko
15	Kersa	35	545	2.4	Kersa
East Hararghe		417	22623	100	-

Source: Zonal Atlas of East Hararghe (2001)

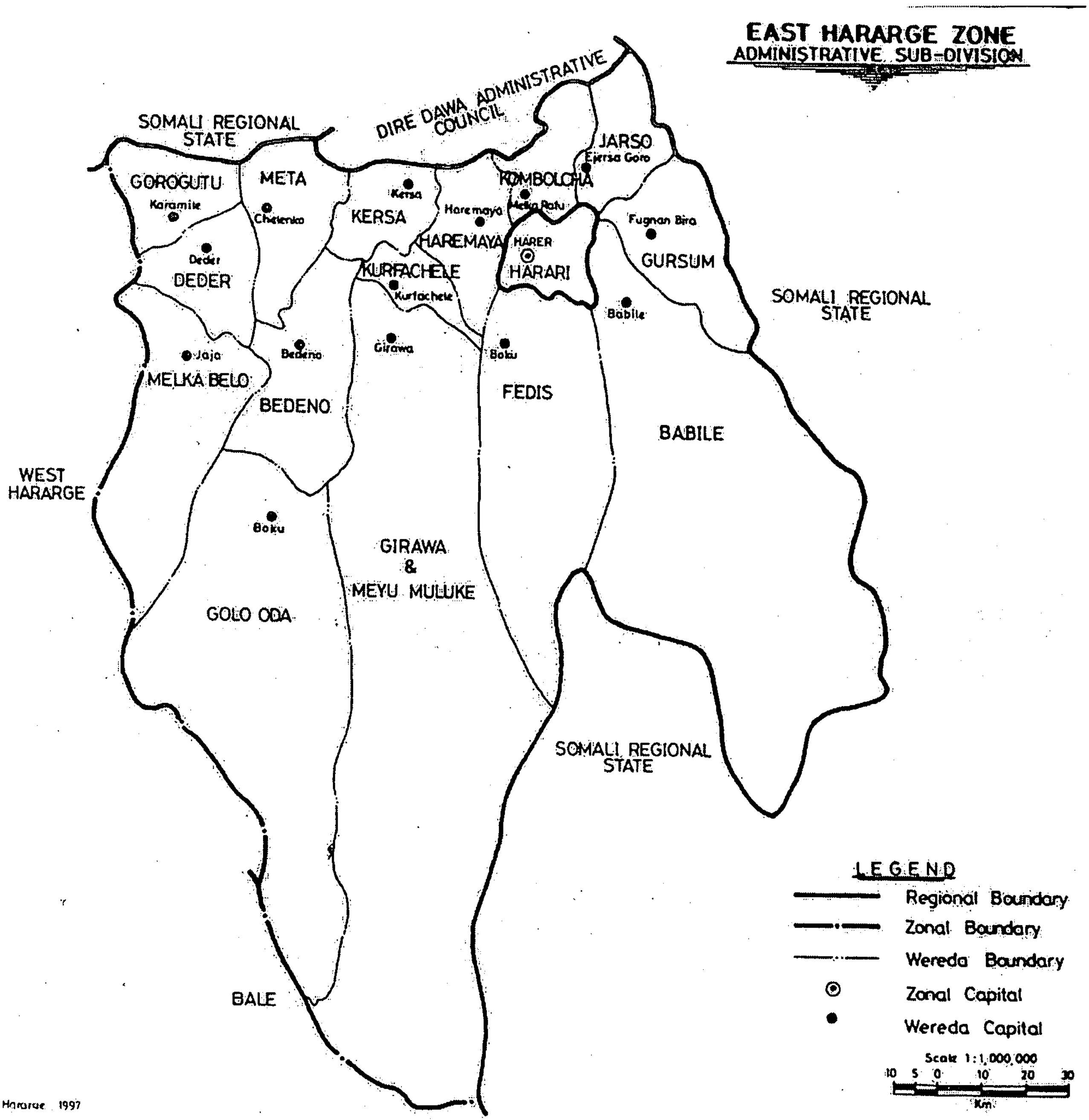


Figure 3.1 East Hararghe Administrative Zone sub-division

Source: Zonal Atlas of East Hararghe (2001)

3.3 Physical characteristics

3.3.1 Climatic regions

Climate is an important geographic factor, which affects human activities and other components of the environment such as plant and animals, soil and geomorphology, and water bodies. In turn the climate of an area is controlled by altitude of the area, latitudinal location, direction of wind and its distance from water bodies.

Climatic regions range from arid and tropical to wet areas and from hot lowlands to cool tropical highlands. Each climatic region has a characteristic vegetation of its own. The climatic regions prevailing in East Hararghe Administrative Zone can be grouped into three major categories.

1. Arid climate
2. Tropical climate - coldest months above 18^0C
3. Tropical highlands – coldest months 3^0C - 18^0C

The arid climatic region is found in the southeastern and northern part of the zone. This climatic region is in turn sub-divided into semi-arid and steppe climate. The semi-arid climatic region is characterized by poor sparse vegetation with mean annual temperatures of 27^0C to 39^0C and mean annual rainfall of less than 450 mm. In this type of climate the rate of evapotranspiration exceeds precipitation. This climatic region is found in the southern tip of the zone, in Girawa district. The steppe climate is characterized by steppe type vegetation with tall and coarse grass, which is less palatable to animals in the dry period. Its mean annual temperature varies between 18^0C and 27^0C. The mean annual rainfall of steppe climate ranges between 400-820mm with noticeable variability from year to year. It forms an intermediate climatic region between the arid and humid climatic regions. This type of climatic region is found in the southern, eastern and northern parts of the zone.

The tropical climatic region is characterized by sub-humid to pre humid with the mean annual rainfall of 600 – 2800mm and the mean temperature of the coldest month is above 18^0C. This climate has savannah vegetation with tall and luxuriant grass with open woods. It has dry months in winter and prevails in areas which have elevations up to 1750 meters above sea level. This climatic region is found in the western and central parts of the zone.

The climatic region of tropical highlands is characterized by dry winter months and 3^0C-18^0C mean temperatures in the coldest months. The annual rainfall is between 1000mm and 2000mm. The altitude at which this region is located is above 3500 meters above sea level. This type of climatic region occupies the western and central highlands of the zone. The agro-climatic zones of East Hararghe Administrative Zone are summarized in Table 3.2.

Table 3.2. Agro-climatic classification of East Hararghe Administrative Zone

Agro climatic zone	Altitude (meter above sea level)	Temperature (^{0}C)	Area coverage in the zone (Km$^{2)}$	Percent of area covered in the zone (%)
Arid climate	500-1500	20-25	14076	62.2
Tropical climate	1500-2300	15-20	5958	26.4
Tropical highlands (temperate)	2300-3300	10-15	2589	11.4
Total	-	-	22623	100

Source: Zonal Atlas of East Hararghe (2001)

3.3.2 Rainfall pattern

In East Hararghe Administrative Zone, southwesterly winds, southeasterly winds, northeasterly winds and high-pressure cells developed over northeast Africa and the Arabian Peninsula mainly control the duration, amount and spatial distribution of rainfall.

The distribution of rainfall in East Hararghe Administrative Zone can be categorized into four seasons:

(1) Summer (June, July and August) – Southwesterly winds cause summer rain for the greater portion of the zone particularly the central high plateau, which stretch from the west to the east. The summer rainfall decreases to both directions, north to south-east of the zone and being nil in southern extreme parts of Girawa, Golaoda, Melkabelo and Babile districts because of the rain shadow effects of central mountain ranges.

(2) Winter (December, January and February) – during this season, the whole of the zone comes under the influence of dry northeast trade winds. In general, it is a dry period.

(3) Spring (March, April and May) – spring is the second highest rainfall season for the zone, particularly for the southeastern low plateau and southern lowlands of the zone.

(4) Autumn (September, October and November) – autumn is the second largest rainfall season for the northern low plateau and plain. For the northern lowland facing plateau and plain, it is the period of high rainfall. However, autumn is a period of least precipitation for the region.

As far as the mean annual rainfall is concerned, the central highlands of East Hararghe Administrative Zone, particularly the western sub-areas of the zone (Chercher-Garamulata mountain ranges) receive between 900 and 1200mm. The eastern sub-areas of the zone receive mean annual rainfall of 600-900mm and the southeastern low plateaus and plains facing Ogaden lowland receive a mean annual rainfall of less than 500mm.

Therefore, as one goes from the central highlands of the zone to south, east and north, the amount of rainfall shows a general decreasing trend. This also implies an increase in variability and a decrease in reliability. In the Oromia region in general and in East Hararghe in particular, where the livelihood for the rural population is based on rain fed agriculture, the rainfall amount and its reliability are very important. The main causes for the considerable variation in the mean annual distribution of rainfall in the zone are the differences in altitude and direction of moisture bearing seasonal air currents.

3.3.3 Altitude, temperature and evapotranspiration

Altitude is one of the determining factors of climatic elements (temperature and rainfall). As altitude increases temperature decreases and the amount of rainfall increases. On the other hand, there is and inverse relationship between altitude and evapo-transpiration, i.e., as altitude increases evapo-transpiration decreases and vice versa.

The lowland parts of East Hararghe Administrative Zone, particularly the south and southeastern lowlands and the Rift Valley escarpment, with altitudes ranging between 800-1500 meters above sea level experiences the highest temperature of about 24-28 degrees Celsius during the warmest month and 20-24 degrees Celsius during the coldest month. The corresponding potential evapo-transpiration to the prevailing altitude and temperature ranges from 1200 to 1600 mm per year, which is the highest in the zone.

On the other hand, low temperatures and low potential evapo-transpiration characterize the highlands of the zone with an altitude of greater than 2300 meters above sea level. This covers most parts of Deder, Meta and Bedeno districts, and northern part of Jarso district. Temperature experienced by this part of the zone ranges from 16-20 degrees Celsius during the warmest month and 13-16 degrees Celsius during the coldest month, and the corresponding evapo-transpiration ranges from 800-1000 mm per year.

The north-central highland part of the zone with altitudes of 1500-2300 meters above sea level experience a potential evapo-transpiration ranging between 1100-1250mm per year with the corresponding temperature range of 16-20 degrees Celsius and 20-24 degrees Celsius during the coldest and warmest months respectively.

3.4 Demographic characteristics

3.4.1 Population size and distribution

According to the 1994 population and housing census report, the total population of East Hararghe Administrative Zone was projected to be 2,054,496 for the year 1999 G.C. by taking the annual growth rate of 2.23% for the rural and 4.11% for the urban areas. East Hararghe Administrative Zone accounts for 9.4% of the population of Oromia region and is the fourth most populous zone in the region following West Shewa, Arsi and Jimma zones. In 1999, of the total population of the zone 94.2% were rural residents while 5.8% lived in urban areas. This implies that the majority of the population of the zone lives in rural areas and relies on subsistent agriculture. The size of the population of East Hararghe Administrative Zone is depicted in the following table (Table 3.3).

The population of the zone is unevenly distributed. The eleven highland districts of the zone, namely Bedeno, Deder, Gorogutu, Gursum, Alemaya, Jarso, Kombolcha, Kurfachele, Melkabelo, Meta and Kersa, which constitute only about 33.6% of the total area of the zone, are inhabited by 76.9% of the zonal population. On the other hand, the lowland and nomadic districts of the zone, despite of their larger area coverage support few people, which is about 23.1% of the total population of the zone. As shown on the population distribution map (Figure 3.2) below, the northern part of the zone, and the central highlands support larger number of population. On the other hand, the southern parts of the zone including Golaoda, Girawa, Fedis, Babile and Melkabelo districts have relatively small populations.

Table 3.3. Total population of East Hararghe Administrative Zone by district

District	Population					Area of district (km^2)	Density (person/ km^2)
	Rural	Urban	Total	Percent of the zone	Percent of urban population		
Babile	45790	11247	57037	2.8	19.7	3022	18.9
Bedeno	190877	5455	196332	9.6	2.8	974	201.6
Deder	184744	17229	201973	9.8	8.5	878	230.0
Fedis	164872	3174	168046	8.2	1.9	2194	76.6
Golaoda	29500	2749	32249	1.6	8.5	3849	8.4
Gorogutu	113206	5300	118506	5.8	4.4	531	223.2
Girawa	212872	5308	218180	10.6	2.4	5966	36.6
Gursum	159391	10589	169980	8.3	6.2	967	175.8
Alemaya	165272	22728	188000	9.2	12.1	522	360.2
Jarso	97895	2123	100018	4.9	2.1	488	205.0
Kombolcha	86323	6716	93039	4.5	7.2	554	167.9
Kurfachele	39978	3370	43348	2.1	7.8	302	143.5
Melkabelo	130997	7048	138045	6.7	5.1	1147	120.4
Meta	185180	8511	193691	9.4	4.4	684	283.2
Kersa	127719	8333	136052	6.6	6.1	545	249.6
Total	1934616	119880	2054496	100	5.8	22623	90.8

Source: Zonal Atlas of East Hararghe (2001)

The unevenness of the distribution of the population of the zone is primarily the result of the differences in the suitability of environmental conditions for settlement and secondly the result of socio-economic and historical factors.

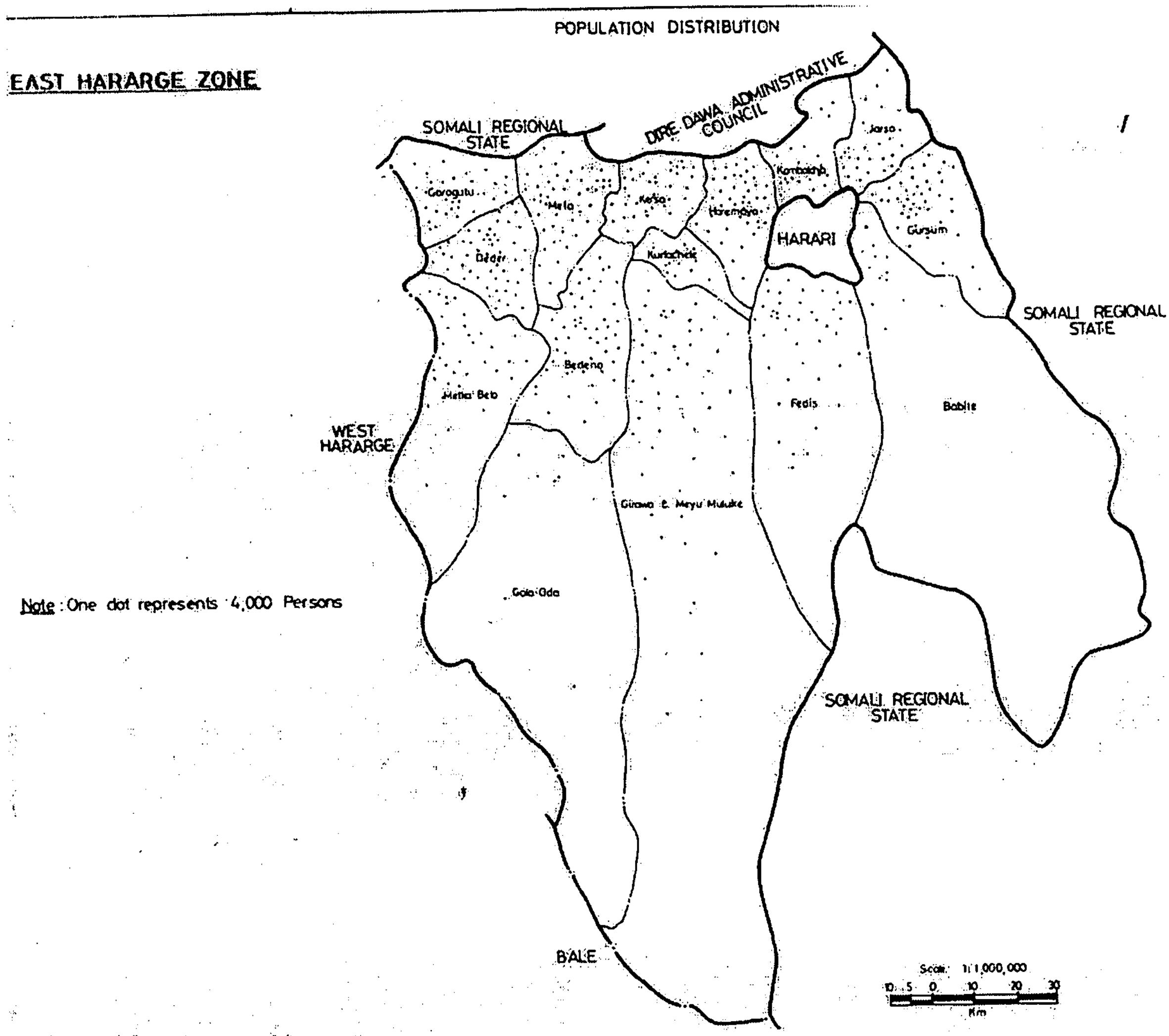


Figure 3.2 Population distribution of East Hararghe Administrative Zone

Source: Zonal Atlas of East Hararghe (2001)

The major environmental factors that influence population distributions are terrain characteristics (relief), climate, soil fertility, water, and disease prevalence for both humans and animals. The non-environmental factors that contribute to the variation of population distribution are accessibility or the development of communication network, base social infrastructure such as schools, health facilities, potable water, etc. Thus the central highlands of the zone, which have suitable environmental conditions for cultivation, better health conditions, and fairly accessible social infrastructure, support a large number of population. On the other hand, the southeastern lowlands, which are characterized by insufficient rainfall, high temperature and high incidence of disease such as malaria, have smaller numbers of population. Here pastoral nomadic activity is the dominant way of earning a living, which force them to move from place to place in search of water and pasture for their livestock. Hence, as shown in Figure 3.2, these areas of the zone are sparsely populated.

Moreover, as shown in Table 3.3, Girawa district accounts for the largest proportion of the zonal population (10.6%), followed by Deder (9.8%), Bedeno (9.6%), Meta (9.4%) and Alemaya (9.2%). The districts of Babile, Kurfachele and Golaoda support the lowest proportions of zonal population, 2.8%, 2.1% and1.6%, respectively.

3.4.2 Population density

East Hararghe Administrative Zone, as indicated earlier, has a total population of 2,054,496 distributed over an area of 22,623 km^2. This gives an overall zonal population density of 90.8 persons per km^2. However, this varies from district to district and ranges from 360.2 persons per km^2 in Alemaya district to 8.4 persons per km^2 in Golaoda district.

As shown in Table 3.3, eleven districts of the zone that together accounted for 33.6% of zonal total land area support about 76.9% of the zonal population, with an average density of 214.6 persons per km^2. These districts are included under the higher density category that ranges from 101 to more than 300 persons per km^2 (see Table 3.4). On the other hand, four districts including Golaoda, Babile, Girawa and Fedis, that constitute about 66.4% of the zonal total area support only 23.2% of the zonal population with an average density of 35.13 persons per km^2. Of these districts, Golaoda and Babile fall under the category of low density (ranges from 15-30 persons per km^2) while Girawa and Fedis district are included under the intermediate density category (ranges from 31-100 persons per km^2).

The most densely populated district in East Hararghe Administrative Zone, as shown in Table 3.3, is the Alemaya district with 360.2 persons per km^2. The districts of Meta, Kersa, Deder, Gorogutu and Jarso stand as the next densely populated ones possessing 283, 249.6, 230.1, 223 and 205.1 persons per km^2 respectively.

Table 3.4 Population density of East Hararghe Administrative Zone by density category

	Area		Population		
Density category	Km^2	Percent of the zone	Number	Percent of the zone	Districts
Low density (15-30 persons per km^2)	6871.1	30.3	89286	4.4	Golaoda and Babile
Intermediate density (31-100 persons per km^2)	8160.2	36.07	386226	18.8	Girawa and Fedis
High density (101 to more than 300 persons per km^2)	7591.3	33.6	1578904	76.9	Bedeno, Deder, Meta, Gorogutu, Jarso, Kersa, Alemaya, Gursum, Kombolcha, Kurfachele, Melkabelo
Total	22623	100	2054496	100	

Source: Zonal Atlas of East Hararghe (2001)

Furthermore, as can be seen in Figure 3.3, areas of low and intermediate density are found in the southern parts of the zone and are characterized by an insufficient rainfall, high temperature, low levels of urbanization and social infrastructure, and high incidence of diseases such as malaria. These areas are often affected by drought. On the other hand, the highland areas (semi-temperate and temperate agro-climatic zones) are characterized by favorable environmental conditions and better social infrastructure, thus, attracting high population density due to lower transaction costs.

In general, the densely populated areas include areas of intensive to moderately cultivated areas where the predominantly practiced land use activity is mixed farming. The farmers have only use rights of the land they cultivate and the land belongs to the government. In the sparsely populated areas, on the contrary, the dominant economic activity is pastoral i.e. livestock rearing and in some parts forest harvesting (incense collection and charcoal production).

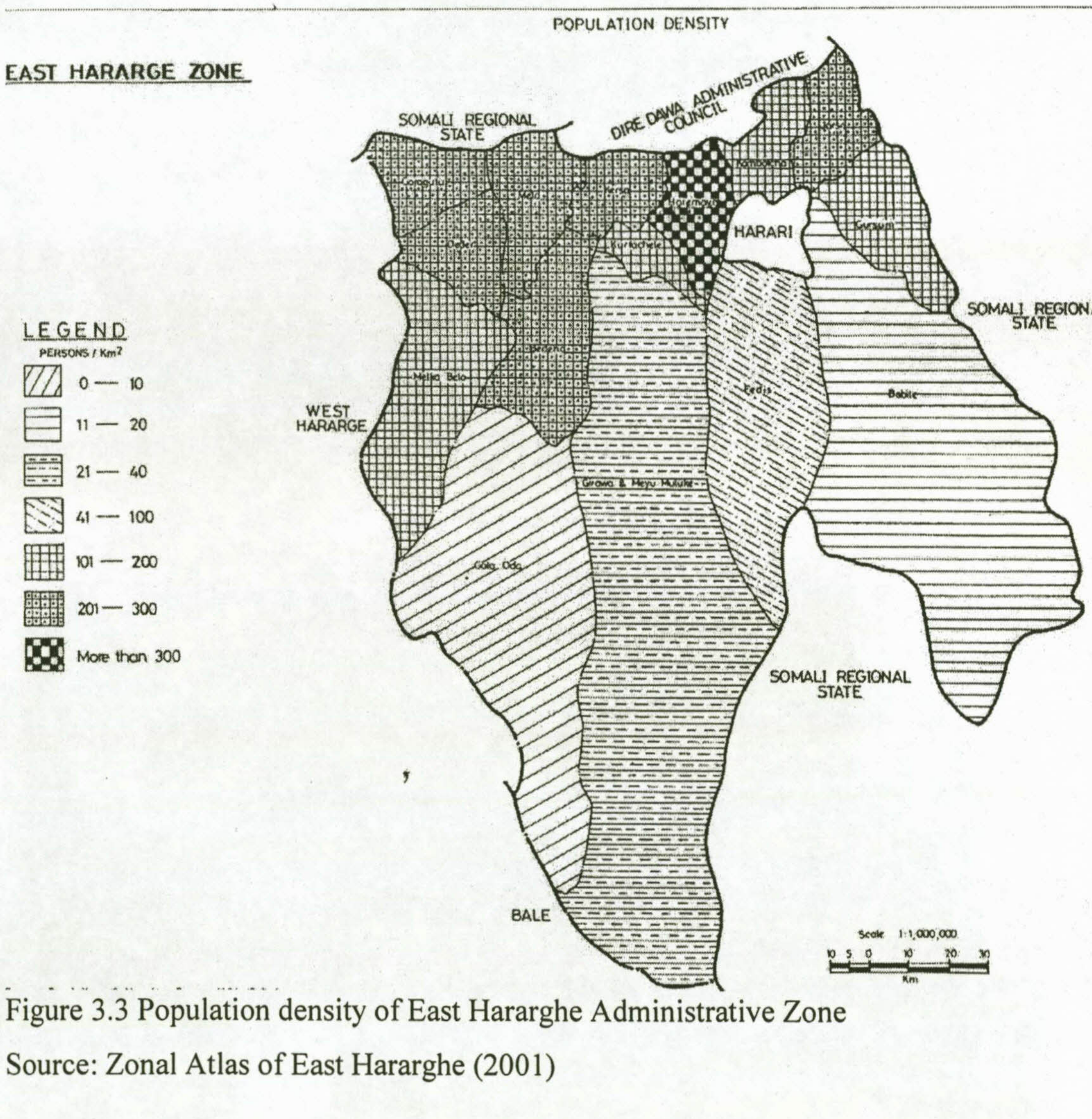


Figure 3.3 Population density of East Hararghe Administrative Zone

Source: Zonal Atlas of East Hararghe (2001)

3.4.3 Population composition and structure

In East Hararghe Administrative Zone, children less than 15 years accounted for 46.9%, the economically active population aged 15-64 accounted for 50.9% and those aged 65 and above accounted for 2.2% of the zonal population. Thus, about half of the population of the zone is not economically active.

The proportion of population by broad age group varies between the rural and urban areas. In urban areas, the proportion of economically active population is slightly higher than that of rural which accounted for 55.02% of the total urban population. This is mainly due to rural-urban migration. On the other hand, the economically inactive population is higher in rural than urban areas and constituted 49.33% of the total rural population. This higher economically inactive population in rural areas than in urban areas is mainly due to a higher fertility rate in rural areas.

The sex ratio, dependency ratio and household size are important characteristics of population composition. Sex ratio is the number of males per 100 females. The average sex ratio of East Hararghe Administrative Zone is 104. However, this varies between rural and urban, among districts, and from one age group to another. The urban sex ratio shows a slight deficit of male or lower sex ratio (99.9 males per 100 females). The rural sex ratio indicates a deficit of females (104.4 males per 100 females) due to female dominance in rural to urban migration (see Table 3.5).

The dependency ratio is the ratio that measures the population that is assumed to be dependent on the active section of the population (15-64 years of age). The dependent population includes people of age group of 0-14, and 65 and above. The average dependency ratio of East Hararghe Administrative Zone is 96%, which means that every 100 economically active persons have an extra 96 persons to feed, shelter and provide other basic necessities such as clothing, health, education, and the like. Of the total population of the zone about 49.1% of the population depends for its livelihood upon 50.9% of the total population. The old age dependency ratio accounts for 2.2%, while the youth accounts for 46.9% of the total population, which is a characteristic of developing countries due to the fertility rate. As shown in Table 3.5, the rural areas have a higher dependency ratio with an average of 97.4% as compared to the urban areas, which is 81.3%.

Table 3.5 Sex ratio, household size and dependency ratio of East Hararghe Administrative Zone by district as of 1999

District	Sex ratio			Household size			Dependency ratio		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total
Babile	97.9	103.6	102.5	4.7	5.7	5.5	94.7	117.2	122.4
Bedeno	94.9	101.8	101.6	4.3	4.4	4.4	88.0	58.0	97.7
Deder	104.4	104.6	104.5	4.8	4.8	4.8	77.65	98.4	96.6
Fedis	91.6	106.1	99.7	4.3	5.2	5.1	73.3	104.4	96.4
Golaoda	101.5	100.6	100.7	4.2	4.6	4.6	101.7	91.0	91.9
Gorogutu	101.1	103.4	103.3	4.5	4.9	4.9	83.9	98.6	97.9
Girawa	99.2	106.5	106.3	4.2	4.6	4.6	67.7	90.7	90.1
Gursum	92.6	102.0	101.4	4.3	5.8	5.7	91.6	111.6	109.7
Alemaya	99.8	103.9	103.5	5.2	4.5	4.5	81.3	92.2	90.8
Jarso	91.4	102.0	101.5	4.6	4.7	4.7	81.6	111.6	109.7
Kombolcha	96.3	106.2	105.5	4.4	4.7	4.7	83.0	88.2	88.8
Kurfachele	111.9	104.2	104.8	4.0	4.3	4.2	85.4	90.2	89.7
Melkabelo	102.7	105.4	105.2	4.8	4.8	4.7	88.4	98.2	91.7
Meta	102.1	104.9	104.8	4.4	4.7	4.7	81.3	88.7	88.2
Kersa	104.4	106.1	105.0	4.0	4.3	4.3	81.3	88.7	88.2
Total	99.9	104.3	104.1	4.6	4.7	4.76	81.3	97.4	96.3

Source: Zonal Atlas of East Hararghe (2001)

Table 3.5 indicates that the average household size in East Hararghe Administrative Zone is 4.76. The rural and urban average household size of the zone is 4.7 and 4.6

respectively. Gursum district with an average household size of 5.7 stands first followed by Babile (5.5) and Fedis (5.1). The smallest average household size is recorded in Kurfachele district (4.2).

3.5 Natural resource structure

3.5.1 Relief and landforms

The landforms of East Hararghe Administrative Zone can be categorized into highlands and lowlands. The highlands include areas which have altitudes over 1500 meters above sea level. The lowlands include areas which have altitudes of less than 1500meters above sea level.

As shown in Table 3.2, the largest proportion of the zonal areas (62.2%) has altitudes below 1500meters, which is categorized as arid and semi-arid climate. The remaining proportion (37.8%) has altitudes above 1500 meters and is categorized as sub-tropics and temperate climate.

The highlands, which are characterized by ragged terrains, are found in the north-central parts of the zone and stretch from west to east. Mount Garamulata (3405meters), mount Gondala (3132meters), mount Serirta (3026meters) and mount Kundudo (2950meters) are the highest peaks in this part of the zone.

The lowlands are extensively found in the southeastern part of the zone. These parts of the zone are characterized by dry and arid climate with barren to steppe vegetation cover and high evapotranspiration.

The differences in altitudes between highlands and lowlands of the zone have effects on climatic condition, vegetation, soil distribution and land use activities. As a result people in the highland areas are mainly engaged in mixed farming while those in the lowlands are nomads or pastoralists.

3.5.2 Mineral resources

The deposition of mineral resources is associated with the geological structure of an area or a region. Due to intensified mineralization of rocks through crystallization in the process of metamorphism, the basement complex form important sources of metallic minerals like gold, platinum, silver, copper, lead, zinc, etc.

Table 3.6 Metallic and non-metallic mineral deposits in East Hararghe

	Non-metallic mineral deposits				Non-metallic mineral deposits		
No.	Type of mineral	Reserve (ton)	Possessing district	No.	Type of mineral	Reserve (ton)	Possessing district
1	Feldspar	-	Babile, Meta Gursum	14	Chalk	-	Jarso
2	Granite	-	Babile	15	Coal	-	Jarso
3	Red clay	-	Babile	16	Silica	-	Meta
4	Mineral water	-	Babile	17	Marble	-	Babile, Fedis, Melkabelo
5	White stone	-	Babile, Deder				
6	Dolomite	-	Fedis, Babile		Metallic mineral deposits		
7	Graphite	-	Deder	No.	Type of mineral	Reserve (ton)	Possessing district
8	Walastonate	-	Deder	1	Iron	-	Deder
9	Kaolin	-	Deder, Kombolcha	2	Nickel	-	"
10	Mica	-	Deder	3	Lead	-	"
11	Sandstone	-	Fedis	4	Galena	-	"
12	Garnet	-	Gursum	5	Molbdnite	-	Fedis
13	Limestone	-	Jarso	6	Copper	-	Melkabelo

Source: Zonal Atlas of East Hararghe (2001)

The sedimentary rocks of the Mesozoic era are important sources of industrial and construction materials and have high potential for mineral oil and natural gas. The sediments of the Cenozoic era form important potential sources of salt, potassium and calcium minerals.

Therefore, the geological structure of East Hararghe Administrative Zone provided the favourable conditions for the occurrence of varieties of mineral resources. Nevertheless, the mineral deposits of the zone have not been fully investigated or studied, and the identified ones are very small. Because of this, one cannot fully know the types and varieties of minerals that are found in the zone. Some of the mineral resources identified in the zone are given in Table 3.6.

At present Babile mineral water and some construction minerals like marble, sandstone, limestone, dolomite and granite are under exploitation in East Hararghe Administrative Zone.

3.5.3 Soils

Different types of soils are found in East Hararghe Administrative Zone based on their origins and variations in the process of their formation. Their agricultural utilities also differ from one type of soil to another. The major types of soils that exit in the zone are discussed below.

1. *Calcic and Vertic Cambisols* – cambisols with calcic horizons or with limestone accumulation are called calcic cambisols. They occur in areas where there is a small amount of precipitation and where there is limestone accumulation. Calcic cambisols are found in southern part of the zone in Girawa and Golaoda districts.

Vertic cambisols are found in the sub-tropical areas where temperature is 15-20^{0}C. Vertic cambisols have fairly good but limited agricultural potential because dry soils are hard and wet soils are sticky to work on. Vertic cambisols are found in Gursum, Alemaya, Kombolcha, Deder, Kurfachele, Melkabelo, Golaoda and Girawa districts, usually in association with other types of soils.

2. *Rendizinal soil* – These are formed on calcareous materials in wet climate of fairly steep slope. Rendizinal soils have good structure and high organic matter. Although these soils have such characteristics, they are not suitable for agriculture because they develop on steep slopes. These type of soils are found in the southern tip of Babile district.

3. *Vertic Luvisols* – Luvisols, which have vertic properties, are called vertic luvisols. Vertic Luvisols are semi-arid to temperate highland soils, which are formed under original temperate climatic coniferous forests. Similar to vertic cambisols and for the same reason, they have fairly good but limited agricultural potential. These soils are found in most parts of Fedis, parts of Babile, Gursum and Alemaya districts. They also occur in the districts of Gorogutu, Deder, Meta, Kersa, Bedeno, Kurfachele, Girawa, and Melkabelo in association with other types of soils.

4. *Calcaric and Eutric Fluvisols* – Fluvisols (alluvial) soils are constantly being replenished by fresh water-born deposits. Fluvisols are highly variable. Fluvisols with calcareous materials are calcaric fluvisols and those with non-calcareous having a base saturation of 50% or more are Eutric Fluvisols. Calcaric fluvisols are found in the southern tip of Girawa district, where as eutric fluvisols are found along the Erer, Daketa, and Fafam rivers. These two types of fluvisols also occur in Alemaya, Kombolcha and Golaoda districts in association with other types of soils.

5. *Eutric Regosols* – Regosols are coarse textured, unconsolidated materials exclusive of recent alluvial deposits and occur on steep slopes in highlands where sandstones are exposed. They occur in areas of little precipitation or on slopes subjected to severe erosion. These soils are found in the southern tip of Babile district. They are also found in parts of Bedeno, Deder, Gorogutu, Meta, Kersa, Kurfachele, Kombolcha, Alemaya, Girawa and Melkabelo districts in combination with other types of soils.

6. *Mollic Andosols* – Andosols are light, loose, porous, have high drainage capacity and absorb much water. They are very fragile and thus get easily detached by rain droplets as well as transported by wind. Mollic Andosols have a mollic A horizon. Most Andosols are good for agriculture. These types of soils are found in the southern tip of Golaoda district.

7. *Chromic Vertisols* - These are heavy clay soils in flat areas, having a pronounced dry season during which they shrink and have deep cracks in a polygonal pattern. During the wet season the clay swells and causes pressure in the sub-soil. Chromic Vertisols are brownish in colour and they are better drained soils.

Vertisols have limited agricultural potentialities. Land preparation for agriculture is difficult because dry soils are hard and wet soils are sticky. This soil has high water retention but a relatively small amount of water is available for plant growth. Rooting depth might be restricted because of the swelling and shrinking properties of the soil. These types of soil are found in southern part of Melkabelo, Golaoda and Girawa districts. They are also found in Babile, Bedeno, parts of Meta and Jarso districts in association with other types of soils.

8. *Luvic Phaeozems* - Luvic Phaeozems are dark in colour and rich in humus. They are mostly associated with areas of livestock raising and browsing. These types of soils are found in the northern tip of Golaoda, southern part of Bedeno and in the eastern corner of Melkabelo districts in association with vertic luvisols.

9. *Lithosols* – Lithosols are soils of limited depth developed over hard rock with 10 cm of the surface and have low or no agricultural value though cultivated in areas of high population pressure. They are found in Meta, in northern tip of Gorogutu, Gursum and south-central part of Jarso districts in association with other types of soils.

10. *Orthic Solonchak* – Solonchak soils exist in dry climates and some have developed horizons of lime or gypsum accumulation. They are highly saline soils that influence

plant growth. They are poor soils, because most plants cannot grow on them at all. These types of soils are found in the southern part of Girawa district in association with Eutric fluvisols.

11. *Other/Rankers* – Rankers are weakly developed shallow soils on consolidated rocks. These soils are found in the northern tip of Gorogutu and Meta districts in association with Eutric Regosols.

3.5.4 Water resources

The direction of the rivers in East Hararghe Administrative Zone is controlled by its relief configuration, which is the result of past geological history. The northern side of the zone is drained by the rivers that flow to the Awash River, while the southern sides is drained to the Wabishebele rivers. There are also some small seasonal streams that flow to lakes such as Alemaya, Finkile and Adele.

In addition to its relief, the seasonal variation of rain affects the volume of the rivers of the zone. This means that the quantity of water occupied by the rivers varies from one season to another.

The central high plateau (Harar high plateau) of the zone which receives the summer, spring and autumn seasonal rainfalls merging together experiences adequate precipitation to give rise to an integrated system of drainage. Hence the highland districts of Deder, Melkabelo, Bedeno, Gorogutu, Kurfachele, Meta and Kersa have relatively high drainage density. On the other hand, the southeastern lowlands, which are characterized by dry climatic conditions, have very low drainage density.

In general due to its relief configuration East Hararghe Administrative Zone is divided into two main drainage basins. These are:

1. The Wabishebele drainage basin
2. The Awash drainage basin

These two drainage basins are separated by the central highland, which stretches from west to east parallel to the Addis Ababa – Harar main road.

The Wabishebele drainage basin is the largest one. It covers 90% of the total area of the zone and drain the whole areas of all districts except the northern limited portion of Gorogutu, Meta, Kersa, Alemaya, Kombolcha and Jarso districts. It includes rivers like Ramis, Mojo, Erer and Daketa. These rivers, which are included in the basin, are the prominent ones that start flowing from the central highland of the zone to the southeastern part and finally drain to the Wabishebele river. The valleys of these rivers have large areas of potentially irrigable land. In addition to this, Erer and Daketa valleys have good potential areas for tourist attraction (wildlife sanctuaries and Daketa valley stones).

The Awash drainage basin covers about 10% of the total area of the zone and includes small seasonal streams. However, the streams are intermittent and end up in the hot dry lowlands through which they flow.

In addition to surface water resources, East Hararghe Administrative Zone has two ground water recharge regions. The first ground water recharge region, which has comparatively medium to high precipitation and low potential evapotranspiration, with high recharge ranging from 150-250mm annually, is found in the northwestern part of the zone (parts of Melkabelo and Deder districts). On the other hand, the second ground water recharge region covers all parts of the zone except the northwestern part. It has relatively low rainfall and increased potential evapotranspiration with corresponding low recharge of 50-150mm annually.

3.5.5 Wildlife and its conservation

The diverse climate and topography in East Hararghe Administrative Zone have provided a wide range of natural environments, which form favourable habitat for a wide variety of fauna and flora. However, due to uncontrolled hunting and destruction of their natural habitat as a result of rapid population growth and human activities, there is a rapid decrease of wildlife both in size, species and distribution.

At present, some of the wildlife that are found in the zone are Baboon, Bush buck, Columbus Monkey, Duiker, Elephant, Lion, Fox, Hare, Laser Kudu, Leopard, Hyenas, Warthog, Monkey and wild pig. A high concentration of these animals is mainly found in wildlife conservation areas of the zone.

The main wildlife conservation areas of the zone are Chercher, Arbagugu-Garamuleta mountain chain (a common name for chains of mountains in Arsi, Bale, east and west Hararghe zones) and Erer-Fafem controlled areas and wildlife sanctuaries.

The Erer-Fafem wildlife sanctuary was established in 1970. The aim of establishing this sanctuary was to conserve the elephant species endemic to the region, which is scientifically known as *Loxadants Africana Ovealonsi*. It includes the valleys of Erer, Fafem and Daketa with an area of 6982 km^2. According to some documented evidences before fifty years the number of elephants found in those valleys exceeded 2000, but due to illegal hunting and killing, today their numbers is estimated to be not more than 200. In addition to elephants, Erer-Fafem sanctuary has a sizeable number of Minilik's bushbuck, leopard, hare and lion.

The Chercher-Arbagugu-Garamuleta mountain chain controlled hunting area of the zone has lower wildlife concentrations. However, it has some wildlife such as duiker, and hare. There are also numerous wildlife which are found outside the conservation areas in the zone. Theses are spotted hyena, Columbus monkey, warthog and foxes.

3.6 Economic conditions and enterprise composition of farms

3.6.1 Land use and land cover

Land use and land cover in East Hararghe Administrative Zone is affected by climate, population distribution and topography. The influence of climate on land use and natural vegetation cover of an area depends on the amount and distribution of rainfall and temperature. The impact of population is manifested through its distribution, size, cultural orientation and practices. The effect of topography on agricultural activity and vegetation cover of an area is manifested through slope, altitude and texture of the soil.

The land use pattern of the zone is correlated with its population distribution. Highland parts of the zone are densely populated as compared to hot lowlands and as a result there is intensive land utilization in the highland parts of the zone. The land use and land cover in East Hararghe Administrative Zone is discussed below.

1. *Intensively cultivated land* – this type of land use includes areas of intensively cultivated peasant mixed farming. The land is mostly used for rain fed grain cultivation as well as sedentary livestock grazing. In this part of the zone, a large proportion of the land is under the annual crop during the rainy season. There is livestock grazing on unimproved pasture and hardly any tree vegetation is visible. The major areas of this type of land use include most parts of Gorogutu, Kersa, Alemaya, parts of Meta and Fedis districts.

2. *Moderately cultivated land* – This differs from intensively cultivated land in that patches of forest or bushes and large areas under natural vegetation are common. During the rainy season, the land used for annual crops is less than that of the intensively cultivated land. The main land use activities of this region are cultivation of grain, livestock grazing and browsing on traditional poor pasture land, fallow land and perennial crop cultivation such as coffee and chat. The major areas of this land use type are Gursum, Babile, Girawa, Deder, Meta, Bedeno and Melkabelo districts.

3. *Dense and low bush land* – The dense bush land occurs on the humid side of the woodland and consists of multi-storied bushes. Open or low bush land is often intermixed with the woodland and the moderately cultivated land region. Pastoral livestock grazing and browsing, and in some parts, forest harvesting (incense and charcoal) are the main activities. The dense bush land region is found in parts of Fedis, Girawa and Alemaya districts, while open or low bush land is found intermixed with moderately cultivated lands largely in Deder, Meta, part of Bedeno and Melkabelo districts.

4. *Dense and open shrub land* - This region occurs on the semi-arid sides and is often composed of patches of dense shrubs interspersing grassland with some scattered trees. Grazing, browsing and collection of incense and fiber are considered to be the major land use activities of this region. The dense shrub land occurs in parts of Babile, Fedis and Girawa districts, while open shrub land occurs in parts of Girawa, Babile, Kurfachele, Alemaya, Golaoda and Melkabelo districts.

5. *Grassland* – The grassland region is found mostly in semi-arid lowlands. On the humid side open grassland and grassland interspersed with some trees are common. In the drier parts, however, patches of shrub or bushes are common. In this region, pastoral livestock grazing and browsing are the main land use activities. This type of land use activity is found in Babile, Girawa and Golaoda districts.

6. *Exposed rock and sand surface* – This region exists in overgrazed parts of the arid and semi-arid areas. For a short period of time in any rainy season, patches of vegetation covers are grazed and browsed by pastorates. But for most of the year, it is bare land and it is found in Babile district.

The land use and land cover of East Hararghe Administrative Zone is depicted in Figure 3.4.

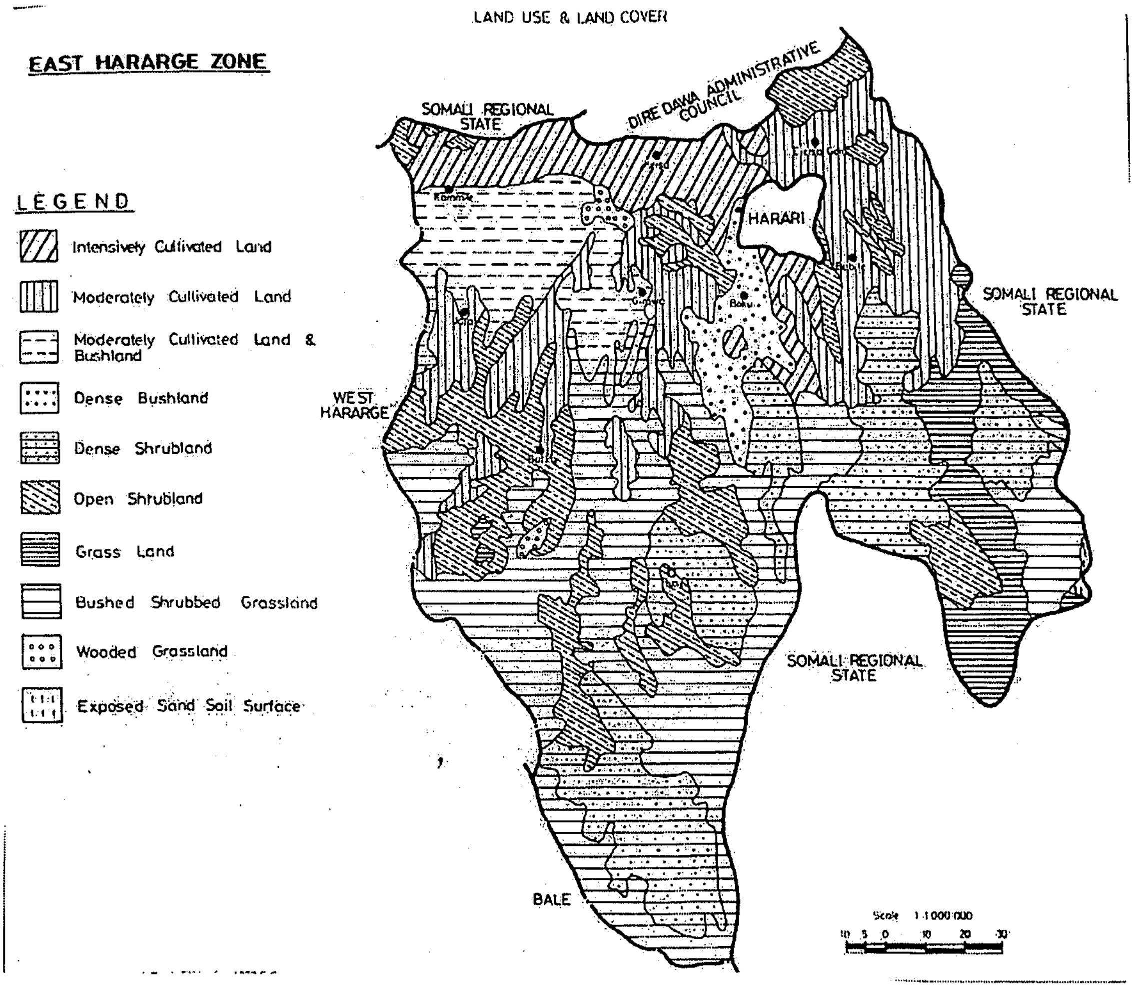


Figure 3.4 Land use and land cover in East Hararghe Administrative Zone
Source: Zonal Atlas of East Hararghe (2001)

3.6.2 General production regions

The majority of people of East Hararghe Administrative Zone live in rural areas where agriculture is their source of livelihood. In general the administrative zone is divided into three major production regions as also shown in Figure 3.5. These are:

1. The mixed farming (cropping and livestock production) region
2. The pastoral region
3. The transitional (between mixed and pastoral farming) region

The mixed farming region accounts for about 40% of the total zonal area. Pastoral areas account for about 50% of the zonal area. The transitional zone where lowland pastoralism is practiced side by side with mixed farming makes up ten percent of the total area of the zone.

Highlands are moderately to intensively cultivated, while lowlands, with high water constraints and low settlement, are practically of no significance in arable farming in contrast to the dominance of pastoral farming.

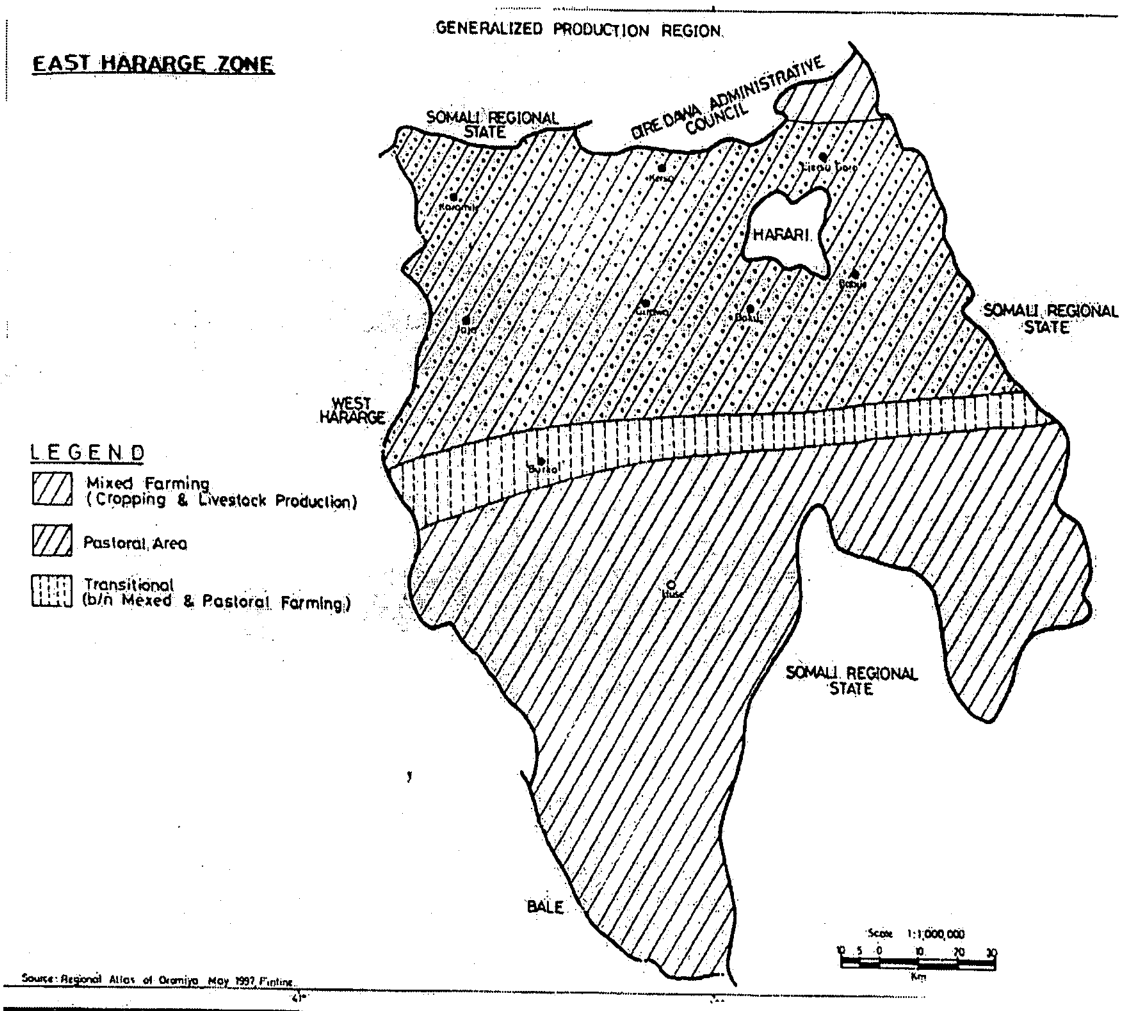


Figure 3.5 General production regions of East Hararghe Administrative Zone
Source: Zonal Atlas of East Hararghe (2001)

3.6.3 Crop production

Different types of crops of which cereal crops shared a larger proportion of the total cultivated areas occupy the crop area of East Hararghe Administrative Zone. According to the zonal Agricultural Development Department report and as depicted in Table 3.7, in 1999/2000, the total area under major crops (cereals, pulses and oilseeds) was 363,503 hectares; cereal crops accounted for 280,392 hectares, pulses 68,427 hectares and oilseeds 14,684 hectares. The largest percentage of the cropped land of the zone is occupied by sorghum, maize, wheat and barley. In general the area under major crops, i.e. 363,503 hectares, accounts for about 16.11% of the total zonal area.

In addition to this, the information obtained from zonal Agricultural Development Department shows that, of the major crops produced in the zone, cereals accounted for the highest yield (1,840,648 quintals) followed by pulses (256,008 quintals) and oilseeds (49,449 quintals). This indicates that the physical environment of the zone is more favorable for cereal crops than others.

Of the major crops produced in East Hararghe Administrative Zone, which are shown in Table 3.7, maize accounts for 35.2% followed by sorghum, which accounts for 33.1% of the total production.

The spatial distribution of these major crops varies from place to place depending on crop suitability factors (soil, rainfall, temperature, etc.). The relative importance and the spatial distribution of some of these major crops in the zone are discussed below.

Sorghum and maize

Sorghum and maize are warm weather crops that grow under temperature that ranges from 18^0C to 25^0C, and rainfall of 1000mm to 2000mm per year. Cambisols and luvisols are types of soils on which they are grown. These crops are hard and drought resistant and therefore do well in areas where rainfall is low and unreliable.

The major sorghum and maize growing areas are found in the north-central highlands of the zone, which extends from west to east. The minor growing areas are found in the eastern part of the zone, which includes Gursum and parts of Babile districts.

As shown in the Table 3.7, the cultivated area of sorghum, which is 125,118 hectares, accounts 34.4% of the total cultivated land of the zone. The cultivated area for maize (92,793 hectares) accounts for 25.5% of the total cultivated land of the zone.

Table 3.7 Land cultivated and production of major crops in EHAZ

Type of crop	Area (hectares)	Production	
		Total (quintals)	Quintals/ hectare
CEREALS	280,392	1,840,648	6.6
• Teff	5771	28,899	5.0
• Barley	18,540	99,599	5.4
• Wheat	35,618	232,706	6.5
• Sorghum	125,118	711,356	5.7
• Maize	92,793	756,501	8.2
• Oats	2,452	11,587	4.7
PULSES	68,427	256,008	3.7
• Horse beans	5,920	30,257	5.0
• Chickpeas	455	1,659	3.6
• Haricot beans	55,210	195,479	3.5
• Field peas	4,836	21,088	4.4
• Lentils	2006	7525	3.8
OILSEEDS	14,684	49,449	3.4
• Linseed	419	1,111	2.7
• Groundnuts	13,754	46,923	3.4
• Others	511	1,415	2.8

Source: East Hararghe Agricultural Development Department (2000)

Barley, wheat and teff

Barley, wheat and teff are cold whether crops. They are predominantly grown on the highlands, which are above 1500meters above sea level, where average annual temperature ranges from 16^0C to 20^0C and the rainfall is from 800mm to 1500mm per year. They grow on well-drained vertisols.

For barley and wheat, the north-central highlands, which stretch from west to east, are suitable areas and for teff, part of the north central highland, which includes parts of Bedeno, Meta, Kersa and Kurfachele districts are considered to be the major producing areas.

Horse beans

Horse beans can be produced at an altitude that ranges from 1800 meters to 3000meters above sea level, but in East Hararghe Administrative Zone it is chiefly produced at an altitude of 2100 to 2400meters above sea level, with mean temperature of 12.5^0C to 17.5^0C and a rainfall of about 650 – 900mm per year. Horse beans are mostly produced on well drained red clay soils though they are also produced on well drained black soils.

Field peas

Peas, often known as green field peas, are mainly grown in areas between 1800 and 2700 meters above sea level. Ideal areas for optimum pea production are altitudes of 2300-3000 meters above sea level with mean temperature of 12.5^0C – 17.5^0C and a rainfall amount of 500-900mm per annum.

Culturally, field pea is a chief source of protein for highland inhabitants. It prefers red soil (luvisols and nitosols) with friable (sandy loam and clay loam) textures and moderately well drained soils. Its production favours soil depth of over 60cm for optimum production.

Chickpeas

Chickpeas require an area which has an elevation of 1800 meters to 2400 meters above sea level and with mean temperature of 15^0C to 20^0C. An annual rainfall that ranges from 650mm to 750mm per annum is highly suitable for chickpeas. They do not grow in areas where rainfall is below 550mm or above 1000mm per year.

The major growing districts of chickpeas are Gursum, parts of Babile, Fedis, Jarso and Kombolcha.

Haricot beans

This crop grows best at altitudes between 1700 – 2000 meters above sea level, with corresponding temperature of 20^0C to 25^0C and a rainfall of 500 – 1000 mm per annum.

Groundnuts

Groundnuts are a lowland crop. The more suitable altitude is zero to 1000 meters above sea level. However, they can also grow at an altitude of 1000 to 1600 meters above sea level. The crop requires high temperature, ranging from 25^0C to 32^0C. But some varieties of lower quality require a temperature of 20^0C to 24^0C for the growing season. Very little yearly amount of rainfall (350mm) is satisfactory. But groundnuts grow best with 500 mm to 700 mm of rainfall per annum. The major groundnuts producing areas are Gursum and parts of Babile districts.

Perennial crops

Coffee

Coffee grows at an altitude of 1500 to 1800 meters above sea level, and at some places it can grow at an altitude of 1100meters to 2200 meters above sea level. The most suitable temperature is 20^0C to 25^0C but coffee can also grow at a temperature of 17.5^0C to 25^0C. For successful growth, it requires a yearly rainfall that ranges from 1300mm to 1600mm per year. However, it also grows in areas where the annual rainfall is as low as 900mm to as high as 2000mm. Well drained soils with a texture of loamy to red clay are highly favourable for coffee production.

In East Hararghe Administrative Zone, the major coffee producing areas are found in the north-central highlands of the zone, which includes parts of Bedeno, Melkabelo, Deder, Meta, Kersa and Kurfachele districts. The minor producing areas are Gorogutu and Alemaya districts.

In the year 1999/2000, the total land cultivated with coffee was 15,423 hectares and the production obtained was 54,870 quintals.

Chat

Chat is a stimulant crop whose leaves are chewed by people. According to the zonal Agricultural Development Department report in 1999/2000, the total area cultivated with chat was 62,200 hectares. This accounts for about 5.8% of the total cultivated area of the zone. On the other hand the production obtained from this cultivated area was 607,229 quintals.

The production of chat differs from one district to the other. The major producers of chat in the zone are Alemaya, Bedeno, Gursum, Deder and Melkabelo districts. On the other hand, Babile and Golaoda are the smallest producers of chat. This may be is due to environmental conditions and closeness to market centers.

In general, chat is produced in large amount in East Hararghe Administrative Zone as compared to other zones in the region of Oromia. It is the major cash crop and source of revenue of the government in the zone.

3.6.4 Livestock numbers, distribution and its role

Livestock play a vital role in the social and economic life of the people of East Hararghe Administrative Zone. Livestock serve as a source of food, as draft power in the process of crop production, as a source of organic fertilizer and as a source of cash income.

As shown in Table 3.8, the types of livestock that are commonly raised in the zone are cattle, sheep, goats, equines, camels, and poultry. The distribution of livestock is affected by climate, disease prevalence, population distribution, farming systems and type of land use. As a result of these factors, the livestock density in the zone varies from district to district. Meta district has the highest livestock density followed by Kersa district, whereas the lowest density is recorded in Girawa district.

In 1999/2000, the total amount of livestock in the zone was estimated to be 2,887,747. The percentage of cattle, sheep, goats, equines, camel and poultry were 37.6, 6.8, 16.8, 5.7, 3.1, and 30 respectively.

Cattle numbers are significant in Girawa and Golaoda districts where there is low population density and large grazing land. On the other hand, Kurfachele, Babile, Fedis and Jarso have low cattle populations because of the unfavourable climatic condition and small grazing land.

The total number of sheep in the zone was 195,973 (6.8% of the total livestock population) in 1999/2000. Kersa and Jarso districts have the largest number of sheep, whereas Babile and Melkabelo have the smallest number of sheep (less than 5000).

The goat population of the zone in 1999/2000 was 486,436. The highest concentration of goats (about 22.8% of the zone) is found in Golaoda and Girawa districts. On the other hand, the lowest number of goats (1.9% of the zone) is found in Babile district.

Table 3.8 Livestock size in East Hararghe Administrative Zone, 1999/2000

	Type of livestock						
District	Cattle	Sheep	Goat	Equines	Camel	Poultry	Total
Babile	19052	4812	9328	1308	3660	10842	49002
Bedeno	96450	10138	40150	14812	0	120000	281550
Deder	66638	17138	23411	15321	0	102410	224918
Fedis	36322	8400	31702	24336	5461	33648	139869
Golaoda	152545	5207	60870	11510	65647	13473	309252
Gorogutu	52431	14865	30803	9524	489	78141	186253
Girawa	139771	13686	50259	8981	5117	78453	296267
Gursum	125480	12875	40235	7526	4545	63884	254545
Alemaya	74632	16234	30182	12888	0	39939	173875
Jarso	35779	22321	35090	6563	973	31347	132073
Kombolcha	44623	16113	43756	11956	100	60885	177433
Kurfachele	19839	6573	14479	4970	211	23872	69944
Melkabelo	56206	3790	13750	6086	852	10280	90964
Meta	78434	15060	38000	15649	2127	156244	305514
Kersa	87580	28761	24421	12888	0	42638	196288
Total	1085782	195973	486436	164318	89182	866056	2887747

Source: East Hararghe Agricultural Development Department (2000)

Equines include donkeys, mules and horses. The total number of equines in East Hararghe Administrative Zone was 164,318 in 1999/2000. Of these the most widely observed equines in the zone are donkeys. There are a small number of horses on the highland parts of the zone, which include Deder, parts of Melkabelo, Meta and Kersa districts. Like other livestock, the distribution of equines also varies from district to district. The largest number of equines, about 42.6%, was found in Fedis, Meta, Deder and Bedeno districts.

Camels are predominant in the lowland parts of the zone mainly in Golaoda, Fedis, Babile and Meta districts. These four districts account for more than 86% of the total camel population of the zone. They serve as meat and milk suppliers for nomads and semi-nomads. Moreover, camels are used as a means of transportation.

In East Hararghe Administrative Zone, the poultry population is undermined because they are not considered as significant assets for households. Farmers in the zone keep poultry not mainly for consumption but rather for cash income. The total poultry population in the zone was 866,056 in the year 1999/2000. Of these 52.78% were found in Bedeno, Meta, Deder and Girawa districts.

3.7 Summary and conclusion

In this chapter an extensive description of the study area was presented. In section 3.1 an attempt was made to introduce Ethiopia, the home country of the study area. Ethiopia was shown to possess a land area of about 1.2 million square kilometers. It has a population of 67.2 million, of which the majority, approximately 88%, lives in the rural areas. Ethiopia has a temperate climate in the highlands where the average temperature is about 20 degrees Celsius and its lowland areas are hot with temperatures averaging 35 degrees Celsius. There are two rainy seasons in the country, the light rains from February to March, and the summer rains from mid June to mid September.

In section 3.2 the location and the administrative sub-divisions of the study area was discussed. As its name declares, East Hararghe Administrative Zone is located in the eastern part of the Oromia region, which is one of the largest regions in Ethiopia. East Hararghe Administrative Zone is divided into 15 districts, which are again sub-divided into 417 peasant associations and 17 urban kebeles. The largest district in the zone is Girawa with an area of 5,9676 km^2 (26.4% of the zonal area), while Kurfachele is the smallest with an area of 302 km^2 (1.3% of the zonal area).

Section 3.3 dealt with the most important physical features of East Hararghe Administrative Zone. Three major climatic regions were shown to prevail in East Hararghe Administrative Zone, namely the arid climate, the tropical climate and the tropical highlands. Aspects of altitude, temperature and the associated evapotranspiration rates, which correspond to the different climatic regions, were also assessed. The seasonal distribution of rainfall in East Hararghe Administrative Zone was categorized into four seasons: the summer season brings rain for a greater portion of the zone, particularly the central high plateau. During the winter season, the whole of the zone comes under the influence of dry northeast trade winds and it is, in general, a dry period. The spring season is the second highest rainfall season for the zone, particularly for the southeastern low plateau and southern lowlands of the zone. The last season, autumn, is the second highest rainfall season for the northern low plateau and plain.

Section 3.4 discussed important aspects of the population of East Hararghe Administrative Zone. The total population of East Hararghe Administrative Zone was projected to be 2,054,596 for the year 1999 G.C. and is distributed over an area of 22,623 km^2. This gives an overall zonal population density of 90.8 persons per km^2. The most densely populated district in East Hararghe Administrative Zone is the Alemaya district with 360.2 persons per km^2. Golaoda district is the least densely populated district in the zone with 8.4 persons per km^2. As far as population composition is concerned, in East Hararghe Administrative Zone, children less than 15 years accounted for 46.9%, the economically active population aged 15-64 accounted for 50.9% and those aged 65 and above accounted for 2.2% of the zonal population. Thus, about half of the population of the zone is not economically active. This gives a dependency ratio of 96%, which means that every 100 economically active persons have an extra of 96 persons to feed, shelter and provide other basic necessities.

The natural resource base of East Hararghe Administrative Zone is introduced in section 3.5. The landforms of the zone are categorized into highlands and lowlands. The highlands include areas which have altitudes over 1500 meters above sea level. The lowlands include areas which have altitudes of less than 1500meters above sea level. The largest proportion of the zonal areas (62.3%) has altitudes below 1500meters, which can be categorized as arid and semi-arid climate. The remaining proportion (37.7%) has altitudes above 1500meters, which is categorized as sub-tropics and temperate climate.

As far as mineral resources are concerned, it was indicated that the geological structure of East Hararghe Administrative Zone has provided favourable conditions for the occurrence of varieties of mineral resources. Nevertheless, the mineral deposits of the zone are not fully investigated or studied, and the identified ones consist of relatively small deposits.

Different types of soils are found in the East Hararghe Administrative Zone. Their agricultural utilities differ from one type of soil to another. Eleven major types of soils that exist in the zone were broadly explained.

As far as the water resource is concerned, in East Hararghe Administrative Zone, two main drainage basins, namely the Wabishebele drainage basin and the Awash drainage basin were identified. The northern side of the zone is drained by the rivers flowing to the Awash River, while the southern sides are drained to the Wabishebele rivers. There are also some small seasonal streams that flow to lakes such as Alemaya, Finkile and Adele. The Wabishebele drainage basin is the largest one. It covers 90% of the total area of the zone and drains all but the northern limited portion of the zone. The Awash drainage basin covers about 10% of the total area of the zone and includes small seasonal streams.

Referring to wildlife presence, the diverse climate and topography in East Hararghe Administrative Zone provide a wide range of natural environments, which form favourable habitats for a wide variety of wildlife. However, due to uncontrolled hunting and destruction of their natural habitat as a result of rapid population growth and human activities, there is a rapid decrease of wildlife both in numbers, species and distribution in the zone.

The last section, section 3.6, presented the economic conditions and enterprise composition of farms in East Hararghe Administrative Zone. It was shown that the land use pattern of the zone is correlated with its population distribution. The highland parts of the zone are densely populated as compared to hot lowlands and as a result there is intensive land utilization in the highland parts of the zone.

As far as agricultural activities are concerned, East Hararghe Administrative Zone is divided into three major production regions. These are: the mixed farming region, the pastoral region and the transitional region. The mixed farming region accounts for about 40% of the total zonal area. Pastoral areas account for about 50% of the zonal area. The transitional zone where lowland pastoralism is practiced side by side with mixed farming makes up 10% of the total area of the zone.

In terms of crop production, different types of crops of which cereals shared a larger proportion of the total cultivated areas occupy the crop area of East Hararghe Administrative Zone. The largest percentage of the cropped land of the zone is occupied by sorghum, maize, wheat and barley. In general the area under major crops accounts for about 16.11% of the total zonal area.

The types of livestock that are commonly raised in the zone are cattle, sheep, goats, equines, camels, and poultry. Cattle takes the lion's share as compared to other livestock in the zone. The livestock density in the zone varies from district to district. Meta district has the highest livestock density followed by Kersa district, whereas the lowest density is recorded in Girawa district.

CHAPTER 4. LITERATURE REVIEW

4.1 Introduction

In this chapter, the literature reviewed in the study will be presented. The focus of the literature review is to present a detailed discussion of similar research activities particularly on those aspects that are relevant to this study. The land resource and the land use will be assessed globally, at the level of developing countries and from an Ethiopian context.

In section 4.2, selected theories of land use, which are found in resource economics and land economics, will be discussed. Institutional aspects of land use in relation to property rights will be identified. Land as an economic resource will be defined and related concepts of sustainable development will be investigated.

In section 4.3, an attempt will be made to outline some methods used in land use analysis and planning. As land use in this study is viewed from an agricultural perspective, the different components of the agricultural sector model will be reviewed. Since land use analysis is usually seen as an aid for agricultural land use planning, certain aspects of regional agricultural planning will also be discussed.

Section 4.4 will investigate the linear programming approach in land use analysis. After discussing the concepts of the linear programming model, its significance in land use analysis will be assessed. This will be followed by the structure of the model in relation to land use analysis.

Finally, the summary and conclusion section will wind up the chapter.

4.1.1 Land resource utilization from a global point of view

Land as an input into production has some unique characteristics. First, it is fixed in location and geoclimatic environment. Second, there is relatively limited supply of land suitable for specific productions activities. Third, land is a heterogeneous resource, varying in soil type, topography, climate, and cultivated vegetation (Miranowski and Cochran, 1993).

Miranowski and Cochran (1993) have stressed that agriculture is an activity that modifies the natural environment for the purpose of enhancing the flow of goods and services from natural resources. According to these authors, these environmental modifications may be accompanied by consequences that impair the long-run potential of the land to sustain production of agricultural goods and services and also the flow of other goods and services from the land, air, and water.

A potential consequence of more intensive agricultural production is increased soil erosion from cropland. Soil loss rates that exceed the rates of generation of new topsoil may reduce soil productivity, at least in the long run. Soil erosion can also result in air and water pollution. Another dimension of the erosion problem is that agricultural practices that result in higher soil erosion rates may disrupt the productivity of the land resource for other uses such as upland wildlife habitat. Fish and wildlife, as well as recreational services, are other goods and services flowing from the land and water. Thus, optimal conjunctive management of the soil resource and environmental quality to maximize the net benefits to society has become a significant social goal (Miranowski and Cochran, 1993).

On the other hand, the debate forwarded by Hayami and Ruttan (1991) indicates that, at present, world agriculture is experiencing a transition from an era when most of the increase in world agricultural production occurred as a result of the expansion in area cultivated to a period when most of the growth in crop and animal production must come from increases in the frequency and intensity of cultivation – from changes in land use which make it possible to crop a given area of land more frequently and more intensively and hence to increase the output per unit area per unit of time.

Hayami and Ruttan (1991) mentioned that in order to sustain agricultural growth it is necessary to make a transition from resource exploitation to, (a) development of resource-conserving or enhancing technologies such as crop rotation and manuring, (b) substitution of modern industrial inputs such as fertilizer for natural soil fertility, and (c) development of modern fertilizer-responsive crop varieties.

4.1.2 Land use in developing countries

The FAO (1993) indicates that in the developing countries, the demands for arable land, grazing, forestry, wildlife, tourism and urban development have become more pressing every year. These demands are greater than the land resources available. Hence, there is bound to be conflict over land use. According to FAO (1993) the population dependent on the land for food, fuel and employment will double within the next 25 to 50 years. Even where land is still plentiful, many people may have inadequate access to land or to the benefits from its use. In the face of scarcity, the degradation of farmland, forest or water resources may be clear for all to see but individual land users lack the incentive or resources to stop it.

Africa is usually cited as the only developing region where agricultural output and yield growth is lagging seriously behind population growth (Savadogo, Reardon and Pietola, 1994; Islam, 1995). In sub-Saharan Africa, for instance, the population doubles every 25 years while growth in agricultural productivity declined from 1.9% to 1.5% during the past 15 years (World Bank, 1997). Nakhumwa and Hassan (2003) indicated that the declining food production in SSA is mainly attributed to the shrinking of the natural resource base (e.g. soil fertility) and unless this resource base is enhanced it will be difficult to reverse the situation. Uma (1990) emphasized the need to increase land and labour productivities to cope with the situation. Place and Otsuka (2000) also indicated that long-term economic growth in most of Sub-Saharan Africa hinges upon sustaining and improving the productivity of its natural resource base and policy makers must face the challenge of identifying appropriate pathways for the utilization and maintenance of these natural resources.

Similarly, Young (1998) argued that the present rate of world population increase, 240,000 people a day, poses immense problems, not least for land resource management. Future growth will nearly all take place in the developing world. Some countries, such as Bangladesh, Ethiopia, Malawi, Pakistan, and much of the African Sahelian zone, are already close to their limit for sustainable support to their people.

Land resources play a critical role in human welfare. Land is no longer abundant, and its productive potential is being reduced by degradation. Sustainability, the combination of production with conservation of resources to meet the needs of future generations, is the key to land management. To ensure this, the ultimate responsibility lies with the people and governments of developing countries though valuable contributions can come from international co-operation. Awareness, and with it the will to bring about change, can only come from within (Young, 1998).

According to Young (1998), population increase will aggravate problems of landlessness, land degradation, and food insecurity. Poverty and undernutrition add to these problems. There are also major consequences for human welfare or its opposite, suffering: direct links between population pressure and famine, and indirect but strong connections with civil conflict and war.

An improvement in land resource management is, as revealed by Young (1998), only possible if awareness of the problems and the recognition of the need for action exist among the developing countries. Internationally there exists a strong measure of agreement on priorities, including poverty reduction, avoidance of land degradation, research, and people's participation in decision-making, and hence, as stated by Young (1998), at national level land resource policies cannot be applied in isolation.

As emphasized by Young (1998), in developing countries, first there is a need for avoiding civil conflict, good government, and attention to the development of the rural sector, leading to recognition of the role of land resources. This provides a framework for a set of national land resource policies, including improved survey and evaluation, efforts to combat land degradation, the effective linking of research with extension, a national land use plan, and monitoring of the national heritage of land resources. This will require strengthening of institutions, with improvements in education and training. As noted by Young (1998), none of the above measures will be fully effective unless accompanied by greater efforts to reduce rates of population growth; demographic policy is an integral part of rural land development.

4.1.3 Overview of the land resource in Ethiopia

Ethiopia is a country struggling to recover from almost three decades of civil war and drought. Nearly two decades of harsh authoritarian rule under a military government has added to these problems. Ethiopia had food security until the1960s, but since the drought of 1975, food production has been very poor and has lagged behind the population growth. As a result a significant volume of food has been received every year especially as food aid. It is expected that these trends will continue. The Food and Agricultural Organization of the United Nations expects the food deficit to reach 2.5 million tons by the year 2010, unless there are sharp increases in agricultural production in the country (Seyoum *et al.*, 1997).

The agricultural sector in Ethiopia, as described clearly by Seyoum *et al.* (1997), is almost entirely dominated by small-scale, resource-poor farmers who produce 90 to 95 percent of all agricultural output. The problems of small-scale agriculture include the use of traditional technology of low productivity, extension services that are inadequately funded, a shortage of oxen for cultivation, and shortages and poor distribution of agricultural inputs.

Ethiopian small-scale farmers traditionally tend to produce more cereals than pulses and oilseeds. Seyoum *et al.* (1997) indicated that traditional cereal farming is not only low yielding but also results in the mining of plant nutrients from the soil. This means that after harvest, traditional farmers remove the stalks and the leaves, and sometimes even the maize stumps and roots, for animal feed, fuel and building materials. These practices leave no crop residue to restore soil nutrients and organic matter.

Ethiopia has a total land area of 111,811,000 hectares. Land higher than 1,500 meters above sea level or the highlands constitute about 45 percent of the area and is inhabited by nearly 80 percent of the population. The highland has very favourable climate with the major portion of the land (i.e., 75 percent) having a growing period that exceeds 180 days. The lowlands in the east, south, northwest and northeast have arid and semi-arid climate with very low growing period and are mainly inhabited by pastoralists. Shifting cultivators and hunter-gatherers occupy the sparsely populated humid and sub-humid lowlands of the west and southwest (Tegegn, 1995).

According to Tegegn (1995), the land resource in the country is classified into five management units based on growing period, soil depth, surface stoniness and slope. The five land management units identified and their area coverage are given in Table 4.1. The table shows that marginal and non-arable land approximate 62% or nearly 2/3 of the total land. The remaining 38% or a little over 1/3 of the total area is potentially cultivable. Of this the vertisol area has a special management requirement that includes good drainage facility and high draught requirements while areas classified as steep land require intensive conservation measures.

Moisture limitation is one criterion for classifying land management units into arable and otherwise. Most of the non-arable lands face severe moisture availability constraints and are found mainly in the lowlands of the country. These lowlands of Ethiopia are however suitable for irrigation and are drained by major drainage basins. From the total non-arable land in lowland areas of the country, the land that is irrigable in the major river basins amounts to about 3,495,795 hectares, which is about 3 percent of the total land area.

Kloos (1990) has earlier also indicated a similar figure of potentially irrigable land in Ethiopia. The addition of irrigable area increases the arable land to 33,685,795 hectares forming approximately 30 percent of the total area (Tegegn, 1995).

Table 4.1. Land management classification

Land management class	Description	Area (Million ha)	Percent of Total Area of Country
Arable land (excluding vertisols)	- Dependable growing period (DGP) more than 90 days - Soils more than 25 cm deep - Surface stoniness less than 50 to 90 percent stone cover	30.2	27
Vertisols	- All areas predominantly covered by heavy black soil	6.7	6
Steep land	- All land over 30 percent slope - All other factors as for arable land	5.5	5
Marginal land	- Land with significant moisture limitations in many years (less than 90 days and more than 60 days of DGP)	14.5	13
Non-arable land	- Land with sever moisture limitations (less than 60 days DGP) - Soils less than 25 cm - Surface stoniness > 50 to 90 percent	54.8	49
Total		111.8	100

Source: Tegegn Gebre Egziabher (1995)

According to Ellis (1992), land reform is defined to be the redistribution of property ownership in land or other rights of access to the use of land.

Dejene and Teferi (1995) indicated that land reform and land systems affect the socio-economic development of a country in many ways. They determine the distribution of incomes, power and the use of land. Their influence goes far beyond the economic sphere to determine social attitudes and social satisfaction. Land systems are linked with national tradition and national character. However, as mentioned by Pinckney and Kimuyu (1994), the importance of land tenure reform to rural development in Sub-Saharan Africa has been a matter of debate for decades.

Ethiopia is said to have had a complex land tenure system until the 1974 revolution. The assessment of landownership in Ethiopia has been difficult due to the existence of so many land tenure systems in the country, coupled with the lack of reliable data. However, the tenure system can be understood in a simple way if one examines it in the context of the basic distinction between landownership patterns in the north and those in the south of the nation (http://www.1upinfo.com/country-guide-study/ December, 2002).

In the northern provinces of Ethiopia the major form of land ownership was a type of communal system known as *rist* (a land tenure system among the Amhara and, with some variations, among the Tigray). The *rist* rights are land-use rights that any Amhara or Tigray, peasant or noble, can claim by virtue of descent from the original holder of such rights. Rist was hereditary, inalienable, and inviolable. No user of any piece of land could sell his or her share outside the family or mortgage or grant his or her share as a gift, as the land belonged not to the individual but to the descent group (a group having political, economic, or social functions). Most peasants in the northern highlands held at least some *rist* land, but there were some members belonging to minority ethnic groups who were tenant farmers (http://www.1upinfo.com/country-guide-study/December, 2002).

Gult, which is an ownership right acquired from the monarch or from provincial rulers who were empowered to make land grants, was the other major form of land tenure. Gult owners collected tributes from the peasantry and, until 1966 (when gult rights were abolished in principle), extracted labor services as payment in kind from the peasants. Gult rights were the typical form of compensation for an official until the government instituted salaries in the twentieth century (http://www.1upinfo.com/country-guide-study/December, 2002).

Samon, mengist, and maderia where the other forms of land tenure in the past. Samon was land the government had granted to the Orthodox Church. Peasants who worked on church land paid tribute to the church rather than to the emperor. The church lost all its land after the 1974 revolution. Mengist and maderia were large tracts of agricultural land that are owned by the state. Mengist was land registered as government property, and maderia was land granted mainly to government officials, war veterans, and other patriots in place of a pension or salary (http://www.1upinfo.com/country-guide-study/December, 2002).

In the southern provinces landownership patterns developed as a result of land grants following the Ethiopian conquest of the region in the late nineteenth and early twentieth centuries. After conquest, the southern land was divided equally in to three parts among the state, the church, and the indigenous population. Warlords who administered the occupied regions received the state's share. They, in turn, redistributed part of their share to their officers and soldiers. The church's share was distributed in the same manner among the church hierarchy. The rest of the land was divided between the traditional leaders and the indigenous people. Thus, the loss of two-thirds of the land to the new landlords and the church made many local people tenants in the southern provinces (http://www.1upinfo.com/country-guide-study/December, 2002).

In the lowland periphery, where pastoralists inhabit, the traditional practice of land holding and the allocation of pastoral land according to tribal customs remained largely undisturbed by the highlanders, who intensely disliked the hot and humid lowland climate and feared malaria. However, beginning in the 1950s, the malaria eradication programs made irrigation agriculture in these areas possible. The government's desire to promote such agriculture, combined with its policy of creating new tax revenues, created pressure on many pastoralists. Then, large tracts of traditional pastoralist grazing land were converted into large-scale commercial farms (http://www.1upinfo.com/country-guide-study/December, 2002).

Many sectors of Ethiopian society favored land reform in the mid-1960s owing to the lack of incentives on the part of the peasant farmers, which emanated from the insecurity of the land tenure. After this period it has become clear that the old land tenure system was one of the major factors responsible for the backward condition of Ethiopia's agriculture and triggered the onset of the 1974 revolution. The Derg announced its land reform program on March 4, 1975. This was followed by the nationalization of rural land by the government without compensation. Through this land reform, the government abolished tenancy, forbade the hiring of wage labor on private farms, ordered all commercial farms to remain under state control, and granted each peasant family only possessing rights of a plot of land not to exceed ten hectares (http://www.1upinfo.com/country-guide-study/December, 2002).

The southern regions of the country welcomed the land reform. But in the northern highlands, where *rist* dominated and tenancy were exceptions, many people resisted land reform. On the lowland peripheries, where pastoralists traditionally maintained their claims over grazing lands, land reform had the least impact. The land reform destroyed the feudal order; changed landowning patterns, particularly in the south, in favor of peasants and small landowners. However, problems associated with declining agricultural productivity and poor farming techniques were still prevalent (http://www.1upinfo.com/country-guide-study/ December, 2002).

The attempts of the government to implement land reform also created problems related to land fragmentation, insecurity of tenure, and shortages of farm inputs and tools. Periodical land redistribution was imposed on peasant associations in order to accommodate young families or new households moving into their area. This process has resulted in smaller farms and the fragmentation of holdings, which were often scattered into small plots to give families land of comparable quality. Consequently, individual holdings were frequently far smaller than the permitted maximum allotment of ten hectares. A study which was conducted around Addis Ababa in 1979 showed that individual holdings ranged from 1.0 to 1.6 hectares and that about 48 percent of the parcels were less than 0.25 of a hectare in size. Increasing pressure to collectivize farms was the second problem related to security of tenure. Many peasants were reluctant to improve their land because they know that they would not receive compensation for upgrades. The third problem developed as a result of the military government's failure to provide farmers with basic items like seeds, oxen, and fertilizer (http://www.1upinfo.com/country-guide-study/December, 2002).

In the proceedings of the fourth annual conference on the Ethiopian economy, Dejene and Teferi (1995), indicated that land issues specific to the Derg period (e.g., periodic redistribution of land, allocation of the best land to producers' cooperatives, the villagization programme, reduced planting of trees on individual plots, etc.) had been largely resolved by the Mixed Economy Policy of March 1990 and subsequently by the Transitional Government Of Ethiopia (TGE), which, in its 1991 economic policy document, ruled that the further redistribution of land ownership was to be determined by a referendum after the general election.

Under Ethiopia's present land tenure system, the government owns all land and provides long-term leases to the farmers; the system continues to hamper growth in the industrial sector, as entrepreneurs are unable to use land as collateral for loans. This has been also extensively explained by Tekie's paper (1998).

Tekie (1998) explains that in accordance with the Ethiopian Constitution enacted in 1994, the right to ownership of rural and urban land, as well as of all natural resources, is exclusively vested in the state. This means that there have been no changes in the pattern of property rights from previous proclamations. Thus, individuals residing in rural areas and leading their livelihood in farming have user rights over the land they have been allotted by the community. According to Tekie (1998), the new rules, which are explained by the above constitution, are identical to previous institutional arrangements as far as sale, mortgage or exchange of tenure is concerned. This is tantamount to saying that land so allotted to individuals in the rural communities shall not be subject to sale or to other means of exchange as declared by Article 40 of the constitution.

However, the current land policy has some differences as compared to the previous regime's policies. Under the 1994 constitution the power to administer land and other natural resources is passed on from the federal government to the Regional States. As a follow up of these provisions of the constitution, the FDRE issued Proclamation Number 89/1989 in 1997, which provides the regional states with the responsibility of drafting laws pertaining to the administration of land under their jurisdiction, with the condition that those do not contradict the fundamental laws of the federal government (Tekie, 1998).

The above proclamation contains details of the conditions under which the Regional States can introduce reallocation of land in rural areas. In order to ensure that all the would-be farmers could get land, a periodic reallocation of individually cultivated land among members of a community is exercised by the regional states. But, as long as the available stock of unutilized land in a village is low, limited or non-existent, for newly-formed households, or immigrants into the village, redistribution is bound to affect existing farming households negatively (Tekie, 1998).

Land use and land cover is influenced both by physical characteristics such as climate and population pressure (Tegegn, 1995) and property rights.

The depiction by Tegegn (1995) of the distribution of land use and land cover in Ethiopia is shown in Table 4.2.

Table 4.2 shows that the cultivated land in the country is about 24 percent of the total land while land under all types of vegetation amounts to 30 percent. Grassland is about 32 percent while bare land and water bodies together account for 14 percent. The land identified as cultivated includes land under fallow and grazing other than cropped land. This land is slightly less than the potential rain-fed arable land, which is 27 percent of the total area. Given the current level of technology, the room for potential expansion of arable land amounts to nearly 3 percent of the total land area of the country. This assumption however has to be cautiously taken because the little room for expansion could be found in inhospitable areas such as land infested with various human and animal diseases. Heavy investment in infrastructure is also required if this type of land were to be effectively utilized (Tegegn, 1995).

Table 4.2 Land use and land cover type distribution

Land use and land cover type	Area in ha	Percent of total area of the country
Cultivated land	26,551,200	23.74
• State farm	58,000	0.05
• Intensively cultivated land	12,078,000	10.80
• Moderately cultivated land	12,445,400	11.13
• Perennial crop cultivation	1,969,400	1.76
Afro Alpine and sub Afro Alpine	200,000	0.17
Forest land	5,417,200	4.84
Woodland	3,092,000	2.76
Riparian woodland	620,000	0.55
Bush land	6,386,400	5.71
Shrub land	18,327,200	16.39
Grassland	35,696,200	31.92
Wetland	983,600	0.87
Bare land	14,723,000	13.17
Water body	681,000	0.60
Total area	112,677,400	100.72

Source: Tegegn Gebre Egziabher (1995)

4.2 Economic theories of land use

4.2.1 Resource economics and natural resources

Resource economics is not a new area of economics. The use of land, and especially the limitations of land in relation to population growth, was one of the main concerns of 'classical' economists such as Malthus and Ricardo. They explored the social, economic and natural conditions determining economic growth. In contrast, contemporary 'neoclassical' or 'conventional' approaches to resource economics are more concerned with the allocative efficiency of the market system and how this affects the exploitation of natural resources (Schipper, 1996).

Resource economics, as elaborated by Randall (1987), is seen as an applied, policy-oriented field of enquiry. It is seen as so thoroughly policy-oriented that it would not exist as an identifiable sub discipline of economics if (a) all resource-related decisions were made by the decentralized, profit-seeking entrepreneurs of competitive microeconomic theory, and (b) the outcomes of such decisions were regularly and predictably efficient and just. If there were no need for resource and environmental policy, there would be no need for applied resource economics (Randall, 1987).

Randall (1987) has also shown that the challenge to humankind is to effectively manage the resources of the planet so as to maximize the satisfaction derived from them. Randall (1987) said that the above challenge of effective resource management has a time dimension that is absolutely critical. According to Randall, if humankind were willing to accept the extinction of civilization within a few generations, resource extraction could proceed without restraint whereby the harvest of renewable resources could exceed equilibrium rates and thus bring about the demise of these resources.

Likewise, as explained by Norton and Alwang (1993), natural resources, including land and its associated soil, water, forests, and minerals, have played an important role in the economic development of many countries. In this regard, as pointed out by Norton and

Alwang (1993), an important question to ask is: Will natural resources continue to be an important source of economic growth or will they be a limitation to future growth?

Schipper (1996) also shares the above concern of Norton and Alwang regarding the continuity of natural resources to supply human needs around the globe. Some of these concerns of Schipper include: Are the land (and water) resources of the earth able to supply sufficient products (food and other) to sustain a growing population and provide the agricultural population with increasing incomes? Will land and water resources be able to maintain their productive capacity over time, and provide sufficient living space and environmental amenities?

Upton (1996) indicated that agriculture and pastoralism could be viewed as ways of exploiting the natural environment. Human labour and man-made capital are employed in harvesting some of nature's gifts. Nonetheless the availability of natural resources limits what can be harvested from a given area using a given technology.

As mentioned by Upton (1996), in so far as natural resources may be destroyed by over-exploitation or misuse, choices arise between current and future consumption. Resources that are conserved for the future might otherwise have been used to increase consumption now. For present purposes it is convenient to assume that users aim to sustain productive capacity over time, or in other words to maintain a steady state. This means that the stock of natural resources is not allowed to deteriorate over time.

Upton (1996) identifies three main categories of natural resources that are important to the farmer. These are: (1) biological, renewable resources such as forests, wildlife and natural rangeland grazing; (2) non-renewable resources of land, consisting of the original and the indestructible properties of the soil; although we know that soil fertility may be destroyed by overcropping or overgrazing and soil may be lost by erosion; and (3) water.
Natural resources are generally treated as the common property of the whole society. In fact, access to natural resources is not open to anyone and is generally limited to members of the nation, lineage or village society. Furthermore, user rights to cultivate

land are allocated to individual households. However, in much of Africa no rents are paid for land use while access to forests and rangelands is open. Open access may result in a higher rate of exploitation than would occur under private ownership (Upton, 1996).

On the other hand, as pointed out by Upton (1996), natural resources could be depleted either as a result of chance, droughts, floods or disease outbreaks or because of conscious decision to do so. In the latter case the users place a higher value on their current consumption than on the welfare of future generations. This might arise as a result of (i) opportunity, such as high prices for wild game, or (ii) need, because of rapid human population growth. In both these circumstances, open access might hasten the rate of resource depletion.

Upton (1996) suggested that where there are risks of natural resource depletion the government might impose some control on the exploitation of natural resources using any of the following alternative approaches depending on the circumstances:

(1) Privatization: through enclosing, fencing and issuing titles to grazing land, or allocating and registering private water rights.

(2) Compulsion: which can be implemented in two ways (a) imposition of quotas, on the number of livestock grazed or the amount of game, firewood or water taken annually and (b) taxes per unit harvested or per head of livestock. In theory, quotas or taxes can be adjusted so as to maintain any desired rate of natural resource use. In practice, adjustment may be difficult because of the uncertainties surrounding the use of natural resources, and there are costs of monitoring and surveillance. Government monopoly of natural resources, and charges for their use may be socially unacceptable.

(3) Persuasion and assistance: Little persuasion may be needed, where farmers are aware of the risks of environmental depletion, as many instances have shown that cultivators and pastoralists can adopt measures for soil and water conservation if

persuaded to do so. Environmental monitoring and information service might enable farmers and pastoralists to adjust their rates usage of natural resources better. Programmes for reducing population growth and raising rural incomes will reduce the pressure on current use of natural resources. In some cases direct assistance may be needed for terracing, reforestation, land reclamation and other conservation measures. As with all spending on rural development the costs must be weighed against the future benefits.

Tietenberg (2000) also indicated that public concern over natural resource scarcity is not new. According to him, the current age structure of the population of the world creates inertia for population growth, which will in turn cause the demand for resources to increase faster than it would if the population were stable.

Tietenberg (2000) suggests three alternative solutions for diffusing those pressures on natural resources, which are caused by population and income growth. These are: (1) exploration and discovery, (2) technological progress, and (3) the substitution of abundant resources for scarce ones.[1]

Furthermore, as stated by Keulen *et al.* (1998), in order to attain the often broad and conflicting objectives of agricultural development policies, which are defined in terms of efficient economic growth, income distribution, and conservation of natural resource base through sustainable land use, it is necessary to identify the economic incentives that influence farmers decisions on land use and allocation of other resources. Similarly, Schipper *et al.* (1995) stressed the importance of economic incentives and agricultural policies in achieving a more sustainable use of natural resources, as these will indirectly influence the land use decisions of individual producers.

[1]The reader is referred to Tietenberg (2000) for further explanation of these three alternative solutions.

4.2.2 Some agricultural resource economics issues

Agricultural and natural resource issues have received considerable attention by economists, biologists, and physical scientists; but the concepts, models, and data are widely scattered. Agricultural resources have unique market, property right, and physical features that set them apart from the conventional production inputs of capital and labour. Models for evaluating natural resources such as petroleum, minerals, fisheries, wildlife, and forestry are similar, but usually not directly usable for many agricultural resource issues (Miranowski and Carlson, 1993).

As stated by Miranowski and Carlson (1993), research on agricultural resources has been conducted by individuals and small groups of researchers, and this implies that there has been limited cross-fertilization of ideas between these individuals and small groups, and little effort to develop general theories and unified methodologies.

The particular nature of agricultural resources and past developments in resource economics provide an outline for which issues are critical in our study of resource problems. One key dimension of agricultural resources is their intertemporal or long run nature and the need to select an optimal time path of use. Owners and managers will make a series of annual use or allocation decisions that will ideally follow an optimal time path of consumption of resources. Consider, as an example, managing the development of pest resistance to a particular pesticide, the erosion of cropland, or the depletion of an aquifer – each of these processes happens gradually over many years. Generally, these processes are surrounded by much uncertainty because of our limited knowledge of resource stocks, future demands for agricultural outputs, and the potential contribution of technology and productivity growth to satisfy future needs. Without a proper understanding of the risky and dynamic nature of agricultural resource decisions, we are possibly solving non-problems, ignoring real problems, and making misguided policy decisions (Miranowski and Carlson, 1993).

Another important characteristic of agricultural resources, as noted by Miranowski and Carlson (1993), is that if managed judiciously, their services are renewable over the long run. Simultaneously, critical resources such as land may have a relatively fixed stock. Thus, wasteful use of the land resource, for example, unmitigated soil erosion or salt accumulation, could ultimately result in exhaustion.

In an attempt to lessen the effect of population pressure on land resources, Hayami and Ruttan (1985) suggested improving land infrastructure and developing seed-fertilizer technology, which they call it internal land augmentation, as opposed to the expansion of cultivated land area called external land augmentation, in order to increase land productivity[1].

4.2.3 Land economics

As a specialization of agricultural economics, land economics is closely related to resource economics (Schipper, 1996). According to Barlowe (1986), land economics was first recognized as a course for collegiate study in 1892 when Richard T. Ely offered a seminar on Landed Property at the University of Wisconsin. Formal recognition as a separate field came in 1919 when a Division of Land Economics was established in the U.S. Department of Agriculture. Foundations were established in the 1920s for much of the work in urban and rural land economics and in real estate economics that followed. The first course materials dealing specifically with this field were published in 1922.

Barlowe (1986) explained that land economics deals with the economic relationships that people have with others respecting land. It is concerned with our economic use of the surface resources of the earth and the physical and biological, technological and economic, and institutional factors that condition and control our use of these resources. Land economics is a social science that deals with those problems in which social conduct is strategically affected by the physical, locational or property attributes of whole surface units.

[1] Refer to Hayami and Ruttan (1985) for detailed explanation of land augmentation

As described by Barlowe (1986), like general economics, land economics is concerned with the allocation and use of scarce resources. Its chief focus is on one particular type of resource – land. But land economists do not give exclusive attention to the land factor for land by itself has little economic value until it is used in conjunction with inputs of capital, labour, and management. Land economics involves a wide variety of economic relationships; but it is always concerned with problems and situations in which land, its use, or its control are regarded as factors of strategic or limiting importance. This factoral approach can be compared with the attention given to the factors of capital, labour, and management in the fields of money and banking, labour economics, and business management respectively.

Land economics is often characterized by its practical, institutional, and problem solving approach. In their attempt to explain human behaviour with respect to land and to provide relevant solutions to land resource problems, land economists frequently find it advantageous to use working tools from other disciplines such as history, law, political science, psychology, sociology, business management, geography, soil science, agronomy, irrigation science, and forestry (Barlowe, 1986).

On the other hand Dovring (1987) explains land economics as a convenient short term for the economics of natural resource use, since land is the origin or the carrier of nearly all natural resources on earth, including access to air and water.

The specifics of land problems, as argued by Dovring (1987), are known to many different kinds of scientists, among them the experts in geology and soil science, agronomy, agricultural economics, mining, and city planning. Land problems are familiar also to people in several practical professions such as farmers, foresters, land developers, real estate brokers, architects, construction engineers, and so on. Dovring (1987) explains that the task of those who pursue land economics as a field of study within the social sciences is to pull together these several elements of specialized knowledge and show how they fit within the wider fabric of the economy at both the macro and micro levels.

In doing so, land economists also need to draw on contributions from other social sciences such as geography, law, political science, and sociology.

Therefore, the purpose of studying land economics, as indicated by Dovring (1987), is both to enlighten us in general and to help prepare those who will choose any of the many careers where knowledge of the economics of land will be part of their life and the tools of their work. Land economics has applications to production both on farms, in forests and in many other branches of the economy such as urban development, real estate transactions, and land tenure decisions. It also applies to resource policy at several levels, including energy policy, water use policy, pollution control, and other measures to protect the environment.

4.2.4 Land and property rights

An important consideration in economic theory is whether property rights influence the use of a natural resource. Economic theory argues that the absence of fully articulated and enforced property rights will lead to free riding and to inefficient resource allocation resulting in soil losses (Schipper, 1996) and economic losses to society.

In their Journal article, Cole and Grossman (2002) expressed that property rights are fundamental in economics and that the allocation of property rights in society affects the efficiency of resource use.

Cole and Grossman (2002), however, indicated that though property rights are so important in economics, no consensus exists among economists with regard to the definition of property rights and is defined variously and inconsistently.

As explained by Schmid (1995), property rights are sets of ordered relationships among people that define their opportunities, their exposure to the acts of others, their privileges, and their responsibilities. It should be emphasized that rights are a relationship among individuals with respect to resources rather than the relationship between an individual and a resource. The latter is the domain of production economics. Rights define the mode of individual participation in resource use decisions and thus are part and parcel of economic power.

Defining property rights properly among resource users can act as an incentive, so that those who use a resource have an interest in conserving it for the future. As economic incentives play an important role in resource conservation, property rights thus replace uncertain ownership that deters conservation. Hence, for both the developing and industrial worlds, the first policy action should be to create property rights in the environment if none exist or to define them more clearly if they are vague or incomplete (Pearce and Warford, 1993). Bonti-Ankomah and Fox (2000) indicated that a property right system that is not well defined is characterized by high transaction costs which are known to be a serious hindrance to exchange processes. Bromley (1995) has also argued that the definition of property right is necessary for policy formulation.

Nelson *et al.* (2001) supported the above idea of Pearce and Warford upon asserting that providing land users with more secure property rights will result in more sustainable land use, preservation of biodiversity, and less deforestation. Place and Hazel (1993) found out that in some east African countries such as Rwanda the right of a farmer to bequeath land is a significant determinant of land improvement investments made by farmers on their land.

Bromley (1993) identifies four possible resource management regimes in which the scope and nature of property rights are inherent. His emphasis is on regimes as human creations whose purpose is to manage people in their use of environmental resources. He defines a resource management regime as a structure of rights and duties characterizing the relationships of individuals to one another with respect to that particular environmental resource. Tisdell and Roy (1997) have also outlined similar classification of property rights.

According to Bromley (1993) these four resource management regimes are classified as State property regimes, Private property regimes, Common property regimes, and Open access regimes. These property regimes are elaborated on below.

The ownership and control over the use of natural resources rest in the hands of the state under a state property regime. Given the permission of the state, individuals and groups may be able to make use of the natural resources. National or state forests, parks and military reservations can be cited as examples of state property regimes.

The private property regime is well known and hence there is no need for broad elaboration. Private property is usually perceived as individual property. However, one must note that all corporate property is also a private property even if a group administers it. There is also a tendency to consider private property as conferring full and absolute control to the owner. But, it is well to keep in mind that an owner is faced with a number of limitations and obligations in the use of the so-called, for example, private land and its related natural resources; few owners are entirely free to do as they wish with such assets.

Common property is the third type of regime. Common property represents *private property for the groups of co-owners* (since all others are excluded from use and decision making) *and individuals have* rights (and duties) in a common property regime. In this sense of exclusion of non-owners, the common property and the private property regimes bear similarities. The groups that own the common property vary in nature, size, and internal structure, but they are social units with a definite membership and boundaries, with certain exclusion of non-owners, common interests, and with at least some interaction among members.

Open access represents the final type of regime in which there is no property right. In this type of regime everybody has got access to the property in question. There are no property rights in an open access situation and hence it can be said that everybody's access is nobody's property. A resource under an open access regime will belong to the party to first exercise control over it. Examples of such properties are a lake of fishery, grazing forage, a common fuel wood site, etc.

Table 4.3. Summary of the four types of property regimes

State property	Individuals have *duty* to observe use/access rules determined by controlling/managing agency. Agencies have *right* to determine use/access rules
Private property	Individuals have *right* to undertake socially acceptable uses, and have *duty* to refrain from socially unacceptable uses. Others (called 'non-owners') have *duty* to refrain from preventing socially acceptable uses, and have a *right* to expect that only socially acceptable uses will occur
Common property	The management group (the "owners") has *right* to exclude nonmembers, and nonmembers have *duty* to abide by exclusion. Individual members of the management group (the "co-owners") have both *rights* and *duties* with respect to use rates and maintenance of the thing owned
Nonproperty	No defined group of users or "owners" and benefit stream is available to anyone. Individuals have both privilege and no right with respect to use rates and maintenance of the asset. The asset is an "open access resource"

Source: Bromley, 1993

According to the explanation of Bromley (1993), the conventional understanding is that private property rights are a necessary condition for the generation of economic wealth. With respect to land this means that private ownership of land is a foundation to the realization of an economic surplus. Eggertsson (1990) also indicates that any restriction on private property dampens the spirit of long-term investment. As noted by Bromley (1993), the creation of private property rights in the tropics has had some very positive effects on economic productivity of certain lands. However, it also seems fair to note that the process of privatization has had some negative effects on natural resource management. That is, the spread of private land – and the attendant individualization of village life – has undermined traditional collective management regimes over natural resources.

As noted by Bromley (1993), the above positive view for private property rights is reflected in the attempts of some economists (notably North and Thomas, 1977) to explain the origin of agriculture. According to the assertion of these economists and as stated by Bromley, " *when common property rights over resources exist, there is little incentive for the acquisition of superior technology and learning. In contrast, exclusive property rights which reward the owners provide a direct incentive to improve efficiency and productivity, or, in more fundamental terms, to acquire more knowledge and new techniques. It is this change in incentive that explains the rapid progress made by mankind in the last 10,000 years in contrast to his slow development during the era as a primitive hunter/gatherer.*"

4.2.5 Land as an economic resource

The term *land* often means different things depending upon the context in which it is used and the circumstances under which it is considered (Barlowe, 1986). Barlowe explains land as having many facets. Most important among these are the views of land as (1) space, (2) nature, (3) a factor of production, (4) a consumption good, (5) situation, (6) property, and (7) capital. Other facets of land may also be noted. Some cultural groups view land as a deity that possesses itself and that can exercise certain controls over the people who use it. Investors sometimes see it as a store of wealth that possesses unique advantages over alternative areas of investment. Others have viewed it as a gene bank – a potential source of new species and products – and as a source of pleasure and recreation (Barlowe, 1986).

Barlowe (1986) has given a definition for each of the above facets of land. According to these definitions, land includes the natural and man-made resources that individuals, groups or communities control through the possession of a portion of the earth's surface.

According to Barlowe (1986), this broad concept of land comprises not only the surface of the earth with the oceans, mountains, valleys, and plains, which provide physical support for people and their activities, but also the space beneath the surface within which minerals are found and from which they might be extracted. In addition to building sites, farm soil, growing forests, and water resources, it also involves access to such natural phenomena as sunlight, rain and wind, and changing temperatures and location with respect to markets and other areas. In short, land refers to the resources it provides to mankind. Moreover, it includes all man-made improvements that are attached to the surface of the earth and cannot be easily separated from it. Barlowe (1986) suggests that the term *land resources* be used instead of the more general term *land*, when applied in economics, in order to avoid the occasional confusion and lack of agreement regarding the precise meaning of the term land.

Barlowe (1986) indicated that the term *land resources* is both broader and narrower than the term *natural resources.* It is broader because it includes the man-made improvements that are attached to land. Natural resources can involve a broader concept in that it includes all nature-given resources from the center of the earth to the highest heavens, whereas the term land resources, when treated as an economic concept, is limited to surface resources together with the thin layer of subsurface and suprasurface resources that people use in their daily life.

Dovring (1987) also supports the above explanation of Barlowe in his definition of the land resource. He says that land has many characteristics that make it different from other basic factors in the economy and society. The highly composite nature of most land includes a whole bundle of things, among them space and raw materials, natural resources (renewable and non-renewable), energy sources, supply limitations (because the earth is finite and not man-made), and the often unclear borders between natural and man-made components of real estate.

Therefore, in the context of the present study land will be viewed as a natural and economic resource that is indispensable for agricultural production, as the use of land is primarily for production, to provide goods and services required to meet human needs and to satisfy economic demand (Dovring, 1987), and since land is first and foremost a factor of production, as most if not all commodities and many services require the use of land to some extent. However, even though there is no land market in the study area some traditional land transfers such as shared-in and shared-out land uses are taken care of in this study as far as land ownership assessment is concerned.

4.2.6 Sustainable development

The concept of sustainable development, as noted by John *et al.* (1996), first appeared in the World Conservation Strategy (WCS) (International Union for Conservation of Nature and Natural Resources, 1980), which had argued from a dominantly conservationist environmentalist standpoint. John *et al.* (1996) indicated that sustainability related issues have been discussed for several years by WCS, and the clash between the interests of environmental conservation and development was very clear in the Stockholm Conference on Human Environment in 1973.

Pearce *et al.* (1990:4) cite a definition of sustainable development given by the economist Robert Repetto, which says, "Sustainable development is a development strategy that measures all assets, natural resources, and human resources, as well as financial and physical assets, for increasing long-term wealth and well-being. Sustainable development, as a goal *rejects policies and practices that support current living standards by depleting the productive base, including natural resources*, and that leaves future generations with poorer prospects and greater risks than our own."

According to the above definition the key necessary condition for achieving sustainable development, as noted by Pearce *et al.* (1990), is the constancy of the natural capital stock, which implies for a non-negative change in the stock of natural resources and environmental quality. In basic terms, this means that the environment should not be degraded further but improvements would be welcome. This implies that sustainable development is an important focus of resource management (Chavas, 1993).

A similar debate has also been outlined by Pearce and Warford (1993). They emphasized that if poverty is to be reduced and the standard of living of the average person improved, economic growth must remain a legitimate objective of national governments and the world community. But most people are now painfully aware that pursuing economic growth without paying adequate attention to the environment is unlikely to be sustainable.

On the other hand Upton (1996:32) gives a broad definition of sustainable development, which he calls a widely quoted definition of sustainable development. He says, "sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs". He continues to indicate that this definition is a rather broad and general statement, subject to various interpretations. He points out that at the more local farm and village level, the essential concern is that the production system should not collapse in the foreseeable future as illustrated in Figure 4.1.

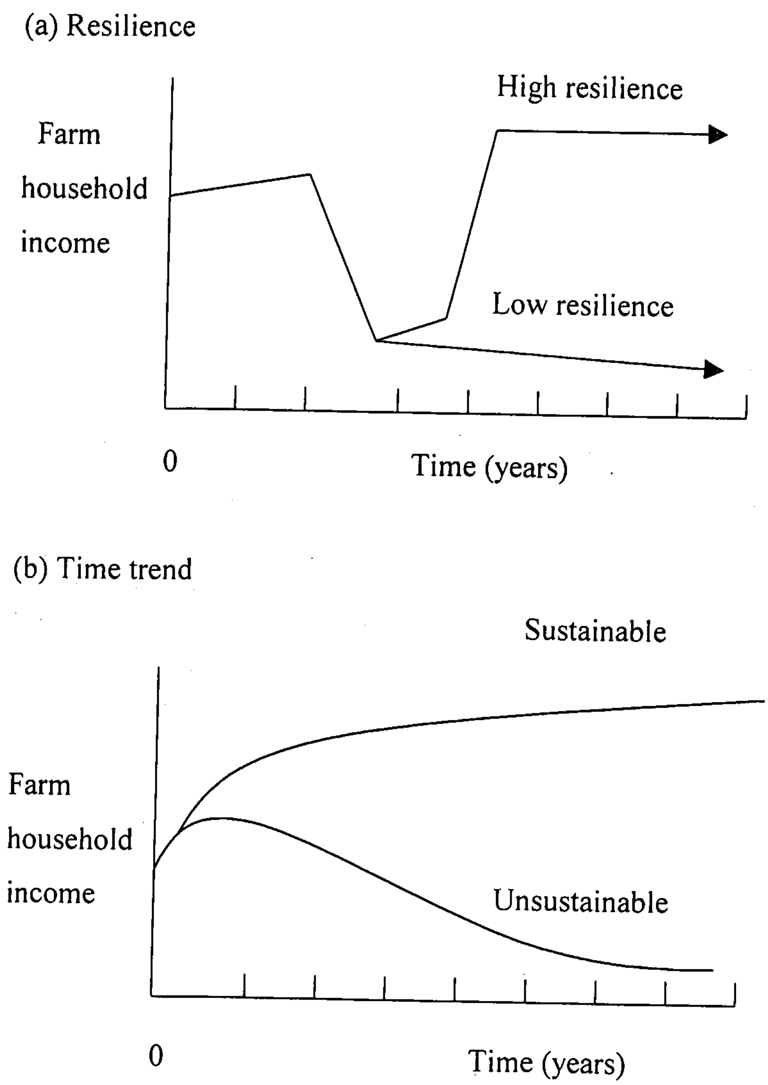


Figure 4.1 Two views of sustainability; (a) Resilient, (b) Time trend
Source: Martin Upton (1996)

As Upton (1996) noted there are two possible ways in which the collapse of the system may occur. One is as a result of a chance fluctuation or shock, such as a drought or flood, from which the system may be unable to recover (Figure 4.1a). If the system is sufficiently resilient or flexible to recover, then it may be sustainable. The other alternative is collapse due to a gradual decline in the stock of resources and household incomes (Figure 4.1b). Sustainability requires that this decline be prevented, by adequate conservation measures or change in property rights.

Ramaswamy and Sanders (1992) have also mentioned that sustainability becomes more problematic at low income levels where some or many of a country's inhabitants are not receiving minimum nutritional levels, or other basic requisites for life. They asserted that, "from a societal perspective, a country's citizens must be adequately fed and provided with other basic social services to fulfill their potential as human beings. Sustainable societies provide these basic social services for their populations."

Despite all the above definitions and concerns for sustainable development, sustainability is proved to be a difficult concept in terms of its operational usefulness, and many practical problems of definition persist (Ellis, 1996). This point will be clarified further upon discussing the application of sustainability in linear programming models in section 4.4.4.2.

Bearing in mind the above facts, therefore, as argued for the Sahel region by Ramaswamy and Sanders (1992), it seems that the most important principle of environmental sustainability for developing countries, including Ethiopia, is to improve the population's quality of life. From, an agricultural perspective, this means a more rapid level of growth in agricultural production. But insecure property rights may prevent this from happening.

4.3 Methods of land use analysis and planning

4.3.1 A skeleton model of the agricultural sector

In order to place the whole discussion about the different forms of analysis and planning of the agricultural sector in a proper perspective, it is useful to present a skeleton model of the agricultural sector (Moll and Schipper, 1994).

As noted by Moll and Schipper (1994), in Figure 4.2, the right-hand side of the model is structured according to the various actors in the agricultural sector and their occupations. Accordingly, different operators in markets, services and infrastructure, who together determine the socio-economic environment in which farm households and primary producers function, are in turn affected by policies and policy measures. The natural resources and the state of technology determine the types and levels of crop, livestock, forestry, and fishery activities, as depicted on the left-hand side of Figure 4.2. As these activities use land they are termed land use types (LUTs). LUTs combined with land units (LUs) form land use systems. Each land use type (LUT) has subtypes that are classified according to technology. A particular combination of a land unit (or parcel) and a LUT with a specific technology is called a LUST.

The farm households make a selection of the LUSTs on the basis of their resources and preferences, and they do so under the influence of the socio-economic environment. The total output of the agricultural sector (in terms of primary products) depends on the actual selection of the LUSTs by the farm households. This output consists of (a) the types and quantities of products, and (b) the negative or positive contribution to determinants of the sustainability of agricultural production, thereby affecting future production possibilities. The farm households are thus the final decision makers in agricultural production, but their behaviour is influenced by both the biophysical and the socio-economic environments (Moll and Schipper, 1994).

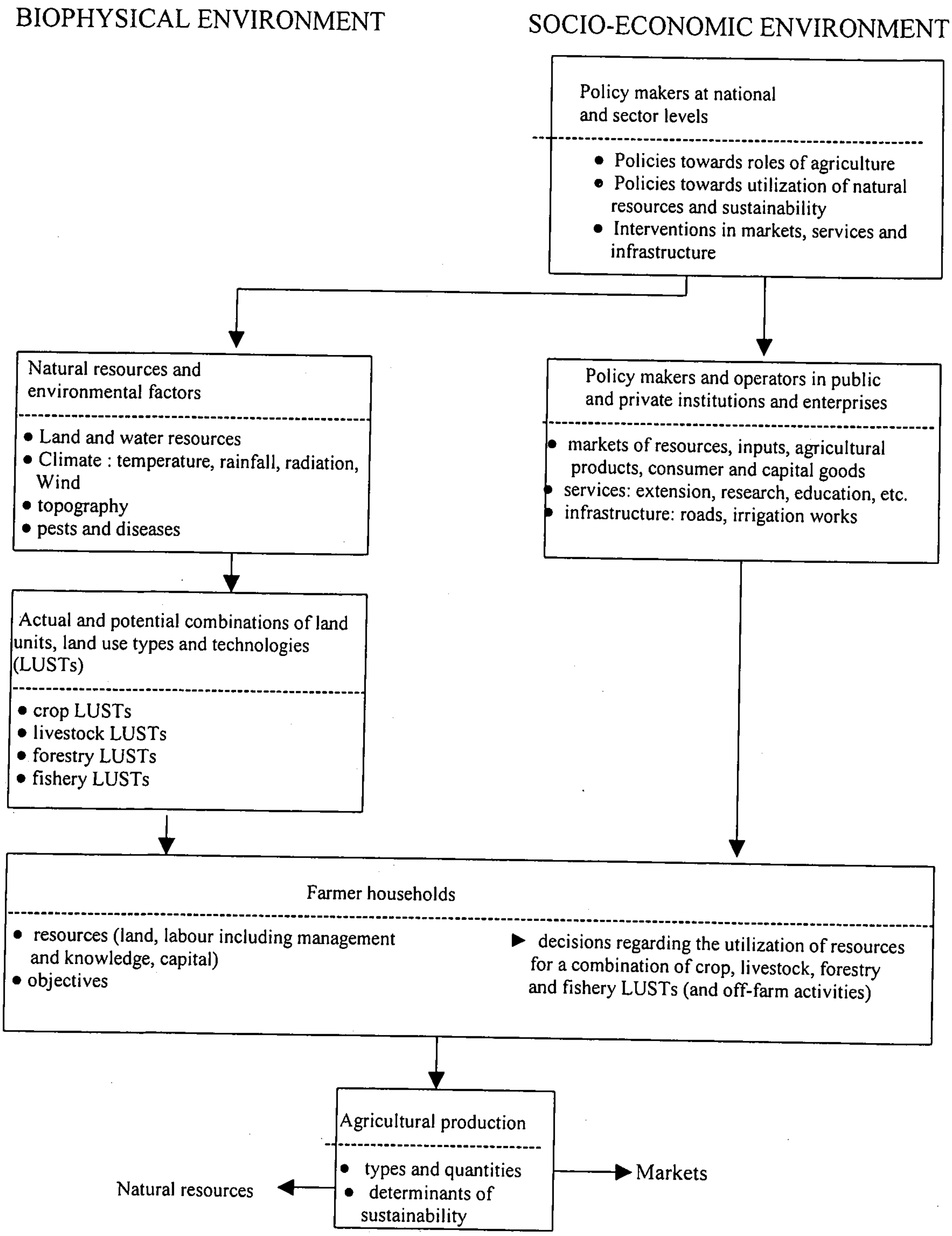


Figure 4.2. The agricultural sector

Source: Moll and Schipper (1994)

4.3.2 Regional agricultural planning

In order to sufficiently understand the concept of regional agricultural planning, and thereby land use planning, one may take note of the explanation given by Fresco *et al.* (1992).

As stated by Fresco *et al.* (1992), regional agricultural planning and land use planning are specific forms of intermediate level planning which may be defined as planning of sectors and regions, within the national economy, with a view to bridging the gap between general macro planning and specific project planning. Macro planning sets guidelines for sectoral growth, but usually does not deal with investment projects and their spatial distribution whereas project planning goes into great detail of costs, benefits, organization and financing, but takes as given the broader socio-economic framework in which the project operates

Regional agricultural planning focuses on the agricultural sector in one region. Since in most developing countries agricultural activities are very important especially at the regional level, as the largest part of the employment and of the income is generated within the agricultural sector, there is profound justification for regional agricultural planning in these countries. In addition to this, the regional approach in agricultural planning provides the possibility to take into account specific environmental conditions and therefore to arrive at realistic identification of projects (Fresco *et al.*, 1992).

However, it is not recommended to analyze the agricultural sector of a region too much in isolation from other sectors and regions of a country, as this might overlook important linkages with, and constraints and opportunities for development in, other economic sectors, as well as comparative advantages elsewhere in the economy. Also, development possibilities in the agricultural sector of a region are dependent on developments in the other sectors and regions (Fresco *et al.*, 1992).

The most important questions that are addressed by regional agricultural planning, as noted by Fresco *et al.* (1992), include: Which crops are most suitable (in view of the objectives, opportunities and constraints) in a given region? What are the advantages of a region in comparison to other regions? What interactions with other regions are important? What are the implications of alternative land uses for income, income distribution and employment? What farm types would be required and are possible? What are the relations between different crops and animals?

In most cases regional agricultural planning starts with a diagnosis of the present situation and then tries to identify possible future developments, taking into account the available resources, such as soils, climate and location, labour, capital (which could include national or local government budgets and international loans or grants), and the organization and management capacity of private or government institutions. The objectives of the regional agricultural plans can be derived in part from national objectives, but should be made region and period specific. In this the goals of the farm households in the region play a key role. In general the interest of different groups in society should be taken into account in the planning process. But this is far from simple and constitutes one of the limitations of planning (Fresco *et al.*, 1992).

As also indicated by Moll and Schipper (1994), it has been realized that regional agricultural planning is time consuming and labour intensive. It has also been criticized on conceptual grounds referring to administration bias, lack of knowledge, uncertain future and harmony versus conflict. In consideration of such criticisms, regional agricultural planning should formulate plans that take into account the contradictions in society and that are realistic with regard to what can be done, here and now, in view of limited resources. Thus, planners have to realize their limitations. Nevertheless, planning is useful and necessary for the acceleration of development.

All in all, as stated by Schipper (1996), the obvious themes for planning are the physical and institutional infrastructure, and the creation of the right conditions for agricultural development.

4.3.3 Land evaluation and farming systems analysis for land use planning

The concept and importance of land use planning has been clearly depicted by FAO (1993), which defined land use planning as a systematic assessment of land and water potential, alternatives for land use and economic and social conditions in order for farmers or planners to select and adopt the best land-use options. The purpose of land use planning, as indicated by this publication, is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future. Hence, the driving force in planning is the need for change, the need for improved management or the need for a quite different pattern of land use dictated by changing circumstances (FAO, 1993).

According to FAO (1993), planning to make the best use of land is not a new idea. Over the years, farmers have made plans season after season, deciding what to grow and where to grow it. Their decisions have been made according to their own needs, their knowledge of the land and the technology, labour and capital available. As the size of the area, the number of people involved and the complexity of the problems increase, so does the need for information and rigorous methods of analysis and planning.

Fresco *et al.* (1992) have indicated the role of land evaluation and farming systems analysis in land use planning which can also be visualized in Figure 4.3 below. As mentioned by Fresco *et al.* (1992), farming system analysis and land evaluation can be regarded as important tools for land use planning as they form the building blocks of the procedure for land use planning.

The main contributions of land evaluation to land use planning are related to three aspects (Fresco *et al.*, 1992):

(1) As land evaluation looks at the potentials for the use of land, for example the potentials for the production of certain crops, and as it looks at future possibilities for the use of land, it addresses the issue which is an important point for land use

planning.

(2) Land evaluation intends to link biophysical disciplines to socio-economic ones by focusing on the above potentials which are based on the evaluation of physical and biological resources, especially land and water, and their possible uses, coupled with an evaluation of economic and social opportunities and constraints. This gives land use planning a more thorough base.

(3) Land evaluation provides land use planning with an overview of the whole region it is supposed to tackle by presenting it with the maps of present land use, the land units, their properties and their potentials for certain land use types, at a specified scale.

As stated by Fresco *et al.* (1992), the contributions of farming systems analysis to land use planning are twofold:

(1) The process of farming systems analysis encompasses the most important ingredients of land use planning. These, among other things, include the diagnoses of the present situation with regard to farming and land use, by categorizing, describing and analyzing farms and their components, like the household system, the cropping and livestock systems; and by indicating and analyzing the linkages of farm systems with aspects of higher-level systems that impose constraints on farm level performance, e.g. input supply, credit, extension, and prices and marketing.

(2) Once the results of farming systems research become available, as a research programme can only be a long-term exercise, they can be used in future cycles of land use planning as farming systems analysis gives insights in possible and necessary improvements in existing ways of farming which can also lead to recommendations with regard to the physical and institutional infrastructure, like a better input supply, and also to specific agricultural research programmes.

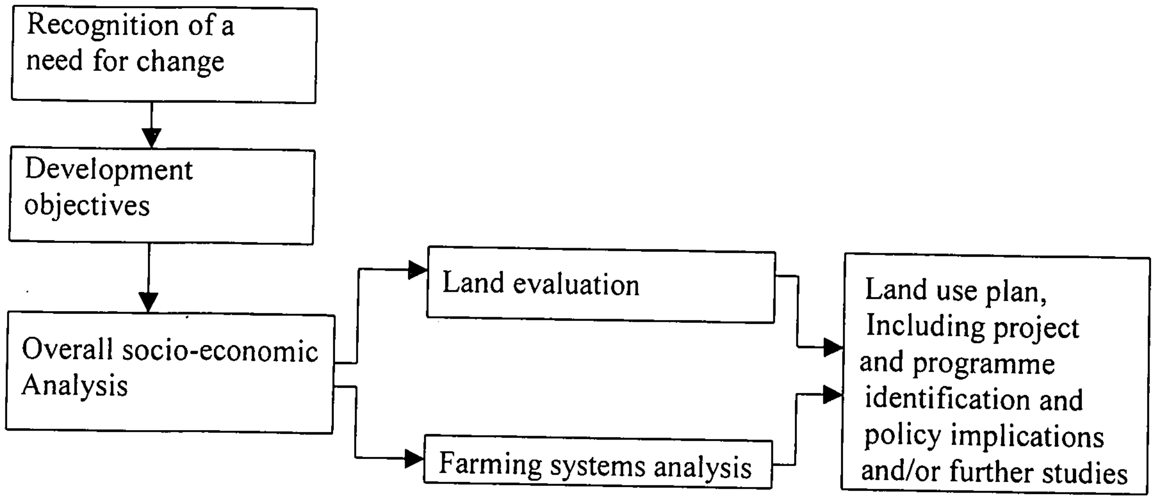


Figure 4.3. A generalized procedure for land use planning
Source: Fresco *et al.* (1992)

4.4 The Linear programming approach to land use analysis

4.4.1 An overview of linear programming

Linear programming is one of a class of operations research methods referred to as mathematical programming. It was developed in the 1940s for use in military operations, but was subsequently found well suited to solving a range of business and commercial planning problems. Today it is one of the most widely used operations research techniques and in agriculture it has been used extensively for planning purposes; for example, in farm enterprise selection, in the determination of optimal routing for transport fleets delivering to or collecting from farms and in the selection of least cost feed mixtures for livestock (Dent *et al.*, 1986).

As explained by Dent *et al.* (1986), the linear programming technique is a general methodology that can be applied to a wide range of problems with the following characteristics:

(1) the manager (that is, the farmer) can exercise a choice in the selection of activities that he wishes to put into operation from the range of activities that are possible;

(2) free selection from the range of activities are prevented by various constraints; and

(3) there is an objective which can be quantified and related to some measure of the manager's utility (for example, profit) associated with each of the activities based on a rational choice of a combination of activity levels

Upton (1996) has also clarified the conditions involved in using linear programming. He indicated that linear programming (LP) is a systematic mathematical procedure for finding the optimal plan or programme for a given set of conditions. To use this method the conditions must be presented in the form of:

(1) a limited choice of several activities;

(2) certain fixed constraints affecting the choice;

(3) straight-line (linear) relationships.

According to the explanation given by Upton (1996) on the above assumptions of linear programming, the alternative activities may correspond with crops and animals which could be produced on the farm being planned. But the word 'activity' as used in linear programming does not necessarily mean the same as the word 'enterprise' and thus buying activities may be considered in drawing up the plan.

The fixed constraints restrict the combinations of activities, which are feasible. A plan that violates any constraint is assumed not to be feasible, which means that the constraint is assumed to be rigidly fixed. On the other hand, the assumption of linearity means that no matter how many units of a particular activity are included in the plan, the cost and return per unit remains the same (Upton, 1996).

Dent *et al.* (1986) has also given a similar explanation concerning the linearity assumption in linear programming. According to Dent *et al.* (1986) linear programming assumes that, for a defined activity, relationships like resource use, resource cost, activity levels and activity returns are all linear. This means, for example, that a two-fold increase in the level at which an activity is conducted will result in a precisely two-fold increase in the amount of each resource absorbed by that activity and in the revenue (total gross margin) derived from it.

4.4.2 Linear programming and economic analysis in agriculture

Hazel and Norton (1986) have sufficiently demonstrated the importance of linear programming, as part and parcel of mathematical programming, to agricultural analysis and the connection between the two. Howitt (1995) has also shown the strong role that programming models can play in agriculture. Studies conducted by Amare (1998) and Belete (1992) have illustrated the relevance of programming techniques in determining the efficient allocation of limited resources to increase production and cash income for resource poor small farmers in Ethiopia.

As described by Hazel and Norton (1986), mathematical programming in agriculture originated in the attempt to model the economics of agricultural production, including its spatial dimension. Mathematical programming, sometimes known as process analysis or activity analysis, is explained by Hazel and Norton (1986) as being particularly suitable for agriculture. This emanates from the behaviour of farmers, agronomists, and other agricultural specialists in thinking about agricultural inputs and outputs in terms of the annual crop cycle, and about input-output coefficients per acre or hectare or other unit of land. In agricultural production, yields are measured in tons or bushels per land unit, fertilizer applications in kilograms per hectare or like units, and so on. Input costs are typically disaggregated into labour, machinery services, draft animal services, fertilizer costs, other chemical costs, etc., per land unit. Hence, as noted by Hazel and Norton (1986), this way of visualizing agricultural production in numbers constitutes a short step in forming the coefficients of inputs and outputs that make up the backbone of the programming model.

Schipper *et al.* (1995) supported the above argument of Hazel and Norton by indicating that farmers and agronomists often think of yields, use of seeds, fertilizers and pesticides, and labour requirements, in terms of certain quantities per hectare. This, as noted by Schipper *et al.* (1995), leads to the construction of fixed input-output production functions, which can be incorporated as activities in a linear programming model.

Hazel and Norton (1986) noted that agriculturalists often employ inequality constraints in formulating their problems, such as putting upper bounds on seasonal resource availability being accustomed to the existence of slack resources in some seasons while the same resources are fully utilized in other seasons. This kind of thinking fits naturally into an analysis via the programming models which actually provides a rather natural framework for organizing quantitative information about the supply side of agriculture, whether at the farm level or the sector level. Schipper *et al.* (1995) have also argued that linear programming models are particularly suited to deal with inequalities.

Different kinds of sensitivity analysis that can be conducted using programming models constitute other important uses of the model. The model can be useful in calculating the implications of different resource endowments, different market conditions, improved or new technologies, etc., at both the farm and sector levels. This kind of information is generated by the model via variations in parameter values, with a new solution obtained for each set of parameter values. At both the farm level and the sector level, the model's solution also assigns valuations to fixed resources, such as land and water supplies, whose prices may not reflect their economic values (Hazel and Norton, 1986).

Dent *et al.* (1986) showed that linear programming has been used a good deal as a farm planning technique in the US, the UK, Europe and Australia, generating valuable information to aid planning decisions on thousands of farms.

Ellis (1996) has further indicated that linear programming is an operational method, which is quite helpful for studying the allocation of resources between enterprises when inputs are limited in their total amounts or otherwise constrained, for example, a particular area of land may be suitable for one type of crop but not others. He showed that, as a methodological approach to resource allocation, linear programming is related to the idea of constrained production possibilities due to restrictions on resource availability. Such constraints are a crucial feature of the economic situation of most peasant farmers, and the idea of identifying the most limiting resource has in the past been widely applied in the design of small farm economic policies.

Likewise, Upton (1996) emphasized that linear programming is a very flexible tool where many different on- and off-farm activities can be included, physical and social constraints can be imposed and it can be adapted to deal with multiple objectives, risk and planning over time. Moreover, its most valuable feature is that it is a whole farm-planning tool, particularly suited to handling the interactions of a complex system. In contrast, if for instance we look at the methodology of partial budgeting in farm economic analysis, this is concerned only with one activity or sub-system.

As mentioned by Upton (1996), the main applications of linear programming are based on the analysis of a typical, average or model farm which is supposed to represent the whole farming population, and is thus used either to predict how the majority of these farmers will respond to technical and economic changes, or to explore how their farming systems might be improved.

Schipper (1996) described that linear programming, as a method of analysis, is best suited to questions of allocation of resources at the farm and sub-regional levels for a given set of market conditions. He indicated that econometric methods are better suited to analyze product and factor markets at higher levels of aggregation while linear programming is more justified at the farm or sub-regional levels than at the regional, sectoral or national level, because of the assumption of fixed prices.

Despite possessing all the above wide areas of application with respect to the economic analysis of the agricultural sector, as mentioned by Dent *et al.* (1986), linear programming has not been used by significant numbers of farmers as a routine planning aid. Given the potential of the technique, the under mentioned factors have been previously cited as important obstacles to its wider adoption (Dent *et al.*, 1986): [1]

(1) doubts as to the appropriateness of the technique to real farm planning;

(2) improper use of the technique;

(3) unavailability of adequate data for farm planning purposes;

(4) high cost of applications;

(5) unavailability of suitable computing facilities;

(6) scarcity of personnel skilled in carrying out a linear programming analysis;

(7) lack of awareness by farmers and their advisors of the potential of the technique.

However, as explained by Dent *et al.* (1986), since the methodology and limitations of linear programming are becoming well understood, an appreciation has been gained of the best manner in which to apply the technique. As also noted by Upton (1996) even the very simple versions of linear programming models can help our understanding of the general problem of optimization subject to constraints. The advent of low-cost, high speed computers with large memory capacity and the increasing availability of linear programming packages for microcomputers means that computing facilities are now available on site for the majority of farm advisors and this will allow a wider use of this tool by researchers and those farm advisers. Consequently, as explained by Dent *et al.* (1986) linear programming is a systematic, versatile and powerful farm planning technique.

[1] For an extensive explanation of these factors the reader is referred to Dent *et al.* (1986). Nowadays most of the above problems have been overcome and various techniques such as risk and risk aversion, non-linear response functions, fixed costs, etc. can be included in the linear programming methodology.

4.4.3 Levels of land use analysis and aggregation problems

Land use planning has connotations of designing and deciding upon land use for the actual land users. However, in most situations land users themselves decide about the use of their land, not the land use planners nor decision makers at a policy level. Thus, land use planning can only analyze possible land uses in the past, at present and in the future and advise about the best land use. Therefore, in an attempt to analyze possible land uses in a given study and for communicating the same, the use of the term 'land use analysis' is preferred over the term 'land use planning' (Schipper, 1996).

Fresco *et al.* (1992) distinguished five levels of land use analysis: national, regional, sub-regional, farm and activity/sub-system. There are different tasks to perform at each level. As also mentioned by Erenstein and Schipper (1993) these levels of analysis are related to levels of decision making and addressing several levels of analysis at the same time gives rise to aggregation issues.

According to Erenstein and Schipper (1993), three issues pose problems in land use analysis: (1) the behaviour of the farm households, who are responsible for the actual use of land, remains unknown in analyzing the use of land. (2) aggregation bias arises, as individual farmers have resources at their disposal in proportions different from the aggregate resources of a region. (3) variables, which are exogenous at the micro level, become endogenous at higher levels.

Schipper (1996) acknowledges that the above problems are well known from the efforts to build linear programming models at regional or national levels.

As also indicated by Hazell and Norton (1986), in the transition from farm-level to sector level analysis, an aggregation bias arises because all farms are not similar. Particularly, small farms with a low level of farm product sales or limited resources are more heterogeneous (Hinson, 1996). Ideally, for the aggregation to be correct, a model should be constructed for every individual farm. These individual models could then be linked together to form a sector model. Since this is not feasible in practice, two approaches may be considered to solve the problem (Schipper 1996):

(1) Aggregate regional models: this involves aggregating the resources of a region and modeling these aggregated variables as if they formed a single large farm

(2) Representative farm model: this implies classification of the whole farms into a smaller number of homogenous groups. A model is then constructed for the representative farm from each group after which these farm models are then aggregated in a sector model using the number of farms in each group as weights. To limit aggregation bias, this procedure places a high demand on the proper definition of the representative farms and the weighting procedure.

As pointed out by Schipper (1996), both the above approaches overstate resource mobility by enabling farms to combine resources in proportions that are not available to them individually. Both approaches also carry the implicit assumption that all farms have equal access to the same technologies of production. Therefore, in general, the value of the objective function (in a maximization problem) of an aggregated model is higher than that of the objective function of a disaggregated one.

Hazell and Norton (1986) have also mentioned that aggregation bias can only be avoided (or minimized) if farms are classified into groups or regions that are defined according to rigid theoretical requirements of homogeneity.

In practice, as stated by Hazell and Norton (1986), the aggregation criteria are reduced to grouping farms according to a few simple rules as indicated below:

(1) similar proportions in resource endowments,
(2) similar yields, and
(3) similar technologies.

The first rule implies grouping farms by size class as it means similar land-to-labour ratios among farms. Grouping farms in this way will help the model to show which farms engage in labour-saving technologies, such as mechanization of plowing and other operations (Hazell and Norton, 1986).

Rule number two implies identifying differences in climate, soils, and elevation which alone (apart from technology employed) cause significant yield differences. This requires at minimum putting irrigated and non-irrigated farms into separate classes. In most cases on a sector-wide basis climate (rainfall), slope of the land, and elevation are more important criteria than soil types as such for grouping farms (Hazell and Norton, 1986).

Separating farms according to predominant crops is the essence of rule number three. For instance, farms with yam-based cropping patterns clearly belong in a different category than sorghum-millet-groundnuts farms in a particular region. Also, some of the technologically more backward areas of a sector simply may not have the household wealth or know-how to grow more sophisticated crops or to use more demanding technologies. Farms in such areas must be placed in a separate category (Hazell and Norton, 1986).

4.4.4 Linear programming as a tool for land use analysis

4.4.4.1 Agricultural sector models

Linear programming models used as a tool for land use analysis at the sub-regional level can be viewed as (mini) agricultural sector models. Potentially they are useful for policy formulation with regard to land use and related (sustainable) agricultural development (Schipper 1996).

Implicitly or explicitly, every sector model's structure contains the following five elements (Hazel and Norton, 1986):

(1) A description of producer's economic behaviour, that is, their decision rules on output composition and scale. In agriculture, the motives of profit maximization and risk aversion usually figure importantly in the decision rules, but other considerations may be important as well (such as production for home retention in subsistence agriculture).

(2) A description of the production functions, or technology sets, available to producers in each region. These functions relate yields to inputs, and they need to be differentiated by farming regime (irrigated vs. non-irrigated, livestock vs. annual crops vs. perennial crops, etc.). Different groups of producers may have very different options in technology and even in the crops they may grow. A subsistent farmer in rain fed areas may not be able to grow all the crops that a farmer with irrigation can, and he may not have access to the same degree of mechanization. Thus, appropriate differentiation of the technology sets can be important for making the model as realistic as possible.

(3) A definition of resource endowments held by each group of producers. These endowments refer chiefly to land, irrigation supplies, and family labour, although for some models it also is important to include initial stocks of tree crops, livestock, and farm machinery. Even with the same technology sets, variations in resource endowments will lead to differences in farmer response, in terms of their output levels and mixes.

(4) A specification of the market environment in which the producer operates. This specification will include market forms plus associated consumer demand functions, and it will include statements about which inputs are efficiently available in perfectly elastic or inelastic supply. It can include market environments such as the market for short-term credit, the cost of marketing and the cost of processing agricultural products. The marketing costs will often vary spatially, and such variations should be included in the model. The marketing environment also includes possibilities for international trade and the corresponding import supply functions, export demand

functions, export quotas, etc.

(5) A specification of the policy environment of the sector. In this case, for example, values are needed for rates of input subsidy (and for amounts of inputs available at the subsidized rates) and a specification is needed for output subsidies when they are relevant. Import quotas and tariffs also fall in the category of policy instruments, but export quotas are included in the description of the market environment, for they are beyond the reach of purely domestic policy.

Sector models differ in their degree of comprehensiveness and detail. Most often they are comprehensive with regard to all sources of supply and demand of the products with in the agricultural sector of a given region, but not with regard to the factors of production. Some factors are sector-specific, for example land, while others can be employed in various sectors, especially labour and capital (Schipper 1996).

4.4.4.2 Sustainability parameters in linear programming models

Ellis (1996) noted that the concept of sustainability has been widely applied to environmental problems in rich and poor countries alike. This concept tries to capture the idea that the living standards of future generations should not be compromised through environmental depletion by the current generation.

In linear programming models, sustainability parameters can be taken care of via the inclusion of sustainability constraints. In these kinds of models, as explained by Schipper (1996), ecological sustainability criteria could be accounted for through constraints in maximizing an objective of farm economic surplus. In such a set up, each activity causes a positive or negative impact, expressed in 'technical' coefficients, on sustainability constraints and the total impact of the sum of all activities is restricted by the 'Right Hand Side' coefficient, which should be an indication of the (renewable) resource availability and /or its regeneration rate, or, in the case of pollutants, of the assimilative capacity of the environment. The economic costs of resource use or pollution can also be deducted from the economic surplus in the objective function through auxiliary variables if necessary and possible.

As stated by Schipper (1996), since linear programming optimizes resource use given a certain objective, it strives for an optimum efficiency for sustainable development. Efficiency is optimized subject to substitutability between resources and technical progress. The effects of substitution can be traced via shadow prices of constraints and sensitivity analysis. The notion of 'technical progress' (or innovations, leading to a more productive use of resources) is part of the model: each land use type is specified according to technology and combined with a land unit (the LUSTs). In the optimal solution the most efficient technologies or LUSTs, and thus resource use, are chosen in view of all options and constraints.

However, as vigorously debated by Ellis (1996), sustainability has been proven to be a difficult concept as far as its operational usefulness is concerned, and many practical problems of definition persist. John *et al.* (1996) has supported this argument of Ellis by indicating that at present over seventy definitions of sustainable development exist and Pearce *et al.* (1989) have also given a collection of definitions as an appendix to their book.

As argued by Ellis (1996), for farming systems, sustainability implies maintaining resource productivity in the long term from one generation to the next. However, this rather simple idea leaves plenty of scope for varying interpretations related to level of technology, robustness in the face of climatic variation, ability to cope with unforeseen stress, and other considerations. For example, whether ' sustainable agriculture' means abandoning high input technology in favour of low input technology is a controversial issue-giving rise to unresolved debate (Ellis, 1996).

Ellis (1996) has further indicated that the ethical issues surrounding obligations to future generations by way of sustainability are far from clear and economists are increasingly becoming doubtful of sustainability ideas, especially in the more general 'sustainable development' sense. He says that these economists have pointed out that as far as technology is changing continuously; when economic growth is occurring and enabling the future generations to have higher income, and therefore more options, than the current generation; and since the current generation cannot anticipate the tastes and preferences of future generations, then the necessity for conserving some types of resources now may become irrelevant in the future.

4.4.5 Structure of linear programming models in land use analysis

In constructing linear programming sector models for an economic analysis of land use, as mentioned by Hazell and Norton (1986), the starting point is the designation of the region, sub-region and products, and possibly the farm size groups or other farm stratifications. The model's variables will probably include at a minimum the sets such as: production activities for crops and possibly livestock; input supplying activities; and miscellaneous accounting activities for items such as farm income. Immediately after the products and technologies, and farm groupings are defined, the next step is to define the inputs to production and their corresponding balances and constraints, including seasonality where relevant.

The first stages in building the model, therefore, are: (1) listing the products and inputs and deciding on the spatial categories (farm groups), and (2) developing in preliminary form the list of equations and variables. These lists will typically be revised in the course of building the model, but it is important to get them down in preliminary form at the outset (Hazell and Norton, 1986).

In line with this, the basic components of the linear programming sub-regional models for land use analysis, as depicted by Schipper (1996), are summarized in the subsequent paragraphs under the headings of objectives, variables and constraints.

Objectives

In both agricultural sector and land use analytical models it is necessary to have a descriptive or positive objective function for an economic appraisal of different policy options. This function should imitate an assumed objective of farm households, thereby introducing an aspect of farm household behaviour into the model. The economic behaviour of farm households and their decision-making can be approached as constrained optimization. Hence, a measure of farm economic surplus can be used as a first approximation of a suitable farm household objective function related to income *earning* of a household. Such a function includes all benefits and costs from the farm household's point of view (Schipper, 1996).

Variables

Consisting of a land unit, a land use type and a technology specification, LUSTs form the nucleus of a land use model and are usually measured in hectares per year. In that way the input and output coefficients can be specified completely depending on their relevance and usefulness. Each coefficient of a variable indicates the use of a constraint (inputs) or the supply to a constraint (outputs). Normally, LUSTs have output coefficients per product and input coefficients related to the use of land, labour and capital (animal traction, equipment, etc.), and variable inputs (e.g. seeds, fertilizers, biocides). The LUSTs variables are specified per farm type for the distinguished farm types in the sub-region (Schipper, 1996).

Constraints

Land constraints are formulated in relation to the LUSTs variables, for each farm type and sub-period, per relevant distinction in land units. The distinctions that exist among land units may be related to, for example, rainfall regimes and altitude classes; rain fed or irrigated land, or soil types. Apart from land constraints, labour constraints are normally part of land use models. Labour constraints are formulated per sub-period, e.g. per month or for certain peak periods in order to take into account the often marked differences in labour use in different periods within the agricultural year. Labour availability in each period could be relatively large, but more restricted for the year as a whole. Household labour is constrained per farm type, while hired labour and off-farm work is constrained at the level of the sub-region. For the capital constraints, a structure comparable to labour constraints can be set up when appropriate and needed (Schipper, 1996).

4.5 Summary and Conclusion

In this chapter a literature study with regard to land use analysis was undertaken. Nowadays various concerns have been expressed about the present and future land use (Miranowski *et al.*, 1993;Young, 1998; Upton, 1996; etc.). Some of the frequently asked questions with respect to this concern over the land use are: Are the land (and water) resources of the earth able to supply sufficient products to sustain a growing population and provide increasing incomes to the agricultural population? Will the land and water resources be able to maintain their productive capacity over time, and provide sufficient living space and environmental amenities?

An attempt was made to investigate and understand the nature of these concerns. In section 4.1 the land resource and land use from a global point of view was assessed. The unique characteristics of the land resource were highlighted. According to Miranowski *et al.*, (1993) agriculture is an activity that modifies the natural environment for the purpose of enhancing the flow of goods and services from natural resources. These modifications, as stated by Miranowski *et al.*, could trigger the impairment of the long-run potential of the land to sustain production of agricultural goods and services and impair the flow of other goods and services from the land, air, and water.

An investigation was also made on the problems that are associated with the use of the land resource amid the ever-increasing population of the developing countries (Young, 1998). Similarly, an extensive study was carried out to introduce the agricultural sector, the land resource and the land use practice in Ethiopia. The agricultural sector in Ethiopia was observed to be almost entirely dominated by small-scale, resource-poor farmers who produce 90 to 95 percent of all agricultural outputs. The problems of small-scale agriculture include the use of traditional technology of low productivity, extension services that are inadequately funded, a shortage of oxen for cultivation, and shortages and poor distribution of agricultural inputs.

In section 4.2 an attempt was made to present some economic theories that facilitate the understanding of the concept of land use and land use analysis. In addition to other resources, the use of land, and especially the limitations of land in relation to population growth, is one of the concerns of resource economics. As a branch of resource economics, land economics is also concerned with the allocation and use of scarce resources, chiefly the land resource. With regard to the issue of property rights, it was clearly debated that the absence of fully articulated and enforced property rights will lead to the free riding problem and to inefficient resource allocation.

Sustainable development is defined as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. However, some researchers have argued that sustainability is a difficult concept when viewed in terms of its operational usefulness owing to the great difficulty in measuring environmental damages and changes, the often enormous margins of errors associated with the attempt to quantify variables such as soil loss due to erosion and the like, and the often unclear assertions regarding the ethical issues surrounding the obligations of the present generations to future generations (Ellis, 1996).

In section 4.3 assessments were made with regard to some methods used in land use analysis and planning. To facilitate the understanding of the different forms of analysis and planning of the agricultural sector in a proper perspective, a skeleton model of the sector was presented. The concepts of regional agricultural planning, land evaluation and farming system analysis were introduced. Land use analysis, which is conducted at regional and sub – regional levels, is an important component that helps in regional agricultural planning. As a method of land use analysis, land evaluation focuses on the potential uses of land, for example, the potential for the production of certain crops, and it looks at future possibilities for the use of land, which is an important dimension of land use planning. Similarly, farming systems analysis diagnoses the present situation with regard to farming and land use, and gives insights into possible and necessary improvements in the existing ways of farming.

Section 4.4 is an overview of the applications and importance of linear programming models in land use analysis. It was shown that mathematical programming, of which linear programming is one technique, has become an important and a widely used tool for economic analysis in agriculture. Its use has been facilitated by major advances in computing technology and in methods of incorporating observed institutional and economic reality into programming models. As Hazell and Norton showed, such models can offer unique advantages over other methods of agricultural sector analysis. Mathematical programming models can address the multivariate and highly interlinked nature of the agricultural sector.

In particular, linear programming is a systematic mathematical programming model for finding an optimal plan or programme, where there is a choice of activities subject to fixed constraints under linear relationships. Linear programming can be a very flexible tool that can be adapted to deal with multiple objectives, risk and planning overtime. It normally requires careful data preparation and use of computer software, and if used intelligently, it can yield valuable insights into the structure and possible improvements of the land use of the farming systems.

CHAPTER 5. RESEARCH METHODOLOGY

5.1 Conceptual framework

5.1.1 Levels of land use analysis

In this study, land use is analyzed at three levels: at farm level (crop production level), at farming systems level (different farm types level) and at sub-regional level (East Hararghe Administrative Zone level). Models are developed at each of these levels. The objective of the different models is to establish land use capacity or attractiveness indicators of different land use types, taking into account not only biophysical parameters, but also economic objectives and constraints, both at farm and at sub-regional level. These models are elaborated on below:

Farm level models

At the farm level, the model is an input - output budget model that utilizes inputs and outputs, both in physical quantities and in monetary values. As described by Schipper (1996), the input and output coefficients derived from these farm level models are used for the preparation of crop budgets, while summary coefficients are used in the farming system and sub-regional level models.

The farm level models are prepared for the most important land use types in East Hararghe Administrative Zone. The farm level data utilized in these models were collected through surveys. The survey was conducted on farm households in the zone. The aim of the survey is the establishment of relationships between land, land use types and economic returns, within a farm. Assessment of these relationships requires investigation into the following information:

1) Relationships between land, land use types (crop) and yields;

2) Input and output relations per land use type;

3) Cultivation methods by land use type;

4) Availability and use of other factors, e.g. labour and capital;

5) Economic returns (incomes) obtained; and

6) Objectives and strategies of farm households.

These data are necessary to assess the economic viability at farm level of different scenarios for sustained land use.

Farming system models

For the different farming systems in a region, based on the grouping of similar farms, separate farm models could be constructed (Schipper, 1996). Hence, to come up with a particular farming system, there is a need to classify individual farms in East Hararghe Administrative Zone into farm types. This grouping of farms is done based on the three rules indicated by Hazel and Norton (1986), particularly rule number two, depending on the attributes of each farm as observed in the survey (see chapter 4 section 4.4.3).

The first rule of Hazel and Norton (1986) means that if household sizes (or more precisely, household labour availability) are similar, grouping can be done by farm size, provided that their land is of similar quality.

The second rule can also be taken into account by grouping the farms according to, for example, agro-ecological zones and land units, and major differences such as irrigated versus non-irrigated land.

The third rule can be addressed by grouping farms according to major cropping patterns and major differences in technology, e.g. large industrial oriented farms versus smallholders producing for the local markets.

As observed in the survey, farms in East Hararghe Administrative Zone were found not to differ in terms of their land to labour ratios, soil types and farm size. Most farmers possess land plots that include all major soil types in the study area. Moreover, their farm size ranges from 0.125 hectares to 2.75 hectares, offering no grounds for farm classification or grouping as indicated in rule one.

On the other hand, all farmers in the study area are subsistence smallholders who produce for home consumption and for the local market. Hence significant differences in their cropping pattern and technology can't be expected. This makes rule number three not applicable for grouping or classifying farms in East Hararghe Administrative Zone.

Consequently, farms in the study area are grouped into three farm types (farming systems) on the basis of their location (area) or agro-ecological zone, as indicated by rule number two. As mentioned earlier, separate farm models can be constructed for the different farming systems in the zone. Typical examples of such models are linear programming models as indicated by Hazel and Norton (1986).

The coefficients of the production activities for the farming system models are the different land use systems, which can be derived from the farm level models. Other activities are related to off / non-farm work, renting of land and capital assets, the hiring of land, labour and capital, buying and selling activities, as well as household activities. The constraints consist mainly of farm level constraints: land availability, household labour availability in different periods (months), capital goods and input availability. Several objective functions are possible, depending on farming system under consideration. For instance, for small and medium farmers, the farming system level objectives could be to supply basic food requirements or to secure continuation of farming or to maximize income. The farming system (farm type) models will be a part of the models at the sub-regional (zonal) level.

Sub-regional level models

The production activities in the sub-regional (zonal) models could be the different land use systems, skipping the farming system. By skipping the farming system is meant that the individual farmer as a decision maker, with his own objectives, opportunities and constraints, is not taken into account. The sub-region is considered to be one farm with one decision maker. The coefficients for the model are also derived from the farm level models. Other activities are related to off/non-farm work, renting of land and non-farm assets, hiring of land, labour and capital, and buying and selling activities.

The constraints consist mainly of sub-regional constraints such as the availabilities of zonal farmland, zonal household and hired labour in different time periods, and capital goods and inputs. Important constraints related to markets for agricultural products (if any) can be built into the model, by constraining the market. Other zonal constraints might be related to the physical or institutional infrastructure. Furthermore, sustainability related constraints could be built into the model. Also, the effects of several objective functions could be explored. Examples of regional objectives might be to increase the incomes of the small and medium agricultural producers, to create sufficient employment for a growing population, to contribute to exports, to use soils in a sustainable way, etc.

5.1.2 Linking the farm and sub-regional levels

The main idea behind linking the farm and zonal models is to give due account to objectives and constraints at both levels. At the farm level, the household objectives are to be maximized with the farm level constraints operative. Regional policy objectives do not play a role, nor are regional constraints binding, e.g. markets and hired labour availability. A further aspect is that prices of inputs, production factors and outputs are considered constant. They are not influenced by the demand for or supply by individual farms. On the other hand, at the regional level, household objectives are not necessarily relevant, nor is it possible to account for all specific farm constraints.

In theory, it might be possible to build a complete model incorporating both the micro objectives and constraints of each farm(ing) system, as well as the regional objectives and constraints. However, such a model can become very complicated and it may not always be wise to attempt. Also, it is part of reality that not all economic decisions are taken simultaneously with perfect knowledge at both decision levels. Micro level decisions are taken without 'knowledge' of the decisions made at the regional level, while the same applies to regional level decisions. Regional level decisions are taken without 'knowledge' of the decisions made by the many individual farm households (Schipper 1996).

Therefore, in this study, the approach followed is to incorporate models of farm types into the zonal model. By doing so, the matrices of farm types models, which contain farm level activities and constraints, will become an integral part of the overall model. As a consequence, the zonal model and the farm models have one common objective, namely, maximizing the sum of the incomes of the farm type models.

5.1.3 Linear programming as a tool for land use analysis

Looking for optimal land use is parallel to the principle of linear programming or other optimization models, in which an objective function is maximized by selecting from alternative activities, subject to constraints. Linear programming can thus be of help in the search for the best land use.

In this study, a linear programming model will be utilized as a tool for land use analysis at sub-regional (zonal) level. With regard to the application of the five elements of every sector model (see Chapter 4), the linear programming model developed in the present study will incorporate the under-mentioned aspects.

Considering the producer's economic behaviour, the model in this study will assume that each farm type maximizes its returns to land, own capital and management of the farm, in conjunction with possible off-farm labour income. Given the elements of economic aspirations in farm household behaviours, this is assumed to be an important goal of farm households.

With regard to the description of production functions or technology sets of producers, they are specified through the LUSTs, which are specific combinations of land, land use types (crops), and technologies with fixed input and output quantities per hectare. The fixed input and output coefficients can also include sustainability parameters, for instance, soil nutrient depletion and biocide use, if found relevant, given the circumstances in EHAZ. However, the model is not comprehensive with regard to the number of agricultural products included. This means that only the most important crops are included in the model as one of the aims of the study is to take the initiative in developing a model for land use analysis in the country.

To take into account the element of resource endowments of producers, resources such as land and household labour are specified per farm type and per month, and the impact of the selected LUSTs on resources is appraised at both the farm and the sub-regional level.

In describing the market environment in which producers operate, it is assumed that the market for agricultural products is to be unaffected by producer decisions in the sub-region (zone): that means, all products can be sold or purchased at fixed prices. However, with respect to the labour market it is assumed that working off-farm as hired labour on other farms inside the zone is limited by the aggregated demand for such labour, while off-farm work outside the zone is not restricted; wages are fixed, depending only on the type of work.

The policy environment is not specified because of the unavailability of output subsidies, input subsidies, policy restrictions on input uses, etc. in the zone, as observed from the survey conducted in the study area.

The applications of the five elements of every sector model to the models used in this study are summarized in Table 5.1.

Table 5.1. Application of the five elements of every sector model in the study

The five elements of every sector model	The applications of these elements in the present study (model)
1. Producer's economic behaviour	- Maximize on-farm income at market prices
2. Production functions (technology sets)	- Annual LUSTs with fixed input and output quantities per hectare
3. Resource endowments held by each producer group	- Land, labour per month, draft power; per farm type and per zone
4. Factor and product markets environments	- Fixed prices for inputs and outputs; off-farm work by hired labour limited by aggregated demand for it inside the zone; off - farm work outside the zone not restricted; fixed wages
5. Policy environment	- Input subsidies (fertilizer and pesticide - if any); restricted pesticide use (if any); restricted fertilizer use (if any)

5.1.4 Sustainability parameters in linear programming models

To apply the concept of sustainability in this study, the definition given by Pearce and Turner (1990) of 'maximizing the net benefits of economic development, subject to maintaining the services and quality of natural resources overtime' can be adopted. This definition implies accepting the following rules: (1) utilize renewable resources at rates less than or equal to the natural rate at which they regenerate; (2) keep waste flows to the environment at or below the assimilative capacity of the environment; and (3) optimize the efficiency with which non-renewable resources are used, subject to substitutability between resources and technical progress.

The given rules for resource use can be applied to the circumstances of the study area. As noted earlier, soil nutrient depletion and biocide use may be considered if found relevant in the study area. These parameters can be related to rules (1) and (2) above, for resource use. Consequently, environmental damage can be estimated concerning the relevant sustainability parameter in the area.

Since the linear programming model optimizes resource use, it already takes care of rule number (3). In a linear programming model efficiency is optimized subject to the substitutability between resources and technical progress. The effects of substitution can be traced via shadow prices of constraints and sensitivity analysis. The notion of 'technical progress' (or innovations, leading to more productive use of resources) is part of the model: each land use type is specified according to technology and combined with a land area (the LUSTs). In the optimal solution the most efficient technologies or LUSTs, and thus resource use, are chosen in view of all options and constraints.

As noted by Sarah and Ehui (1996), a research methodology that ignores the environment in which the farmers operate and its implications for farmers' resource allocation could be misleading. Therefore, maintaining an objective that is based on economic behaviour, e.g. maximizing farm economic surplus implies that ecological sustainability criteria should be accounted for via constraints.

5.1.5 Overview of the LP model used in the study

In this section an overview of the linear programming model for the economic appraisal of the land use in the study area is given. The emphasis will be on the model for the sub-region (zone), in which different farm types are distinguished.

A sub-region is considered to be a geographic part of a region, which in turn is a part of a country. The main difference between a region and a sub-region is the relative size in comparison to the size of a country. A sub-region is sufficiently small compared to the country, that neither the quantity of outputs nor inputs (including factors of production) produced or demanded influences their prices. In contrast, a region is considered an important or large part of the economy of a country. Given the pragmatic distinction between a sub-region and a region, which must be assessed in practice case by case, it is assumed that prices are fixed in a sub-region for all outputs and inputs, while this is not necessarily so in a region.

One of the objectives of this study is to classify the farms of the zone into different farm types. Based on the distinguished farm types of the zone, a definition of farm type specific activities and constraints will be made. Consequently, these farm type specific activities and constraints are incorporated into the overall sub-regional (zonal) LP model. The different parts of the zonal linear programming model are discussed below under the headings of objectives, variables and constraints.

Objectives

In both agricultural sector and land use analysis models, there is usually a need to have a descriptive or positive objective function. This objective function should reflect a realistic objective of farm households where by an aspect of farm household behaviour is introduced into the model.

In discussing the behaviour of peasant farmers, Lipton (1968) indicated that the small farmer is often seen as maximizing utility. However, the behaviour of farm families usually indicate that they strongly strive for economic benefit in their farming operations (Schipper, 1996). Their decision-making can, therefore, be approached as constrained optimization. A measure of a farm economic surplus can be used as a first approximation of a suitable farm household objective function related to income earning of a household. Such a function includes all benefits and costs from the farm household's point of view.

To take into account the behaviour of a farm household more realistically and to qualify the maximization of economic surplus, there is a need to introduce a minimum consumption requirement, which is going to be produced on - farm in this case. Obviously, such requirements are not part of the objective function, but formulated as constraints.

Certain aspects of risk could also be incorporated into the objective function through special variables in conjunction with risk specific constraints. Nevertheless, it is beyond the scope of the present study to elaborate on this theme, as this itself can be a very broad separate research undertaking.

Variables

The natural resources and the state of technology determine the types and technology levels of cropping activities. As described by Schipper (1996), since these activities use land, it is customary to call them land use types (LUTs). LUTs combined with land form land use systems (LUSs). Each land use type (LUT) has subtypes, which are classified according to technology. A particular combination of a land unit (or parcel) and a LUT with a specific technology is called a LUST (a specified land use type on a given land unit with a defined technology).

As farm types are distinguished with in the sub-region, the LUSTs variables are specified per farm type. Labor variables should be introduced per farm type for hiring labor and for off-farm work.

Constraints

In sub-regional land use models, the land constraint is formulated in relation to the LUSTs variables, for each farm type and sub-region. In addition to land constraints, labor constraints are normally part of land use models. In view of the often marked differences in labor use in different periods with in agricultural year, labor constraints are formulated per sub-period, e.g. per month or for certain peak periods.

Household labor is constrained per farm and farm type, while hired labor and off-farm work is constrained at the level of the sub-region. The constraints can be made specific for each type of labor. The most appropriate way to combine labor variables with labor constraints is to first introduce labor accounting rows, in which the demand for labor by LUSTs is balanced by the supply of labor from each source (household labor, hired labor), per sub-period and labor type. Subsequently, each labor source, combined with off-farm labor work, is then limited in each (sub) period at the appropriate level (farm, farm type, sub-region).

Considerations of risk in the model

Crop production is usually a risky venture particularly in rain-fed agriculture. In studies that aim at identifying the optimal agricultural planning under a situation of risk there can be a need to employ risk programming models and techniques to particularly represent the risky crop production areas as well as risky crops. Results of a risk programming model can help to show farmers the relatively risk free crops that should be included in the optimal plan while excluding the more risky type of crops.

Hazell and Norton (1986) demonstrated several techniques for incorporating risk-averse behaviour of farmers in mathematical programming models. Some of these techniques include the mean-variance analysis, quadratic programming and linear programming approximations in which the MOTAD model figures prominently. Ortmann and Nieuwoudt (1987) developed a linear programming model to analyze the social cost of alternative sugar policies in South Africa and incorporated variance-covariance matrices in the model to account for risk in production. Such risk programming models, however, usually incorporate broad research considerations and are often dealt with as a separate research undertaking (Schipper, 1996).

Several regular linear programming land use models have been developed and utilized to determine land use options among different farming communities though not incorporating risk programming aspects due to the broadness of the research areas and/or models. An important work in this area is the Ph.D. research conducted by Schipper (1996) in the Atlantic Zone of Costa Rica. Other examples include articles published by R.A. Schipper, H.G.P. Jansen, J.J. Stoorvogel and D.M. Jansen (1995) and by R.A. Schipper, J.J. Stoorvogel and D.M. Jansen (1995) in the Netherlands Journal of Agricultural Sciences, as well as the study conducted by Erenstein, O.C.A. and R.A. Schipper (1993). In this research activities regular linear programming land use models are utilized to determine land use options that provide higher farm incomes while maintaining the productive capacity of the land resource of the study area and also evaluating policies for sustainable land use.

An example of similar research undertaking in South Africa is the research conducted by H.N. Balyamujura and H.D. Van Schalkwyk which is published on Agrekon (1997). They studied the optimization of different land use regimes in the Mhala district of Mpumalanga province. The methodology applied in this study includes a multi criteria analysis model with a trade off between economic, social and environmental objectives. The model is developed and used to determine land use or combinations of land uses that will maximize the welfare of the community and at the same time conserve the area for future generations.

In the above studies no risk programming techniques were explicitly incorporated in the models as the aim of the research activities were to determine alternative land use options, through optimization techniques, which will lead towards the attainment of increased household farm income and social welfare.

Similarly the aim of the research activity in this study not risk programming as such. If this were the case, the study would have used a another research proposal and different data sets, other than the ones' in this study. It is also not the intention of the study to tell and convince subsistence farmers, who grow multiple crops on their very small farms for their food security and who have no financial reserves to purchase crops on markets that are not readily accessible to them, to avoid a certain crop that is designated as a risky crop through risk modeling. The separation of crops into risky and non-risky categories through risk programming is not considered a realistic solution to the problems of extreme subsistence farming as this will go contrary to cropping patterns where farmers must produce almost all of the crops that they require for home consumption on their own farms despite the riskiness of the crop. They tend to avoid crop failure particularly during drought by diversifying the mix of crops they produce and that is what is dealt with in this thesis; incorporating thus implicitly this form of risk aversion behaviour.

However, in the present study the application of regular linear programming model in land use analysis is demonstrated while incorporating certain aspects of risk in different scenarios. As noted by Stockil and Ortmann (1997) farm operators are often faced with variable weather conditions. In peasant subsistence farming, particularly in Ethiopia, the risk of crop production is mainly associated with rainfall. In East Hararghe administrative zone, the production of major crops usually rely heavily on the uncertain amount of rainfall. This situation, however, differs from one farm type to the other.

Hence, to take into account the aspects of risk in subsistence farming, two different scenarios are incorporated in this thesis. In one of these scenarios a risky production situation was assumed through the possibility of the occurrence of drought in the study area. Under the drought condition, due to the risk of crop failure, the yield per hectare of the farmers is reduced by certain percentages from the normal production year (as observed during the survey) based on the susceptibility of the different farm types to drought as explained in Chapter 7 section 7.8. The percentage reductions in yield differs from one farm type to the other because, as FAO (2000) indicated, an area with high yearly rainfall variability will experience larger fluctuations of yields, particularly in peasant farming areas. The optimum solutions of these scenarios are then compared with the results obtained from a relatively less risky production year (in terms of rainfall shortage) and the magnitude of the farm input as well as food support that is required for the farming community is studied.

In the other scenario it was assumed that the availability of household labour might sometimes pose risky situations when, particularly due to unforeseen circumstances such as illness, the household labour becomes unable to be involved in production. Under this situation the farm household might be compelled to hire most of its labour force to undertake the production operations. Hence, to take into account this element of risk in household labour, an opportunity cost was attached to the household labour through a reservation wage rate and the same is introduced in the model. The outcome of this scenario is compared with the outcome of the normal production year in which household labour is not priced.

These considerations and assumptions take into account the element of risky production conditions in subsistence farming and indicate the types of crops that might be included in the optimal land use plans.

5.2 A land use model for EHAZ

5.2.1 The setting

This section presents the sub-regional linear programming model constructed for East Hararghe Administrative Zone. The model is named EASTHAR for the sake of convenience. This land use analysis aims at deriving relevant land use options for land use, by incorporating economic criteria for agricultural production and ecological criteria. The results of the model are presented in chapter 7, where land use scenarios are analyzed to examine whether incomes of farmers in the zone can increase through an improved land use from the point of view of sustainability.

An important aspect of the methodology used in this study is the differentiation between levels of analysis. At each level of analysis different decisions are made. In East Hararghe

Administrative Zone, as a sub-region of the Oromia region in Ethiopia, land use decisions are made at the farm level, influenced by policy decisions at sub-regional, regional, and national levels. Hence, in the linear programming model two levels of decision making are incorporated: land use decisions at the farm level and policy decisions at the sub-regional level, the latter thus including decision-making at levels higher than the farm level.

Because of aggregation issues, modeling land use is complicated and reality needs to be simplified. In the methodology, the first aggregation issue, decision-making both at the farm as well as the sub-regional level, is approached by using a linear programming objective function for farm households in the model which maximizes the difference between the value and the cost of production, including household and hired labor, plus off-farm earnings. This objective function can be called economic surplus and is calculated as the farm household income minus a valuation of on-farm household labor. In that way the effects of policies at the sub-regional level on land use decisions can be studied. The second aggregation issue, aggregation bias, is diminished by incorporating three farm types in the sub-regional model, each with specific resource availabilities with regard to land and household labor. The third aggregation issue, exogenous variables becoming endogenous, is sidestepped by assuming that the sub-region is sufficiently small in relation to the country and that the supply from the sub-region is too small to influence the prices of products. Moreover, a restricted sub-regional labor supply forms part of the model: all farms together cannot hire more labor than is available within the sub-region and the price of hired labor is fixed.

5.2.2 Land use systems

Land use activities (LUSTs) are the main components of the EASTHAR model. They are defined as a combination of land use type and a specified technology. According to the information obtained from Ministry of Agriculture (1995), Ethiopian farmers produce more maize than any other crop. Maize and other major cereals, such as wheat, barley, sorghum and teff (a cereal grain that is unique to Ethiopia), supply about 70 percent of calories in Ethiopian diets (Ministry of Agriculture, 1995). The EASTHAR model contains eight land use types: maize, sorghum, wheat, barley, horse beans, groundnuts, potatoes, and green pepper.

Different technologies are specified for each land use system. Each LUST is described quantitatively as a sequence of operations and summarized in input and output coefficients (quantities or values per hectare) for use in the linear programming model: Land requirements, labor requirements, costs of variable inputs, input quantities, prices, labor costs, production specified per product, soil nutrient depletion with regard to Nitrogen (N), Phosphorus (P) and Potassium (K) - (if data are available on these nutrients in the study area), and a biocide use index value(if any). The coefficients are either averages per month (land and labor use) or per year (soil nutrient depletion of N, P and K, and the biocide use index value), or the values of the LUSTs (production, input costs and labor use), assuming constant prices over time.

In the sub-regional linear programming model EASTHAR, a number of variables are included per farm type such as LUSTs, and the use of farm household and hired labor. Farm household labor can either work on farm or off-farm. Off-farm work may consist of two types of work: work on other farm types with in East Hararghe Administrative Zone (EHAZ), or work outside EHAZ. All labor variables are specified per month.

In addition to variables, a number of constraints are stipulated per farm type as well namely, the availability of land and the availability of household labor, both specified per month. The latter is also specified per year.

5.2.3 General formulation of the land use model of the zone (EASTHAR)

The linear programming land use model of East Hararghe Administrative Zone (EASTHAR) is formulated to consist of 27 equations. The complete specification of the model is given below. The symbols used in the model are defined in the tables that follow the model (Tables 5.2 - 5.4).

The objective function as described earlier, represents the economic surplus. It is calculated as benefits less costs: value of production, less variable input costs, less costs of on - farm household labour, less hired on - farm labour costs, plus off-farm work labour income (Birr / year). All monetary values are expressed in Birr, the currency of Ethiopia.

The Model

Objective function: production value less input costs less value of household labour less hired labour costs plus off-farm work labour income

$$Max\ Z = \sum_{l} p_l Q_l - \sum_{i} p_i C_i - \sum_{m} r_m F_m - \sum_{m} w_m H_m + \sum_{o}\sum_{m} z_{om} . O_{om} \qquad 5.1$$

The objective function is maximized subject to a number of constraints. These constraints consist of real constraints and balances. Real constraints (equations 5.9 - 5.13, 5.16, 5.18, 5.20, 5.22, 5.24 and 5.26) can restrict the objective function; if binding, the value of the objective function is less than without such a constraint. Balance equations (equations 5.2 - 5.8, 5.14, 5.15, 5.17, 5.19, 5.21, 5.23 and 5.25), or accounting rows, serve merely for calculating certain variables for ease of pricing in the objective function, and/or for the computation of an aggregate. The specification of the equations is as follows:

Balances for each product, in which the physical production figures per LUST are summed in order to obtain production per farm type and total production (kg/year):

$$\sum_{s}\sum_{l}\sum_{t} y_{fslt} \cdot X_{fslt} - Q_{lf} \leq 0 \qquad all\ f \qquad 5.2$$

$$\sum_{f} Q_{lf} - Q_l \leq 0 \qquad all\ l \qquad 5.3$$

Balances for input use, in which the inputs per LUST are summed to obtain input uses per farm type and total input use (kg/year):

$$\sum_s \sum_l \sum_t c_{fslt}.X_{fslt} - C_{if} \leq 0 \qquad all\ i,f \qquad 5.4$$

$$\sum_f C_{if} - C_i \leq 0 \qquad 5.5$$

Sum of labour use by LUSTs per farm type per month, balanced by on-farm household and hired labour supply per farm type per month (mandays/month):

$$\sum_s \sum_l \sum_t e_{fsltm}.X_{fslt} - F_{fm} - H_{fm} \leq 0 \qquad all\ f,m \qquad 5.6$$

$$\sum_f F_{fm} - F_m \leq 0 \qquad all\ m \qquad 5.7$$

$$\sum_f \mathrm{H}_{\mathrm{fm}} - H_m \leq 0 \qquad all\ m \qquad 5.8$$

Sum of land use by LUSTs per farm type per land unit, constrained by land availability per farm type per land unit (ha/year):

$$\sum_l \sum_t X_{fslt} \leq b_{fs} \qquad all\ f,s \qquad 5.9$$

On-farm household and off-farm work, constrained by household labour availability per farm type per month (mandays/month):

$$\sum_o O_{ofm} + F_{fm} \leq g_{fm} \qquad all\, f,\ m \qquad 5.10$$

Sub-regional off-farm other work (outside EHAZ; o=2) availability per month (mandays/month)-if any:

$$\sum_f O_{o=2,fm} \leq p_{o=2,m} \qquad all\ m \qquad 5.11$$

Sub-regional hired work, summed over the farm types, per month, balanced by availability of off-farm labour of all farm types together with in the sub-region (o=1)(mandays/month), if any:

$$\sum_{f} H_{fm} - \sum_{f} O_{o=1,fm} = 0 \qquad all\ m \qquad 5.12$$

Hired work availability per farm type per month, which can not be more than the sum of the off-farm labour of the other farm types within the sub-region (o=1)(mandays/month), if any:

$$\sum_{f \neq q} O_{o=1,fm} - H_{f=q,m} \leq 0 \qquad all\ \ m, q = 1,2,3 \qquad 5.13$$

Labour: calculation of sub-regional total household labour, off-farm work per month, specified per off-farm work type (mandays/month):

$$\sum_{f} O_{ofm} - O_{om} \leq 0 \qquad all\ m,o \qquad 5.14$$

After the balances and restrictions regarding production and input, land and labour use, equations related to sustainability indicators, of which soil nutrient depletion and biocide use are taken as a demonstration, are provided next.

These equations can be utilized if data regarding rates of nutrient depletion, restrictions on nutrient depletion and biocide use are available. Unfortunately, in East Hararghe Administrative Zone, none of these data were found during the survey. Therefore, the under listed equations were not utilized in the present model. However, it is decided to demonstrate the construction of such sustainability indicators below, as these are part of a complete methodology for land use analysis.

The data on nutrient depletion per LUST are aggregated for each nutrient N, P, K in steps: 1) per land units within farm types (equation 5.15), 2) per land units summed over farm types (equation 5.17), 3) per farm type summed over the land units (equation 5.19), 4) summed over the farm types and over the land units (equation 5.21). At each of these steps, the depletion can be restricted. In order of steps 1 to 4, these restrictions are equations (5.16), (5.18), (5.20) and (5.22), respectively.

Nutrient depletion balance per nutrient per farm type per soil type (kg/year);

$$\sum_{l}\sum_{t} h_{nfslt}.X_{fslt} - N_{nfs} = 0 \qquad all\ n, f, s \qquad 5.15$$

Restriction on nutrient depletion per nutrient per farm type per soil type (kg/year);

$$N_{nfs} \leq k_{nfs} \qquad all\ n, f, s \qquad 5.16$$

Nutrient depletion balances per nutrient per soil type (kg/year);

$$\sum_{f} N_{nfs} - N_{ns} = 0 \qquad all\ n, s \qquad 5.17$$

Restriction on nutrient depletion per nutrient per soil type (kg/year);

$$N_{ns} \leq k_{ns} \qquad all\ n, s \qquad 5.18$$

Nutrient depletion balances per nutrient per farm type (kg/year);

$$\sum_{s} N_{nfs} - N_{nf} = 0 \qquad all\ n, f \qquad 5.19$$

Restriction on nutrient depletion per nutrient per farm type (kg/year);

$$N_{nf} \leq k_{nf} \qquad all\ n, f \qquad 5.20$$

Nutrient depletion balances per nutrient (kg/year);

$$\sum_{f}\sum_{s} N_{nfs} - N_n = 0 \qquad all\ n \qquad 5.21$$

Restriction of sub-regional total nutrient depletion per nutrient (kg/year);

$$N_n \leq k_n \qquad all\ n \qquad 5.22$$

The data on biocide use by LUSTs (expressed as an index value per ha per year) is first aggregated at the farm level (equation 5.23; expressed as an index value per year) and restricted at that level (equation 5.24). Thereafter, the biocide use is summed over the farm types to provide a sub-regional total (equation 5.25) and restricted to that level (equation 5.26). In detail:

Balances of biocide use per farm type (index value/year);

$$\sum_{s}\sum_{l}\sum_{t} u_{fslt}.X_{fslt} - B_f = 0 \qquad all\ f \qquad 5.23$$

Restriction on biocide use per farm type (index value/year);

$$B_f \leq v_f \qquad all\ f \qquad 5.24$$

Balance of total biocide use per year (index value/year);

$$\sum_{f} B_f - B = 0 \qquad 5.25$$

Restriction on sub-regional total biocide use (index value/year);

$$B \leq v \qquad 5.26$$

Balances for consumption requirement of each product, in which the physical production figures per LUST are summed to obtain the minimum consumption requirements per farm type (kg/year):

$$\sum_s \sum_l \sum_t y_{fslt}.X_{fslt} - J_{tf} \geq 0 \qquad all\ f \qquad 5.27$$

On the following pages the subscripts, variables and coefficients used are presented in Table 5.2, Table 5.3 and Table 5.4, respectively.

Table 5.2. Subscripts of EASTHAR

Subscripts	Description	Elements
i	inputs	variable inputs - materials and services
		- seed (kg/ha), fertilizer (kg/ha)
		- pesticides (liter/ha), herbicides (liter/ha)
		- oxen use (oxen-pair days/ha)
f	farm type	1= FT1, 2= FT2, 3= FT3[1]
s	land unit	depends on the selection of LUSTs[2]
l	land use types	sorghum, maize, wheat, barley, horse beans,
		groundnuts, potatoes, green pepper
t	technology	depends on selection of LUSTs
o	off-farm work	1= otherfarm, 2=otherwork[3]
m	months	1=jan, 2=feb, 3=mar, 4=apr, 5=may, 6=jun,
		7=jul, 8=aug, 9=sep, 10=oct, 11=nov, 12=dec
n	nutrients	1=N, 2=P, 3=K[4]

[1]Element '1=FT1' to '3=FT3' stand for farm types 1 to 3.

[2]The elements of subscript s, land units, refer to soil types (if available).

[3]The element ' 1= otherfarm' refers to family labour working off-farm on other farm types within EHAZ, while element '2= otherwork' refers to family labour working off-farm on other works outside EHAZ; both measured in mandays.

[4]The three elements ' 1= N', '2=P' and '3=K' of subscript n stand for nitrogen, phosphorus and potassium respectively.

Table 5.3. Variables in EASTHAR

Variables[1]	description	unit of measurement
Z	value of objective function	Birr/year
Q_l	production per land use type	kg/year
Q_{lf}	production per land use type per farm type	kg/year
C_i	quantity of variable input use per input	kg/ha
C_{if}	quantity of variable input use per input per farm type	kg/ha
J_{lf}	minimum consumption requirements per land use type per farm type	kg/year
X_{fslt}	LUSTs (land use per farm type per land unit per land use type per technology)	ha/year
F_m	on-farm work by family members per month	mandays/month
F_{fm}	on-farm work by family members per farm type per month	mandays/month
H_m	on-farm work by hired labour per month	mandays/month
H_{fm}	on-farm work by hired labour per farm type per month	mandays/month
O_{om}	off-farm work by family members per work type per month	mandays/month
O_{ofm}	off-farm work of family members per work type per farm type per month	mandays/month
N_{nfs}	nutrient content per farm type per land unit	kg/year
N_{ns}	nutrient content per land unit	kg/year
N_{nf}	nutrient content per farm type	kg/year
N_n	total nutrients	kg/year
B_f	biocide use per farm type	index value/year
B	biocide use	index value/year

[1]All variables in the table are continuous and larger than, or equal to, zero, except N_{nfs}, N_{ns}, N_{nf} and N_n, which are free continuous variables (larger than minus infinity).

Table 5.4. Coefficients in EASTHAR

Coefficients	description	units of measurement
p_l	product price per product (OBJ) [1]	Birr/kg
p_i	inputs price per input (OBJ)	Birr/kg
r_m	household labour wage (OBJ)	Birr / manday
w_m	hired labour wage (OBJ)	Birr / manday
z_{om}	off-farm work wages per work type (OBJ)	Birr / manday
y_{fslt}	yield of a LUST[2]	kg/ha
c_{fslt}	input uses of a LUST	kg/ha
b_{fs}	land availability per farm type per land unit (RHS) [3]	ha/year
e_{fsltm}	labour use of a LUST per month	mandays /ha
g_{fm}	household labour availability per farm type per month (RHS)	mandays/month
g_f	household labour availability per farm type (RHS)	mandays/year
$p_{o=2}$	other employment availability (RHS)	mandays/year
h_{nfslt}	average nutrient loss or gain of a LUST	kg/ha
k_{nfs}	permissible nutrient loss or gain per nutrient per farm type per land unit (RHS)	kg/year
k_{ns}	permissible nutrient loss or gain per nutrient per land unit (RHS)	kg/year
k_{nf}	permissible nutrient loss or gain per nutrient per farm type (RHS)	kg/year
k_n	permissible nutrient loss or gain per nutrient (RHS)	kg/year
u_{fslt}	average biocide index value of a LUST	index value/ha
v_f	permissible biocide index value per farm type (RHS)	index value/ha
v	permissible biocide index value (RHS)	index value/ha

[1]OBJ: objective function coefficients

[2]LUST: variable X_{fslt}, see table 5.3

[3]RHS: right hand side coefficient

CHAPTER 6. FARM CLASSIFICATION AND DESCRIPTION OF SURVEY DATA

6.1 Introduction

In this chapter, the farms in the study area are grouped into farm types. This helps to distinguish between the farm and the sub-regional levels of analysis, and will lay the foundation for the latter analysis in Chapter 7. Furthermore, distinguishing between farm types will provide an understanding of the difference that exist among farm types with regard to land use and income distribution aspects. Moreover, in this chapter, a description of the surveyed data is presented. Various tables are employed in order to present summary statistics of information with regard to the extent, availability, and intensity of the use of land, material inputs, human labour, animal traction, outputs of crops, prices of inputs and outputs, and levels of costs and incomes. In addition to this, information on the relative importance of the major crops in each farm type and district, household demographic features and the farming problems of farmers are discussed.

6.2 Determination of farming systems in the zone

6.2.1 Systems of grouping farms

Considering the relation between the farm and the sub-regional level, each farm in a sub-region is seen as a system (farm system) and considered to be a subsystem of that sub-region. It would be ideal to analyze each farm system individually, but this is impossible, given the time and resources available. On the other hand, considering all farm systems as alike would be a far too general approach. A compromise between the two extremes is sought by classifying individual farms into farm types (Schipper, 1996).

One of the problems with grouping farms is whether this can or should be done before or after a survey. Grouping farms before a survey, or stratification, requires a priori information on all farms in a sub-region before sampling of farms can be done. It is likely that the classification in that case will be based on simple straightforward criteria e.g. location or farm size. However, it is not certain at all that such a classification is sufficient for the grouping exercise. Therefore, it is most likely that the grouping of farms will be done after a survey on the basis of the attributes of each farm as observed in the survey (Schipper, 1996).

Three comprehensive sets of conditions, which are indicated as theoretical requirements of homogeneity, have been formulated by Day (1963) for classifying farms into groups:

1) each farm should have the same production possibilities, the same type of resources and constraints, the same levels of technology, and the same level of managerial ability (Day termed this first requirement as 'technological homogeneity');
2) the second requirement demands that individual farms in a group hold the same expectations about unit activity returns that are proportional to average returns; (Day termed this requirement 'pecunious' proportionality); and
3) the third requirement is that the constraint vector of the programming model for each individual farm should be proportional to the constraint vector of the average or aggregate farm. (Day termed this requirement 'institutional' proportionality).

These requirements are usually sufficient to guarantee unbiased aggregation. However, the requirements are very demanding and several authors have tried to derive less stringent conditions (Hazell and Norton, 1986).

In practice, the aggregation criteria usually are reduced to grouping farms according to a few simple rules (Hazell and Norton, 1986). According to Hazell and Norton, these rules are 1) similar proportions in resource endowments, 2) similar yields, 3) similar technologies. The first rule is often approached through similar land-to-labour ratios, which means, if household sizes or household labour availabilities are similar, grouping can be done by farm size (Schipper, 1996). Hazell and Norton indicated that grouping farms in this way would help the model to show more accurately which farms engage in labour-saving techniques, such as mechanization of plowing and other operations.

However, as noted by Schipper, this method can only be advisable if the land is also of similar quality. If the land is not of similar quality, some weighting of different parcels (land units) has to be done before summing the parcels per farm.

Grouping the farms according to agro-ecological zones and major differences such as irrigated versus non-irrigated land, is the way to approach the second rule of Hazell and Norton. The third rule can be approached by grouping farms according to major cropping patterns and major differences in technology, for example, large industrial export-oriented farms versus smallholders (Schipper, 1996).

6.2.2 Method used to group farms in the zone

Grouping the universe of farms into a smaller number of homogeneous groups or farm types is essential as it is not feasible in practice to model each individual farm. Hence, as noted by Hazell and Norton (1986), there is a need for the sector model to be based on representative farms, or aggregate regional or farm types models.

The three criteria formulated by Day (1963) for classifying individual farms into groups help to obtain a perfect aggregation in linear programming models. According to Day (1963) all farms in one group must have proportional revenue expectations per unit activity (proportional objective function coefficients), they must have the same technology for each activity (the same coefficients in the matrix of constraint use for each activity), and they need to have proportional availability of resources (proportional availability of constraining factors). But, as indicated by Hazell and Norton (1986), these requirements are very demanding and in practice impossible to achieve.

Therefore, as mentioned by Schipper (1996), it is only possible to approximate homogeneous groups by classifying farms according to, for instance, agro-climatic zone, major soil type, distance to markets, availability of irrigation, crops cultivated or farm size.

In East Hararghe Administrative Zone, as observed in the survey, farms do not differ significantly from one another in terms of their land to labour ratios, soil types and farm size. Most farmers possess land plots that include all major soil types in the study area. Moreover, their farm size ranges from 0.125 hectares to 2.75 hectares. Hence, farm size, soil types and land to labour ratios cannot form the ground (cannot be a criteria) for farm classification or grouping in East Hararghe Administrative Zone.

All farmers in the study area are subsistence smallholders who produce for home consumption and for the local market, and cultivate the same crops. Hence significant differences in their cropping pattern and technology can't be expected. This makes the notion of cultivated crops or cropping pattern not applicable for grouping or classifying farms in East Hararghe Administrative Zone. Also, because linear programming is used to determine land use, it does not make sense to classify the farms according to present land use.

However, farms in the zone differ especially with regard to their location. The farms within East Hararghe Administrative Zone are located in diverse agro-ecological zones. Consequently, farms in the study area are grouped into three farm types (farming systems) on the basis of their location (area) or agro-ecological zone, as indicated by rule number 2 of Hazell and Norton (1986). The question of how many farm types should be formed is a matter of good judgment and convenience. At present, three groups of farms or farm types were formed by assuming that it will be logical and convenient to form the same number of farm types as that of the number of agro-ecological zones in the study area to take into account all the important features of each climatic region of East Hararghe Administrative Zone.

6.2.3 The different farm types of the zone

All three prominent agro-ecological zones of Ethiopia are observed in East Hararghe Administrative Zone. This makes the zone a typical representation of the country, as far as agro-ecological zones are concerned, and enables the stratification of farms into separate farming systems based on agro-ecological zones and analyze the land use accordingly. Moreover, the results of the study could be applicable countrywide as it is based on data collected from all the prominent agro-ecological zones of the nation.

The agro-climatic zones prevailing in East Hararghe Administrative Zone are grouped into three major categories. These are the arid climatic zone, the tropical climatic zone and the tropical highlands climatic zone. These agro-climatic zones are also sometimes referred to as semi-desert, semi-temperate and temperate climatic zones (Planning and Economic Development Department, 1994).

The arid climatic zone includes districts found in the southern, eastern, southeastern and northern part of the zone. The altitude for this climatic zone ranges from 500-1500 meters above sea level. The semi-arid part of this climatic zone is characterized by poor and sparse vegetation with mean annual temperature of 27^0C to 39^0C and mean annual rainfall of less than 450 mm. In this type of climate the rate of evapotranspiration exceeds precipitation. The other part of this climatic zone is the steppe climate, which is characterized by steppe type vegetation. Its mean annual temperature varies between 18^0C and 27^0C and the mean annual rainfall ranges between 400-820mm. The steppe climate forms an intermediate climatic region between the arid and humid climatic regions (Planning and Economic Development Office for EHAZ, 2001). The southern tip of Girawa, Golaoda and Babile districts are grouped under this arid climatic zone. This climatic zone covers about 51.1% of the zone (Planning and Economic Development Department, 1994).

The tropical or the semi-temperate climatic zone is found in areas with an altitude range of 1500-2300 meters above sea level. It is characterized by sub-humid to pre humid with the mean annual rainfall of 600 – 2800mm and a mean annual temperature of 15-20^0C. This climatic zone is found in the western and central parts of the zone.

The climatic zone of tropical highlands or the temperate climatic zone encompasses areas with an altitude of more than 2300 meters above sea level. The annual rainfall of this climatic zone is between 1000mm to 2000mm and its mean annual temperature ranges from $10^0C - 15^0C$. This climatic zone occupies the western and central highlands of the zone such as most parts of Meta, Deder and Bedeno districts.

However, this demarcation of climatic zones is not exclusive due to the fact that some districts labeled as semi-temperate may partly have certain mountain peaks tending to the temperate climatic zone and certain other districts, for example Fedis, that have an extensive part lying below an altitude of 1500 meters above sea level could enter arid climatic zone (Planning and Economic Development Department, 1994).

Table 6.1. Agro-ecological (agro-climatic) classification of surveyed peasant associations and districts of East Hararghe Administrative Zone

No.	Agro-climatic zone	Number of total peasant associations	Name of peasant association	Name of home district	Number of districts
1	Arid climatic zone	3	Ifa	Babile	3
			Belina Arba	Fedis	
			Awdal	Gursum	
2	Tropical climatic zone	4	Sodu	Kersa	4
			Hora Weligela	Gorogutu	
			Orde	Kurfachele	
			Burka Gudina	Girawa	
3	Temperate climatic zone	7	Burka Jalala	Meta	7
			Kara Walteha	Deder	
			Burka Nega	Melkabelo	
			Ilili Derartu	Bedeno	
			Ifa Oromia	Alemaya	
			Bilisuma	Kombolcha	
			Ifa Jalala	Jarso	
Total		14	-	-	14

Based on the grouping of the agro-climatic zones of East Hararghe Administrative Zone and in accordance with the information obtained from zonal and district level agricultural offices and field observations made during the survey, the surveyed peasant associations and their respective districts are categorized in the three agro-ecological (agro-climatic) zones summarized in Table 6.1.

According to the above agro-ecological classification of the surveyed districts and peasant associations, the three farm types that are identified and the farmers included in each farm type are indicated in Table 6.2.

Table 6.2 Farm types in East Hararghe Administrative Zone

Farm type	1	2	3	Total
Number of farms	45	60	105	210
Total available land (timad)	533	311.7	547	1391.7
Total cultivated land by all crops (timad)	484.5	268.2	523.8	1276.5
Land for other type of uses (timads)	48.5	43.5	23.2	115.2

6.3 Description of survey data

6.3.1 Land holdings among farmers

The study area, Eastern Hararghe Administrative Zone, comprises 15 districts, which are subdivided into 417 Peasant Associations (PAs) and 17 urban kebeles. The study covers 14 of these districts. The investigation excludes the district called Golaoda due to its remoteness and security problems, which made virtually impossible the collection of data from the district. The data sets described here, therefore, represents the information gathered from 210 sample farmers in the 14 surveyed districts of the zone.

6.3.1.1 Land holding of farmers by soil type

Land holdings of sample farmers in East Hararghe Administrative zone are scattered over all types of soils. Each farm contains plots of the main soil types in the zone. As the farmers are small-scale subsistence farmers who grow multiple of crops, there is no specialization in any one or two types of crops, which could be linked to a particular soil type for crop production.

This can be clearly seen from Table 6.3, which shows the land holdings of farmers in the zone based on the soil types under their possession. In farm type one, which in total contains 45 farmers, 16 farmers possess land plots of black soil, 35 of them have sandy soil plots, 20 have got light while soil plots, 13 possess red soil plots and 16 farmers have other types of soils. This indicates that almost every farm contains plots of several soil types. A similar trend is observed in other farm types as well.

Table 6.3 Land holding of sample farmers by soil type, 2001

Number of farmers possessing plots of each soil type				
Farm types	1	2	3	Total
Total farmers in each farm type	45	60	105	210
Soil types				
Black soil	16	52	83	151
Sandy soil	35	31	28	94
Light white soil	20	21	14	55
Garden land	20	11	19	50
Red soil	13	1	12	26
Other type of soils	16	3	19	38
Average number of soil types per farmer	3	2	2	2

The concentration of land holdings on similar soil types can be better understood when examining the situation in terms of the total farmers included in the survey. As is evident from Table 6.3, the land holdings of the farmers in the zone are concentrated on similar soil types particularly the black soil locally called *merere* and on the sandy soil. Almost all the farmers have these two main soil types in their land holdings. From the 210 sample farmers included in the study, 151 of them possess farm plots of the black soil type. This means that about 72% of the farmers in East Hararghe Administrative Zone cultivate their crops on black soils. On the other hand, 94 farmers or 45% of the sampled farmers possess plots of the sandy soil type. This is one important feature that hindered the classification of farms in East Hararghe Administrative Zone by soil types as explained in section 6.2.

6.3.1.2 Land availability per farm type

The total land available to sample farmers in East Hararghe Administrative Zone was found to be very small as observed in the survey. As is depicted in both Table 6.4 and Table 6.5, the 210 farmers included in the study possess a total of only 1392 timads of land for agricultural production as well as other uses.

The total land holding size of farm type 1 which has 45 farmers is 533 timads whereas the total landholding of farm type 2, with 60 farmers, is only 312 timads. Likewise, the land holding of farm type 3, which consists of 105 farmers, is 547 timads. This indicates that in the semi-temperate and temperate agro-ecological zones there exist high population concentrations that resulted in extreme fragmentation of land. This argument is supported by the evidence given in Table 6.5, which indicates that in farm types 2 and 3 there exist farmers who have a land holding of just one timad on which to grow crops for their livelihood. This survey result supports the secondary data information that is presented in Chapter 3 expressing the concentration of population in highland areas as compared to lowland parts of the zone.

From the total land holding of 1392 timads possessed by the farmers included in the study, the black soil, with a share of 563 timads, remains the dominant type of soil and accounts for about 40% of the total land holding of the sample farmers in the zone. This is followed by the sandy type soil that accounts for about 24.8% of the total land holding of the surveyed farmers in the zone and it is in fact the dominant soil type in farm type 1 which represents the lowland areas of the zone.

Table 6.4 Total land availability and land use of sample farmers per farm type (timads), 2001

Farm types	1	2	3	Total
Number of farms	45	60	105	210
Land holdings by soil type				
Black soil	57	182	324	563
Sandy soil	213	58	74	345
While soil	93	50	39	182
Garden land	41	13	24	78
Red soil	81	1	44	126
Other soils	48	8	42	98
Total land holding	533	312	547	1392
Land use				
Land rented in	23	1	10	34
Land rented out	0	0	4	4
Land shared in	0	9	35	44
Land shared out	2	1	2	5
Total cultivated land	484.5	268.0	524.0	1276.5
Total grazing land	21	26	14	61
Total fallow land	25.5	17.0	3.0	45.5

In Table 6.4, the land rented in represents the land that a farmer rented from another farmer. On the other hand land rented out indicates land that belongs to a farmer but is rented to some other farmers. Land shared in is a land that belongs to other farmers but was given out to the farmer in question for him/her to use for crop production and redeem the owner with a share of the produce from the land. By the same token, land shared out is land that belongs to a farmer but was given out to some other farmers to use for crop production and redeem the owner with a share of the produce from the land.

The smallness of the rented in land is due to two important reasons. The first and foremost reason is the discouraging policy of the government. As the land does not belong to the farmers, who have only use rights, they are not allowed to rent or sell their land (http:/www.irinnews.org/re, Dessalegn Rahmato, August, 2003). And the second reason, as observed in the survey, is the problem of financial constraints on the part of the farmers. They lack money to spend on land rent. On the other hand, due to the small size of their farms, the ability of the farmers in the zone to rent out land, to share in land and to share out land is extremely restricted and usually unthinkable. In Table 6.4 the rented in land is shown to exceed the rented out land. This is so because some of the land rented in by the sample farmers comes from other farmers or individuals that are not included in the sample.

As shown in Table 6.4, 92% of the total land available to the farmers included in the study is utilized for crop production. The remaining 8% of the land is divided between other land uses (see Table 6.2) such as grazing land, fallow land, rented out land and shared out land.

In farm type 1, 91% of the total available land is allocated for the production of crops and 3.9 % is utilized for animal grazing. The rest 4.8% of the total available land is kept as fallow land. In farm type 2, the cultivated land is 86% of the total available land. Only 8.2% of the total available land is utilized for grazing purposes and the quantity kept for fallow is 5.5%. In farm type 3, the cultivated land accounts for 95.8% of the total available land. The grazing and fallow lands represent 2.5% and 0.6% of the total available land of this farm type respectively.

In percentage as well as absolute terms more land is cultivated in farm type 3 as compared to farm type 1 and 2. This shows that in the temperate agro-ecological zone, because of population pressure, there exists an extreme shortage of agricultural land and the land is subject to intensive cultivation leaving little room for the use of the available land for other purposes such as animal grazing. In farm type 1, the relatively large amount of land put under cultivation has to do with the dominance of the sandy type of soil which is actually less fertile and obliging farmers to till large areas in order to obtain a reasonable harvest.

Table 6.5 Summary of the land holdings of sample farmers in the zone (timads), 2001

Farm types	1	2	3	Total
Number of farms	45	60	105	210
Total land holding	533	312	547	1392
Average land holding	11.84	5.20	5.21	-
Maximum land holding	22	15	18	-
Minimum land holding	6	1	1	-

In Table 6.5 as well as in other similar subsequent tables in this chapter the compilation of average and percentage figures for farm types and the zone is done by treating the overall sample as one large sample and there by calculating the simple arithmetic means as well as averages but not weighted figures. With this approach larger districts could be relatively under represented in the overall farm type and zonal figures. However, given the high rate of similarity within each farm type regions this bias is not that significant as confirmed by a test conducted on the yield of maize (one of the most important food crop in the zone) for all farm types.

In comparing the land holdings among farmers of the three farm types, it is clear from Table 6.5 that farmers belonging to farm type 1 have relatively larger areas of farmland as compared to those in farm type 2 and 3. The minimum land holding of just 1 timad in farm type 2 and 3 indicates that there are some farmers in these farm types who earn their livelihood from an extremely small plot of farmland. This exemplifies the above argument of the relative congestion of farmland in temperate and semi-temperate agro-ecological zones.

6.3.2 Land allocation to main crops

The allocation of farmland to the eight major food crops that are incorporated in the study is presented next. The analysis starts with discussion of farm level land allocation followed by zonal land utilization as observed from the sample farmers. An analysis of farmland utilization by farm types will also form part of the discussion.

6.3.2.1 Farm and district level land allocation to main crops

Meta district

In Meta district, maize is found to be the crop that is planted by most of the sample farmers. From the total of 15 farmers included in the survey, 14 farmers grow maize. The land allocated to maize is 70% of the total area cultivated to the eight main crops (Table 6.6).

Wheat is the second crop, next to maize, in terms of its area coverage. The total area allotted to wheat production is 12% of the cultivated land. Barley and horse beans are the next favored crops.

Being the fifth crop in its importance, the total area allotted to sorghum production is only 2.5 timads and only two sample farmers grow sorghum in the district. As it is indicated in Table 6.6, the sample farmers in the district do not produce the other food crops namely groundnuts, potatoes and green pepper.

Table 6.6 Cropland allocation by sample farmers in Meta district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
1	4	0	0	0	0	0	0	0	4
2	2	0	0	0	0	0	0	0	2
3	3	0	0	1	0	0	0	0	4
4	2	0	0	0	3	0	0	0	5
5	4	0	0	1	0	0	0	0	5
6	8	0	0	0	0	0	0	0	8
7	2	2	0	0	0	0	0	0	4
8	4.5	0.5	0	0	0	0	0	0	5
9	3	0	0	1	0	0	0	0	4
10	4	0	0	0	0	0	0	0	4
11	2	0	2	0	0	0	0	0	4
12	1	0	1	1	1	0	0	0	4
13	1	0	2	0	0	0	0	0	3
14	0	0	2	0	0	0	0	0	2
15	1	0	0	0	0	0	0	0	1
Total farmers	**14**	**2**	**4**	**4**	**2**	**0**	**0**	**0**	**15**
Total Area	41.5	2.5	7	4	4	0	0	0	59
Average Area	2.96	1.25	1.75	1.00	2.00	0	0	0	3.93
Maximum Area	8	2	2	1	3	0	0	0	
Minimum Area	1	0.5	1	1	1	0	0	0	

Kersa district

Sorghum is the main crop of the sample farmers in Kersa district. Sorghum takes a share of 46.4% of the total cultivated area of food crops. All the farmers sampled in Kersa district produce sorghum. Maize, wheat and barley range from second to fourth in their importance as seen from the number of farmers growing the crops and the total cultivated area they occupy (Table 6.7). The sample farmers of Kersa district do not produce horse beans, groundnuts and green pepper, and only one farmer produces potatoes on an area of just one timad.

Table 6.7 Cropland allocation by sample farmers in Kersa district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
16	2	4	0	0	0	0	0	0	6
17	2	4	0.5	2	0	0	0	0	8.5
18	6	1	3	1	0	0	0	0	11
19	1	1.5	0	0.5	0	0	0	0	3
20	1	1	0	0	0	0	0	0	2
21	2	1	0	0	0	0	0	0	3
22	2	4	0	0	0	0	0	0	6
23	4	2	0	0	0	0	0	0	6
24	0	3	2	0	0	0	0	0	5
25	0	2.5	0	0	0	0	0	0	2.5
26	4	2	0	0	0	0	0	0	6
27	3	2	1	0	0	0	1	0	7
28	0	3	0	1	0	0	0	0	4
29	0	3	0.5	0	0	0	0	0	3.5
30	1	1.5	0.5	0	0	0	0	0	3
Total farmers	**11**	**15**	**6**	**4**	**0**	**0**	**1**	**0**	**15**
Total Area	28.0	35.5	7.5	4.5	0	0	1	0	76.5
Average Area	2.55	2.37	1.25	1.13	0	0	1	0	5.1
Maximum Area	6	4	3	2	0	0	1	0	11
Minimum Area	1	1	0.5	0.5	0	0	1	0	2

Deder district

In the district of Deder, maize is the main food crop of the sample farmers. All the farmers included in the survey are producers of maize. The area allocated to maize production constitutes 43.2 % of the total area occupied by the eight main food crops.

Barley is the second important food crop. Out of the 15 sample farmers, 14 produce barley. Horse beans, wheat and sorghum stand third, fourth and fifth in their importance. As is clearly seen from Table 6.8, the other three crops are not grown by the sample farmers in Deder district.

Table 6.8 Cropland allocation by sample farmers in Deder district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
31	4	0	3	2	2	0	0	0	11
32	2	0	3	0	2	0	0	0	7
33	5	0	3	1	1	0	0	0	10
34	3	0	0	1	1	0	0	0	5
35	2	0	0	2	1	0	0	0	5
36	1	0	2	1	0.5	0	0	0	4.5
37	3	0	0	3	2	0	0	0	8
38	3	0	2	3	2	0	0	0	10
39	4	0	0	2	2	0	0	0	8
40	5	0	0	5	0	0	0	0	10
41	2	1	0	2	0	0	0	0	5
42	2	0	0	2	0	0	0	0	4
43	2	0	0	2	1	0	0	0	5
44	5	0	1	1	1	0	0	0	8
45	3	0	1	2	0	0	0	0	6
Total farmers	**15**	**1**	**7**	**14**	**11**	**0**	**0**	**0**	**15**
Total Area	46.0	1.0	15.0	29.0	15.5	0	0	0	106.5
Average Area	3.07	1	2.14	2.07	1.41	0	0	0	7.1
Maximum Area	5	1	3	5	2	0	0	0	
Minimum Area	1	1	1	1	0.5	0	0	0	

Melkabelo district

The crop production pattern of the sample farmers in Melkabelo district is similar to that of Deder district. The five crops, namely maize, barley, horse beans, wheat and sorghum stand from first to fifth in their importance in Melkabelo district similar to that of the Deder district.

All the farmers included in the survey produce maize. The total area cultivated with maize accounts approximately for 56 % of the total area under food crop production. Sorghum is the least attractive crop produced, with only two farmers growing it. The other three crops are not grown by the sample farmers in the district (Table 6.9).

Table 6.9 Cropland allocation by sample farmers in Melkabelo district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
46	1	0.5	0	0.5	0.5	0	0	0	2.5
47	3	0	0	0	0	0	0	0	3
48	2	0	0.5	0.5	0	0	0	0	3
49	2.5	0	0.5	0	0.5	0	0	0	3.5
50	2.5	2	1	1	0	0	0	0	6.5
51	4	0	0	1	1	0	0	0	6
52	1	0	0.5	0.5	0	0	0	0	2
53	2	0	2	1	1	0	0	0	6
54	6.5	0	0	1	2	0	0	0	9.5
55	2	0	1	1	2	0	0	0	6
56	2	0	0	2	1	0	0	0	5
57	1	0	0	0	1	0	0	0	2
58	1.5	0	0	1	0.25	0	0	0	2.75
59	2	0	0	0	0	0	0	0	2
60	3	0	0	1.5	0	0	0	0	4.5
Total farmers	**15**	**2**	**6**	**11**	**9**	**0**	**0**	**0**	**15**
Total Area	36.00	2.50	5.50	11.00	9.25	0	0	0	64.25
Average Area	2.40	1.25	0.92	1.00	1.03	0	0	0	4.28
Maximum Area	6.5	2	2	2	2	0	0	0	
Minimum Area	1	0.5	0.5	0.5	0.25	0	0	0	

Gorogutu district

The sample farmers in Gorogutu district produce only three crops namely, sorghum, maize and wheat (Table 6.10). Sorghum is the main crop in terms of its area coverage. It occupies approximately 56% of the total area cultivated by the 3 main crops. Maize is the second crop in terms of its area coverage and wheat is the only other crop grown by farmers sampled in this district.

Table 6.10 Cropland allocation by sample farmers in Gorogutu district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
61	0	5	0	0	0	0	0	0	5
62	2	3	0	0	0	0	0	0	5
63	2	4	2	0	0	0	0	0	8
64	0	6	0	0	0	0	0	0	6
65	1	3	0	0	0	0	0	0	4
66	2	2	0	0	0	0	0	0	4
67	0.5	1.5	0	0	0	0	0	0	2
68	4	0	0	0	0	0	0	0	4
69	2	0	0	0	0	0	0	0	2
70	2	2	0	0	0	0	0	0	4
71	1	2	0	0	0	0	0	0	3
72	1	1	0	0	0	0	0	0	2
73	2	0	0	0	0	0	0	0	2
74	1	0	0	0	0	0	0	0	1
75	1	2	1	0	0	0	0	0	4
Total farmers	**13**	**11**	**2**	**0**	**0**	**0**	**0**	**0**	**15**
Total Area	21.5	31.5	3.0	0	0	0	0	0	56
Average Area	1.65	2.86	1.5	0	0	0	0	0	3.73
Maximum Area	4	6	2	0	0	0	0	0	
Minimum Area	0.5	1	1	0	0	0	0	0	

Kurfachele district

Like the farmers in Gorogutu district, the sample farmers of Kurfachele district grow only three crops namely sorghum, maize and wheat. Sorghum is their main crop and constitutes 65.2% of the total area. Maize is the second important crop as seen from the number of farmers growing the crop and the total cultivated area it occupied (Table 6.11).

Table 6.11 Cropland allocation by sample farmers in Kurfachele district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
76	0	3	0	0	0	0	0	0	3
77	0	4	0	0	0	0	0	0	4
78	0	2	1	0	0	0	0	0	3
79	0	4	0	0	0	0	0	0	4
80	0	5	0	0	0	0	0	0	5
81	2	4	0	0	0	0	0	0	6
82	2	2	1	0	0	0	0	0	5
83	1	3	0	0	0	0	0	0	4
84	0	4	0	0	0	0	0	0	4
85	4	6	0	0	0	0	0	0	10
86	4	0	0	0	0	0	0	0	4
87	2	2	0	0	0	0	0	0	4
88	4	0	0	0	0	0	0	0	4
89	1	3	0	0	0	0	0	0	4
90	2	3	0	0	0	0	0	0	5
Total farmers	**9**	**13**	**2**	**0**	**0**	**0**	**0**	**0**	**15**
Total Area	22	45	2	0	0	0	0	0	69
Average Area	2.44	3.46	1	0	0	0	0	0	4.6
Maximum Area	4	6	1	0	0	0	0	0	
Minimum Area	1	2	1	0	0	0	0	0	

Girawa district

According to Table 6.12, sorghum is the main food crop of the sample farmers in Girawa district. The sorghum land constitutes 33.2 % of the total area occupied by the main four food crops.

Maize is the second most important crop followed by horse beans. The fourth favored crop is wheat. As it is seen from Table 6.12, the farmers sampled in the district of Girawa do not produce the other food crops considered, namely barley, groundnuts, potatoes and green pepper.

Table 6.12 Cropland allocation by sample farmers in Girawa district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
91	0.25	1	0	0	0	0	0	0	1.25
92	0.5	0.5	0	0	0	0	0	0	1
93	0.5	0.5	0	0	0	0	0	0	1
94	0.5	0.5	0	0	0	0	0	0	1
95	2	1	0	0	0	0	0	0	3
96	0.5	1	0	0	0	0	0	0	1.5
97	0	1	0.5	0	0	0	0	0	1.5
98	2	2	0	0	2	0	0	0	6
99	0	2	1	0	0	0	0	0	3
100	0	1.5	1	0	1.5	0	0	0	4
101	0	2	0	0	2	0	0	0	4
102	2	0	2	0	2	0	0	0	6
103	2	1	0	0	2	0	0	0	5
104	0	1	2	0	0	0	0	0	3
105	2	0	2	0	0	0	0	0	4
Total farmers	**10**	**13**	**6**	**0**	**5**	**0**	**0**	**0**	**15**
Total Area	12.25	15.00	8.50	0	9.50	0	0	0	45.25
Average Area	1.23	1.15	1.42	0	1.90	0	0	0	3.02
Maximum Area	2	2	2	0	2	0	0	0	
Minimum Area	0.25	0.5	0.5	0	1.5	0	0	0	

Bedeno district

The farmers sampled in Bedeno district have a similar pattern of crop production as that of Melkabelo and Deder districts. The three crops, namely maize, wheat and sorghum rank respectively from first to third in importance.

All the farmers included in the survey of Bedeno district produce maize. The area cultivated to maize accounts for approximately 59% of the total area under the three food crops. Thirteen farmers produce wheat and only 3 farmers grow sorghum. Barley, horse beans, groundnuts, potatoes and green pepper are not grown by the sample farmers of Bedeno district (Table 6.13).

Table 6.13 Cropland allocation by sample farmers in Bedeno district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
106	1	4	2	0	0	0	0	0	7
107	1.5	0	1	0	0	0	0	0	2.5
108	6	0	1	0	0	0	0	0	7
109	1	0	0.5	0	0	0	0	0	1.5
110	1.5	0	4	0	0	0	0	0	5.5
111	1	0	0	0	0	0	0	0	1
112	2	0	0.5	0	0	0	0	0	2.5
113	2	0	1	0	0	0	0	0	3
114	1.5	0	0	0	0	0	0	0	1.5
115	0.5	0.5	0.5	0	0	0	0	0	1.5
116	3	0	1	0	0	0	0	0	4
117	0.5	0	0.5	0	0	0	0	0	1
118	2	0.5	1	0	0	0	0	0	3.5
119	3	0	1	0	0	0	0	0	4
120	2	0	0.5	0	0	0	0	0	2.5
Total farmers	**15**	**3**	**13**	**0**	**0**	**0**	**0**	**0**	**15**
Total Area	28.5	5.0	14.5	0	0	0	0	0	48.0
Average Area	1.9	1.67	1.12	0	0	0	0	0	3.2
Maximum Area	6	4	4	0	0	0	0	0	
Minimum Area	0.5	0.5	0.5	0	0	0	0	0	

Alemaya district

The sample farmers of Alemaya district are engaged in the production of only two crops, namely sorghum and maize. Sorghum is main food crop of the farmers. The area allocated to sorghum production is approximately 74% of the total land under the two main crops (Table 6.14).

Table 6.14 Cropland allocation by sample farmers in Alemaya district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
121	0	2	0	0	0	0	0	0	2
122	0	4	0	0	0	0	0	0	4
123	3	2	0	0	0	0	0	0	5
124	0	4	0	0	0	0	0	0	4
125	0	3	0	0	0	0	0	0	3
126	0	5	0	0	0	0	0	0	5
127	3	0	0	0	0	0	0	0	3
128	0	4	0	0	0	0	0	0	4
129	0	3	0	0	0	0	0	0	3
130	0	4	0	0	0	0	0	0	4
131	0	3	0	0	0	0	0	0	3
132	0	4	0	0	0	0	0	0	4
133	3	0	0	0	0	0	0	0	3
134	0	5	0	0	0	0	0	0	5
135	6	0	0	0	0	0	0	0	6
Total farmers	**4**	**12**	**0**	**0**	**0**	**0**	**0**	**0**	**15**
Total Area	15	43	0	0	0	0	0	0	58
Average Area	3.75	3.58	0	0	0	0	0	0	3.87
Maximum Area	6	5	0	0	0	0	0	0	
Minimum Area	3	2	0	0	0	0	0	0	

Kombolcha district

The farmers surveyed in Kombolcha district grow five crops. Sorghum, maize, potatoes, horse beans and wheat rank respectively from first to fifth in their importance. As a main crop, the area occupied by sorghum is approximately 46% of the total area cultivated with the five crops.

Maize is second in importance, if seen from the share of land it covers, even though an equal number of farmers as that of sorghum produce it. Potatoes are the third important crop followed by horse beans and wheat. Barley, groundnuts and green pepper are not grown by the sample farmers in this district (Table 6.15).

Table 6.15 Cropland allocation by sample farmers in Kombolcha district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
136	2	4	0	0	0	0	0	0	6
137	4	3	0	0	0	0	0	0	7
138	1.5	2	0.5	0	0	0	0	0	4
139	3	2	0	0	0	0	0	0	5
140	3	4	0	0	0	0	4	0	11
141	3	4.5	0	0	0	0	0.5	0	8
142	3	0	0	0	1	0	0	0	4
143	0	3	0	0	0	0	0	0	3
144	0	5	0	0	1.5	0	0	0	6.5
145	3	1	0	0	1.5	0	1	0	6.5
146	3	0	0	0	1	0	0.5	0	4.5
147	1	2	0.5	0	0	0	0	0	3.5
148	1	2	0	0	0	0	0	0	3
149	1	2	0	0	0	0	0	0	3
150	2	2	0	0	0	0	0	0	4
Total farmers	**13**	**13**	**2**	**0**	**4**	**0**	**4**	**0**	**15**
Total Area	30.5	36.5	1.0	0	5.0	0	6.0	0	79.0
Average Area	2.35	2.81	0.5	0	1.25	0	1.5	0	5.27
Maximum Area	4	5	0.5	0	1.5	0	4	0	
Minimum Area	1	1	0.5	0	1	0	0.5	0	

Babile district

Sample farmers of Babile district produce three crops namely groundnuts, sorghum and maize (Table 6.16). Groundnuts are the main crop with approximately 45% of the total area occupied it. Sorghum is the second most important crop in terms of its area coverage followed by maize. The area occupied by sorghum is close to 44% of the total area cultivated under the three main crops.

Table 6.16 Cropland allocation by sample farmers in Babile district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
151	2	8	0	0	0	5	0	0	15
152	0	8	0	0	0	8	0	0	16
153	2	3	0	0	0	8	0	0	13
154	1	5	0	0	0	7	0	0	13
155	0	6	0	0	0	6	0	0	12
156	1	8	0	0	0	6	0	0	15
157	0	6	0	0	0	7	0	0	13
158	0	3	0	0	0	3	0	0	6
159	3	8	0	0	0	5	0	0	16
160	2	4	0	0	0	4	0	0	10
161	1	4	0	0	0	6	0	0	11
162	1	2	0	0	0	2	0	0	5
163	0	0	0	0	0	7	0	0	7
164	2	5	0	0	0	0	0	0	7
165	4	8	0	0	0	6	0	0	18
Total farmers	**10**	**14**	**0**	**0**	**0**	**14**	**0**	**0**	**15**
Total Area	19	78	0	0	0	80	0	0	177
Average Area	1.9	5.57	0	0	0	5.71	0	0	11.8
Maximum Area	4	8	0	0	0	8	0	0	
Minimum Area	1	2	0	0	0	2	0	0	

Gursum district

As indicated in Table 6.17, four crops, namely; sorghum, groundnuts, maize and green pepper are produced by the sample farmers of Gursum district. Gursum is the only district in which the farmers included in the survey were found to grow green pepper. According to the area it occupies, sorghum can be seen as the main crop of the farmers. The area occupied by sorghum constitutes 35% of the total area cultivated to the four main crops. Groundnuts are the second most important crop followed by maize and green pepper.

Table 6.17 Cropland allocation by sample farmers in Gursum district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
166	2	2	0	0	0	4	0	0	8
167	2	2	0	0	0	4	0	0	8
168	2	3	0	0	0	1	0	1	7
169	2	2	0	0	0	1	0	1	6
170	3	0	0	0	0	4	0	1	8
171	2	4	0	0	0	2	0	1	9
172	2	3	0	0	0	2	0	1	8
173	1	2	0	0	0	2	0	0	5
174	1	1	0	0	0	1	0	1	4
175	1	2	0	0	0	2	0	0	5
176	2	2	0	0	0	1	0	1	6
177	1	5	0	0	0	1	0	1	8
178	2	2	0	0	0	1	0	0	5
179	1	2	0	0	0	1	0	1	5
180	1	2	0	0	0	1	0	1	5
Total farmers	**15**	**14**	**0**	**0**	**0**	**15**	**0**	**10**	**15**
Total Area	25	34	0	0	0	28	0	10	97
Average Area	1.67	2.43	0	0	0	1.87	0	1	6.47
Maximum Area	3	5	0	0	0	4	0	1	
Minimum Area	1	1	0	0	0	1	0	1	

Jarso district

Wheat, maize and potatoes are the three crops cultivated by sample farmers in Jarso district (Table 6.18). In terms of the area it occupies, wheat is the main crop. All the farmers sampled in the district grow wheat and the area occupied by wheat constitutes 63% of total land cultivated to the three crops. Maize is the second most important crop followed by potatoes.

Table 6.18 Cropland allocation by sample farmers in Jarso district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
181	1	0	3	0	0	0	0	0	4
182	0	0	3	0	0	0	1	0	4
183	2	0	4	0	0	0	0	0	6
184	1	0	2	0	0	0	0	0	3
185	1	0	2	0	0	0	0	0	3
186	0	0	2	0	0	0	1	0	3
187	0	0	2	0	0	0	1	0	3
188	2	0	3	0	0	0	0	0	5
189	0	0	4	0	0	0	1	0	5
190	0	0	2	0	0	0	1	0	3
191	0	0	3	0	0	0	2	0	5
192	2	0	2	0	0	0	0	0	4
193	2	0	3	0	0	0	1	0	6
194	1	0	2	0	0	0	1	0	4
195	2	0	4	0	0	0	1	0	7
Total farmers	**9**	**0**	**15**	**0**	**0**	**0**	**9**	**0**	**15**
Total Area	14	0	41	0	0	0	10	0	65
Average Area	1.56	0	2.73	0	0	0	1.11	0	4.33
Maximum Area	2	0	4	0	0	0	2	0	
Minimum Area	1	0	2	0	0	0	1	0	

Fedis district

In the district of Fedis, the sample farmers grow three crops, namely; sorghum, maize and wheat. Sorghum is by far the main crop in terms of its area coverage and all the farmers included in the survey grow sorghum. The area occupied by sorghum accounts for approximately 90% of the total area cultivated by the three crops. Maize and wheat are respectively the second and third most important crops in terms of area (Table 6.19).

Table 6.19 Cropland allocation by sample farmers in Fedis district (timads), 2001

Farmer Number	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total Cultivated Land
196	1	10	0	0	0	0	0	0	11
197	0	6	0	0	0	0	0	0	6
198	0	4	0	0	0	0	0	0	4
199	0	8	0	0	0	0	0	0	8
200	0	9	0	0	0	0	0	0	9
201	3	8	1	0	0	0	0	0	12
202	0	10	0	0	0	0	0	0	10
203	0	6	0	0	0	0	0	0	6
204	0	6	0	0	0	0	0	0	6
205	0	10	0	0	0	0	0	0	10
206	0	8	0	0	0	0	0	0	8
207	0	7	0	0	0	0	0	0	7
208	1	7	0	0	0	0	0	0	8
209	4	6	0	0	0	0	0	0	10
210	0	6	2	0	0	0	0	0	8
Total farmers	**4**	**15**	**2**	**0**	**0**	**0**	**0**	**0**	**15**
Total Area	9	111	3	0	0	0	0	0	123
Average Area	2.25	7.40	1.50	0	0	0	0	0	8.20
Maximum Area	4	10	2	0	0	0	0	0	
Minimum Area	1	4	1	0	0	0	0	0	

6.3.2.2 Zonal land allocation to main crops

The sub-regional (zonal) land allocation to major food crops is depicted in Table 5.20. The figures in this table are compiled with information obtained from the total 210 farmers sampled in the zone.

According to the sample information, the district of Babile has the largest share of the total cultivated area in the zone. The area occupied by the three crops, namely groundnuts, sorghum and maize, that are produced by the sample farmers in Babile district is approximately 16% of the total land cultivated by the eight main crops. The district of Fedis is second with a share close to 11% of the total cultivated area. The sampled farmers in this district also produce only three crops. Deder is third with a share of 9.5% of the total area planted by the eight food crops. The district of Deder is one of three districts that produce six of the eight crops included in the survey.

The district that possesses the smallest cultivated area is Girawa. The area cultivated by its sample farmers is only four percent of the total cultivated area in the zone. Paradoxically, this district is one of the largest districts in the zone, in terms of the total square kilometers it occupies. The reason for its low cultivated area has to do with the extensive part of its land that lies in the arid climatic zone, which remains unfavorable for agricultural production.

Table 6.20. Zonal land allocation to major food crops by sample farmers (timads), 2001

		Maize		Sorghum		Wheat		Barley		Horse beans		Groundnuts		Potatoes		Green pepper		Total area
No.	District	NF[1]	AC[2]	NF	AC	NF	AC	NF	AC	NF	AC	NF	AC	NF	AC	NF	AC	cultivated
1	Meta	14	41.5	2	2.5	4	7	4	4	2	4	0	0	0	0	0	0	59
2	Kersa	11	28	15	35.5	6	7.5	4	4.5	0	0	0	0	1	1	0	0	76.5
3	Dedar	15	46	1	1	7	15	14	29	11	15.5	0	0	0	0	0	0	106.5
4	Melkabelo	15	36	2	2.5	6	5.5	11	11	9	9.25	0	0	0	0	0	0	64.3
5	Gorogutu	13	21.5	11	31.5	2	3	0	0	0	0	0	0	0	0	0	0	56
6	Kurfachale	9	22	13	45	2	2	0	0	0	0	0	0	0	0	0	0	69
7	Girawa	10	12.25	13	15	6	8.5	0	0	5	9.5	0	0	0	0	0	0	45.3
8	Bedeno	15	28.5	3	5	13	14.5	0	0	0	0	0	0	0	0	0	0	48
9	Alemaya	4	15	12	43	0	0	0	0	0	0	0	0	0	0	0	0	58
10	Kombolcha	13	30.5	13	36.5	2	1	0	0	4	5	0	0	4	6	0	0	79
11	Babile	10	19	14	78	0	0	0	0	0	0	14	80	0	0	0	0	177
12	Gursum	15	25	14	34	0	0	0	0	0	0	15	28	0	0	10	10	97
13	Jarso	9	14	0	0	15	41	0	0	0	0	0	0	9	10	0	0	65
14	Fedis	4	9	15	111	2	3	0	0	0	0	0	0	0	0	0	0	123
Total		157	348.25	128	440.5	65	108	33	48.5	31	43.25	29	108	14	17	10	10	1123.5
Average		11.21	24.89	9.85	33.88	5.91	9.82	8.25	12.13	6.2	8.65	14.5	54	4.7	5.67	10	10	80.3
Maximum		15	46	15	111	15	41	14	29	11	15.5	15	80	9	10	10	10	177
Minimum		4	9	1	1	2	1	4	4	2	4	14	28	1	1	10	10	45.3
ND[3]		14	14	13	13	11	11	4	4	5	5	2	2	3	3	1	1	14

[1] NF = Number of farmers cultivating the crop
[2] AC = Area cultivated by the crop
[3] ND = Number of districts producing the crop

Based on the sample data, the average area cultivated to the eight main crops in the zone is 80.3 timads. This means that, on average, 80.3 timads of the land in each of the districts of the zone is cultivated by the eight main food crops.

The relative importance of each of the main food crop in the zone, as observed from the sample, is elaborated on below. The assumption is made that the sample is a true representation of the total zone.

Sorghum production

According to the information compiled from the sample farmers in the zone sorghum is the main staple food crop in East Hararghe Administrative Zone. From the fourteen sampled districts in the zone thirteen of them produce sorghum and the area occupied by the crop is approximately 39% of the total food crops land in the study area. Moreover, approximately 61% of the sampled farmers in the zone grow sorghum.

The district of Fedis is the main sorghum producing district in the zone. Of the total area occupied by sorghum in the zone, the share of Fedis is approximately 25%. Babile is second with a share of approximately 18%. The smallest sorghum producing district in the zone is Deder district.

Maize production

Maize is the only crop that is produced by all the fourteen districts in East Hararghe Administrative Zone. It is also the crop that is planted by most sample farmers. Out of the total farmers included in the survey, 75 percent of them are producers of maize crop.

In terms of area cultivated, maize is the second most important food crop and the land allocated to its production is approximately 31% of the total land cultivated to the eight main food crops.

District wise, it can be clearly seen from Table 5.20 that the district of Deder is the most important one in maize production. The maize area in Deder district amounts to 13.2% of the total maize land in the zone and all the sample farmers in the district produce maize. Meta is the second largest maize growing district with approximately 12% of the total land occupied by maize, followed by Melkabelo with 10%. The smallest maize producing district is Fedis.

Wheat production

In terms of the area it occupies and the number of farmers producing the crop, wheat is the third most important crop in East Hararghe Administrative Zone. The area occupied by wheat is 10% of the total land cultivated to the eight main crops in the zone and approximately 31% of the total 210 farmers included in the study produce wheat.

Jarso is the main wheat producing district in the zone followed by Bedeno and Girawa. Kombolcha is the smallest wheat producing district in the zone.

Barley production

In terms of the area it occupies, barley is the fifth most important crop in the study area. It is produced in only four districts of the zone. The area occupied by barley is approximately 4% of the total food crops area in the zone and approximately16% of the sampled farmers in East Hararghe Administrative Zone grow barley. As shown in Table 5.20, the district of Deder is the main barley producer with Meta the smallest.

Horse beans production

Horse beans are the most important pulse crop in East Hararghe Administrative Zone. However, in comparison with all the other main crops in the zone, it is the sixth most important crop, next to barley. The total land allocated to horse beans production is four percent of the total land cultivated with the eight main food crops and around 14.8 % of the farmers sampled in the zone grow horse beans.

Groundnuts production

Groundnuts are the main oilseed crop in East Hararghe Administrative Zone. However, in terms of its area coverage, groundnuts is the fourth largest food crop and is produced in only two of the 14 districts in the zone. The area occupied by groundnuts is approximately 10% of the total food crops area of the zone and 13.8% of the sample farmers grow groundnuts.

From the two districts involved in groundnuts production, the district of Babile is the main producer of groundnuts. The area allocated for groundnuts production in Babile district is more than 74% of the total land occupied by groundnuts in the zone.

Potatoes production

As it is evident from Table 5.20, potatoes are produced in only three districts of East Hararghe Administrative Zone. It is the most important vegetable crop in the zone. However, as far as the total area occupied is concerned, potatoes are ranked seventh in importance, next to the pulse crop of horse beans.

Green pepper production

As observed from the sample farmers, green pepper is the least important vegetable crop in East Hararghe Administrative Zone and is only produced by the district of Gursum. The land occupied by green pepper is only 0.9% of the total land cultivated to the eight main crops in the zone and approximately five percent of the sampled farmers in the zone are producers of green pepper.

6.3.2.3 Land utilization by farm types

The land use of the three identified farm types for the eight major food crops included in the survey is presented in Table 6.21.

In terms of both the amount of cultivated area and the number of farmers producing the crop, sorghum is the main food crop in farm type 1. This is due to the fact that sorghum is a warm weather crop, which is a characteristic feature of farm type 1. From the total land cultivated by the eight major crops in this farm type, sorghum takes a share of 56.2% with about 96% of the sample farmers included in this farm type growing sorghum. Groundnuts, being a low land crop as well, are the second most important crop in farm type1, based on land coverage. The area planted to groundnuts constitutes 27.2% of the total cultivated land in this farm type. It is produced by an equal number of farmers as that of maize, which is the third most important food crop in this farm type. Barley, horse beans and potatoes are not produced in farm type one. Barley is not grown in this farm type, as it is a cold weather crop. Horse beans are also grown at an altitude that exceeds 1800 meters above sea level and this is an altitude beyond the reach of farm type one.

In farm type 2, the area cultivated to sorghum exceeds that of other crops indicating that sorghum remains the main crop in this farm type as well. It occupies an area that equals 51.5% of the total cultivated land of the eight major crops in this farm type. The second most important crop in this farm type is maize. It is cultivated on an area close to 34% of the total cultivated land of farm type 2. Wheat, being cultivated on highlands, is the third ranking crop in this farm type. As is evident from Table 6.21, horse beans and barley are cultivated to a lesser extent. The mainly lowland crop of groundnuts and green pepper are not produced in this farm type.

Maize is the most widely cultivated crop in farm type 3. The maize area accounts for more than 44% of the total cultivated land of this farm type and 81% of the farms produce the crop. Area wise, sorghum and wheat are the second and third most important crops respectively. The land occupied by sorghum covers 19% of the total cultivated land of farm type 3. Barley and horse beans, the other cool weather crops, are also grown. A significant number of farms produce potatoes in this farm type as opposed to farm types 1 and 2 where hardly any potatoes are produced. The lowland crop of groundnuts is obviously not grown here. Green pepper is also not cultivated.

Table 6.21 Land allocation by farm types (timads), 2001

	Maize	Sorghum	Wheat	Barley	Horse beans	Ground-nuts	Potatoes	Green pepper	Total
Farm type 1									
Total farmers	29	43	2	0	0	29	0	10	45
Total Area	53	223	3	0	0	108	0	10	397
Average Area	1.83	5.19	1.50	0	0	3.72	0	1.00	8.82
Maximum Area	4	10	2	0	0	8	0	1	18
Minimum Area	1	1	1	0	0	1	0	1	4
Farm type 2									
Total farmers	43	52	16	4	5	0	1	0	60
Total Area	83.75	127.00	21.00	4.50	9.50	0	1	0	246.75
Average Area	1.95	2.44	1.31	1.13	1.90	0	1	0	4.11
Maximum Area	6	6	3	2	2	0	1	0	11
Minimum Area	0.25	0.5	0.5	0.5	1.5	0	1	0	1
Farm type 3									
Total farmers	85	33	47	29	26	0	13	0	105
Total Area	211.50	90.50	84.00	44.00	33.75	0	16.00	0	479.75
Average Area	2.49	2.74	1.79	1.52	1.30	0	1.23	0	4.57
Maximum Area	8	5	4	5	3	0	4	0	11
Minimum Area	0.5	0.5	0.5	0.5	0.25	0	0.5	0	1

According to Table 6.21, the total cultivated land in farm type 1, which comprises only 45 sample farms, exceeds that of farm type 2, which contains 60 sample farms. The reason for this has been explained in section 6.3.1.2. In conformity with this the maximum cultivated land per farm is found in farm type 1. In fact, more than 22% of the farms (farmers) in farm type 1 have a cultivated area that exceed the maximum cultivated land of farm type 2 and 3 (see Table 6.16 and 6.19).

Of the total land cultivated to the eight major crops in the zone (see Table 6.20) the share of farm types 1, 2 and 3 are 35.3%, 22% and 42.7% respectively. This corresponds well with the share of the three farm types with regard to the total available land in the zone (see Table 6.2 and 6.4). Even though maize and sorghum are warm weather crops they remain the dominant crop in all agro-ecological zones and farm types, as they are the staple food of the local people.

6.3.3 Household family structure and labour utilization

The household family structure of the sample farmers in East Hararghe Administrative zone is discussed in the following sub-sections.

6.3.3.1 Household family size per district

The household family size per district is depicted in Table 6.22. The family composition in the zone are scattered among all age groups. The households sampled in each district are fifteen and the total number of households in the study are 210.

As it can be observed from Table 6.22, most of the households in East Hararghe Administrative Zone have large family size. The average family size of the sample farmers in the zone is 7 persons per household. This figure is higher than the one obtained from secondary sources for the year 1999 and mentioned in Chapter 3 section 3.4.3. The maximum family size is recorded in Kombolcha district.

Table 6.22 Family size of sample households in each district, 2001

Age group	0-14		15-60		Over 60		Total		Total	Total house-	Average family	Maxi-mum family	Mini-mum family
District	M	F	M	F	M	F	M	F	people	holds	size	size	size
Meta	12	15	29	27	1	0	42	42	84	15	5.6	11	2
Kersa	21	30	23	31	2	0	46	61	107	15	7.1	13	3
Deder	29	22	33	23	2	2	64	47	111	15	7.4	10	5
Melkabelo	29	27	23	25	1	0	53	52	105	15	7.0	11	2
Gorogutu	28	16	23	20	0	2	51	38	89	15	5.9	9	3
Kurfachele	31	18	22	20	0	0	53	38	91	15	6.1	10	3
Girawa	26	40	33	28	2	3	61	71	132	15	8.8	16	3
Bedeno	23	21	20	22	2	3	45	46	91	15	6.1	10	3
Alemaya	23	24	20	22	1	1	44	47	91	15	6.1	9	2
Kombolcha	30	31	30	34	2	3	62	68	130	15	8.7	20	3
Babile	17	13	36	42	3	2	56	57	113	15	7.5	11	4
Gursum	46	39	21	26	2	3	69	68	137	15	9.1	18	4
Jarso	20	19	21	20	0	1	41	40	81	15	5.4	9	2
Fedis	36	30	22	28	1	0	59	58	117	15	7.8	12	5
Zonal	371	345	356	368	19	20	746	733	1479	210	7.0	20	2

The district of Gursum has got the largest household size followed by Girawa and Kombolcha districts. This result of the study is in fact similar to the one mentioned in Chapter 3 section 3.4.3. The districts of Girawa, Kombolcha and Fedis are second, third and fourth in their average family size. The smallest average family size is observed in the District of Jarso.

The zonal active labour force of sample farmers, found in the age group of 15–60 years, is 724 persons. This active population constitutes 49% of the total population of the sample farmers. The dependent population, which includes those with in the age group of 0-14 and over 60 years, are observed to be 755 people. This inactive segment of the population corresponds to 51% of the total population of the sample farmers. This means that 51% of the population of the farmers sampled in the zone depend upon 49% of the population for its livelihood. This result corresponds well with the census figures mentioned in Chapter 3. However, an important difference here is that the active labour force is considered to be people within the age group of 15-60 instead of those between 15 and 64 years of age. The researcher assumes that people beyond 60 years of age can no longer be considered active labour force participants with regard to the hard physical work involved in agricultural production.

The total size of the population of the 210 sample households is 1479. Children under the age of 14 make up 48.4% of the total population of the sampled farmers. On the other hand the old age people (those over 60 years of age) constitute 2.6% of the total population. As far as the sex composition is concerned, Table 6.22 indicates that the number of males is close to that of the females. According to this table, the sex ratio of the sample farmers is 102 males per 100 females. This result is also very close to the one obtained from secondary sources for the entire zone (see Chapter 3).

The district of Babile has the largest active labour force relative to the total population of its sample farmers followed by Meta district. The active population of the sample farmers in Babile district constitutes 69% of its total population while that of the Meta district represents 67% of its population. The Babile district is found in the arid agro-ecological zone unlike Meta, which is one of the districts in the temperate agro-ecological zone. The size of the active labour force may well correspond to the contribution of each district in terms of the total agricultural production in the zone. Therefore, it remains to be seen if these two districts contribute a significant amount of production to the zonal total (section 6.3.5). According to Table 6.22, the district whose sample farmers possess the smallest proportion of active labour force is Gursum. This district was in fact the one that contains the largest average family size in the zone. It has an active labour force that makes up only 34.3% of the total population of its sample farmers.

6.3.3.2 Household labour availability per farm type

In computing the household labour available to sample farmers for farm work, only the active labour force in each district, which is in the age group of 15-60, was taken into consideration. Of this active labour force some are found to be full time farm workers and others are part time farm workers. Most of the full time farm workers are in turn found to work less than eight hours per day on their farms. Therefore, for the purpose of computing the actual yearly available household labour force in mandays, the numbers of full time and part time farm workers were multiplied by their respective working hours. These two figures were then summed and multiplied by the total working days in Ethiopia which is 270 days in a year excluding Saturdays, Sundays and public holidays. Consequently, to estimate (compute) the number of mandays that a farm family can work, taking into account that one manday is equivalent to eight hours of work by an active worker (age 15-60); the above resulting figure was divided by eight hours. The following formula summarizes the above discussion:

$$HHLabour / year = \frac{[(FT \times Whf) + (PT \times Whp)] \times 270 days}{8\ hrs}$$

Where:

HHLabour/year = Yearly available household labour per farmer (in mandays)
FT = Number of full-time farm workers in the family
Whf = Working hours of full-time farm workers
PT = Number of part-time farm workers in the family
Whp = Working hours of part-time farm workers

For computing the monthly available household labour force, the annual estimate was divided by 12 (months in a year):

$$Monthly\ labour = \frac{HHLabour / year}{12}$$

Based on this computation, the household labour of sample farmers that is available for farm work in each month for the three farm types is presented in Table 6.23.

Sample farmers in farm type 1 have got the largest monthly and yearly average available family labour as compared to both farm type 2 and 3. In farm type 1, the average monthly household labour that is available for farm work is 58 mandays. This means that on average the sample farms in farm type 1 have 58 mandays of family labour each month to conduct their farming operations. On the other hand, sample farmers in farm type 2 and 3 can rely on a monthly available household labour of only 46 and 48 mandays respectively. As shown in Table 6.23, the yearly average household labour available to sample farmers in farm type 1 also exceeds that of farm type 2 and 3. This could be attributed to the large family size as well as the higher percentage of the active age group (particularly in Babile) that is contained by the districts that constituted this farm type, as explained in section 6.3.3.1.

Table 6.23 Household labour availability of sample farmers per farm type (mandays), 2001

Farm type	Total farmers	Monthly available labour (January-December)		Yearly available labour	
		Total mandays	Average mandays per farm type	Total mandays	Average mandays per farm type
1	45	2616	58.1	31392	697.6
2	60	2739	45.7	32868	547.8
3	105	5084	48.4	61008	581.0
Zonal	210	10439	49.7	125268	596.5

At zonal level the average monthly and yearly household labour that is available to each of the sample farms in the zone are 50 and 597 mandays respectively. The yearly average household labour that is available for sample farms in farm type 1 exceeds the yearly average household labour that is available to all sample farms at the zonal level.

6.3.3.3 Household labour utilization by farm types

According to the results of the survey (Table 6.24), household labour use is dispersed throughout the year in East Hararghe Administrative Zone. However, June is the month of peak household labour use for the total sample farmers in the zone followed by the month of May. Of the total 305 mandays/timad of the household labour utilized by all sample farmers, in the production of the 8 major crops in 2001 in the zone, the share of June constitutes 17%. May and June fall into an important rainy season during which crop production intensifies in the zone (see Chapter 3 section 3.3.2). August is also a month in which most weeding (particularly for wheat and barley) and some harvesting (for horse beans and potatoes) operations are performed thus commanding relatively large amount of household labour.

The months of October and December as well as November and January show the use of a significant amount of household labour because in these months most of the harvesting and threshing activities are performed in the zone. March and April are the months in which the activities of sowing and fertilizing take place and hence imply a significant use of household labour. The months of February and September are the months in which the smallest amount of household labour is needed for farm operations. This is because, in February, some small land preparation activities are conducted which do not necessarily command much labour as this month follows January when threshing has been performed. September lies between months of weeding and harvesting and hence it is a month of less agricultural activities in the zone.

Table 6.24 Household labour utilization by sample farmers per farm type, crop and month (mandays/ timad), 2001

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Farm type 1												
Maize	0	0	2.12	2.42	0	3.3	0	0	0	2.75	1.5	3.41
Sorghum	0	0	1.12	2.44	2.64	2.94	3.5	0	0	0	2.49	2.51
Wheat	0	0	0	0	0	1.5	3.5	4.5	0	3.5	2.5	0
Groundnuts	0	0	2	1.54	0	3.22	0	0	0	3	0	3.52
Green pepper	0	0	0	2.2	3	2.6	0	0	0	3.33	0	0
Total	0	0	5.23	8.60	5.64	13.57	7	4.5	0	12.58	6.49	9.43
Farm type 2												
Maize	2.94	0	2.71	3.44	3.94	4.59	0	0	0	2.17	2.58	3.20
Sorghum	3	0	2.83	2.67	4.78	4.71	0	0	0	0	0	2.90
Wheat	3	0	0	0	2.5	2.18	2.69	3.75	0	3.17	2.67	2.63
Barley	0	0	0	0	0	2.5	1.75	2.5	0	2	1.75	0
Horse beans	0	0	2	0	2.6	2.8	0	2.4	2.2	0	0	0
Potatoes	0	0	0	2	3	8	0	6	0	0	0	0
Total	8.94	0	7.54	8.12	16.82	24.79	4.44	14.65	2.2	7.33	7	8.73
Farm type 3												
Maize	3.16	2.35	2.84	2.58	1.78	4.22	0	0	0	3.5	2.17	2.88
Sorghum	3.17	2.4	2.82	3	2.96	3.75	0	0	0	0	0	2.39
Wheat	2.37	0	0	0	1.48	2.25	2.53	3.9	1.93	0	3.67	2.74
Barley	0	2.28	1.7	0	3.35	0	3.32	0	2.71	2	0	0
Horse beans	2.53	0	0	0	1.53	0	1.47	3.5	4.06	1.5	3.33	1.57
Potatoes	0	1.11	2.89	2	4.75	2.69	1.89	4.25	0	0	0	0
Total	11.23	8.14	10.25	7.58	15.85	12.92	9.21	11.65	8.71	7	9.17	9.59
Zonal total	20	8	23	24	38	51	21	31	11	27	23	28

According to Table 6.24, a relatively large use of household labour is observed for sample farmers in farm type 3. From the total household labour used by all sample farmers in the zone, about 39.7% is utilized by the farmers in this farm type. Sample farmers in farm types 1 and 2 utilize 23.9 and 36.4% respectively of the total zonal household labour during the production year.

In Table 6.24 most of the months in which household labour is not used represent months in which agricultural activities are minimum in the respective farm type and the amount of labour that is needed for any farm activity during the respective month is filled by hired labour (see Table 6.25 in section 6.3.3.4).

The crops for which the farmers have planted both local and improved varieties, the household labour use per month shows very little discrepancies for each variety. Hence, for the purpose of demonstrating the household labour use per crop, the labour use differences that exist between improved and local varieties were not regarded necessary to be shown in Table 6.24. However, at the moment of data analysis in Chapter 7, the household labour use is disaggregated between the improved and local varieties, for each crop, to take into account labour use differences among varieties.

6.3.3.4 Hired labour utilization by farm types

Farmers sampled in East Hararghe Administrative Zone do not hire much labour as shown in Table 6.25. From the total farmers producing the eight main crops, only 30.6% of them hired labour in 2001 production year. The remaining 69.4 % of the farmers rely solely on household labour to produce their crops. According to the information obtained from group discussions with farmers there are two important reasons for not hiring much labour in the zone. First, since the farmers have got very small plots of agricultural land, family labour may suffice to perform most of the farm operations on these small farms. Second, as the farmers are subsistence producers they don't have much produce for sale and hence they lack sufficient financial resources to pay for hired labour.

According to Table 6.25, the hiring of labour shows slight variation among crops that are produced by sample farmers in the zone. Maize is the crop that commands a relatively high amount of hired labour as compared to other crops. As maize is produced by the majority of sample farms in the zone, its large use of both household labour and hired labour is justifiable.

Table 6.25 Proportion of sample farmers that hired labour in the zone, 2001

No.	Crop	Total farmers growing the crop	Farmers that hired labour	Farmers not hiring labour
1	Maize	157	43	114
2	Sorghum	128	28	100
3	Wheat	65	19	46
4	Barley	33	17	16
5	Horse beans	31	14	17
6	Groundnuts	29	10	19
7	Potatoes	14	5	9
8	Green pepper	10	7	3
Total		467	143	324
Percentage		100	31	69

The amount of labour hired by each farm type for the production of the eight major crops is shown in Table 6.26. The total labour hired by all farm types in 2001 is 171 mandays/timad. Similar to the use of household labour, farm type 3 is the one that has hired relatively large amounts of labour as compared to the other two farm types. From the total labour hired during the year, the share of farm type 3 is 46.3%.

Table 6.26 Hired labour utilization by sample farmers per farm type, crop and month (mandays / timad), 2001

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Farm type 1												
Maize	0	0	1.36	1.71	0	3.57	0	0	0	2	0	2.75
Sorghum	0	0	0	1.4	1.67	0	2.67	0	0	0	1.63	2.13
Wheat	0	0	0	0	0	0	0	0	0	0	0	0
Groundnuts	0	0	1.13	1.57	0	1.95	0	0	0	1.75	0	2.88
Green pepper	0	0	0	1.71	1.83	2	0	0	0	2	0	0
Total	0	0	2.5	6.4	3.5	7.52	2.67	0	0	5.75	1.63	7.75
Farm type 2												
Maize	1.67	0	2	2.5	1.5	1.75	0	0	0	1	2	2.00
Sorghum	1.71	0	1.8	2	0	2.5	0	0	0	0	0	1.57
Wheat	3.5	0	0	0	3	2	2.25	3.5	0	1	3	3.33
Barley	0	0	0	0	0	0	1	2	0	1	1.5	0
Horse beans	0	0	0	0	1	1	0	1	0	0	0	0
Potatoes	0	0	0	0	0	0	0	0	0	0	0	0
Total	6.88	0	3.8	4.5	5.5	7.25	3.25	6.5	0	3	6.5	6.91
Farm type 3												
Maize	2.4	2.36	2.47	3.17	1	3.45	0	0	0	3.33	0	2.04
Sorghum	2	1.5	2.22	3	2.67	3	0	0	0	0	0	1.89
Wheat	1.63	0	0	0	2.2	2.25	1.5	2.1	1	0	1.67	1.30
Barley	0	2.07	1.15	0	2.36	0	2.07	0	2	1.82	0	0
Horse beans	1.64	0	0	0	1.78	0	1.43	0	2	1	1	1.60
Potatoes	0	0	1	1	1	1.2	1	2	0	0	0	0
Total	7.66	5.93	6.85	7.17	11	9.9	6	4.1	5	6.15	2.67	6.83
Zonal total	14.5	5.93	13.2	18.1	20	24.7	11.9	10.6	5	14.9	10.8	21.5

June is the month in which a large quantity of labour is hired in the zone followed by the month of December. As explained in section 6.3.3.3, June is a month of peak agricultural activities in the zone, as it marks the beginning of the main rainy season. December also commands more hired labour because of the harvesting and threshing activities that are performed during this month. September is the month with the minimum hired labour in the zone. February is the next month that commands very low amounts of hired labour.

6.3.3.5 Off-farm work by family members per farm type

Howard and Swidinsky (2000) indicate that assessing and understanding whether a farmer works off-farm or not, and for how many hours, has implications for policies and programmes directed toward rural economies and the well-being of farm families. Gebremedhin and Christy (1996) also mentioned that off-farm employment nowadays has become a critical and an important alternative income source to small farmers. However, in East Hararghe Administrative Zone off-farm household activities are extremely limited. From the total of 210 sample farmers included in the study, about 125 of them indicated that none of their family members engaged in any off-farm work during the whole year of 2001 (Table 6.27). This means that around 60% of the sample farmers in the zone do not pursue off-farm employment opportunities, which could have been an additional source of income. The farmers of the zone have cited various reasons for not engaging in such opportunities. The majority indicated that they do not possess the financial resources that are required to launch small businesses. Lack of the knowledge as to how to look for jobs has also been suggested as a potential reason for not engaging in off-farm activities. Others indicated that due to the remoteness of their location and home place they do not have access to job opportunities that are found elsewhere.

Off-farm activities are particularly restricted during the farming seasons. Of the total 210 sample farmers only 18.6% engage in off-farm work during farming seasons. The remaining 81.4% of the sample farmers in the zone concentrate only on their own agricultural activities during this season. The majority of the farmers (about 59%) that are engaged in off-farm activities during the farming season tend to work on agricultural duties in some other farms. They mainly perform sowing, weeding and harvesting activities on the farms on which they are employed. The remaining 41% of the farmers that perform off-farm activities during farming seasons engage in other duties such as small trading.

Table 6.27 Off-farm work by sample farmers per farm type, 2001

Farm type	Total farmers	Farming season		Non-farming season		Entire year	
		Farmers engaging in off-farm activities	Farmers not engaging in off-farm activities	Farmers engaging in off-farm activities	Farmers not engaging in off-farm activities	Farmers engaging in off-farm activities	Farmers not engaging in off-farm activities
1	45	6	39	9	36	13	32
2	60	8	52	28	32	32	28
3	105	25	80	28	77	40	65
Zonal total	210	39	171	65	145	85	125

Off-farm activities tend to rise slightly during non-farming seasons. In this season, about 31% of the total sample farmers of the zone engage in off-farm activities unlike during the farming season where only 18.6% of the zonal sample farmers perform off-farm work. But still, as is evident from Table 6.27, even during the non-farming season, the majority of the farmers are not involved in off-farm work. From the total sample farmers who engaged in off-farm activities during slack periods, about 60% perform small trading businesses such as the selling of vegetables, chat and milk. The remaining 40% engage in making handicraft materials and work on other minor types of jobs such as being daily labourers and being guards or watchmen in some public or private facilities.

In terms of the different farm types, as it is indicated in Table 6.27, farm type 2 has a larger number of farmers engaging in off-farm activities as compared to the other farm types. In fact, when seen from an entire year's perspective, this farm type is the only one in which the number of farmers who engaged in off-farm activities exceeded those who were not engaged in off-farm works. This is mainly due to the fairly large number of farmers who perform off-farm activities during the slack period. In farm type 2 about

53% of the sample farmers are involved in some kind of off-farm activities during the year.

Farm type 1 has the smallest number of farmers engaging in off-farm activities. In this farm type only 29% of the sample farmers work off-farm and the other 71% are mostly occupied by their own farming operations during the entire year. In farm type 3 as well, the number of farmers who do not work off-farm by far exceeds those that engage in off-farm activities. In this farm type only 38% of the sample farmers undertake some kind of off-farm works while the remaining 62% are confined to their own farm activities.

6.3.4 Variable inputs utilization

6.3.4.1 Agricultural input use per crop and farm type

The variable inputs used by sample farmers in the production of the eight major crops and the quantities utilized are illustrated in Table 6.28. In this table the use of the different inputs are indicated separately for local and improved varieties of each crop as input uses differ significantly among varieties.

The sample farmers in East Hararghe Administrative Zone plant improved varieties of maize, sorghum and wheat. Maize 1, sorghum 1 and wheat 1 represent the local varieties. Maize 2, sorghum 2 and wheat 2 are the improved varieties of the crops. As it can be seen from Table 6.28, the improved variety of maize is planted in all the three farm types. However, the improved variety of sorghum is planted only in farm type 1. The improved variety of wheat is planted by few farmers in farm type 2 and by a relatively larger number of farmers in farm type 3 (see Table 6.29).

There are also some variations in the prices of agricultural inputs among districts and hence farm types. These variations in input prices, which are attributed to the location of each farm type as compared to the distribution centers, which are usually the capital town of the districts, are taken into account in computing enterprise incomes.

Table 6.28 Farm input utilization by sample farmers (kilograms or liters/timad and oxen-pair days/timad)[1], 2001

Crops	Seed	Fertilizer		Biocides		Oxen use
		DAP	Urea	Pesticides	Herbicides	
Farm type 1						
Maize1	5.3	11.96	12.25	0.25	0	2.55
Maize2	3.12	11.67	9.85	0.25	0	2.31
Sorghum1	5.01	10.75	8.80	0	0	2.36
Sorghum2	4.75	12.5	6.25	0	0	2.00
Wheat1	17.5	0	0	0	0	2.50
Groundnuts	6.16	0	0	0	0	2.28
Green pepper	14.7	12.5	12.5	0	0	2.80
Farm type 2						
Maize1	6.98	12.5	12.5	0	0.5	2.05
Maize2	3.14	12.19	12.06	0.38	0.5	2.10
Sorghum1	4.74	12.08	11.46	0	0.25	2.80
Wheat1	16.55	12.5	16.67	0	0.5	2.36
Wheat2	16.1	12.5	15	0	0	2.25
Barley	24	0	10	0	1	1.75
Horse beans	10	0	0	0	0	0
Potatoes	200	0	0	0	0	3.00
Farm type 3						
Maize1	7.19	12.5	12.5	0.25	0	1.87
Maize2	3.10	12.41	12.41	0.25	0	1.86
Sorghum1	7.52	12.36	12.38	0.33	0	1.64
Wheat1	19.85	12.13	16.80	0	0.25	2.20
Wheat2	18.44	12.28	12.28	0	0	1.00
Barley	19.93	11.25	0	0	0	2.00
Horse beans	12.64	0	0	0	0	1.47
Potatoes	115.39	12.5	9	0	0	1.00

[1]Seed and fertilizer are measured in kilograms and biocides in liters

6.3.4.2 Proportion of input applying farmers in the zone

Table 6.29 depicts the proportion of sample farmers that have utilized each agricultural input for each crop, at each farm type and at the zonal levels. The number of farmers producing each crop, in the different farm types, was also indicated in Table 6.21 while discussing land allocation to main crops. In Table 6.21 farmers producing each crop were not separated by crop varieties. However, in Table 6.29, since the number of farmers producing the crops is separated by crop varieties, each farmer can be counted twice if he/she produces two different varieties of the same crop. Hence, in Table 6.29, the total number of farmers producing each crop will be greater than those indicated in Table 6.21 owing to the double counting in the latter. For instance, in Table 6.21, the total number of farmers producing maize in farm type 1 is 29. But in Table 6.29, the total number of farmers producing maize (maize 1 plus maize 2) is 33. Four farmers in farm type 1 produced both varieties of maize and hence were counted twice.

In East Hararghe Administrative Zone the use of agricultural inputs is found to be very small. At the zonal level, from the total sample of farmers only 44% have utilized DAP (Di ammonium phosphate) fertilizer and 42.5% utilized urea fertilizer. As elaborated in Chapter 1, biocide use is extremely insignificant. Pesticides are utilized by less than 2.7%, while herbicides are used by only 1.2%, of the zonal sample farmers.

The very subsistence nature of agriculture in the zone is further reflected by the wide use of oxen in crop production. Almost 85% of the farmers sampled in the zone employ oxen in cultivating their crops.

Input use also differs significantly among farm types. Large use of fertilizer is observed in farm type 3. Of all the farmers in this farm type 52.7% have utilized DAP fertilizer and 49.8% used urea. Farmers in farm type 2 used the least amount of fertilizer in the zone. Only 29.6% of the farmers in this farm type have utilized both DAP and urea fertilizers.

Table 6.29 Proportion of sample farmers using farm inputs per crop and farm type, 2001

Crops	Total farmers growing the crop	Number of farmers who used the input					Number of farmers not using the input				
		DAP	Urea	Pest-icide	Herb-icide	Oxen	DAP	Urea	Pest-icide	Herb-icide	Oxen
Farm type 1											
Maize1	20	10	10	1	0	20	10	10	19	20	0
Maize2	13	10	11	1	0	13	3	2	12	13	0
Sorghum1	43	24	23	0	0	42	19	20	43	43	1
Sorghum2	2	1	1	0	0	2	1	1	2	2	0
Wheat1	2	0	0	0	0	2	2	2	2	2	0
Groundnuts	29	0	0	0	0	29	29	29	29	29	0
Green pepper	10	4	4	0	0	10	6	6	10	10	0
Total	119	49	49	2	0	118	70	70	117	119	1
Farm type 2											
Maize1	26	3	2	0	1	21	23	24	26	25	5
Maize2	21	20	20	4	1	20	1	1	17	20	1
Sorghum1	52	6	6	0	1	40	46	46	52	51	12
Wheat1	11	3	3	0	1	11	8	8	11	10	0
Wheat2	5	5	5	0	0	4	0	0	5	5	1
Barley	4	0	1	0	1	4	4	3	4	3	0
Horse beans	5	0	0	0	0	0	5	5	5	5	5
Potatoes	1	0	0	0	0	1	1	1	1	1	0
Total	125	37	37	4	5	101	88	88	121	120	24
Farm type 3											
Maize1	48	16	14	2	0	37	32	34	46	48	11
Maize2	45	45	45	2	0	43	0	0	43	45	2
Sorghum1	33	18	20	3	0	22	15	13	30	33	11
Wheat1	27	17	11	0	1	20	10	16	27	26	7
Wheat2	20	19	19	0	0	18	1	1	20	20	2
Barley	29	2	0	0	0	25	27	29	29	29	4
Horse beans	26	0	0	0	0	17	26	26	26	26	9
Potatoes	13	10	11	0	0	10	3	2	13	13	3
Total	241	127	120	7	1	192	114	121	234	240	49
Zonal total	485	213	206	13	6	411	272	279	472	479	74

The small biocides uses that are observed at zonal level largely come from farm types 2 and 3. In farm type 2, 3.2% of the sample farmers have used pesticides and four percent of them utilized herbicides. In farm type 3, 2.9% of the farmers have applied pesticides and only 1 farmer has used herbicides. In farm type 1 there is no use of herbicide at all and only two farmers utilized pesticides on the maize crop. Oxen use is very significant in farm type 1 as compared to the other two farm types where there is proportional use of oxen among farmers. The farmers who are not employing oxen usually rely on hand used tools in tilling the land to cultivate their crops.

6.3.5 Crop production, farm income and off-farm earnings

6.3.5.1 Crop production per farm type

In Table 6.30 the outputs of the eight major crops in each farm type are outlined. The average yields per timad of the crops are shown separately for each variety of a crop as yields differ significantly among varieties.

From Table 6.30, it is clear that the yield performance of improved varieties exceeds that of local varieties for all crops at both zonal and farm type levels. At the zonal level, for the three crops of maize, sorghum and wheat for which improved varieties are utilized by the sample farmers, the yields obtained per timad for the improved varieties were almost double of the amount obtained from local varieties.

According to Table 6.30, crop yields are highest for farm type 3 followed by farm type 2. The warm weather crops of maize and sorghum have performed very well in farm type 2 and 3 as compared to farm type 1. The highest yield of maize, for both the local and improved varieties, is recorded in farm type 3. Similarly, the yield obtained for the local variety of sorghum is higher in farm type 3 followed by farm type 2. The relatively high performance of these two crops in the semi-temperate and temperate farm types is related to their high rainfall requirement that can be available in these farm types unlike in farm type1.

Table 6.30 Yield per crop of sample farmers per farm type (kilogram / timad), 2001

	Farm type 1		Farm type 2		Farm type 3		Zonal	
Crops	Number of farmers producing the crop	Average yield per timad	Number of farmers producing the crop	Average yield per timad	Number of farmers producing the crop	Average yield per timad	Total farmers producing the crop	Average yield per timad
Maize 1	20	214	26	176	48	240	94	223
Maize 2	13	185	21	464	45	489	79	350
Sorghum 1	43	153	52	182	33	230	128	177
Sorghum 2	2	300	-	0	-	0	2	300
Wheat 1	2	58	11	192	27	244	40	219
Wheat 2	-	0	5	343	20	471	25	455
Barley	-	0	4	150	29	239	33	231
Horse beans	-	0	5	80	26	133	31	121
Groundnuts	29	154	-	0	-	0	29	154
Potatoes	-	0	1	1500	13	2475	14	2418
Green pepper	10	112	-	0	-	0	10	112
Total farmers	119		125	-	241	-	485	-

The yield of wheat is extremely low in farm type 1 because wheat is a cool weather crop. Moreover, the local as well as the improved varieties of wheat achieve higher yields in farm type 3 as compared to farm type 2 and this shows that wheat grows well in cooler areas of higher rainfall.

The other important cold weather crops, barley and horse beans, are also well cropped in farm type 3. As explained in Chapter 3, these crops are predominantly produced on the highlands.

In maize production it was only in farm type 1 where the local variety gave higher yield per timad than the improved variety which could be the result of the low rate of agricultural inputs such as fertilizer that is applied in the production of the improved variety (see Table 6.28).

6.3.5.2 Farm income and off-farm earnings

During the survey an important price variation was observed for crops between the districts included in the study. This means that output price variations are also likely at the level of each farm type. The farm income is, therefore, computed by taking into account these output price variations. The data on off-farm earnings are entirely dependent on the information discussed in section 6.3.3.5. The off-farm earnings are computed based on the off-farm work performed by farmers and their family members.

Table 6.31 shows that agriculture is the major source of income for the sample farmers of East Hararghe Administrative zone. Of the total income obtained during the 2001 production year in farm type 1, agricultural incomes constitute 85%. In farm type 2 the share of agricultural income is 62% of its total annual income and in farm type 3, 75%. This implies that agriculture remains the economic base of the zone.

As shown in Table 6.31, income obtained from selling crops exceeds the incomes earned from other sources in all farm types. In farm type 1 the income obtained from crop production is 60% of the total income earned by the sample farmers during the year. In farm types 2 and 3, income from crops constitutes 36% and 45% of total income respectively. This indicates that crop production is the major source of cash income for farmers in the study area.

Table 6.31 Farm and off-farm incomes of sample farmers per farm type (in Birr), 2001

Farm type	1	2	3	Zonal
Source of income				
Crop sales	43151.4	17965.3	70293	131409.7
Livestock sales	9604	8390	37797	55791.0
Sale of animal products	7993	4199	9859	22051.0
Total agricultural income	60748.4	30554.3	117949	209251.7
Off-farm earnings	2955	2007.5	5905	10867.5
Other incomes	7638.5	16708	32311.8	56658.3
Total income	71341.9	49269.8	156165.8	276777.5
Number of farm households	45	60	105	210
Income/household	1585.4	821.2	1487.3	1317.9
Average family size	8	7	6.6	7
Income/family member	198.2	117.3	225.3	188.3

Total income per household varies among the different farm types. Sample farmers in farm type 3 have generated higher income per household and per family member as compared to farmers in the other two farm types. This is related to the higher crop outputs obtained (Table 6.30) and the higher income generated from the sale of livestock in this farm type during the year.

6.3.6 Livestock ownership

As was explained in section 3.6.4 of Chapter 3, livestock play an important role in the social and economic life of the people of East Hararghe Administrative Zone. Livestock serve as a source of food, as draft power in the process of crop production (especially oxen), as a source of natural fertilizer and as a source of cash income.

An analysis of livestock in the zone indicated that a sizable share of the farmers' income comes from livestock (Table 6.31). According to this study more than 54% of the farmers of the zone keep livestock for earning additional cash income through the sale of live animals or animal products.

Table 6.32 Livestock of sample farmers in East Hararghe Administrative Zone, 2001

Type of Livestock	Farm type 1		Farm type 2		Farm type 3		Zonal	
	Number of livestock	Number[1] of farmers	Number of livestock	Number of farmers	Number of livestock	Number of farmers	Number of livestock	Number of farmers
Cattle								
Oxen	67	35	46	37	110	67	223	139
Bulls	1	1	1	1	14	9	16	11
Cows	68	31	62	47	104	75	234	153
Heifers	25	13	14	13	28	24	67	50
Calves	15	8	19	18	46	34	80	60
Total cattle	176	88	142	116	302	209	620	413
Goat	60	20	45	18	76	26	181	64
Sheep	22	13	12	7	137	39	171	59
Poultry	53	14	140	25	122	24	315	63
Camel	7	3	0	0	0	0	7	3
Equine								
Donkey	26	20	26	22	52	47	104	89
Horses	0	0	0	0	12	10	12	10
Total equines	26	20	26	22	64	57	116	99
Total livestock	344	158	365	188	701	355	1410	701

[1]Number of farmers refer to farmers owning livestock

As shown in Table 6.32, the types of livestock that are commonly raised in the zone are cattle, sheep, goats, equines, camels, and poultry. Cattle in turn include oxen, bulls, cows, heifers and calves. Equines include donkeys, horses and mules. The livestock distribution in the zone varies among the farm types. According to the information gathered from sample farmers, 50% of the total livestock of the zone is found in farm type 3, which contains the districts mentioned in Chapter 3 as contributing the bulk of the zone's livestock such as the Meta district. In farm type 3, the combined cattle, goats, sheep, poultry and equine population by far exceeds those contained in both farm types 1 and 2.

The cattle population of the sample farmers in the zone exceeds those of other livestock. Cattle are 44% of the livestock followed by poultry, which accounts for 22.3%. Goats, sheep, equines and camel range from third to sixth in their number, possessing a percentage of 12.9, 12.1, 8.2 and 0.5 respectively. This result exactly corresponds to the one mentioned in Chapter 3. However, the percentage of camels was very small in comparison to the figure mentioned in Chapter 3.

Oxen and cows are the most widely reared cattle. In farm type 1, from the total of 45 farmers that are contained in this farm type, 78% of them own oxen, as oxen are needed for ploughing in subsistence agriculture. In farm types 2 and 3, 61.7% and 63.8% of the farmers respectively own oxen. Cows, heifers and calves are kept mainly for cash income and for home consumption, and sometimes for breeding purposes.

Goats and sheep are largely raised for cash income. Equines are mainly kept for transport purposes. Sometimes equines are also used for draft power. In farm types 2 and 3, there are three farmers who try to keep beehives for producing some honey for home consumption and for cash income.

Some sample farmers do not own livestock in East Hararghe Administrative Zone. Of the total of 45 farmers that make up farm type 1, five of them do not own any livestock. In farm types 2 and 3, two and 11 farmers do not have livestock respectively. This means that about 8.6% of the total sample farmers do not own livestock.

6.4 Farm problems in the study area

Farmers in East Hararghe Administrative Zone face a multitude of farm problems. At zonal level, the lack of capital, the lack of enough agricultural land and the lack of adequate rainfall are the most severe problems that the farmers are facing (Table 6.33).

Table 6.33 Agricultural problems of sample farmers in EHAZ, 2001

No.	Type of farm problem	Number of farmers facing each farm problem			
		Farm type 1	Farm type 2	Farm type 3	Zonal
1	Lack of land	19	44	89	152
2	Lack of labour	19	33	71	123
3	Lack of capital	22	54	88	164
4	Lack of technology (seed, fertilizer, etc.)	27	19	61	107
5	Lack of knowledge	16	23	55	94
6	Water logging	7	7	31	45
7	Poor soil fertility	38	33	67	138
8	Lack of rainfall	44	45	62	151
9	Disease and insect problem	28	42	61	131
10	Other problems	11	2	1	14
Total farmers		45	60	105	210
Farmers not declaring any problem		1	1	1	3

From the total of 210 sample farmers included in the study, 164 of them, which amounts to 78.1% of the total farmers, seriously complained about the lack of financial resources to purchase agricultural inputs and implements. Agricultural inputs such as fertilizers were subsidized by the government to help small farmers until 1997. However, this subsidy was eliminated to allow the private sector to participate in the fertilizer market and this has substantially increased input prices. Hence, inability to afford for agricultural inputs can be a potential problem for farmers in the study area. This is a typical problem of subsistence agriculture. On the other hand, 72.4% of the farmers do not have enough land for crop production. This is clearly evident from their extremely small land holdings as indicated in Table 6.6 through Table 6.19. Around 72% of the farmers indicated that lack of rainfall severely affects their annual crop harvests. Poor soil fertility, and crop diseases and insects are also among the pressing problems of the farmers of the zone. Some 65.7% and 62.4% of the sample farmers of the zone have shown that they are facing soil fertility and disease and insect problems respectively.

There seems to be slight variations in the priority of the problems among the farm types. In farm type 1, lack of rainfall is the most serious problem followed by poor soil fertility. From the 45 farmers included in this farm type 97.8% indicated that severe shortage of rainfall usually hampers their crop production. This is to be expected as farm type 1 has an arid climate. In addition since most of the farmers in farm type 1 cultivate their crops on sandy soils, the poor fertility complaint is well founded. Crop diseases and insects are the next most important problems of the farmers in this farm type. Such problems are often characteristics of arid climates.

In farm type 2, lack of capital is the most pressing problem. Around 90% of the farmers in this farm type stressed that the lack of capital is the main problem that handicapped them in properly conducting their farming operations. Lack of rainfall, lack of land, crop diseases and insects rank from second to fourth in their severity in farm type 2. Of the total farmers contained in this farm type, 75% indicated that lack of adequate rainfall jeopardizes their crop production and 73.3% said that the lack of land is one of their pressing problems.

Lack of adequate agricultural land and lack of capital are the two most conspicuous problems of the sample farmers in farm type 3 as well. Of the total sample farmers in this farm type, 84.8% claimed that the lack of land is the most severe problem that they face in producing their crops. This also confirms the explanation given in section 6.3.1.2 concerning the land shortages in farm type 3 relative to the lack of capital which is the second most important bottleneck of their farming activities.

6.5 Summary and conclusion

In this chapter, the classification of the sampled farms in the study area into farm types and the description of the survey data were undertaken.

In section 6.2 it was explained that the grouping of farms into farm types provides an understanding of the difference that exist among farm types with regard to land use and income distribution. Grouping the universe of farms into smaller number of homogeneous groups or farm types is justified, as it is not feasible in practice to model each individual farm. Consequently, the sampled farms in East Hararghe Administrative Zone were grouped into three farm types on the basis of agro-ecological classification of the surveyed districts and peasant associations.

Section 6.3 presented a description of the surveyed data. In this section various tables were utilized in order to present summary statistics of information with regard to the extent, availability, and intensity of the use of land, material inputs, human labour, animal traction, outputs of crops, prices of inputs and outputs, and levels of costs and incomes for the sampled farmers. In addition to this, information on the relative importance of the major crops in each farm type and district, and household demographic features were discussed.

In section 6.3.1 an attempt was made to briefly describe the pattern of land holdings in the zone as observed from the sample farmers. The land holdings of sample farmers in the zone were seen to be scattered among all types of soils. Each and every farm contains farm plots of the main soil types in the zone. The total land available for farmers was found to be very small as observed in the survey. The 210 farmers included in the study possessed a total of only 1392 timads of land for agricultural production as well as other uses. As far as the land holdings of the farm types are concerned, farm type 1 possesses the largest holdings as compared to farm type 2 and 3, even though it contains the smallest number of sample farmers.

The allocations of farmland to the 8 major food crops that are incorporated in the study were discussed in section 6.3.2. An attempt was made to study the farm level, the farm types and the zonal land allocation to the main crops. The total area cultivated by the sample farmers for the 8 main food crops in the study area amounts to 1123.5 timads. The district of Babile takes the largest share of the total cultivated area of the zone, approximately 16%. The district that possesses the smallest cultivated area is Girawa district. The total cultivated area occupied by this district is only 4% of the total cultivated area of the sampled farms. Sorghum and maize are the two most important crops in the zone.

In section 6.3.3 the family structure of the surveyed farming community and its pattern of labour utilization was explained. The family composition in the zone are scattered among all age groups. Most of the sampled households in East Hararghe Administrative Zone have a large family size. The average family size is 7.04 persons per household. The maximum and the minimum household sizes are 20 and 2 respectively. The maximum family size is recorded in Kombolcha district. The smallest average family size is observed in the District of Jarso. At zonal level the average monthly and yearly household labour that is available to each of the sample farms in the zone are 50 and 597 mandays respectively. Farm type 1 has got the largest monthly and yearly average available family labour as compared to both farm type 2 and 3.

Household labour use is dispersed throughout the year in the zone. However, June is the month of peak household labour use followed by the month of May. August is also a month in which most weeding and some harvesting operations are performed, thus commanding relatively large amounts of household labour use. The months of October and December as well as November and January show the use of a significant amount of household labour because in these months most of the harvesting and threshing activities are performed in the zone. March and April are the months in which the activities of sowing and fertilizing take place and hence imply a significant use of household labour. The months of February and September are the months in which the smallest amount of household labour is needed for farm operations. A relatively large use of household labour is observed in farm type 3 as compared to farm type 1 and 2.

The sample farmers in East Hararghe Administrative Zone do not hire much labour. Only 30.6% of these farmers have hired labour in the 2001 production year. The other 69.4 % of the farmers rely solely on household labour to produce their crops. Off-farm household activities are also extremely limited in the zone. About 60% of the sampled farmers in the zone do not pursue off-farm employment opportunities, which could have been an additional source of income.

The pattern of variable inputs utilization was discussed in section 6.3.4. In East Hararghe Administrative Zone the use of agricultural inputs is found to be minimum as seen from the survey results. At the zonal level, from the total sample farmers, only 44% have utilized DAP fertilizer and 42.5% utilized urea fertilizer. Biocide use is even extremely insignificant. Pesticides are utilized by less than 2.7% while herbicides are used by only 1.2%. Almost 85% of the zonal farmers employ oxen in cultivating their crops. Input use also differs significantly among farm types. Large use of fertilizer is observed in farm type 3. Farmers in farm type 2 make the least use of fertilizers. The small biocides uses that are observed in the zone largely come from farm type 2 and 3. Oxen use is very significant in farm type 1 as compared to the other two farm types who have relatively proportional use of oxen among their farmers. The sampled farmers in the zone have planted improved varieties of maize, sorghum and wheat.

Section 6.3.5 explained aspects of crop production, farm income and off-farm earnings of the sample farmers. The yields obtained from improved varieties significantly exceed those obtained from local varieties for all crops at both zonal and farm type levels. Crop production was relatively good in farm type 3 followed by farm type 2. The highest yield of maize, for both the local and improved varieties, is recorded in farm type 3. Similarly, the yield obtained for the local variety of sorghum is higher in farm type 3 followed by farm type 2. The yield of wheat is extremely low in farm type 1. The local as well as the improved varieties of wheat have given higher yield in farm type 3 as compared to farm type 2. Barley and horse beans were also well harvested in farm type 3. Farm income is computed by taking into account the variations in output prices for each farm type. On the other hand, off-farm earnings are computed based on the off-farm work performed by farmers and their family members. Agriculture, particularly crop production, is the major source of income for the sample farmers of East Hararghe Administrative zone.

Aspects of livestock ownership and use were elaborated on in section 6.3.6. The investigation of the livestock of the zone indicated that a sizable amount of the income of the sample farmers come from livestock. The types of livestock that are commonly raised in the zone are cattle, sheep, goat, equine, camel, and poultry. According to the results of the survey, the livestock distribution in the zone varies among the farm types. 50% of the total livestock of the zone is found in farm type 3. The cattle population exceeds those of other livestock in the zone. The percentage of cattle is 44 followed by poultry, which accounts for 22.3% of the livestock of the zone. Goats, sheep, equines and camel range from third to sixth in their importance possessing percentages of 12.9, 12.1, 8.2 and 0.5 respectively. Oxen and cows are the most widely reared cattle in the zone. Oxen are very essential for ploughing in subsistent agriculture. Cows, heifers and calves are kept mainly for cash income and for home consumption, and sometimes for breeding purposes. Goats and sheep are largely raised for cash income. Equines are mainly kept for transport purposes in the zone. Sometimes equines are also used for draft power. In farm type 2 and 3, there are very few sample farmers who try to keep beehives for producing honey for home consumption and for cash income. Some 8.6% of the farmers included in the survey do not own livestock.

Section 6.4 gives an explanation of the most important farming problems of the sampled farmers in the zone. Farmers in East Hararghe Administrative Zone face a multitude of farm problems. At zonal level, lack of capital, lack of enough agricultural land and lack of adequate rainfall are the most severe problems that the farmers are facing. Poor soil fertility, crop diseases and insects are also among the pressing problems of the farmers in the zone. There seems to be slight variations in the priority of the problems among the farm types. In farm type 1, lack of rainfall is the most serious problem followed by poor soil fertility. Crop diseases and insects are the other important problems of the farmers in this farm type; as such problems are usually characteristics of arid climates. In farm type 2 lack of capital is the most pressing problem. Lack of rainfall, lack of land, and crop diseases and insects rank from second to fourth in their severity. Lack of adequate agricultural land and lack of capital are the two most conspicuous problems of the sample farmers in farm type 3.

CHAPTER 7. RESULTS AND DISCUSSION OF THE LAND USE MODEL OF THE STUDY AREA

7.1. Introduction

This chapter deals with the analysis of the sub-regional model of land use for the entire zone. It begins with a discussion of the most important resource availabilities of the zone such as land, household labour and oxen. This is followed by the specification of the zonal land use model in the GAMS programming language. The results of the analysis with respect to the main objective of developing a workable research methodology for land use analysis are discussed. This is followed by the discussion of the results of the land use model, which is developed in this study. The results are discussed through the incorporation as well as the study of possible scenarios and their combinations. The different scenarios help to show the effect of changing land use determinants or different policies regarding land use and farm incomes, at sub-regional level. The chapter ends with a summary and conclusion section that recaptures the most important findings discussed in the chapter.

7.2. Overview of basic model ingredients

By way of introduction, certain elements or aspects of the model may need some clarification. In EASTHAR, the land use sub-regional model of East Hararghe Administrative Zone, the objective function consists of the net benefits to all farms namely; the economic surplus, defined as the value of production, less input costs, less hired labour costs, less value of on-farm household labour, plus off-farm work labour income. Because the objective function differs from one scenario to another it will be introduced when discussing the particular scenario. The objective function of the zone is the sum of the objective functions of each farm type. A condensed sample matrix of the EHAZ land use model is given in appendix c.

7.2.1 Total land available for crop production

The total land available in the zone is divided amongst several uses. The land cultivated with major crops of cereals, pulses and oil seeds accounts for about 16% of the total zonal area.

The land available for producing the eight main crops is calculated by taking the total area occupied by only these crops in each farm type and is depicted in Table 7.1. This land, which is utilized in the EASTHAR model, represents 81.6% of the total presently cultivated area under all the major crops in the zone.

Table 7.1 Land utilized for the production of the main crops (hectares), 2001

Farm type	1	2	3	Zonal
Maize 1	6215	24596	39941	70752
Maize 2	9323	2733	9985	22041
Sorghum 1	36090	35184	53215	124489
Sorghum 2	737	0	0	737
Wheat 1	2121	15163	14029	31313
Wheat 2	0	798	3507	4305
Barley	1680	6798	10062	18540
Horse beans	0	1085	4835	5920
Groundnuts	11968	250	1619	13837
Potatoes	74	398	3141	3613
Green pepper	1198	0	0	1198
Total land (hectares)	69406	87005	140334	296745
Total land (timads)	555252	696040	1122672	2373964
Land per household (hectares)	1.5	1.2	0.9	1.1

Source: Survey data, 2001

7.2.2 Total household labour availability

The household labour that is available for crop production for the entire region is calculated from the rural population in the zone. This assumption is made by the fact that the rural populations are full-time farmers as compared to the urban population who engage in several non-farm activities. The economically active population comprises 49% of the total zonal population as observed from the result of this study. This proportion is utilized as the total household labour force that is available for agricultural activities in the zone and are as shown in Table 7.2 and Table 7.3.

Table 7.2. Full-time and part-time farm workers per farm type, 2001

Farm type	1	2	3
Total farm workers (15-60 years age groups)	181326	241950	510231
Percent of full-time workers	79.4	71	75.4
Average working hours/day	5.59	5.7	5.86
Percent of part-time workers	20.6	29	24.6
Average working hours/day	1.63	1.76	1.56

Source: Survey data, 2001

Table 7.3 shows the total household labour that is available to each farm type and for the entire zone after making use of the proportions of full-time and part-time workers in the total labour force, as shown in Table 7.2, and using the formula specified in chapter 6 section 6.3.3.2.

Table 7.3 Household labour availability (mandays), 2001

Farm type	1	2	3	Zonal
Total rural farm households	46257	70539	148755	265551
Total rural population	370053	493775	1041288	1905116
Active labour force (15-60 years age groups)	181326	241950	510231	933507
Number of full-time workers	143973	171784	384714	700471
Number of part-time workers	37353	70166	125517	233036
Total labour per year (mandays)	29217162	37214835	82695326	149127323
Total labour per month (mandays)	2434764	3101236	6891277	12427277

Source: Survey data, 2001

7.2.3 Total oxen availability

The availability of oxen for farming operations in the entire zone is calculated by taking the oxen available to the rural population. This is assumed because most of the livestock is kept in rural areas and it will be only the oxen that are available in rural areas that the farmers are able to use for farming purposes. The oxen available in the urban areas are not that significant and are also not readily available for farming purposes particularly in this zone. Table 7.4 shows the total number of oxen available in the zone.

Table 7.4 Number of oxen per farm type, 2001

Farm type	1	2	3	Zonal
Number of oxen in rural areas	64489	92864	154552	311905
Number of oxen in urban areas	4359	4196	10361	18916
Total number of oxen available	68848	97060	164913	330821

Source: Survey data, 2001

In accordance with the observation during the survey, in farm type 1 a pair of oxen is assumed to work on average for 4.9 hours a day. In farm types 2 and 3, a pair of oxen can work on average for 5.5 hours a day. This means that a pair of oxen can work relatively longer hours in farm type 2 and 3 as compared to farm type 1 owing to the semi-temperate and temperate type of agro-climatic environments in which these farm types are situated and which allows less exhaustion for the oxen. To compute the total oxen-pair days available in rural areas, the average working hours of oxen in each farm type in a day is multiplied by the total oxen available in each farm type. This figure is then multiplied by 270, which are the average working days in a year in Ethiopia. The resultant figure was again divided by eight hours by assuming that the working hours in a day should be equal to eight hours. Finally the figure thus obtained is divided by two to obtain the total oxen-pair days available in rural areas. This computation is illustrated in Table 7.5.

Table 7.5 Oxen availability per farm type (oxen days), 2001

Farm type	1	2	3	Zonal
Total oxen in rural areas	64489	92864	154552	311905
Average working hours/day	4.9	5.5	5.5	5.3
Total oxen working hours/day	315996	510752	850036	1676784
Average working days in a year	270	270	270	270
Total oxen working hours/year	85318947	137903040	229509720	452731707
Total oxen days/year	10664868	17237880	28688715	56591463
Total oxen-pair days/year	5332434	8618940	14344358	28295732
Total oxen-pair days/average month	444369	718245	1195363	2357977

7.2.4 Consumption requirements of rural and urban population

In subsistence agriculture the consumption requirements of farm households must be met from within their own farms. There will not be much reliance on external purchases as the markets around these farmers are not well developed and it will be improbable for the farmers to travel long distances elsewhere to purchase their consumption requirements. This means that, for subsistence farmers, the production of their consumption requirements on their own farms is a necessary condition for their food security. Reutilinger (1984) defined food security as the assurance of a minimally adequate level of food consumption. Hence, the minimum amount of grain that the farm households require for home consumption as well as seed purposes must be produced within the farms of each farmer in each farm type, with very little exception that these outputs can also be produced on other farms within the same zone provided that there exists inter-farm type product exchange through local markets or other traditional ways.

Hence the total consumption requirements of the rural population for each crop is calculated based on the consumption needs of the sampled farm households in each farm type. This means that, to obtain the total minimum consumption requirements of the total rural population of each crop in each farm type the total rural population in each farm type is multiplied by the average yearly consumption requirement of a person as observed from the survey results. This computation is depicted in Table 7.6.

The consumption demand of the urban population is assumed to be met by the produce sold by the farmers in the zone. This means that the EASTHAR model must be formulated in such a way that a certain minimum consumption requirement of the urban population is produced in each farm type and sold to the urban population of that farm type. Even though the urban population is expected to purchase its consumption needs from different sources, it was thought necessary that certain minimum amount of crops need to be produced in each farm type to guarantee the minimum consumption requirements of the urban population being met from farms in the specific location. Hence, the total minimum consumption requirement of the total urban population in each farm type for each crop is calculated by using a similar procedure as that for the rural population as shown in Table 7.6.

The dietary needs of the rural and urban households are assumed to be similar in terms of the types of crops included in their consumption requirements. This assumption is made from the observation that the rural and urban population of the zone do not significantly differ in terms of the types of crops consumed at home in both areas.

Table 7.6 Minimum consumption requirements of zonal population (tons/ year), 2001

Farm type	1		2		3	
	Rural	Urban	Rural	Urban	Rural	Urban
Maize	8381.7	566.5	27511.2	1243.1	89370.5	5991.6
Sorghum	25775.7	1742.0	20192.9	912.4	24274.2	1627.4
Wheat	35.3	2.4	4872.9	220.2	33136.4	2221.5
Barley	0	0	783.7	35.4	12907.2	865.3
Horse beans	0	0	851.4	38.5	5096.8	341.7
Groundnuts	5734.9	387.6	0	0	0	0
Potatoes	0	0	4569.5	206.5	11569.9	775.7
Green pepper	349.9	23.6	0	0	0	0

Source: Survey data, 2001

7.2.5 Land constraint for green pepper and potatoes

There was a need to limit the maximum area of land that can be planted to green pepper and potatoes in order for the model's outcome to reflect the real circumstances in the study area with regard to the allocation of land to major crops. If this constraint or limitation is not imposed, the model will allocate a very large tract of land to these crops in its pursuit of maximization of income, as these crops command higher output prices and relatively lower input costs which is associated with their low use of crop inputs such as fertilizer, particularly potatoes, as observed from the survey results. Such an allocation of a large area of land to these crops and thereby a very large production of these crops will not be realistic given the existing condition in the study area where these crops do not represent the staple food of the local population. Moreover, such a situation will leave less land to be available for the most important grain crops such as maize and sorghum which represent the main consumption needs of the population of the zone. Therefore, the maximum land that can be planted to green pepper and potatoes are constrained and limited to the level that corresponds to the amount of land they currently occupy in the zone as shown in Table 7.7 below[1].

Table 7.7 Land constraints for potatoes and green pepper, 2001

Farm type	1	2	3	Zonal
Maximum land for green pepper (hectares)	1198	0	0	1198
Maximum land for potatoes (hectares)	0	398	3141	3539

7.2.6 Valuation of farm labour input

Hired labour on any one farm type is restricted by the available off-farm labour from the other farm types within East Hararghe Administrative Zone. This is a mutual constraint, as for every month the supply of off-farm labour is equal to the demand for hired labour in the zone. In other words, inside East Hararghe Administrative Zone farmers or their families can do off-farm work only on the farms of their neighbours and vice versa. As mentioned by Schipper (1996), this way of modeling the labour market inside the zone is a reasonable first approximation of reality. As the farming systems of the zone are very subsistence in nature, it is less likely that outsiders would look for employment inside East Hararghe Administrative Zone.

Hired labour and off-farm work are valued at the going wage rates and labour can be exchanged between different farm types within the sub-region.

[1] Lyne, Ortmann and Vink (1991) imposed an upper constraint on their programming model for KwaZulu to take account of the restriction on sugar-cane production due to the presence of quotas in the region. They, moreover, restricted the quantities of certain crops which are sold locally to a level less than or equal to local purchases. This shows that the production quantities of certain crops need to be constrained in a model depending on the existing production restrictions and the realities in a given study area.

A complication arises in valuing the household labour working on-farm. One approach might be to value household labour at the off-farm wage rate. However, farm households often have a preference for working on their own farm over off-farm work. By not valuing household labour (which would mean a zero on-farm wage rate), the model will first use household labour before hiring labour. No one, however, would like to do work that does not earn a certain minimum return per hour worked (in view of the mentioned preference, lower than the off-farm wage). By remunerating or compensating household on-farm work with a wage equal to such a minimum return, the programming model will not select an activity with a return to household labour lower than the minimum return, while still employing household labour before hiring labour. The minimum expected return to household labour is often called 'reservation' wage. A reservation wage can also be interpreted as reflecting the preference for leisure of a farm household (Schipper, 1996).

Hazell and Norton (1986) have also indicated that the reservation wage can reflect the preference for leisure by the farm household. They have indicated that as incomes rise above subsistence levels and the required hard work to earn a living is reduced, farmers typically display a strong preference to reduce their manual work. Therefore, if family labour is priced at a cost reflecting the marginal value of leisure to the farm household, this takes account of the preference for leisure. In line with this, Hazell and Norton (1986) have also shown examples of some agricultural models in which all the family labour is charged at a reservation wage that is equal to a certain percentage of the market wage rate for hired labour.

In East Hararghe Administrative Zone there is no well-established hired labour wage rate. During the survey it was found that the price paid to hired labour differs among the districts in the zone. Hence, by taking into account the hired labour wage variations in the different districts of the zone and by applying the approaches of Hazell and Norton, a reservation wage is assumed for valuing the household labour in the analysis of the EASTHAR model in the opportunity cost scenario of the present study.

7.3 Model specification using GAMS

GAMS is an algebraic modeling language that helps to formulate, analyze and solve large mathematical programming problems. For example, in addition to handling other complex problems, the mathematical specification of cropping patterns in agriculture can be represented in GAMS (Brooke, *et al.* 1998). In this study the GAMS software is utilized to specify and analyze the land use model of the study area. A sample of the model, which is specified in the linear programming mathematical format in Chapter 5, is presented in GAMS programming language below.

```
$Title   Land use model of East Hararghe Administrative Zone (EASTHAR)

$Ontext

This is a linear programming land use model of East Hararghe Administrative Zone
(EASTHAR). The model is formulated based on a primary data collected from 14
districts in the zone. The data is compiled from 210 sample farmers, which are grouped
into three farm types, contains 8 principal crops (maize, sorghum, wheat, barley, horse
beans, groundnuts, potatoes and green pepper) and 7 basic inputs (land, seed, fertilizer,
household and hired labor, oxen, pesticides and herbicides).

$Offtext

Sets j  farm types / FT1, FT2, FT3/

     c  land use types (crops) /maz1, maz2, sor1, sor2, whe1, whe2, bar, hor-b,
                    grn, pot, grp/
     i  variable inputs / sed, Dap, Ure, pes, her /
    m months / jan, feb, mar, apr, may, jun, jul, aug, sep, oct, nov, dec /

   crops   aggregated cultivars /maz, sor, whe, bar, hor-b, grn, pot, grp/
```

maize(c) all maize cultivars /maz1, maz2/

sor(c) all sorghum cultivars /sor1, sor2/

whe(c) all wheat cultivars /whe1, whe2/

bar(c) barley crop /bar/

horb(c) horse beans corp /hor-b/

grn(c) groundnuts crop /grn/

pot(c) potatoes crop /pot/

grp(c) green pepper crop /grp/;

alias(j,f);

Table landuse(j,c) land utilization by land use types(crops) (timads)

$include "C:\Hassen1\Landuse.prn"

Table inputuse (j,c,i) input utilization by land use types (kg(liter)per timad)

$include "C:\Hassen1\inputuse.prn"

Table Oxenuse(j,c,m) oxen utilization by land use types per month (oxen-pair days per timad)

$include "C:\Hassen1\ Oxenuse.prn"

Table labouruse(j,c,m) labour utilization by land use types per month (mandays per timad)

$include "C:\Hassen1\Labouruse.prn"

```
Table yield (j,c) crop yields (kg per timad)
$include "C:\Hassen1\yield.prn"

Table price(j,c) crop output prices (Birr per Kg)
$include "C:\Hassen1\price.prn"

Table inprice (j,c,i) Prices of variable inputs ( Birr per Kg)
$include "C:\Hassen1\inputprice.prn"
Table reservation (j,c,m) price of household labour input (Birr per mandays)
$include "C:\Hassen1\Reservation.prn"

Table wage(j,c,m) price of hired labour input (Birr per mandays)
$include "C:\Hassen1\wage.prn"

Table famlabm(j,m) household labour availability per month per farm type (mandays per
month)
$include "C:\Hassen1\famlabm.prn"

Table consumption(j,c) consumption requirement for rural population (kilogrammes)
$include "C:\Hassen1\consumption.prn"

Table consumption1(j,c) consumption requirement for urban population (kilogrammes)
$include "C:\Hassen1\consumption1.prn"

Parameter farmsize(j) land availability per farmtype (timads)
/FT1=555252, FT2=696040, FT3=1122672/ ;

Parameter Oxenavail(j) Oxen availability per farm type per month (oxendays)
/FT1=444370, FT2=718245, FT3=1195363 / ;

Parameter Potmax(j) maximum land for potatoes production (timads)
```

/FT1=0, FT2=3184 , FT3=25128/ ;

Parameter Grpmax(j) maximum land for green pepper production (timads)

/FT1=9584, FT2=0, FT3=0/;

Positive variables

QCROP (j,c)	area of crop grown
SELL (j,c)	sell produce
OXEN (j,f,m)	oxen hired by a farm type from another farm type
LABOUR (j,f,m)	labour hired by a farm type from another farm type per month
INUSE (j,c,i)	variable inputs utilization per crop
INUSE2 (j,i)	total variable inputs utilization by all crops
LABUSE (j,m)	labour input utilization by crops
OXUSE (j,m)	oxen input utilization by crops;

Free variable

Z	objective function value;

Equations

OBJ	objective function
CONSUMEMAZ (j,crops)	home consumption requirements of maize for rural use
CONSUMESOR (j,crops)	home consumption requirements of sorghum for rural use
CONSUMEWHE (j,crops)	home consumption requirements of wheat for rural use
CONSUMEBAR (j,crops)	home consumption requirements of barley for rural use
CONSUMEHOR (j,crops)	home consumption requirements of horse beans for rural use
CONSUMEGRN (j,crops)	home consumption requirements of groundnuts for rural use
CONSUMEPOT (j,crops)	home consumption requirements of potatoes for rural use
CONSUMEGRP (j,crops)	home consumption requirements of green pepper for rural use
HIRE_OXEN (j,m)	oxen hired tie
HIRE_LABOUR (j,m)	hired labour tie
LANDBAL (j)	land use balance

CONSUMEMAZ1 (j,crops)	consumption requirements of maize for urban use
CONSUMESOR1 (j,crops)	consumption requirements of sorghum for urban use
CONSUMEWHE1 (j,crops)	consumption requirements of wheat for urban use
CONSUMEBAR1 (j,crops)	consumption requirements of barley for urban use
CONSUMEHOR1 (j,crops)	consumption requirements of horse beans for urban use
CONSUMEGRN1 (j,crops)	consumption requirements of groundnuts for urban use
CONSUMEPOT1 (j,crops)	consumption requirements of potatoes for urban use
CONSUMEGRP1 (j,crops)	consumption requirements of green pepper for urban use
MAXLANDPOT (j)	maximum land for potatoes
MAXLANDDRP (j)	maximum land for green pepper
INPUTBAL1 (j,c,i)	input uses per crop per farm type
INPUTBAL2 (j,i)	total input uses by all crops per farm type
LABAL (j,m)	labour balance per farm type per month
OXBAL (j,m)	oxen balance per farm type per month;

```
OBJ..                                          sum((j,c),SELL(j,c)*price(j,c))-
sum((j,c,i),inputuse(j,c,i)*QCROP(j,c)*inprice(j,c,i)) =E= z;

CONSUME     (j,"maz")..                  sum(maize,-QCROP(j,maize)*yield(j,maize))
+sum(maize,SELL(j,maize)) =L= sum(maize,-consumption(j,maize));

CONSUME1    (j,"maz")..          -   sum(maize,SELL(j,maize))=L=    sum(maize,-
consumption1(j,maize));

CONSUMESOR (j,"sor").. sum(sor,-QCROP(j,sor)*yield(j,sor)) + sum(sor,SELL(j,sor))
=L= sum(sor,-consumption(j,sor));

CONSUMESOR1 (j,"sor").. - sum(sor,SELL(j,sor))=L= sum(sor,-consumption1(j,sor));
CONSUMEWHE        (j,"whe")..        sum(whe,-QCROP(j,whe)*yield(j,whe))        +
sum(whe,SELL(j,whe)) =L= sum(whe,-consumption(j,whe));
```

CONSUMEWHE1 (j,"whe").. - sum(whe,SELL(j,whe))=L= sum(whe,-consumption1(j,whe));

CONSUMEBAR (j,"bar").. sum(bar,-QCROP(j,bar)*yield(j,bar)) + sum(bar,SELL(j,bar)) =L= sum(bar, -consumption(j,bar));

CONSUMEBAR1 (j,"bar").. - sum(bar,SELL(j,bar))=L= sum(bar,-consumption1(j,bar));

CONSUMEHOR (j,"hor-b").. sum(horb,-QCROP(j,horb)*yield(j,horb)) + sum(horb,SELL(j,horb)) =L= sum(horb,-consumption(j,horb));

CONSUMEHOR1 (j,"hor-b").. - sum(horb,SELL(j,horb))=L= sum(horb,-consumption1(j,horb));

CONSUMEGRN (j,"grn").. sum(grn,-QCROP(j,grn)*yield(j,grn)) + sum(grn,SELL(j,grn)) =L= sum(grn,-consumption(j,grn));

CONSUMEGRN1 (j,"grn").. - sum(grn,SELL(j,grn))=L= sum(grn,-consumption1(j,grn));

CONSUMEPOT (j,"pot").. sum(pot,-QCROP(j,pot)*yield(j,pot)) + sum(pot,SELL(j,pot)) =L= sum(pot,-consumption(j,pot));

CONSUMEPOT1 (j,"pot").. - sum(pot,SELL(j,pot))=L= sum(pot,-consumption1(j,pot));

CONSUMEGRP (j,"grp").. sum(grp,-QCROP(j,grp)*yield(j,grp)) + sum(grp,SELL(j,grp)) =L= sum(grp,-consumption(j,grp));

CONSUMEGRP1 (j,"grp").. - sum(grp,SELL(j,grp))=L= sum(grp,-consumption1(j,grp));

```
HIRE_OXEN (j,m).. sum(c,QCROP(j,c)*Oxenuse(j,c,m))-sum(f$(not sameas(f,j)),OXEN(j,f,m)) +sum(f$(not sameas(f,j)),OXEN(f,j,m)) =L=Oxenavail(j);

HIRE_LABOUR (j,m).. sum(c,QCROP(j,c)*Labouruse(j,c,m))- sum(f$(not sameas(f,j)),LABOUR(j,f,m)) +sum(f$(not sameas(f,j)),LABOUR(f,j,m)) =L=famlabm(j,m);

LANDBAL (j).. sum(c, QCROP(j,c)*landuse(j,c)) =l= farmsize(j);
MAXLANDPOT (j).. sum(pot, QCROP(j,pot)*landuse(j,pot)) =l= Potmax(j);

MAXLANDDRP (j).. sum(grp, QCROP(j,grp)*landuse(j,grp)) =l= Grpmax(j);

INPUTBAL1 (j,c,i).. QCROP(j,c)*inputuse(j,c,i)- INUSE(j,c,i)=l=0;

INPUTBAL2 (j,i).. sum(c, QCROP(j,c)*inputuse(j,c,i))- INUSE2(j,i)=l=0;

LABAL (j,m).. sum(c, QCROP(j,c)*labouruse(j,c,m))-LABUSE(j,m)=l=0;

OXBAL (j,m).. sum(c,QCROP(j,c)*Oxenuse(j,c,m))- OXUSE(j,m)=l=0;

Model EASTHAR Land use model /all/;

Solve EASTHAR using LP maximizing z;
```

7.4 Scenarios in land use analysis

In Chapter 5 and section 7.3 the land use model EASTHAR was presented mathematically as well as in GAMS programming language format. The purpose of this model is to study the effects of changes in factors that influence land use. The analyses are firstly related to the use of land itself and in the second place to the consequences of land use on other factors such as the incomes of the farming community, employment and environmental parameters[1].

As a model is an abstraction of reality, a sound approach is either to assess these effects in relation to a standard solution of the model, which may be called a base case, or to compare one solution with another. As explained by Schipper (1996), each different situation with regard to a variation in a factor having a bearing on land use can be called a scenario, or a variant of a scenario. Alfaro *et al.* (1994) defined scenarios in the context of land use studies as, "possible trends in land use determinants and/or policy measures". A number of factors influencing land use can be looked into when incorporating scenarios in land use analysis. These factors may include population growth, labour wages, relative product prices, and natural events like drought and flooding. Assumptions can be made with regard to these factors as to how they will occur or change in the future. Each of these assumptions corresponds to a scenario or a variant thereof.

In this study three scenarios were envisaged worth investigating. These scenarios are named the base scenario, opportunity cost scenario and drought case scenario. The base scenario helps to come up with optimum land use by taking into account only the actual land use practices of the farmers in the zone at present. This means that it incorporates the actual cropping pattern, the actual input use, the actual expenses of the farmers and the present state of labour utilization. In this scenario household labour is not priced in the objective function. The implication here is to include only the actual expenses of farmers in the objective function and hence not attaching wages to household labour, as the farmers do not pay wages to themselves. In the case of hired labour, because the analysis is at the zonal level and because farmers in one farm type can hire labour only from within the zone[1], it means that the hired labour cost for one farm type will be an income for another farm type in the zone and these will ultimately cancel out in the

[1]The EASTHAR model is validated by comparing its results with the actual data on the farming conditions in the study area. As mentioned by Lyne et al (1991) a model can be validated through such comparisons. Since the EASTHAR model solutions do not exhibit conspicuous deviations from the real farming circumstances of the study area, it is clearly valid as far as attaining the objectives of the study are concerned.

overall objective function of the zone. But the hired labour cost will actually affect and reduce the gross margin of the respective farm type which hired labour even though it will not affect the overall gross margin at the zonal level. In addition to this, since the model must first utilize household labour before hiring labour, the incorporation of hired labour wage in the objective function will help to discourage the model from using hired labour ahead of household labour.

The opportunity cost scenario refers to the situation where an opportunity cost is attached to household labour in order to reflect the foregone chances of the farmers by being engaged in their own farms. This means that, if the farmers are not working on their farms, there can be a possibility for them to work outside East Hararghe Administrative Zone and earn some off-farm income. But because they are working on their own farms it means that they have forgone the income they could have earned by being employed in other farms or jobs outside the zone[2]. This opportunity cost of household labour is reflected in the model by attaching a reservation[3] wage to the household labour. In this case, the model will be discouraged from utilizing hired labour ahead of household labour as the wage rate attached to the hired labour use in the objective function of this scenario is higher than the reservation wage. Under this scenario, the optimum solution will show the optimum land use patterns given the potential household labour costs of producing outputs in the zone.

The last scenario incorporated in this study is the drought scenario. This scenario helps to determine the consequences for land use in case a drought occurs in the zone, which actually helps to analyze and meet the recurring problem of Ethiopian farmers and particularly the rural population. In this scenario the assumption is that if a drought occurs there will automatically be yield losses. This means the yield produced per farmer per hectare is going to be negatively affected. Therefore, the yield per hectare of the farmers was reduced by a certain percent from the base case scenario for the different

[1] The explanation and the reason for hiring labour only from within the zone is given in section 7.2.6
[2] If such an employment opportunity is within the zone, it cannot be incorporated in the model as the incomes and costs of that off-farm work will cancel out in the overall objective function for the zone.
[3] See section 7.2.6 for the explanation of the reservation wage.

farm types, depending on the extent of the effect of the drought on each farm type (see section 7.8). Drought is one important factor that usually causes short-term food insecurity (Jayne and Chizvo, 1991). Short-term food insecurity is when some groups of people cannot satisfy their nutritional requirements on a temporary basis (McCalla, 1999) due to factors such as flood and drought. Hence, the optimum solutions of this scenario help one to observe the potential food problems that the farming community could face as a result of the occurrence of drought as well as its consequences on the land use for the zone. Table 7.8 provides an overview of the three different scenarios presented in this chapter.

Table 7.8 Overview of land use scenarios

Name	Base scenario
Constraints	Available land, labour and oxen per farm type, restriction on the maximum land available to potatoes and green pepper production, no restriction on biocide use and nutrient depletion
Data	Actual land use, actual yields of crops, actual input uses, no on-farm household labour wage, actual hired labour wage
Results	Optimum land use under present conditions of the zone
Name	Opportunity cost scenario
Constraints	As in base scenario case
Data	Actual land use, actual yields of crops, actual input uses, reservation wage for on-farm household labour, actual hired labour wage
Results	Optimum land use under assumed labour cost condition
Name	Drought case scenario
Constraints	As in base scenario case
Data	Actual land use, assumed drought case yields of crops (reduced by 50%, 33% and 24% for farm type1, 2 and 3 respectively from the base scenario), actual input use, no on-farm household labour wage, actual hired labour wage
Results	Optimum land use under drought condition in the zone

7.5 Basic result of the land use model - EASTHAR

Linear programming techniques are more often utilized in resource allocations for the agricultural sector at individual farm level than at a regional level. In this study the application of linear programming techniques is illustrated for resource allocation at a wider research domain. The study combines the farm and the sub-regional levels in order to analyze and plan land use at the sub-regional level.

The main objective of this study is the development of a research model that can be utilized for land use analysis at a sub-regional level, which has so far not been looked into in Ethiopia. This model helps to make land use related policy recommendations at sub-regional level and can also be extended to the regional and national levels. It has been possible to fulfill this objective and the model was developed as outlined in Chapter 5 and in section 7.3 above. The model was then tested by using empirical data that was collected from 14 peasant associations and 210 sample farmers in East Hararghe Administrative Zone for which the results of the tests are presented in sections 7.6 through 7.9 under different scenarios. The result of the testing of the model has meaningfully revealed that its application at a sub-regional level will yield successful land use analysis that can aid in the formulation and recommendation of policy measures that can be utilized to rectify the land use system in the sub-region as well as in the region and the nation.

Moreover, since the model is a linear programming model, it is possible to include many land use systems, each with a number of technological options. Because it is a model for the sub-regional level, incorporating different farm types, it also permits a more detailed formulation than models for higher (e.g. regional, national) levels of analysis.

The results of the analysis are presented in the following subsequent sections.

7.6 Results of base scenario

In the base scenario, each of the three farm types in the model can choose from the available land, land use types and input combinations. No restriction is placed on the biocide use and on the depletion of soil nutrients N, P and K. The reservation wage for on-farm household labour is zero. The actual hired labour wage, as observed during the survey, is incorporated for the hired labour of each farm type for the smooth and neat functioning of the model as explained in section 7.4. All input and output prices are 2001 market prices.

The results of the base scenario are presented under four headings: farm production economics, income structure and employment; land use; variable input and draft power utilization; and land and labour productivities of farms. Land and labour productivities are computed because growth in output per unit of area and per unit of worker in agriculture is generally recognized as a necessary condition for economic development. The great differences in the productivity of farms are caused by the supply of land, labour and technical inputs (improved seed and fertilizer). Hence land and labour productivities of the different farm types of the zone are analyzed to investigate the contributions of these farm types in the overall agricultural growth of the zone. Each time the outcomes are presented both for the sub-region, East Hararghe Administrative Zone, as well as per farm type. To save space and time the results per farm household are presented only for production economics results and income structure. The result for the zone shows the average or the sum for all farm types and the result per farm type provides an understanding of the differences between farm types.

7.6.1 Farm production economics, income structure and employment

The value of the objective function, or the economic surplus, in the base scenario is around 646 10^6 Birr per year (Table 7.10 and Table 7.36). This is equivalent to US$ 75.9 million per year[1]. The objective function value differs per farm type, which is reflected

[1] On average, 1 US$ = 8.5 Birr in 2001

in the differences with regard to the production economics results (Table 7.9). This becomes particularly evident when comparisons are made between farm types with regard to the gross margin or the return to land, own capital and management of the farm. These results are somewhat related to the available land resources per farm type and per farm household that are shown in Table 7.1 section 7.2.1.

Table 7.9 Production economics results per farm type (10^6 Birr/year) and per farm household (Birr/year): base scenario, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Value of production[1]	3805	176	3870	273	2709	403	3209	852
Input costs[2]	735	34	1035	73	665	99	776	206
Hired labour[3]	0	0	255	18	0	0	68	18
Hired oxen[4]	4	0.2	0	0	0	0	1	0.2
Gross margin[5]	3066	141.8	2580	182	2044	304	2364	627.8
Own labour[6]	0	0	0	0	0	0	0	0
Return to land, own capital and management of farm[7]	3066	141.8	2580	182	2044	304	2364	627.8

[1] Value of production excludes produce retained for home consumption and it is output sold at market prices
[2]Input costs: costs for variable inputs (seed, fertilizer and biocides)
[3] Hired labour: costs for hired labour
[4]Hired oxen: costs for hired oxen
[5] Gross margin = value of production – input costs –hired labour - hired oxen
[6] Own labour: valuation of on-farm labour at a reservation wage
[7] Return to land, own capital and management of farm = Gross margin – Own labour

At farm types level, farm type 1 has the lowest gross margin or return to land, own capital and management. Farm type 3 has the largest returns and gross margin, while the returns of farm type 2 is in between farm types 1 and 3. However, at households level, the farm households in farm type 1 have a relatively larger land endowment as compared to those households in farm type 2 and 3 (see Table 7.1). Since the average land endowment of farmers in farm type 3 is the smallest, the gross margin or returns to land, own capital and management they obtained is also the lowest. Farmers in farm type 1 have the largest farm area and show the best returns and gross margin, while the returns of the farm households in farm type 2 is in between those of farm types 1 and 3 similar to their farmland endowment. Thus, as is inherent to a linear programming model with an economic objective function, there is a close relationship between the quantity of the land resources of a farm and its gross margin or farm economic returns.

Table 7.10 Income structure per farm type (10^6 Birr/year) and per farm household (Birr/year): base scenario, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Gross margin	3066	141.8	2580	182	2044	304	2364	627.8
Work on other farms[1]	237	11	0	0	47	7	68	18
Oxen-rent income[2]	0	0	3	0.2	0	0	1	0.2
Farm household income[3]	3303	152.8	2583	182.2	2091	311	2433	646
Own labour	0	0	0	0	0	0	0	0
Economic surplus[4]	3303	152.8	2583	182.2	2091	311	2433	646

[1] Work on other farms: is remuneration for work on other farm types within EHAZ.
[2] Oxen-rent income: income obtained from renting oxen to other farm types
[3] Farm household income = Gross margin + work on other farms + oxen-rent income.
[4] Economic surplus = Farm household income – own labour. It is equivalent to the objective function value per farm type and for the entire sub-region (EHAZ).

The income structure of each farm type and their farm households is shown in Table 7.10. The employment generated for the household labour in each farm type is indicated in Tables 7.11 and 7.12. From the farm household income point of view farm type 3 earns larger total income at farm types level. Farm type 1 has earned the lowest total household income while the earnings of farm type 2 is in between farm types 1 and 3. From each household's point of view, farmers in farm type 1 enjoy greater household income as compared to those in farm type 2 and 3. Farmers in farm type 3 earned the smallest household income while the earnings of those in farm type 2 is in between that of farm type 1 and 3. This result is similar to the one obtained in comparing the returns to land, own capital and management of the farm as indicated in Table 7.9. Moreover, this result is comparable with the household income from crop sales which were observed from the survey for sample farmers. Sample farmers in farm type 1 have been those that obtained the largest income per household from the sale of crops as shown in Table 6.31, Chapter 6.

A very interesting result to note is the considerable improvement observed in the household income of each farm household that can be obtained from crop sales with the adoption of the envisaged optimum land use system. The household income generated from the sale of crops grows by 244% per household per year in farm type 1. In farm type 2, this growth is amazingly by 763% while in farm type 3, the household income from the sale of crops will increase by 212% per annum (compare the figures in Table 6.33 Chapter 6 and Table 7.10).

As far as the generation of employment for the household labour is concerned (Table 7.11 and Table 7.12), 31% of the total available mandays of the labour force in farm type 1 for the year have been employed either in its own farms or in other farm types during the year. In farm type 2, the yearly utilized own household labour amounts to 57% of the total available labour force in this farm type for the entire year. Farm type 3 has utilized 44% of its available labour force for the year. This result shows that farm type 2 has performed well in terms of employment provision for its labour force. Farm type 1 provided the least in terms of employment generation for the available labour force. The percentage of employment generated by farm type 3 is in between farm type 1 and 2.

Labour use peaked in the months of June, December and May for the entire zone. In June 83% of the entire available labour force is utilized. This result confirms the observation made during the survey that showed June as the month of high agricultural undertakings in the zone as described in chapter 6. This also corresponds well to the reality, as June is the month that marks the on-set of the rainy season in Ethiopia during which crop production intensifies. December is the second month in terms of labour utilization followed by May. In December and May 68% and 61% of the total monthly available labour force is utilized respectively. However there is no month in which the entire monthly available labour force is exhausted in the zone.

Table 7.11 Labour use by farm type per month (10^3 mandays): base scenario, 2001

Farm type	1	2	3	Zonal
January	0	3060	4292	7352
February	0	0	1568	1568
March	735	1961	2082	4778
April	2193	3717	1356	7266
May	46.3	3560.1	3976.4	7582.8
June	1481	4918	3941	10340
July	2.3	122.7	3779	3904
August	3.0	155.7	3411.5	3570.2
September	0	24.5	2545	2569.5
October	448.8	1870.9	1375.4	3695.1
November	991.2	1499.3	2641.3	5131.8
December	1224.4	3445.1	3824	8493.5
Total	7125	24334.3	34791.6	66250.9

If looked from each farm type's point of view, one can clearly observe from Table 7.11 that the months of April, June and December are those that provide the highest household labour employment in farm type 1 during the year. In these months the entire labour force, which is available for each month, is exhausted not only because of internal labour use, but also as a result of hiring labour to farm type 2 (Table 7.12). In April about 90% of the total monthly available labour in this farm type is engaged in farming activities within the farm type itself and the remaining 10% is transferred to farm type 2. In June some 39% of the available labour is hired to farm type 2 and the remaining 61% is involved in internal agricultural activities in the farm type. In December, farm type 1 transferred 14% of its monthly available labour force to farm type 2 while 50% is engaged in internal farming. Farm type 1 experiences no labour shortages for internal farming operations any month, and hence no hiring of labour by this farm type was observed in the optimal solution.

Table 7.12 Labour transfer among farm types per month (10^3 mandays): base scenario, 2001

Labour to farm type		1	2	3	Zonal
	Labour from				
April	Farm type 1	0	241.8	0	241.8
	Farm type 2	0	0	0	0
	Farm type 3	0	374	0	374.0
	Total	0	615.8	0	615.8
May	Farm type 1	0	458.9	0	458.9
	Farm type 2	0	0	0	0
	Farm type 3	0	0	0	0
	Total	0	458.9	0	458.9
June	Farm type 1	0	954.1	0	954.1
	Farm type 2	0	0	0	0
	Farm type 3	0	862.7	0	862.7
	Total	0	1816.8	0	1816.8
December	Farm type 1	0	343.9	0	343.9
	Farm type 2	0	0	0	0
	Farm type 3	0	0	0	0
	Total	0	343.9	0	343.9
Total yearly transferred labour		0	3235.4	0	3235.4

Farm type 2 exhausts all its available labour forces in June, April, May and December, and is forced to hire some labour from both farm types 1 and 3. Except in April, thus in each of the remaining three months, the amount of labour hired by farm type 2 from farm type 1 exceeds the amount hired from farm type 3 (Table 7.12). The largest labour use is observed in June followed by April, May and December consecutively. June claims 56% of the total labour hired by this farm type during the year, while April, May and December utilize 19, 14 and 11% of the total hired labour respectively. As is clearly evident from Table 7.12, farm type 2 is the only farm type in the zone that hires labour for its farming activities during the year.

In farm type 3 the months of January, May, June and December are those that provide the largest household labour employment. In April and June, in addition to the internal use of the household labour, there is a transfer of some hired labour to farm type 2 (Table 7.12). January is the month that provides the highest internal labour employment in farm type 3 where about 62% of the total monthly available labour is engaged in farming activities within the farm type itself. In April about 20% of the monthly available labour force is employed on the farm type itself and some 5% is transferred to farm type 2. In June about 13% of the available labour is rented to farm type 2 while about 57% of the monthly available labour force is involved in internal agricultural activities in the farm type. In December about 55% of the total monthly available labour force is engaged in internal farming operations. However, in this farm type, like farm type 1, there are no labour shortages for internal farming operations and hence no hiring of labour from other farm types was observed in the optimal solution.

An important result which could be envisaged from Table 7.11 and 7.12 and which is a peculiar characteristic of subsistence agriculture is that the household labour in all farm types largely work on their own farms and hence do not command significant off-farm income. Because of the subsistence nature of the agriculture in this zone, the labour force is largely confined to their own farms. For instance, in farm type 1, 78% of the total labour force that is involved in agricultural production during the year work on their own farms and only 22% are employed in other farm types. In farm type 2 no household labour is employed elsewhere. In farm type 3, only about 3% are employed in other farm types.

7.6.2 Land use

The creation of household income and employment in East Hararghe Administrative Zone is largely based on the use of land by the different farm types. Table 7.13 shows the allocation of land to different crops in the optimal solution. According to this table all the zonal land that is available for the production of the main crops is fully utilized. Moreover, at the zonal level, all the crops included in the model have been selected in the zonal optimum land use. This is important, as most of the food requirements of the subsistence farmers should necessarily be met from within their own farms.

Table 7.13 Land planted to each crop per farm type (hectares/year): base scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	5227	0	0	5227
Maize 2	0	68182.5	24376	92558.5
Sorghum 1	0	14495	14078	28573
Sorghum 2	57931	0	0	57931
Wheat 1	81	0	0	81
Wheat 2	0	1856	86425	88281
Barley	0	682.5	7203	7885.5
Horse beans	0	1391	5111	6502
Groundnuts	4969.5	0	0	4969.5
Potatoes	0	398	3141	3539
Green pepper	1198	0	0	1198
Total area	69406.5	87005	140334	296745.5

The three main food crops of maize, sorghum and wheat occupy the bulk of the zonal land. Maize is planted on an area of land that corresponds to 33% of the total zonal available land for main crops production. The share of sorghum is close to 29% of the total zonal land. These shares of maize and sorghum match well with the real circumstances in the zone; these crops were shown as the most important staple crops in the zone in Chapter 6. Wheat takes a share close to 30% of the zonal land even if it is ranked as the third important crop in the zone. The relatively small increase in the land allocated to wheat over that of sorghum emanates from the land allocation in farm type 3 that is slightly biased towards wheat.

An important result of the optimum land use at the zonal level is how the different varieties of maize, sorghum and wheat were selected in the optimal solution of this scenario. At zonal level, both the local and the improved varieties of these crops are incorporated in the optimum land use. However, from the total zonal land planted to maize, its local variety gets only a 5% share with the improved variety being assigned 95%. In the case of sorghum, the improved variety occupies 67% of the land allocated to it and the local variety 33%. Wheat is no exception in favoring the improved variety over the local variety. The improved wheat variety should be planted on 99% of the total wheat land in the zone. The result with this scenario clearly indicates that the improved varieties of the different crops perform better than the local varieties. This result is really enormous in terms of boosting research activities and in adopting policy measures. As the above result implies, research for even better varieties of maize, sorghum and wheat will be beneficial, and will affect the three farm types differently. Purchase (1996) mentioned that variety or cultivar choice is an important production decision and if correctly planned, could greatly contribute to reducing risk and optimizing yields.

The allocation of land to the most important crops, in order of their importance in the zone, indicates that the land use model which is developed to aid land use analysis at sub-regional level is proven to be a satisfactory representation of the farming practices in the zone. Likewise, the selection of both the local and improved varieties of the main crops in the optimal solution shows that the model was successful in picking the usually observed behaviour of farmers in developing countries. Farmers in developing countries are usually seen to allocate a portion of their land to traditional varieties while also adopting improved varieties in their farming practices. This behaviour of farmers is well explained by microeconomic theories of joint production as mentioned by Smale, Just and Leathers (1994).

The optimal land use shows some variations among the three farm types. In farm type 1 most of the land is allocated to sorghum production followed by maize and groundnuts. In farm type 2, the land allocated to maize by far exceeds the land assigned to the remaining other selected crops. In farm type 3, the bulk of the land is allocated to wheat production.

Table 7.14 Optimum production of outputs per farm type (tons/year): base scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	8948	0	0	8948
Maize 2	0	253093	95360	348453
Sorghum 1	0	21105	25903	47008
Sorghum 2	139035	0	0	139035
Wheat 1	38	0	0	38
Wheat 2	0	5093	325649	330742
Barley	0	819	13772	14591
Horse beans	0	890	5438	6328
Groundnuts	6123	0	0	6123
Potatoes	0	4776	62192	66968
Green pepper	1073	0	0	1073

The amount of land allocated to each crop clearly indicates that the improved variety of sorghum is the main crop in farm type 1. This is especially true when we look at the optimum production of sorghum in farm type 1 as compared to farm types 2 and 3 (Table 7.14). Of the total output of sorghum to be produced in the zone, farm type 1 produces 75%, while farm types 2 and 3 produce only 11% and 14% respectively.

On the other hand farm type 2 largely specializes in maize production as seen both from the area allocated to the crop and from the share of farm type 2's maize output in the total zonal maize produce. The share of farm type 2 is more than 70% of the total zonal maize production, whereas farm type 1 and 3 will only contribute an amount of 3 and 27% of the total zonal maize output respectively.

According to Table 7.14, wheat production is undoubtedly the specialization of farm type 3. Wheat takes the largest share of the total land available in farm type 3 and almost the total zonal wheat output has to be produced in farm type 3 (about 98.5% of the total zonal wheat output). This result conforms the information indicated in Chapter 3 regarding the production of wheat in the zone. As was mentioned in Chapter 3, wheat is a cold weather crop which is predominantly grown on the highlands. As this farm type is representative of this agro-ecology and as it comprises the districts that are considered to be the major wheat producing areas, the specialization of wheat in this farm type is realistic. Wheat production is almost nonexistent in farm type 1(only 0.01% of the total zonal wheat production) and farm type 2 will produce around 1.54% of the total zonal wheat output.

Surpluses of outputs in each farm type can be expected, as specialization on different crops is favored in the optimum land use plan at farm types level and at zonal level. Table 7.15 shows output excesses over the minimum consumption requirements of the rural as well as the urban population of each farm type. This table also indicates the total surpluses of outputs generated at zonal level for the crops in question.

In farm type 1, some amount of surplus over the minimum consumption requirements of the rural and urban population is produced of its specialization crop, sorghum (Table 7.15). It constitutes the total surplus production of sorghum at zonal level. The other crop for which some surplus exists in farm type 1 is green pepper. As discussed in Chapter 6, no significant amount of green pepper is produced in farm types 2 and 3, and the excess green pepper generated in farm type 1 will definitely be absorbed in farm types 2 and 3.

Farm type 2 produces surplus output of only maize, its crop of specialization given the optimum land use in the base scenario. Farm type 3 generates surpluses of wheat and potatoes. These crops are not produced in farm type 1 and hence their excess amounts would probably largely be absorbed in the zone itself, especially in farm type 1.

Table 7.15 Surpluses produced above rural and urban use in each farm type (10^3 tons/ year): base scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	0	0	0	0
Maize 2	0	224.3	0	224.3
Sorghum 1	0	0	0	0
Sorghum 2	111.5	0	0	111.5
Wheat 1	0	0	0	0
Wheat 2	0	0	290.3	290.3
Barley	0	0	0	0
Horse beans	0	0	0	0
Groundnuts	0	0	0	0
Potatoes	0	0	49.85	49.85
Green pepper	0.7	0	0	0.7

It is important to note, however, that such surplus products at sub-regional level should actually be linked to regional and national demands in order to know where these excess outputs can be absorbed. This is in fact a potential use of the model developed in this study where an extension of the domain of land use analysis, to the regional level or national level, can be readily incorporated when the need arises. However, such an investigation is beyond the scope of the present study and the issue can be an important future research theme for the researcher himself or any other interested researchers. Nevertheless, as the present state of the country is far from self-sufficient in food production and as the problem of food shortage is always threatening, the production of surplus outputs in East Hararghe Administrative Zone would undoubtedly be good news to the Oromia region as well as to the country as a whole. The surpluses can also contribute to Ethiopia's foreign trade potential.

7.6.3 Variable inputs and draft power utilization

The use of variable inputs for the production of crops in the optimum solutions is shown in Table 7.16 and Table 7.17. Table 7.16 shows the optimum seed input use and Table 7.17 illustrates the optimum use of fertilizers and biocides. In these tables the use of the different inputs are indicated being separated between local and improved varieties of each crop as input uses differ significantly among varieties.

Table 7.16 Total seed input used by each farm type (tons/year): base scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	221.6	0	0	221.6
Maize 2	0	1712.7	604.5	2317.2
Sorghum 1	0	549.6	846.9	1396.5
Sorghum 2	2201.4	0	0	2201.4
Wheat 1	11.4	0	0	11.4
Wheat 2	0	239	12749	12988
Barley	0	131	1148.5	1279.5
Horse beans	0	111.2	516.5	627.7
Groundnuts	245	0	0	245
Potatoes	0	637	2899	3536
Green pepper	141	0	0	141

As far as the use of seed is concerned, farm type 1 is required to use seed for the improved variety of sorghum, as its local variety does not appear in the optimal solution. For maize and wheat, the local varieties are selected in the optimum land use plan, necessitating the use of local variety seeds for these crops as shown in Table 7.16. Farmers in farm type 2 and 3 will require seed of the improved varieties of maize and wheat unlike farmers in farm type 1. However, as discussed in Chapter 6, the improved variety of sorghum was planted only in farm type 1 and farm types 2 and 3 will use the seed for the local sorghum variety.

The optimum fertilizer input differs significantly among farm types (Table 7.17). Large uses of both DAP and urea fertilizers are observed in farm type 3, requiring 48% of total optimum zonal DAP fertilizer use. Its urea fertilizer share is close to 52% of the optimum total zonal urea fertilizer use. This result matches the circumstances of the farmers in farm type 3. In Chapter 6, it was indicated that more than half of the farmers in farm type 3 use DAP fertilizer and about half of them use urea fertilizer. Farm type 1 utilizes the smallest amount of both DAP and urea fertilizers. At the moment, its share of DAP use is 23% and its urea utilization is only around 14% of the total zonal use. Farm type 2 is in between farm type 1 and 3 as far as fertilizer uses are concerned.

Table 7.17 Total fertilizes and biocides used by each farm type (10^3 tons or liters/year)[1]: base scenario, 2001

Farm type	1	2	3	Zonal
DAP fertilizer	6.4	8.2	13.3	27.9
Urea fertilizer	3.5	8.2	12.5	24.2
Pesticides	10.4	207.3	85.9	303.6
Herbicides	0	307.2	0	307.2

[1] Fertilizer is measured in tons and biocides in liters

At the zonal level, DAP fertilizer use exceeds the use of urea. The quantity of herbicides used at zonal level slightly exceeds the use of pesticides, even though herbicides use is indicated only for farm type 2. Pesticides are to be utilized in the optimum land use plan of all the three farm types. However, in the optimum land use plan for the zone, large use of biocides is linked to farm types 2 and 3. About 68.3% of the total zonal pesticide use is associated with farm type 2 and 28.3% in farm type 3. This result is consistent with the observation described in Chapter 6 that the small biocide use observed in the zone largely come from farm types 2 and 3 (section 6.3.4.2).

Table 7.18 Oxen use by a farm type per month (10^3 oxen-pair days): base scenario, 2001

Farm type	1	2	3	Zonal
January	0	497.8	769.4	1267.2
February	0	0	325.7	325.7
March	79.7	684.6	100.8	865.1
April	428.8	294.1	12.6	735.5
May	195	3.1	728.5	926.6
June	0.65	17.7	0	18.3
July	0.33	6.3	222.6	229.2
August	0	0	0	0
September	0	0	40.3	40.3
October	0	0	0	0
November	0.65	3.8	0	4.45
December	447.6	15.1	0	462.7
Total oxen-pair days	1152.73	1522.5	2199.9	4875.1

With respect to draft power use, in no month is the entire monthly available oxen power exhausted at zonal level. In the optimum land use pattern, only 17% of the total yearly available oxen power is used during the year. This result, which shows a relatively low use of oxen in crop production, may reflect the very subsistence nature of agriculture in the zone where only hoe and shovel-like hand tools are utilized. Draft power use is relatively high in January, May and March for the entire zone (Table 7.18). These correspond to the months of land preparation, tilling and threshing activities. In January, 54% of the total available zonal oxen-pair days are utilized. In May and March respectively 39% and 37% of the total monthly available oxen-pair days are utilized. In the optimal land use plan for the zone, the month of peak oxen use does not correspond to the month of peak labour use. June is the month in which large usage of agricultural labour is indicated. This result indicates that oxen use in the zone is mainly for threshing purposes.

Concerning the yearly use of oxen at farm types level, one can clearly observe from Tables 7.18 and 7.5 that farm type 1 is the most intensive user of oxen in percentage terms. It utilizes 22% of its total yearly available oxen-pair days in the optimum solution. Farm type 2 and farm type 3 use 18% and 15% of their total yearly available oxen-pair days respectively. This finding corresponds well to the real situation in the zone with regard to oxen use as observed during the survey. In section 6.3.4.2 of Chapter 6, it was indicated that use of oxen is very significant in farm type 1 as compared to the other two farm types where a relatively proportional use of oxen occurs among farmers; the same was found in the optimal solution of this base scenario.

In farm type 1, a large use of oxen-pair days is observed in December, April, and May. In December the total monthly available oxen-pair days are fully employed and an additional 3,230.5 oxen-pair days are rented from farm type 2. This is the only month in which hired oxen are included in the optimum land use for the zone and it is the month in which almost all threshing activities are performed in farm type 1. This result may correspond well to reality because it is very unlikely that oxen hiring is practiced in the zone particularly from one farm type to another. Oxen are less mobile than labour and in reality there will not be much hiring of oxen across farm types. In April about 96.5% of the monthly available oxen-pair days are involved in agricultural activities in this farm type. In the month of May, farm type 1 has to engage 44% of its monthly available oxen-pair days in farming operations.

March, January and April represent the months of large oxen utilization in farm type 2. The biggest oxen use is observed in March where about 95% of the total monthly available oxen-pair days are employed. This is followed by January in which about 69% of the available oxen-pair days are utilized. April claimed 41% of the total monthly available oxen-pair days in this farm type.

In farm type 3, January, May and February exhibited the largest oxen utilization. In January, about 64% of the total monthly available oxen-pair days were engaged in farming activities, compared to about 61% in May and 27% in February.

7.6.4 Land and labour productivities

Production performances of farm types can be judged from labour and land productivities[1] (the need for this analysis is explained in section 7.6). Labour productivity shows the output per unit of labour use while land productivity indicates total output per unit of land used. This means that a separate productivity estimate can be calculated for each crop. However, in this analysis overall land and labour productivities are computed for each farm type and at the zonal level by summing the values of the total outputs produced in each farm type for all crops during the year and comparing this with the total yearly utilized labour and land to produce these products. Hence, the values of all the optimum outputs indicated in Table 7.14 are summed together over each farm type and over the entire zone to compute land and labour productivities as shown in Table 7.19.

Table 7.19 Land and labour productivities per farm type and for the zone: base scenario, 2001

Farm type	1	2	3	Zonal
Total value of outputs (10^6 Birr)	237	347	597	1181
Total labour use (10^6 mandays/year)	7.125	24.3343	34.7916	66.2509
Labour productivity (Birr/manday)	33.3	14.3	17.2	17.8
Total land use (hectares/year)	69406.5	87005	140334	296745.5
Land productivity (Birr/hectare)	3414.7	3988.3	4254.1	3979.8

Table 7.19 indicates that farm type 3 has higher land productivity as compared to farm type 1 and 2. Farm type 2 has higher land productivity as compared to farm type 1. However, in terms of labour productivity farm type 1 is shown to possess the highest labour productivity in the zone. This backs the result given in section 7.6.1, which showed that farm type 1 has the best returns as far as production economics results per farm household are concerned.

[1] These are averages not marginal productivities

7.7 Results of opportunity cost scenario

The difference between the opportunity cost and the base scenarios is that in the former the on-farm household labour is valued at a reservation wage of 60% of the wage rate for hired labour in each farm type. The assumption of 60% is arbitrary, not based on a research finding. However, for a smooth functioning of the EASTHAR linear programming model such a wage rate has to be lower than the lowest wage rate for working off-farm. A reservation wage reflects a household's preference for leisure. Theorists have often argued that a person or a household has a choice between work and leisure; the wage rate or income per unit of time determines the proportion in which people's time will be allocated between work and leisure. A wage rate of zero will not induce people to work (Nicholson, 1992).

In order to save space and time, the results of the opportunity cost scenario will be discussed only in comparison with those of the base scenario.

In the opportunity cost scenario, as in the base scenario, each of the three farm types can choose from the available land, land use types and input combinations. No restriction is placed on the biocide use and on the depletion of soil nutrients N, P and K. The reservation wage for on-farm household labour is set at 60% of the hired labour wage rate. The actual hired labour wage, as observed during the survey, is incorporated for valuing the hired labour in each farm type; all input and output prices are, like the base scenario, 2001 market prices.

In the results of this scenario, only the value of the objective function, the farm production economics results and the income structure of the farm households differed from the base solution. There was no change in optimum land use, labour use, labour transfers between farm types, variable input use, draft power utilization, and land and labour productivities from the base scenario. Therefore, also the crop surpluses remained unchanged. The prominent changes that occurred in the opportunity cost scenario are elaborated in the following sections.

7.7.1 Farm production economics and income structure

The value of the objective function of the zone, or the economic surplus, in the opportunity cost scenario is 430 10^6 Birr per year (Tables 7.21 and 7.36), equivalent to US$ 50.6 million per year and 33% lower than in the base scenario.

After valuing the own labour of the households at the assumed reservation wage rate, the return to land, own capital and management of each farm type has also shown some changes in relation to the base scenario. One can compare the returns to land, own capital and management of each farm type to observe these changes. As shown in Table 7.20, at farm types level farm type 3 still shows larger overall returns to land, own capital and management of the farm. Farm type 2, which was the second in terms of these returns at farm types level in the base scenario, does not outperform farm type 1 in this sense in this scenario; the difference in their returns to land, own capital and management of the farm is small enough to be regarded as not significant.

Table 7.20 Production economics results per farm type (10^6 Birr/year) and per farm household (Birr/year): opportunity cost scenario, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Value of production	3805	176	3870	273	2709	403	3209	852
Input costs	735	34	1035	73	665	99	776	206
Hired labour	0	0	255	18	0	0	68	18
Hired oxen	4	0.2	0	0	0	0	1	0.2
Gross margin	3066	141.8	2580	182	2044	304	2364	627.8
Own labour	606	28	978	69	800	119	813	216
Return to land, own capital and management of farm	2460	113.8	1602	113	1244	185	1551	411.8

At the level of each household, however, the farm households in farm type 1 still have the highest economic returns as compared to those households in farm types 2 and 3. The gross margin or the returns to land, own capital and management of the farmers in farm type 3 remains the smallest while the returns of the farm households in farm type 2 is still in-between those of farm type 1 and 3.

Under the assumption that own labour remuneration should be deducted from economic surplus, the objective function value of the opportunity cost scenario differs per farm type, as shown in Table 7.21. As in the base scenario, farm type 3 has the largest overall objective function value. Farm type 2 now generates the smallest total economic surplus and the total economic surplus earned by farm type 1 is in-between those of farm types 2 and 3. Nevertheless, at household level, farm households in farm type 1 still command the highest economic surplus and household income like the base scenario. Similarly, farmers in farm type 2 obtained higher household income and economic surplus than farmers in farm type 3.

Table 7.21 Income structure per farm type (10^6 Birr/year) and per farm household (Birr/year): opportunity cost scenario, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Gross margin	3066	141.8	2580	182	2044	304	2364	627.8
Work on other farms	237	11	0	0	47	7	68	18
Oxen-rent income	0	0	3	0.2	0	0	1	0.2
Farm household income	3303	152.8	2583	182.2	2091	311	2433	646
Own labour	606	28	978	69	800	119	813	216
Economic surplus	2697	124.8	1605	113.2	1291	192	1620	430

At the zonal level, the total economic surplus decreased by 33% as compared to the one obtained in the base scenario. Large reductions in the economic surplus are observed in farm type 2 and 3. In both these farm types the total objective function value has reduced by 38% compared to the base scenario. In farm type 1 the overall objective function value has reduced by 18%.

However, it is important to note that the reduction in the objective function values of farm types in relation to the base scenario are completely the result of the pricing of the own labour of the households (opportunity cost) and does not necessarily imply a real expense incurred by each farm type. The large reduction of the total economic surplus of farm type 2, in this opportunity cost scenario, also indicates that this farm type has actually generated the largest employment opportunity for its labour force. As also explained in section 7.6.1, a higher percentage of household labour participated in production in farm type 2 as compared to the other farm types. Farm type 2 utilizes 57% of the total yearly available household labour as on-farm labour. In farm type 1 and 3, only 24% and 42% respectively of the total yearly available household labour is utilized as on-farm labour.

It was indicated in section 7.6.1 that, as far as the generation of employment for the household labour is concerned, be it on-farm or off-farm, farm type 2 has given work to more than half of its yearly available own household labour. Hence, valuation of own on-farm labour at a reservation wage must arithmetically considerably erode the total economic surplus.

7.7.2 Sensitivity for assumed reservation wage

In both section 7.2.6 and section 7.4, an explanation was offered as to why a reservation wage for on-farm household labour was needed and assumed. It was fixed at 60% of the hired labour wage observed in each farm type. The highest possible price for the reservation wage would be the wage for off-farm employment within East Hararghe Administrative Zone, while the lowest would be zero per manday. The latter means effectively abandoning the idea of a reservation wage. The result of such an investigation is the one shown in section 7.6, under the base scenario and it represents a condition of the highest objective function value.

When using a reservation wage that equals the hired labour wage in East Hararghe Administrative Zone, the value of the objective function will be approximately 286 million Birr per year and will decrease by 56% as compared to the base scenario case. This represents a situation of the smallest objective function value. This is tantamount to saying all the labour force utilized in agricultural production in the zone is treated as hired labour and the land use is also planned accordingly. Choosing a reservation wage that is in-between the these two extremes results in an objective function value that lies between those obtained for the base case scenario and the case when all labour is treated as a hired labour.

7.8 Results of drought case scenario

The third scenario incorporated in this study is the drought case scenario. As explained in section 7.4, it tries to analyze the consequences for land use if drought occurs in the study area. Drought is and has been a recurring problem for Ethiopians, particularly the rural population. Ethiopian agriculture is mainly subsistence in nature and is also rain fed. The year 2001 was regarded as a normal production year based on the fairly adequate rainfall that prevailed during the year and the relatively good yield which was obtained for the different crops. This has been observed during the survey and also confirmed by the farmers during group discussions. However, in times of drought there will automatically be yield decreases in almost every part of the country.

The mean annual rainfall received by the three farm types in the study area differs from one another. Farm type 1, which includes most of the southeastern lowland districts of the zone on average receives a mean annual rainfall of less than 500mm. Farm type 2 includes the eastern sub-areas of the zone and it receives a mean annual rainfall between 600 and 900mm. Farm type 3, comprises most of the central highlands and the western sub-areas of East Hararghe Administrative Zone, and receives a mean annual rainfall between 900 and 1200mm.

Given the above facts, the occurrence of drought might not affect all areas of the zone in the same manner. Since, high rainfall variability is observed in the lowland part of the zone where rainfall reliability is very low, farm type 1 can be expected to be affected most by drought. On the other hand, in the highland part of the zone relatively low rainfall variability is observed and has a relatively high rainfall dependability (reliability). Hence, farm type 3 will be less affected compared to the other farm types. The effect that farm type 2 suffers will obviously be in between that of farm type 1 and 3.

Therefore, in the drought case scenario, based on the susceptibility of the different farm types to drought, the yield per hectare of the farmers was made to reduce by 50, 33, and 24% for farm type 1, 2 and 3 respectively from that of the base scenario case. FAO (2000) indicates that an area with high yearly rainfall variability will experience larger fluctuations of production, particularly in peasant farming areas. The EASTHAR model is then re-analyzed with such a condition and the optimum solution observed. The optimum solution of this scenario helps one to observe the potential food problems that the population and the farming community could face as a result of the occurrence of drought as well as its consequences on the land use for the zone.

In the drought case scenario, each of the three farm types in the model can allocate the available land to the land use types with their assumed yields per hectare and input combinations. Like in the other scenarios, no restriction is placed on the biocide use and on the depletion of soil nutrients. The reservation wage for on-farm household labour is zero. The actual hired labour wage, as observed during the survey, is incorporated for hired labour. All input and output prices are 2001 market prices.

Most of the results of this scenario will be presented under two headings: farm production economics and income structure; and labour, land, variable input, and draft power uses of each farm types and the zone. Similar to the presentation made in the other scenarios, the results per household are shown only for production economics results and income structure. The outcome of the drought case scenario is discussed in comparison with the base scenario.

7.8.1 Farm production economics and income structure

In this drought case scenario no economic surplus is generated at any farm types level, at household level and, naturally neither at the zonal level. The value of the objective function, or the economic surplus, shows a total loss of 123 10^6 Birr per year in the zone (Tables 7.23 and 7.36). This is equivalent to US$ 75.9 million per year. This loss of economic surplus varies per farm type and per farm household as can be seen in Table 7.23. Farm type 1 is most severely affected and suffers the largest percentage loss in economic surplus both at household and farm type levels compared to the base scenario. Farm types 2 and 3 are relatively less affected by the drought. The production economics results of the drought condition are also depicted in Table 7.22.

Table 7.22 Production economics results per farm type (10^6 Birr/year) and per farm household (Birr/year): drought case scenario, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Value of production	86	4	43	3	87	13	75	20
Input costs	605	28	553	39	511	76	538.5	143
Hired labour	43	2	0	0	0	0	7.5	2
Hired oxen	151	7	0	0	0	0	26	7
Gross margin	-713	-33	-510	-36	-424	-63	-497	-132
Own labour	0	0	0	0	0	0	0	0
Return to land, own capital and management of farm	-713	-33	-510	-36	-424	-63	-497	-132

The results of the analysis indicate that the home consumption requirements of the farming population are met at household level, at each farm types level and at the zonal level. The amount of output sold is also equal to the consumption requirements of the urban population of each farm type. Thus under such a drought condition it is not possible to produce surplus products over and above the consumption requirements of the rural and urban population of each farm type (see Table 7.27).

In the drought case scenario the percentage decline of the value of production of the three farm types, as compared to the base scenario, are somewhat close to one another. The total value of production has reduced by 98% in farm type 1. In farm type 2 and 3, the total value of production decreased by 99% and 97% respectively. The percentage reductions in the value of production per household is similar to these figures.

Table 7.23 Income structure per farm type (10^6 Birr/year) per farm household (Birr/year): drought case scenario, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Gross margin loss	-713	-33	-510	-36	-424	-63	-497	-132
Work on other farms	0	0	28	2	0	0	8	2
Oxen-rent income	0	0	28	2	34	5	26	7
Farm household income loss	-713	-33	-454	-32	-390	-58	-463	-123
Own labour	0	0	0	0	0	0	0	0
Economic loss	-713	-33	-454	-32	-390	-58	-463	-123

Variable input costs have also reduced significantly. At the zonal level the total costs of the variable inputs is 31% lower than in the base scenario. In farm type 1, total variable inputs costs reduced by 18%. In farm type 2 and 3, the total variable input costs have decreased by 47% and 23% respectively. This reduction in variable input costs is related to the low use of the inputs, particularly fertilizers and biocides (see section 7.8.2 and

Table 7.29). Variable inputs are utilized only to produce the consumption requirements of the rural and urban population of each farm type and not to generate surpluses for the market. Moreover, in the optimal land use under this scenario, the improved varieties of all crops were not selected by the model in a bid to avoid the higher seed cost. The model selected only the local varieties.

The economic returns of the farm types and the farm households under this rainfall stress condition correspond well to the agro-ecological conditions of their environment. Farm type 1 has the largest percentage economic loss because it is located in an arid agro-ecological environment. Because farm type 2 has a better rainfall pattern, its economic loss is percentage wise somewhat lower than that of farm type 1. Farm type 3 is the most favored farm type as far as the pattern of rainfall distribution in the zone is concerned (see section 7.8 above) thus incurring lower farm economic losses, in percentage terms, as compared to farm type 1 as well.

An important result obtained from analyzing this drought case scenario is the amount of farm support that might be required in the case of such a drought condition. Each farm type has produced the amount of grain required for home consumption of its population residing both in the rural as well as in the urban areas. In the process of producing these consumption requirements, the farms have incurred the amount of input costs indicated in Table 7.22. Because of the smallness of the sold produce and due to the lack of surplus output, the gross margins as well as the economic surplus have become negative. This outcome suggests two important solutions from which one must choose. The first solution is that if the farmers should be able to produce almost just enough for their consumption requirements, then a case can be made to subsidize them to the amount of their lost gross margins. This subsidy can be minimized if the farmers are encouraged beforehand to save and have some financial reserves for rainy days. Government must also convince donors to contribute to the subsidy, as this cost can be lower than food aid. The second policy option, less inviting from the researcher's point of view, is to fully supply their consumption requirements as food aid and cease production altogether under such drought condition. This second option is less inviting because the dependence on international markets for food aid cannot be a preferable alternative. As indicated by FAO (2001), to supply enough food to the growing population of developing countries, without increasing the dependence on international markets for food aid, more food has to be produced where people live. The choice between the two policy options is left to the capable policy maker.

An encouraging feature of the result is that a recurring drought of the severity portrayed in this scenario will not necessarily lead to a food crisis in East Hararghe. It however reduces incomes substantially. This may indirectly cause food problems. Income reductions invariably lead to worse poverty. It has been shown that it is not that much existence of food, but entitlement to food, including the ability to purchase food, that often causes famine (Sen, 1981).

7.8.2 Labour, land, variable input and draft power utilization

Labour use

In this drought case scenario, the overall yearly zonal household labour use increased slightly compared to the base scenario (Table 7.24). This increase mainly occurs in farm types 1 and 3. In farm type 1, some 47% of the total available mandays of the labour force for the year is employed; an increase of 16% over the amount utilized in the base scenario. In farm type 3, about 45.4% of the yearly available household labour force is employed; this amounts to 1.4% increase over that of the base scenario. The increase in labour use can be realistic, as farmers would substitute labour for other inputs such as fertilizers and biocides to avoid costs (compare Tables 7.17 and 7.29). In farm type 2, yearly labour use decreases. In this farm type, the yearly-utilized household labour, on-farm as well as off-farm, amounts to 44.6% of the total available labour force. This represents an annual decrease of around 12.4% in comparison to the amount employed in the base scenario. Thus farm type 2 which created the largest employment opportunity for its household labour force in the base scenario is the smallest generator of employment under the drought condition.

Table 7.24 Labour use by a farm type per month (10^3 mandays): drought case scenario, 2001

Farm type	1	2	3	Zonal
January	0	2250.7	4596	6846.7
February	0	0	3570.2	3570.2
March	950.6	2010.9	3109.2	6070.7
April	1985.7	2306.3	3789.6	8081.6
May	1582.6	2199.3	2293.1	6075
June	2154.3	2865.3	5650.6	10670.2
July	2223.9	184.6	1269.1	3677.6
August	5.8	442	1431.7	1879.5
September	0	36.3	682.7	719
October	830.9	920	4390.1	6141
November	1617.9	1260.9	2440.3	5319.1
December	2741.8	1822.1	4305.1	8869
Total mandays	14093.5	16298.4	37527.7	67919.6

As with the base scenario, labour use peaks in the months of June and December for the entire zone. In June 86% of the entire available labour force is used. In December 71% of the total monthly available labour force is employed. In both June and December, the labour use in the drought case scenario has increased by 3% over that of the base scenario. Unlike the base scenario, April is the third month in terms of agricultural labour use in the drought case scenario. There is no month in which the entire monthly available labour force is exhausted in the zone in this drought case scenario.

As one can observe from Table 7.24, December, July and June are the months that provide the highest household labour employment in farm type 1. July, which showed low agricultural labour use in the base scenario, has now become the second important month in terms of employing labour force in farm type 1. Table 7.25 shows that farm type 1 is the only one to have hired labour for its farming activities during this drought year.

Table 7.25 Labour transfer among farm types per month (10^3 mandays): drought case scenario, 2001

Labour to farm type		1	2	3	Zonal
	Labour from				
April	Farm type 1	0	0	0	0
	Farm type 2	0	0	0	0
	Farm type 3	0	0	0	0
	Total	0	0	0	0
May	Farm type 1	0	0	0	0
	Farm type 2	0	0	0	0
	Farm type 3	0	0	0	0
	Total	0	0	0	0
June	Farm type 1	0	0	0	0
	Farm type 2	0	0	0	0
	Farm type 3	0	0	0	0
	Total	0	0	0	0
December	Farm type 1	0	0	0	0
	Farm type 2	307	0	0	307
	Farm type 3	0	0	0	0
	Total	0	0	0	0
Total yearly transferred labour		307	0	0	307

In Farm type 2, the largest labour use is observed in the month of June followed by April. This is similar to the labour use pattern observed in the base scenario. In farm type 3 the months of January and October are those that provide the largest household labour employment during the year.

One of the adverse effects of the drought is the restriction of labour transfers between farm types and in the zone. As shown in Table 7.25, no significant transfer of labour between farms was observed except in December when farm type 1 hired 307,036 mandays from farm type 2.

Land use

Table 7.26 shows the land allocated to the different crops in the optimal solution of the drought case scenario. According to this table, the drought condition did not allow the full utilization of the total zonal land available for the production of the main crops; only 85% was used to produce the crops and the rest (15%) was left idle. This clearly shows the adverse effect of drought on land use. All the crop types included in the model appear in the zonal optimum land use, as most of the food requirements of the subsistent farmers should be met from within their own farms.

Table 7.26 Land planted to each crop per farm type (hectares/year): drought case scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	10453	30460	65496	106409
Maize 2	0	0	0	0
Sorghum 1	44964	21624	18501	85089
Sorghum 2	0	0	0	0
Wheat 1	162	4935	23890	28987
Wheat 2	0	0	0	0
Barley	0	1014	9459	10473
Horse beans	0	2060	6731	8791
Groundnuts	9939	0	0	9939
Potatoes	0	594	821	1415
Green pepper	834	0	0	834
Total area	66352	60687	124898	251937

In this drought case scenario, like in the base scenario, the three main food crops of maize, sorghum and wheat occupy most of the zonal land. Maize is planted on 36% of the total zonal land used for the production of the main crops. The land occupied by maize has increased by 3% as compared to the base scenario. The share of sorghum, which is 29% of the total zonal land, indicates no change from that of the base scenario. The share of wheat is close to 10% of the zonal land; its share dropped by some 20% from that in the base scenario.

A striking feature is how in this scenario, compared to the base scenario, the different varieties of maize, sorghum and wheat appear in the optimal solution. In the base scenario, both the local and the improved varieties of these crops were incorporated in the optimum land use. Moreover, the improved varieties were allocated the largest share while the local varieties were assigned very small tracts of land. However, in the case of the drought scenario all the improved varieties were completely eliminated from the optimum solution and only the local varieties appear in the land use scheme. The reason is the high seed costs of the improved varieties. Thus, it is correct decision making under such drought conditions where the performance of crops in terms of yield are severely affected, for farmers not to purchase seeds of improved varieties. Therefore, this result clearly indicates that there is a need to hugely subsidize farmers in terms of drought resistant improved varieties under such drought stress condition in order for them to be benefited from improved seed technologies.

The optimal land use in the drought case scenario also shows some variations among the three farm types. In this scenario, no farm type fully utilizes all its available land. In farm type 1, about 96% of the land available for the production of the main crops is utilized. In farm type 2 and 3, 70% and 89% of their available land is used respectively. Farm type 1, which is more affected by drought, uses most of its available land for crop production. This result may seem strange. However, since farm type 1 produces most of the warm weather crops such as sorghum, maize and groundnuts that are relatively less affected by moisture stress, its proportionally large amount of land use could be justifiable.

Table 7.27 Optimum production of outputs per farm type (tons/year): drought case scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	8948	28754	95362	133064
Maize 2	0	0	0	0
Sorghum 1	27518	21105	25902	74525
Sorghum 2	0	0	0	0
Wheat 1	38	5093	35358	40489
Wheat 2	0	0	0	0
Barley	0	819	13772	14591
Horse beans	0	890	5438	6328
Groundnuts	6123	0	0	6123
Potatoes	0	4776	12346	17122
Green pepper	374	0	0	374

For farm types 1 and 2, the proportion of land allocated to the different crops in the drought case scenario is similar to that observed in the base scenario. In farm type 1, the bulk of the land utilized for crop production is allocated to sorghum followed by maize and groundnuts. In farm type 2, the land allocated to maize by far exceeds the land assigned to the other crops. Sorghum and wheat are allocated second and third most land. Unlike the base scenario, in the drought case scenario most of the cultivated land of farm type 3 is allocated to maize production. The second and the third important crops in terms of area of cultivated land in this farm type are wheat and sorghum.

As discussed in section 7.8.1, output production in this scenario has been restricted to the fulfillment of the home consumption requirements of the rural and urban population of each farm type. The optimum output of each crop for each farm type, shown in Table 7.27, is exactly equal to the consumption requirements of the population of each farm type and of the zone (compare Tables 7.6 and 7.27). Hence, in this scenario, the specialization of farm types in a particular crop, as identified in the base scenario, cannot be observed. It will be very unlikely for farm types to specialize in the production of a certain crop, when no surplus products are produced, as in this scenario.

The share of each farm type in the total zonal output of the main crops did not change much from what was observed in the base scenario. This is especially true when we look at the optimum production of each crop in the zone. From the total output of sorghum to be produced in the zone, farm type 1 takes the largest share followed by farm type 3. Farm type 2 is the smallest contributor of sorghum in the zone. As far as maize is concerned, farm type 2 and farm type 3 are the largest producers while farm type 1 produces the smallest maize output in the zone. According to Table 7.27, the largest zonal wheat output is obtained from farm type 3. Farm type 2 and farm type 1 are the second and third contributors of the zonal wheat output respectively.

Variable inputs and draft power utilization

The optimum use of the variable inputs in the drought case scenario is shown in Table 7.28 and Table 7.29. Table 7.28 illustrates the optimum seed input use while Table 7.29 depicts the optimum use of fertilizers and biocides. These tables show the different variable inputs utilized only by the local varieties as the improved varieties of the crops do not appear in the optimal land use solution for the drought case scenario (see Table 7.26). At the zonal level, the amount of seed inputs of the main crops (maize and sorghum) used in the drought case scenario are greater than the amount observed in the optimal solution of the base scenario. This is related to the use of the local varieties of these crops that command lower seed cost in the drought case scenario.

As in the base scenario, a relatively greater amount of DAP than urea fertilizer is used in the drought case scenario. The herbicides used at zonal level once again exceed the pesticides use. However, unlike the base scenario, herbicides are used by farm type 2 and 3 and pesticides are utilized by farm type 1 and 3. Large uses of biocides are still linked to farm types 2 and 3 similar to the result for the base scenario. The uses of fertilizers as well as biocides have, as expected, significantly decreased in the drought case scenario relative to the base scenario situation. This is also the result of utilizing local varieties of the major crops for which the farmers do not apply much of these inputs, and it is also related to the planting of less land to the crops.

Table 7.28 Total seed input used by each farm type (tons/year): drought case scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	443	1701	3767	5911
Maize 2	0	0	0	0
Sorghum 1	1802	820	1113	3735
Sorghum 2	0	0	0	0
Wheat 1	23	653	3794	4470
Wheat 2	0	0	0	0
Barley	0	195	1508	1703
Horse beans	0	165	680	845
Groundnuts	490	0	0	490
Potatoes	0	950.5	757	1707.5
Green pepper	98	0	0	98

As Table 7.29 indicates, the optimum fertilizer use of the drought case scenario varies significantly among farm types. Relatively large uses of both DAP and urea fertilizers are observed in farm type 3. Farm type 1 utilizes the smallest amount of both DAP and urea fertilizers. This outcome is similar to the results of the base scenario.

Table 7.29 Total fertilizes and biocides used by each farm type (10^3 tons or liters/year)[1]: drought case scenario, 2001

Farm type	1	2	3	Zonal
DAP fertilizer	4.95	5.6	11.6	22.15
Urea fertilizer	4.3	5.8	11.7	21.8
Pesticides	0.021	0	0.2	0.221
Herbicides	0	0.2	0.048	0.248

[1] Fertilizer is measured in tons and biocides in liters

The draft power use at zonal level has decreased by 2% in this scenario as compared to the base scenario; only 15% of the total yearly available oxen power is used during the year in the zone. In no month is the entire monthly available oxen power been used at zonal level, similar to the result of the base scenario. As shown in Table 7.30, draft power use is relatively high in January, March and April for the entire zone. January and March were also months associated with high utilization of oxen in the base scenario. In January, the total zonal oxen-pair days used in the drought case scenario decreases by 16% from that of the base scenario. In March the reduction is 4%. This result is well expected as the total output and the total work done during a period of drought would undoubtedly be less. Similar to the result in the base scenario, the month of peak oxen use does not correspond to the month of peak labour use in the drought case scenario. June is the month with the largest use of agricultural labour. But intensive use of oxen is observed in the month of January. As stated earlier, such a result indicates that in the zone oxen are mainly used for threshing purposes.

At farm types level, farm type 1 shows an increase of 2% in the use of the yearly available oxen. This may correspond to the relatively large percentage of land that is cultivated in farm type 1 as compared to the other farm types in this scenario and the substantial rise in the production of maize, sorghum and groundnuts will also increase the need for oxen in this farm type. Farm type 2 and farm type 3 show a decrease in the use of their yearly available oxen in this scenario as compared to that of the base scenario.

This finding is identical to the solution observed in the base scenario and it corresponds well to the real situation in the zone with regard to oxen use as discussed in section 6.3.4.2 of Chapter 6.

Table 7.30 Oxen use by a farm type per month (10^3 oxen-pair days): drought case scenario, 2001

Farm type	1	2	3	Zonal
January	0	307	597.8	904.8
February	0	0	695.7	695.7
March	159.4	426.9	202	788.3
April	474.9	259.5	3.3	737.7
May	114.6	4.8	226.7	346.1
June	1.3	46	0	47.3
July	0.65	15.8	96.4	112.85
August	0	0	0	0
September	0	0	53	53
October	0	0	0	0
November	1.3	5.7	0	7
December	513.3	39.9	0	553.2
Total oxen-pair days	1265.45	1105.6	1874.9	4245.95

In farm type 1, December and April are associated with high usage of oxen-pair days. In these months, unlike in the base scenario, the available oxen-pair days are fully utilized in this farm type and additional 68,940.5 and 30,500.5 oxen-pair days are rented from farm types 3 and 2 respectively. Similar to the result in the base scenario, it is in March and January when a large degree of use of oxen-pair days is observed in farm type 2. In farm type 3 oxen use is high in February and January.

7.9 Results of the variants of the drought scenario

In this scenario a comparison is made between the case where farmers in East Hararghe Administrative zone continue with their traditional land use system and are faced with a drought vis-à-vis a case where the farmers adopt the optimum land use pattern of the base scenario and are faced with a similar drought. The result of this investigation is discussed in the two sections below.

7.9.1 Effect of drought on the current cropping pattern

In this section the results of the combination of the current land use patterns of the farmers in EHAZ and the drought case scenario are discussed. In here an attempt is made to investigate what will happen to the food situation in EHAZ if farmers continue to plant crops according to their current actual land use patterns and now suddenly face a serious drought of the type discussed in section 7.8. This investigation helps one to know whether or not there should be a change in the current land use system of the farmers in the zone in order to alleviate the problems of drought on the food security of the zone.

Consider a situation were the farmers in the zone used their land according to their accustomed way (Table 7.1) and planted crops according to their usual tradition. Now assume that a drought, similar to the one discussed in section 7.8, occurred during this production period in the zone. Then what will be the food situation and the economic surplus of the farm types in the zone at the end of this production season?

The changes in the total output that occurred in each farm type and in the entire zone under the occurrence of the assumed drought condition and with the traditional way of farming are shown in Table 7.31. There is a need to compare the minimum consumption requirements of the zonal population indicated in Table 7.6 with the total production shown in Table 7.31 in order to observe what the food situation can look like in the zone when farmers continue with their traditional farming practices and are faced with a drought.

Table 7.31 Total production of outputs per farm type (tons/year): combination of the current land use pattern and the drought case scenario, 2001

Farm type	1	2	3	Zonal
Maize 1	5320	23219	58154	86693
Maize 2	6899	6799	29716	43414
Sorghum 1	22087	34339	74501	130927
Sorghum 2	884	0	0	884
Wheat 1	492	15648	20763	36903
Wheat 2	0	1468	10045	11513
Barley	0	5493	14649	20142
Horse beans	0	469	3907	4376
Groundnuts	7372	0	0	7372
Potatoes	0	3200	47266	50466
Green pepper	537	0	0	537

The comparison between Tables 7.6 and 7.31 shows that under the traditional production pattern of the farmers in the zone and with the occurrence of drought East Hararghe Administrative Zone could not fulfill the total minimum consumption requirements of its population (rural and urban) for maize, the most important staple food crop of the zone, and for horse beans. Moreover, the economic surplus at zonal level shows a loss of 167 million Birr/year (Table 7.32). As is evident from Table 7.32 all the farm types are also incurring huge economic losses when farmers continue their traditional land use system and are faced with a drought. Besides, all the farm types are not also fulfilling the minimum consumption needs of their population for most of the crops locally. Farm type 1 is not able to satisfy the minimum consumption requirements of its population for sorghum, which is the second important food crop of the people. Farm type 2 shows a deficit for horse beans and potatoes whereas farm type 3 is not fulfilling the minimum consumption requirements of its population for the most important staple food crops of maize and wheat as well as for horse beans.

Table 7.32 Production economics results and income structure per farm type (10^6 Birr/year) and per farm household (Birr/year): combination of the current land use pattern and the drought case scenario, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Value of production	158	7.3	551	38.9	545	81	479	127.2
Input costs	1275	59	1266	89.3	981	146	1108	294.3
Gross margin	-1117	-51.7	-715	-50.4	-436	-65	-629	-167.1
Own labour	0	0	0	0	0	0	0	0
Return to land, own capital and management of farm	-1117	-51.7	-715	-50.4	-436	-65	-629	-167.1
Farm household income	-1117	-51.7	-715	-50.4	-436	-65	-629	-167.1
Economic surplus	-1117	-51.7	-715	-50.4	-436	-65	-629	-167.1

In contrast to the result in Table 7.32, when farmers adopt the optimum land use patterns of the base scenario, all the different farm types can make positive economic surplus and fulfill their consumption requirements without being much affected by the drought (Table 7.35). Therefore, it is evident that there are benefits in changing the present land use pattern of the zone in order to insure food security to the population of East Hararghe Administrative Zone and higher farm economic surplus.

On the other hand, it is important to make some comparison, at this junction, between the results obtained in section 7.8 under the optimization of the land use in the drought case scenario with the results mention in section 7.9.1. According to the optimum land use result of the drought case scenario, with only 85% of the zonal land put into use and with a remarkably minimum input costs, it was possible to produce the consumption needs of the total zonal population (rural and urban). However, in the case of looking into the effect of a similar drought (similar to the one discussed in section 7.8) on the present land use system of farmers in section 7.9.1, the minimum consumption needs of the total zonal population was not met for most crops and no income was generated at zonal level to finance the food deficits on top of incurring huge input costs.

Therefore, it will be extremely difficult to suggest that the present way of land use by farmers of the zone can symbolize efficient land use system given the lack of sufficient output for the consumption needs of the total zonal population, the lack of enough economic surplus to finance the food deficit, and the enormous pressure put on the zonal land and the environment.

7.9.2 Effect of drought on the base scenario optimum cropping pattern

This section presents the results obtained when combining the base scenario solutions with the drought case scenario. In here an attempt is made to investigate what will happen to the food situation and the economic surplus in EHAZ if farmers use their land and plant crops according to the results of the base scenario and are then faced with a serious drought of the type discussed in section 7.8.

Assume that through extension work the farmers in the zone are advised and convinced to use their land according to the optimum solutions of the base scenario. Then assume that after the planting of crops has taken place, a drought of the magnitude mentioned in section 7.8 has occurred and the yield per timad and/or hectare has reduced according to the percentages indicated in the drought case scenario (see section 7.8). Now what will be the food situation and the economic surplus in the zone after this condition?

The changes in the total output that occurred in each farm type and in the entire zone under the occurrence of the assumed drought condition after the adoption of the base scenario solutions are depicted in Table 7.33. To observe what the food situation can look like in the zone, we need to compare the minimum consumption requirements of the zonal population indicated in Table 7.6 with the total production shown in Table 7.33.

Table 7.33 Total production of outputs per farm type (tons/year): combination of base and drought case scenarios, 2001

Farm type	1	2	3	Zonal
Maize 1	4474	0	0	4474
Maize 2	0	169638	72544	242182
Sorghum 1	0	14147	19709	33856
Sorghum 2	69518	0	0	69518
Wheat 1	19	0	0	19
Wheat 2	0	3415	247521	250936
Barley	0	552	10488	11040
Horse beans	0	601	4130	4731
Groundnuts	3061	0	0	3061
Potatoes	0	3200	47266	50466
Green pepper	537	0	0	537

Based on this comparison, with the adoption of the base scenario optimum land use pattern and under the assumed drought condition, at zonal level, East Hararghe Administrative Zone was able to produce and fulfill the total minimum consumption requirements of its entire population (rural and urban) for the major food crops of maize, sorghum and wheat, as well as for potatoes and green pepper. It was only for barley, horse beans and groundnuts that the zone was not able to produce enough output to fulfill the minimum consumption requirements of the zonal population under the assumed severe drought condition. However, as the economic surplus generated in this condition is positive (Table 7.35) it will be possible for the zone to purchase the consumption requirements, which are not fulfilled in this drought situation.

Table 7.34 Production economics results per farm type (10^6 Birr/year) and per farm household (Birr/year): combination of base and drought case scenarios, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Value of production	1448	67	2424	171	1929	287	1977	525
Input costs	735	34	1035	73	665	99	776	206
Hired labour	0	0	255	18	0	0	68	18
Hired oxen	4	0.2	0	0	0	0	1	0.2
Gross margin	709	32.8	1134	80	1264	188	1132	300.8
Own labour	0	0	0	0	0	0	0	0
Return to land, own capital and management of farm	709	32.8	1134	80	1264	188	1132	300.8

The economic surplus that can be generated is 319 10^6 Birr per year (Table 7.35). As compared to the base scenario, it is lower by 51% but significantly higher than the one indicated in section 7.8 under the drought case scenario. This means that if farmers adopt the optimum solutions of the base scenario and adjust their land use system, East Hararghe Administrative Zone can still make a positive economic surplus even under severe drought condition let alone fulfilling its population's consumption requirements. There is also significant improvement with regard to the gross margin, the return to land, own capital and management of the farm as compared to the results shown in the drought case scenario (see Table 7.34).

Therefore, it is an exciting outcome that the adoption of the base scenario land use patterns would bring and contribute a lot to insure food security to the population of the zone while still enabling the farming community to generate higher economic surplus (Table 7.35) as compared to the traditional land use practices of the zonal farmers (Table 7. 32) even under the occurrence of severe drought. Moreover, as the zone will be able to finance the purchases of its unfulfilled consumption requirements through the internally generated economic surplus, this will reduce the burden on the government with regard to the provision of subsidy to the zone in case of drought unlike the result observed in section 7.9.1.

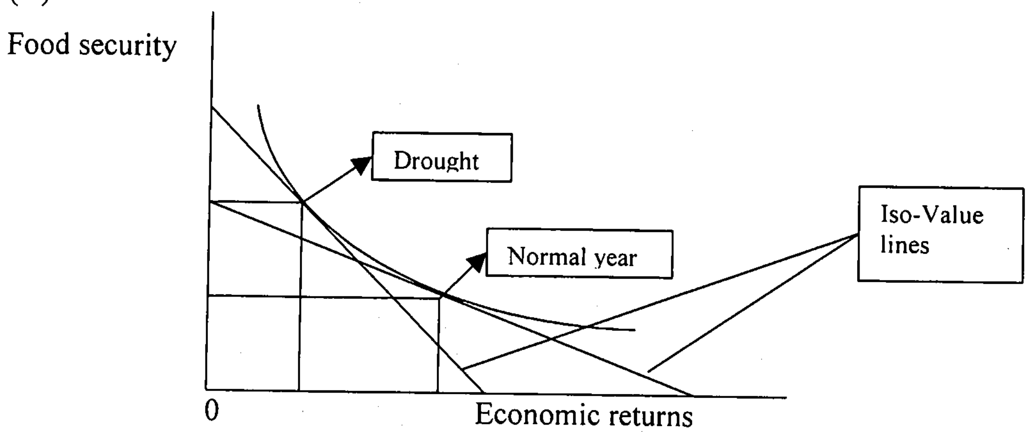
Table 7.35 Income structure per farm type (10^6 Birr/year) and per farm household (Birr/year): combination of base and drought case scenarios, 2001

Farm type	1		2		3		Zonal	
	Per HH	Total	Per HH	Total	Per HH	Total	Per HH	Total
Gross margin	709	32.8	1134	80	1264	188	1132	300.8
Work on other farms	237	11	0	0	47	7	68	18
Oxen-rent income	0	0	3	0.2	0	0	1	0.2
Farm household income	946	43.8	1137	80.2	1311	195	1201	319
Own labour	0	0	0	0	0	0	0	0
Economic surplus	946	43.8	1137	80.2	1311	195	1201	319

However, there is a need to make a remark at this junction with regard to the food security issue in the zone. In the EASTHAR model it was implicitly assumed through the food self sufficiency constraint (minimum consumption requirement) that farmers in the zone will prefer food security, or at least some degree of food security, over economic returns. If food is scarce all over Ethiopia (perhaps all over North East Africa), the additional income generated in the base scenario under drought may possibly not secure food (transport and trade infrastructure not really sufficient for large scale imports and Ethiopia is a land-locked country).

One can argue that in a drought year, farmers will play safe - sacrifice some economic return for food security. This can be illustrated in a way similar to the income vs. leisure theme - indifference curves (Groenewald, 2003). In a drought year, the subjective value of food security over that of economic return becomes larger than in a normal year - thus a steeper slope for the iso - value line (Figure 7.1 A).

(A)



Or since more of both is possible in a normal year, the choice can resemble the one shown in Figure 7.1 B.

(B)

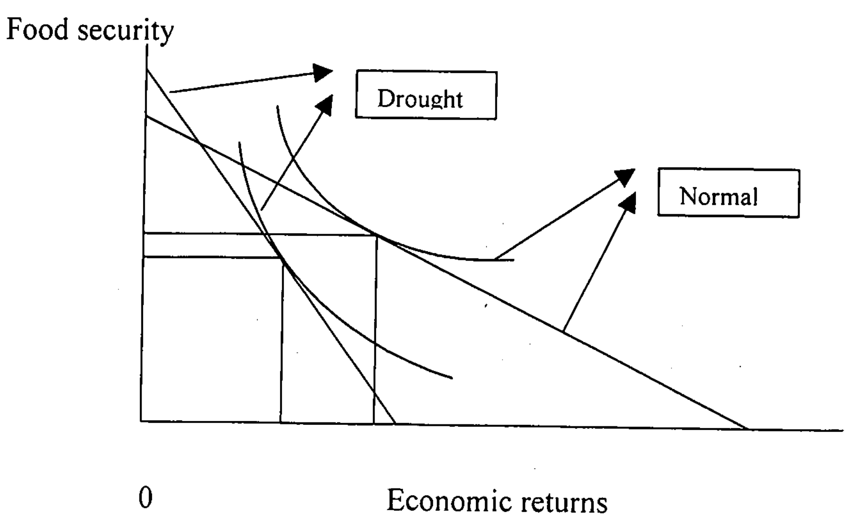


Figure 7.1 Trade-offs between economic returns and food security

7.10 Comparison of the different scenarios

The economic surpluses of the different scenarios are summarized in Table 7.36 for ease of comparison. The valuation of the household labour (opportunity cost scenario) reduces the economic surplus by 33% as compared to the base scenario while drought causes an economic loss. However, if drought strikes the zone, the economic surplus that can be generated is much higher when planting of crops commences according to the base scenario as compared to when planting is done according to the present land use. The economic surplus at zonal level shows a loss in the latter case. This signifies the need for a change in the present land use pattern in order to insure food security to the population of East Hararghe Administrative Zone through higher farm economic surplus.

Table 7.36 Economic surpluses of the different scenarios (10^6 Birr/year), 2001

Farm type	1	2	3	Zonal
Base scenario	152.8	182.2	311	646
Opportunity cost scenario	124.8	113.2	192	430
Drought case scenario	-33	-32	-58	-123
Base scenario after drought	43.8	80.2	195	319
Present land use after drought	-51.7	-50.4	-65	-167.1

7.11 Summary and conclusion

This chapter presented the analysis, results and discussion of the land use model of the study area. The basic elements of the land use model appear in section 7.2. It included the total land resource, the total household labour and the total draft power available for the production of the eight main crops in the zone. These resources were the main ingredients of the EASTHAR model. In addition to this, the consumption requirements of the rural and urban population of the different farm types, the land constraints that need to be imposed for some crops, and the assumptions and principles underlying the valuation of farm labour input were briefly discussed in this section.

Section 7.3 was devoted to the specification of the land use model using the GAMS programming language. GAMS is an algebraic modeling language that helps to formulate, analyze and solve large mathematical programming problems such as the mathematical specification of cropping patterns in agriculture. In line with this, the section discussed the use of the GAMS software to analyze the land use model of the study area and the EASTHAR-model was written and presented extensively in the GAMS programming language.

The most important objectives of the land use model of East Hararghe Administrative Zone-EASTHAR has been the development of a research model that can be utilized for land use analysis at a sub-regional level and to test the model through the evaluation of the effects of changing trends in land use determinants on land use decisions. As elaborated in section 7.5, the land use model developed in this study helps to make land use related policy recommendations at sub-regional level and can also be extended to the regional and national levels.

As explained in this chapter, a land use model that is developed to evaluate land use decisions should be a model that represents as closely as possible the situation of the farm households. Based on this standing, section 7.5 through 7.8 presented the analysis and results of the land use model of East Hararghe Administrative Zone-EASTHAR which is based on the data collected from farm households of the zone and described the optimum solutions of the model for the study area under three different scenarios. Scenarios where incorporated in this study because, as argued in section 7.4, the effects of changes in factors that influence land use decisions are studied in scenarios. The outcome of a scenario is then compared with the solution in the base scenario.

Section 7.6 presented the results of the base scenario. In this scenario, each of the three farm types in the model can choose from the available land, land use types and input combinations as gathered during the survey. The results indicated that, under this base condition, the value of the objective function, or the economic surplus, is positive for the entire zone, for the different farm types and for the farm households. The model has explicitly indicated how land has to be allocated to the different crops at zonal level and at each farm type level. The most important staple food crops of the population of the zone are all incorporated in the optimum land use. The optimum labour, variable inputs and draft power utilization are also indicated. The results have shown that in the optimum solution, land use is dominated by maize and sorghum production at zonal level. This matches with the real situation in the zone as these crops represent the dominant staple food items of the zone's population. Within the optimum solution for the entire zone, the result has also shown the potential for specialization among the different farm types in the zone.

In the modeling exercise, the results of the base scenario were compared with the results of an opportunity cost scenario (Section 7.7). The opportunity cost scenario differed from the base scenario due to the valuation of the on-farm household labour at a reservation wage of 60% of the wage rate for hired labour in the zone. The assumption of a reservation wage is justified because of the forgone opportunity of working in other jobs or to reflect the preference for leisure of a farm household. The zonal economic surplus in the opportunity cost scenario is 33% lower than in the base scenario. The valuation of the on-farm household labour thus has a negative effect on the incomes of the farm households. However, land use as well as labour, variable input and draft power uses did not change from that of the base scenario. This shows that the mere valuation of the on-farm household labour will not automatically disturb land use decisions. Hence, at least as formulated in EASTHAR, linear programming can be a useful technique to explain land use.

Comparison of the base scenario with a scenario of an assumed drought condition is outlined in section 7.8. The drought case scenario tries to analyze the consequences for land use in case a serious drought occurs in the study area. Drought is a recurring problem in Ethiopia. The results of the analysis indicate that almost every land use defining variable is subject to change when drought occurs. According to the results of the drought case scenario, it can be said that the trade-off between a reduction in yield per unit of land as a result of a decline in rainfall, and the economic surplus is unfavorable.

These results have explicitly made it clear that in subsistence agriculture, which is solely rain fed, a decline in the annual rainfall will undoubtedly lead to large reductions in the income of the farming population.

In the drought case scenario there was no economic surplus generated at any of the farm type levels, at household level and thus, automatically, neither at the zonal level. The value of the objective function, or the economic surplus, showed a large loss at all levels. The arid farm type, farm type 1, was severely affected by the drought condition and incurred the largest percentage loss in economic surplus in comparison with the figures in the base scenario. However, the home consumption requirements of the farming population were met at household level, at each farm type level and at the zonal level. The amount of output sold was only equal to the consumption requirements of the urban population of each farm type. Under such drought condition it was not possible to produce surpluses over and above the consumption requirements of the rural and urban population of each farm type.

Land use, labour use, variable input use and draft power use in the drought case scenario differ considerably from the base scenario. Unlike the base scenario, the total zonal land that is available for the production of the main crops couldn't be fully utilized and only the local varieties of the three main crops were incorporated in the optimum solution of the drought case scenario. The overall yearly zonal household labour use is seen to have increased slightly in the drought case scenario as compared to the base scenario while labour transfers between farm types were much restricted in the drought case scenario. Seed input use has increased slightly in the drought case scenario due to the use of local varieties of crops that have lower seed cost. However, the use of fertilizers as well as biocides have significantly decreased in the drought case scenario relative to the base scenario which is also the result of utilizing local varieties of the major crops for which the farmers do not apply much of these inputs in their production, and also is related to the planting of less land to the crops than observed in the base scenario. At zonal level, draft power use has decreased in the drought case scenario as compared to the base scenario.

Section 7.8 has also outlined the policy options that need to be considered in case of the occurrence of a drought of the present nature in the zone. According to the optimum solutions of the drought case scenario, two policy options were discussed in this section. The first option is that if the farmers should be able to produce the amount of their consumption requirements, then there is a need to subsidize them to the amount of their lost gross margins. The second policy option, which is not supported by the researcher, is to fully supply their consumption requirements as food aid and cease production all together under such a drought condition.

In section 7.9 a comparison is made between the case where farmers in East Hararghe Administrative Zone plant crops according to their traditional land use system and are faced with a drought vis-à-vis a case where the farmers adopt the optimum land use pattern of the base scenario and are faced with a similar drought. This comparison revealed that the adoption of the base scenario land use patterns would bring and contribute enormous to insure food security to the population of EHAZ while still enabling the farming community to generate higher economic surplus as compared to the traditional land use practices of the zonal farmers even under the occurrence of severe drought.

CHAPTER 8. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS[1]

8.1 Introduction

This study involves a linear programming approach to land use analysis. The study aims at developing and applying a model for land use analysis in order to identify a form of land use that provides sufficient and rising incomes to the agricultural population of East Hararghe Administrative Zone, and at the same time maintains the productive capacity as well as other environmental services of the land resources of the zone.

This chapter provides a summary of the main points of each chapter. The chapter also provides conclusions and recommendations regarding the proposed approach for land use analysis.

8.2 Summary

8.2.1 The research problem

The study started with the elaboration of the problem statement, objectives, hypothesis and significance of the study in Chapter 1.

8.2.1.1 Problem statement

East Hararghe Administrative Zone has a higher agricultural potential and better natural resource endowment compared to other areas of the Oromia region in Ethiopia. However, the closure of the gap between the zonal crop production and the population growth is not attained despite a substantial expansion of cropland in the zone. This shows the existence of numerous deficiencies in the land use system of the zone for attaining food crops self-sufficiency in conformity with the needs of the ever-increasing population of the zone.

[1]Conclusions and recommendations must be interpreted with proper cognizance of the assumptions of the study. For instance risk aversion behaviour of farmers was not explicitly taken into account in the model specification.

In the zone, land use needs to change to meet new demands. There is a need to focus on the efficient utilization of zonal potential resources, especially land. In some areas of the zone various problems have prevented the use of large parcels of potentially productive land. Moreover, most agricultural producers of the zone are subsistence farmers with smallholdings, often divided into several plots. Most of these farmers are squeezed into and live on the highlands. Therefore, there is an urgent need to closely investigate the land use systems of the farming community of the study area in order to come up with an optimum and efficient land use pattern that would overcome the acute land shortages as compared to the ever-increasing population of East Hararghe Administrative Zone.

8.2.1.2 Objectives of the study

The major objective pursued in this study is to develop and apply a model for land use analysis that aims at a form of land use that provides sufficient and rising incomes to the agricultural population of East Hararghe Administrative Zone, and at the same time maintains the productive capacity of the land.

The specific objectives of the study were to:

1. Build a farm and a sub-regional level linear programming model in land use analysis, for East Hararghe Administrative Zone, which can also be applied in other zones and at the national level
2. Classify farms into different farm types according to their farming operations and on the basis of their agro-ecological zones
3. Determine whether the current land use system makes the best use of the limited resources through the application of optimization techniques so as to come up with an optimal land use as well as a cropping pattern in view of accepted objectives, opportunities and constraints.
4. Make policy recommendations that can help to move from the existing situation to the optimal and sustainable land use system.

8.2.1.3 Research hypothesis

The research hypothesis that guided the investigation in this study stated that:

The current land use system of the farming community in East Hararghe Administrative Zone does not allow optimal and best use of the limited zonal resources. Through the development and application of a research model for land use analysis that utilizes optimization techniques, it is possible to assess the current levels, manner and combinations in which the land as well as other resources in the zone are used and formulate an optimal land use system and cropping pattern in view of accepted objectives, and of environmental and societal opportunities and constraints.

8.2.1.4 Importance of the research

Most of the agricultural economics research activities in Ethiopia have so far focused and been conducted in a very narrow geographical location such as in a single district. This approach may lack the ability to indicate what is needed for an improvement in broader community development and policy formulation at regional, national and country level and could be unable to show sub-regional potentialities.

This study was initiated to address the above issues by focusing on a wider research domain with quite broader, tangible and primary data based research, and with the aim of developing a land use model at a sub-regional level. The study included fourteen districts. Therefore, this research is probably the first of its kind in Ethiopia and will provide contributions in widening the research outlook of agricultural economics researchers in the nation, and thereby enhancing national agricultural development. The model and the outcome of the study will also play important roles in formulating sub-regional, regional or national agricultural policies and thereby helping policy makers in overcoming fragmented action plans to upgrade the living standard of the rural community.

8.2.2 The research approach

The sequences and / or the approaches followed in conducting the present study are explained in Chapter 2 and summarized under the headings below.

8.2.2.1 Identifying research problem

The identification of the research problem for this study was conceived after observing the ever-increasing recent concerns for land use around the globe as well as in Ethiopia. Some of these concerns include: Are the land and water resources able to supply sufficient products to sustain a growing population and provide the agricultural population with sufficient as well as increasing incomes?

In Ethiopia, a continuous redistribution and reallocation of individually cultivated land occurs among members of the rural farming community for the purpose of ensuring that the would-be-farmers or the newly formed households could get land. This automatically leads to extreme fragmentation of land, which could actually reach a point of no economic significance in terms of agricultural production. Hence, there is a shortage of cultivated area in many parts of Ethiopia, particularly in the highlands, of which East Hararghe is one.

In view these concerns, the researcher was convinced of pursuing an economic analysis of land use in the study area in order to deal with the acute land shortages as compared to the ever-increasing population of the area as well as the country.

8.2.2.2 Selecting study area

The selection of the study area was based on the following arguments and reasons:

1. First and foremost, the study was planned to be conducted on a wider geographical area, such as a sub-region, for the very reasons that are explained in Chapter one. Such a

wider research perspective has got its own relevance, particularly when it comes to land use analysis and agricultural economics research activity, and the reader is referred to Chapter 1 for a better understanding of the importance thereof. As a result, in comparing different sub-regions for the purpose of selecting a study area, East Hararghe Administrative Zone was found to possess the advantage of being close to the vicinity of the work place of the researcher, Alemaya University. Consequently, it was found convenient in terms of arranging transport facilities, obtaining skilled enumerators and for other logistical purposes.

2. All three prominent agro-ecological zones of Ethiopia (which are elaborated on in Chapter 3) are found in East Hararghe Administrative Zone. This renders the zone to be representative of the country, as far as agro-ecological zones are concerned, and enables the stratification of farms into separate farming systems based on agro-ecological zones and analyze the land use accordingly. Moreover, the model of the study could be applicable countrywide as it is based on data collected from all the prominent agro-ecological zones of the nation.

3. East Hararghe Administrative Zone is one of the most populous administrative zones of the Oromia region in Ethiopia. It is the fourth most populous zone in the region. Moreover, in terms of agricultural production it is the leading zone in crop production consisting of large areas of cropped land. This makes East Hararghe Administrative Zone suitable for land use study owing to the large number of the population living in rural areas that solely depend on the land (through farming) in obtaining its livelihood.

8.2.2.3 Conducting literature study

An extensive literature study was conducted by consulting a wide variety of books, journal articles, dissertations and other relevant documents, in order to determine a research model to be used in the study, to obtain a theoretical framework for questionnaire development, and to compare and substantiate the present theme of land use analysis with previous similar research activities.

8.2.2.4 Determining the model to apply

After a thorough study of the literature, a model for land use analysis was developed. A linear programming optimization model was found suitable for this study. This is because farmers, agronomists, and other agricultural specialists share a somewhat similar way of thinking about agricultural inputs and outputs in terms of the annual crop cycle, and about input-output coefficients per unit of land. Yields are conceived of in tons per land unit, and fertilizer applications in kilograms per hectare or similar units. In farm-level cost of production studies, input costs are typically disaggregated into labour, machinery services, draft animal services, fertilizer costs, other chemical costs, credit costs, etc., per land unit. This way of visualizing agricultural production in numbers is a short step to forming the column vectors of inputs and outputs that constitute the backbone of the linear programming model.

Similarly, agriculturalists often pose their problems in terms of inequality constraints, such as upper bounds on seasonal resource availability. And they are accustomed to the existence of surplus resources in some seasons while the same resources may be fully utilized in other seasons. This kind of thinking fits naturally into an analysis via programming models. This led to the choice of a linear programming model for land use analysis at farm and zonal levels.

8.2.2.5 Developing questionnaire

Both primary and secondary data were used. The primary data was collected from the study area through a farm survey by utilizing structured questionnaires. The questionnaire was intended to obtain primary information concerning present land use such as farm size, crop types, farm labour, material inputs, animal power, outputs of crops, levels of costs and incomes, prices of inputs and outputs, and current farm problems in the study area.

8.2.2.6 Sampling

In order to conduct the survey in the zone it was necessary to identify the number of districts and peasant associations in the zone. There was also a need to identify the number of farm households, total population and total land use at each district level. This preliminary information was obtained from the zonal agricultural head office and respective district agricultural offices.

The study area, eastern Hararghe administrative zone, comprises 15 districts, which are subdivided into 417 Peasant Associations (PAs) and 17 urban kebeles. The study covers 14 of these districts. The investigation excludes the district called Golaoda due to its remoteness and security problems, which made the collection of data from the district virtually impossible.

Based on this information, 15 sample farmers were randomly selected from a randomly chosen peasant association in each of the fourteen surveyed districts in the zone and the total sample consisted of 210 farmers.

8.2.2.7 Conducting fieldwork

The fieldwork started with the activity of pretesting the questionnaire. This was successfully conducted and some relevant modifications were incorporated into the final questionnaire based on the information grasped through the pretesting activity.

In launching the actual survey enumerators were employed in order to assist the researcher in conducting interviews with the sample farmers. The enumerators were trained by the researcher to familiarize them with the content of the questionnaire and the basic theme of the research work. This task has been accomplished successfully and the fieldwork was conducted in the year 2001/2002.

8.2.2.8 Analyzing the data

Following the data collection, the data were coded and entered into the Excel worksheet and subsequently into the GAMS linear programming computer package. As a preliminary step of data analysis, a descriptive analysis of the surveyed data was done by using percentages, means, maximum and minimum values. In addition to this, various tables and figures were employed in order to present summary statistics of information with regard to the extent, availability, and intensity of the use of land, material inputs, human labour, animal traction, outputs of crops, prices of inputs and outputs, and levels of costs and incomes. Moreover, information on the relative importance of the major crops in each district, the climatic conditions, natural resources, development status, and aspects of human and livestock population were thoroughly described.

The major part of the data analysis was done by developing a linear programming land use model and applying the GAMS computer programme. The model is referred to as a sub-regional land use model that can be classified as an agricultural sector model as it is formulated for the agricultural sector of the study area. The land use analysis, which is based on the linear programming model, aims at deriving relevant land use options by balancing economic criteria for agricultural production with ecological criteria.

8.2.3 The study area

The description of the study area was presented in Chapter 3. The home country of the study area, Ethiopia, possesses a land area of about 1.2 million square kilometers. It has a population of 67.2 million, of which the majority, approximately 88%, lives in the rural areas. Ethiopia has a temperate climate in the highlands where the average temperature is about 20 degrees Celsius and its lowland areas are hot with temperatures averaging 35 degrees Celsius. There are two rainy seasons in the country, light rains from February to March, and the summer rains from mid June to mid September.

East Hararghe Administrative Zone is located in the eastern part of the country. This zone is divided into 15 districts, which are again sub-divided into 417 peasant associations and 17 urban kebeles. Three major climatic regions prevail in the zone, namely the arid climate, the tropical climate and the tropical highlands. The landforms of East Hararghe Administrative Zone are separated into highlands and lowlands. The largest proportion can be categorized as arid and semi-arid climate. Two main drainage basins, namely the Wabishebele drainage basin and the Awash drainage basin exist in the zone.

The land use pattern of the zone is correlated with its population distribution. The highland parts are densely populated as compared to hot lowlands and as a result the land utilization in the highland parts of the zone is intensive. The zone is divided into three major production regions:. the mixed farming region, the pastoral region and the transitional region. The mixed farming region accounts for about 40% of the total zonal area. Pastoral areas account for about 50% of the zonal area. The transitional zone where lowland pastoralism is practiced side by side with mixed farming makes up 10% of the total area of the zone.

Different types of crops of which cereals shared a larger proportion of the total cultivated areas occupy the crop area of East Hararghe Administrative Zone. The major portion of the cropped land is occupied by sorghum, maize, wheat and barley. In general the area under major crops accounts for about 16% of the total zonal area.

8.2.4. Findings and results

8.2.4.1 The literature study

In Chapter 4 a literature study with regard to land use analysis was undertaken. Various concerns have recently been expressed about present and future land use. Some of the frequently asked questions with respect to this concern over the land use are: Are the land (and water) resources of the earth able to supply sufficient products to sustain a growing population and provide increasing incomes to the agricultural population? Will the land and water resources be able to maintain their productive capacity over time, and provide sufficient living space and environmental amenities?

Land resource and land use was assessed from a global point of view and this helped the understanding and investigation of the nature of the above concerns. The unique characteristics of the land resource have been duly studied. Agriculture is an activity that modifies the natural environment for the purpose of enhancing the flow of goods and services from natural resources. These modifications could trigger the impairment of the long-run potential of the land to sustain production of agricultural goods and services and impair the flow of other goods and services from the land, air, and water.

The problems associated with the use of the land resource, amid the ever-increasing population of the developing countries were investigated. Similarly, an extensive study was carried out to introduce the agricultural sector, the land resource and the land use practice in Ethiopia. The agricultural sector in Ethiopia is almost entirely dominated by small-scale, resource-poor farmers who produce 90 to 95 percent of all agricultural outputs. The problems of small-scale agriculture include the use of traditional technology of low productivity, extension services that are inadequately funded, a shortage of oxen for cultivation, and shortages and poor distribution of agricultural inputs.

Some economic theories that facilitate the understanding of the concept of land use and land use analysis were also reviewed. In addition to other resources, the use of land, and especially the limitations of land in relation to population growth, is one of the concerns of resource economics. As a branch of resource economics, land economics is also concerned with the allocation and use of scarce resources, chiefly the land resource. The issues of property rights need also to be properly addressed to facilitate the better use of scarce resources. The absence of a fully articulated and enforced property rights regime will lead to the free rider problem and inefficient resource allocation.

Sustainable development is defined as a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. However sustainability is a difficult concept when viewed in terms of its operational usefulness owing to the great difficulty in measuring environmental damages and changes, the often enormous margins of errors associated with the attempt to quantify variables such as soil loss due to erosion and the like, and the often unclear assertions regarding the ethical issues surrounding the obligations of the present generations to future generations.

Some of the methods used in land use analysis and planning were also examined. The concepts of regional agricultural planning, land evaluation and farming system analysis have been studied. Land use analysis, which is conducted at regional and sub – regional levels, is an important component that helps in regional agricultural planning. As a method of land use analysis, land evaluation focuses on the potential uses of land, for example, the potential for the production of certain crops, and it looks at future possibilities for the use of land, which is an important dimension of land use planning. Similarly, farming systems analysis diagnoses the present situation with regard to farming and land use, and gives insights into possible and necessary improvements in the existing ways of farming.

The study of the applications and importance of linear programming models in land use analysis consisted an important component of the findings in the literature study. Mathematical programming, including linear programming, has become an important and a widely used tool for economic analysis in agriculture. Its use has been facilitated by major advances in computing technology and in methods of incorporating observed institutional and economic reality into programming models.

8.2.4.2 The research methodology

The literature study formed the basis of the research model utilized in this study as described in Chapter 5. The discussions of the conceptual framework of the land use model started with the elaboration of the different levels of land use analysis. This was followed by the discussion of linear programming as a tool for land use analysis. The different parts of the zonal linear programming model were discussed under the headings of objectives, variables and constraints. This was followed by the general formulation of the land use model of the zone called EASTHAR.

This linear programming land use model of East Hararghe Administrative Zone (EASTHAR) consisted of 27 equations. After giving the complete specification of the model, the necessary and desirable elements of the model as well as the symbols used in the model were defined in the tables that followed the model.

8.2.4.3 Description of surveyed data and farm classification

The survey results and the classification of the sampled farms in the study area into farm types are presented in Chapter 6.

The grouping of farms into farm types provided an understanding of the differences that exist among farm types with regard to land use and income distribution. Grouping the universe of farms into a smaller number of homogeneous groups or farm types is justified, as it is not feasible in practice to model each individual farm. The sampled farms in East Hararghe Administrative Zone were grouped into three farm types on the basis of agro-ecological classification of the surveyed districts and peasant associations.

Summary statistics of the surveyed data covered the extent, availability, and intensity of the use of land, material inputs, human labour, animal traction, outputs of crops, prices of inputs and outputs, and levels of costs and incomes of the sampled farmers. Information on the relative importance of the major crops in each farm type and district, and household demographic features were also discussed.

The survey results showed that the land holdings of the farmers in zone were scattered among all types of soils. Each farm contains farm plots of the main soil types in the zone. The total land available for farmers was found to be very small. The 210 farmers included in the study possessed a total of only 174 hectares of land for agricultural production as well as for other uses.

The family composition is scattered among all age groups. Most of the sampled households in East Hararghe Administrative Zone have large family sizes. Household labour use is dispersed throughout the year in the zone. However, June is the month of peak household labour use followed by the month of May. August is also a month in which most weeding (particularly for wheat and barley) and some harvesting (for horse beans and potatoes) operations are performed thus commanding relatively large amounts of household labour use. The sample farmers in East Hararghe Administrative Zone do not hire much labour. Only 30.6% of these farmers have hired labour in the 2001 production year. The remaining (69.4 % of the farmers) rely solely on household labour to produce their crops. Off-farm household activities are also extremely limited in the zone. Around 60% of the sampled farmers in the zone do not pursue off-farm employment opportunities.

In the survey, the use of agricultural inputs in East Hararghe Administrative Zone was found to be minimal. The sampled farmers in the zone plant improved varieties of maize, sorghum and wheat. The results of the survey indicated that the yields obtained from improved varieties significantly exceed those obtained from local varieties for all crops at both zonal and farm type levels.

The investigation indicated that most of the non-crop earnings of the sample farmers come from livestock. According to this study, more than 54% of the sampled farmers of the zone keep livestock for earning additional cash income through the sale of live animals or animal products. Farmers in East Hararghe Administrative Zone face a multitude of problems. According to the results of the survey, at zonal level, the lack of capital, the lack of enough agricultural land and the lack of adequate rainfall are the most severe problems. Poor soil fertility, and crop diseases and insects are also among the pressing problems of the farmers of the zone.

8.2.4.4 EASTHAR model results

The analysis, results and discussion of the sub-regional land use model of the study area-EASTHAR are presented in Chapter 7. The basic elements of the land use model included the total land resource, total household labour and total draft power available for the production of the eight main crops in the zone. These resources were the main ingredients of the model. The home consumption requirements of the rural and urban population of the different farm types, the land constraint needed to be imposed for some crops, and the assumptions and principles underlying the valuation of farm labour input were other important ingredients of the model. The EASTHAR model was analyzed by using the GAMS computer programme after it was formulated in the GAMS programming language.

The most important objectives of the land use model of East Hararghe Administrative Zone-EASTHAR has been the development of a research model that can be utilized for land use analysis at a sub-regional level and to test the model through the evaluation of the effects of changing trends in land use determinants on land use decisions. The basic results of the model indicted that the land use model developed in this study has yielded successful land use analyses that can aid in the formulation and recommendation of policy measures that can be utilized to rectify the land use system in the sub-region as well as in the region and the nation.

The specific results and the optimum solutions of the model for the study area were presented in three different scenarios. The results of the base scenario indicated a positive value of the objective function, or the economic surplus, for the entire zone, for the different farm types and for the individual farm households. The model explicitly indicated how land has to be assigned to the different crops at zonal level and at each farm type level. The most important staple food crops of the population of the zone are all incorporated in the optimum land use. The optimum labour, current inputs and draft power utilization have also been indicated together with the optimum land use. The results have shown that, in the optimum solution, land use is dominated by maize and sorghum production at zonal level. This corresponds with the real situation in the zone as these crops represent the dominant staple food items of the population of the zone. Within the optimum solution for the entire zone, the result has also shown the potential for specialization among the different farm types of the zone.

A comparison of the results of the base scenario with the results of an opportunity cost scenario represented an important outcome of the model. The opportunity cost scenario differed from the base scenario in the valuation of the on-farm household labour at a reservation wage of 60% of the wage rate for hired labour in the zone. The zonal economic surplus in the opportunity cost scenario is 33% lower than in the base scenario. The valuation of the on-farm household labour thus has a negative effect on the incomes of the farm households. However, land use as well as labour, current input and draft power uses did not change from those of the base scenario. This shows that the mere valuation of the on-farm household labour will not automatically disturb land use decisions. Hence, at least as formulated in EASTHAR, linear programming can be a reliable technique to explain land use.

An interesting outcome was obtained when comparing the results of the base scenario with the results of a scenario of an assumed drought condition. Drought is a recurring problem for Ethiopians especially the rural population. The results of the analysis indicated that almost every land use defining variable is subject to change when drought occurs as compared to the base scenario. Based on the results of the drought case scenario, the trade-off between a reduction in yield per unit of land as a result of a decline in rainfall, and the economic surplus is unfavorable. According to these results, in a subsistence agriculture which is solely rain fed, a decline in the annual rainfall will undoubtedly lead to large reductions in the income of the farming population.

The results of a comparison made between the case where farmers in East Hararghe Administrative Zone plant crops according to their traditional land use system and faced with a drought vis-à-vis a case where the farmers adopt the optimum land use pattern of the base scenario and face with a similar drought was also presented. This comparison revealed that the adoption of the base scenario land use patterns would bring and contribute enormous to insure food security to the population of EHAZ while still enabling the farming community to generate higher economic surplus as compared to the traditional land use practice of the zonal farmers even under the occurrence of severe drought.

8.3 Conclusions

The major findings and results that can be concluded from the present research are:

- As formulated and analyzed in the EASTHAR land use model, linear programming models can be used as a tool for land use analysis. The constituent parts of linear programming models, such as objectives, options and constraints, fit into the idea of searching for the best land use. However linear programming models have some drawbacks. For example, these types of models can be biased towards land use types that have high profits irrespective of the importance of the products to the land user. In the EASTHAR model this problem was tackled by constraining the maximum land area that can be assigned to these kinds of land use types.

- The land use model developed in this study has yielded successful land use analysis. Since the EASTHAR model is a linear programming model, it is possible to include many land use types, each with a number of technological options. Because it is a model for the sub-regional level (incorporating different farm types), it permits a more detailed formulation than models for higher (e.g. regional, national) levels of analysis. Moreover, the allocation of land to the most important crops, in order of their importance in the zone, indicates that the land use model which is developed to aid land use analysis at sub-regional level is proved to be a satisfactory representation of the farming practices in the zone. This is a valuable outcome that undoubtedly helps in the formulation and implementation of policy measures that can be utilized to put right the land use system in the sub-region.

- Under a normal production year (like the base scenario case), the EASTHAR model has been effective in facilitating and showing future land use decisions and options in East Hararghe Administrative Zone at the zonal, farm types and farm household levels. Given yields, input use, and the relative input and output prices, in the optimum solution of the base scenario, land use is dominated by maize and sorghum production at zonal level. This result supports the real situation in the zone as these crops represent the dominant staple food items of the population of the zone. The results of this scenario have also explicitly pointed out the potential for specialization that can exist within the zone.

- Resource availabilities, particularly land and labour significantly influence land use decisions. However, the mere valuation of the on-farm household labour, for the purpose of taking into account its opportunity cost, will not automatically disturb land use decisions.

- Land use decisions can be highly influenced by natural calamities such as drought. The results of the EASTHAR model indicated that almost every land use defining variable was subject to change when drought occurs in the study area. In the drought case scenario there was no economic surplus generated either at each farm types level or at the zonal level and hence the farmers cannot even produce the amount of their home consumption requirements unless subsidized with the necessary farm inputs.

- The comparison of the base scenario land use options and the traditional land use systems of the farmers of the zone in case of drought shows that the adoption of the base scenario land use options could withstand firmly the occurrence of severe drought and still yield higher farm incomes.

8.4. Recommendations

8.4.1 Policy recommendations

The under listed policy interventions need to be made by the government for the adoption of the research outcomes of the present study.

1. There is a need to implement the land use alternatives envisaged in the optimum solutions of the base scenario in view of the need for the alteration of the present poor income earning capacity of the farm households of the zone and for a better environmental impact of the cropping activities.

2. Implementing the land use outcomes at sub-regional level through the participation of the farmers of the zone and the realization of the results of the zonal land use model would require a convincing policy framework and effective extension activity that aim at explaining the merits and demerits of adopting the proposed land use patterns to the farming community.

3. Needless to say also that the realization of the base scenario outcomes that illustrated the optimum land use patterns in the zone would largely require a thorough analysis of the marketing prospects for the land use types whose optimum production can be in excess of the absorbing capacity of the zone.

4. The results obtained from analyzing the drought case scenario and the traditional land use system of farmers in case of drought have revealed the amount of farm support that might be required in case of a drought condition of the present nature in the study area. Under the drought case scenario, each farm type was able to produce the amount of grain required for home consumption of its population residing both in the rural as well as in the urban areas. In the process of producing these consumption requirements, the farms have incurred large input costs for which they can't pay. Because of the smallness of the sold produce and due to the lack of surplus output, the gross margins as well as the

economic surplus have become negative. This outcome suggests two important solutions from which we must choose:

a) The first solution is that if the farmers should be able to produce the amount of their consumption requirements and ensure their food security, then there is a need to subsidize them to the amount of their lost gross margins. Farmers must also be encouraged to save and have financial reserves for unforeseen adverse production conditions through the establishment of appropriate saving institutions to limit the subsidy. It may also be necessary for the government to approach donors to contribute to the subsidy, as this contribution will hopefully be lower than the cost of food aid in monetary terms.

b) The second policy option is to fully supply their consumption requirements as food aid and cease production all together under such drought condition. The second option is less inviting from the researcher's point of view since the dependence on food aid cannot be a preferable alternative and to supply enough food to the growing population of the region more food need to be produced by the zone itself. However, the choice between the two policy options is left to the capable policy maker.

8.4.2 Future research recommendations

Future similar and complementing research undertakings need to focus in the following areas:

1. The results of the base scenario revealed that improved varieties of the different crops perform better than the local varieties. This finding is really important in terms of fostering research activities for improving the yield performance of the local varieties and is an encouraging outcome to the researchers involved in this field. The result implies that research for even better varieties of maize, sorghum and wheat will be beneficial for increasing agricultural output in the zone.

2. Sustainable land use calls for the inclusion of sustainability indicators when outlining land use options. Two sustainability indicators were thought relevant in this study: biocide use and soil nutrient depletion. Where there exists high rate of biocide use, unlike the present study area, biocide use might be restricted by prohibiting use over a certain maximum level, which can be dealt in a separate scenario. The same holds true for soil nutrient depletion. However, because of the limitations explained in chapter 1 and 5, these two sustainability indicators were not incorporated in the present study even though their specification has been properly outlined in the developed land use model. Therefore, there is a need to incorporate the data of these or any other relevant sustainability indicator in future research works to enrich the present study.

3. There is a need to incorporate as many land use types as possible in future similar research activities for a more comprehensive outcome of the developed land use model based on the importance of these land use types for the farming community of the study area.

4. In the analysis conducted under the drought case scenario there was a need to include price changes that may occur during drought conditions. To investigate how prices might change when drought occurs and yield per hectare reduces, it was planned that the assumptions for the alteration of the prices be done based on the price elasticities of demand for both the crops and the inputs. However, it was extremely difficult to obtain the data on the price elasticities of demand as almost no research activity was done on this area in Ethiopia. Therefore, if the availability of this information is improved, it will be necessary to investigate the effect of drought on the demand side of the market in future research activities and make the required price changes for both outputs and inputs as these could have repercussion on land use decisions during drought situations.

5. Some of the most pressing farm problems of the study area have been described in this study. Future research activities in the zone need to be geared towards solving these acute problems of the farmers in the zone. Government policy should also help researchers in tackling the same.

6. This research activity has been conducted on sub-regional level with the inclusion of farm types. In order to apply the findings and the recommendations to lower levels such as the individual farm, there is a need to conduct a further supplementary research work that can test and verify the implications of the different land use alternatives at farm levels.

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APPENDICES

APPEDDIX A: SURVEY QUESTIONNAIRE

Objective: This questionnaire is prepared to obtain primary information concerning present land use (Farm size, crop types, farm labor, etc.) and current farm problems in the study area during 1992/1993[1] cropping season.

Date of interview: ________________ Questionnaire No._______
Enumerator's name:________________
Study area: Woredas in Eastern Hararghe Administrative zone, Oromia Region

A. Farmer's identification

1. Farmer's name: _____________________
2. Peasant Association (PA): ____________
3. Farmer's number: ________________
4. Village_____________________________
5. Woreda: ___________________________

B. Household demographic characteristics

6. Head of Household: 1. Male______ 2. Female_____
7. Age: ________ years
8. Education: 1. Illiterate____________
   2. Read and write_______
   3. Elementary education (1-6)______
   4. Secondary education (7-12)_____
   5. Higher education (above 12)____
   specify____________
9. Religion: ______________

C. Use of labor resource

10. Farm family size (number): 1. Male ______ 2. Female____

11. The number of household members between 15 years old and 60 years old (both inclusive): 1. Male ______ 2. Female ____

12. The number of household members less than 15 years old:
    1. Male ______ 2. Female ____

13. The number of household members more than 60 years old
    1. Male _____ 2. Female ____

14. Any dependents in the household: 1. Male ____ 2. Female ____

15. Number of full time farm workers in the household:

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[1] 1992/1993 Ethiopian Calendar is same as 2000/2001 Gregorian Calendar

1. Male ______ 2. Female _____

16. Number of part-time farm workers in the household:
    1. Male _____ 2. Female _____

17. Do you have enough family members (workers) to do the main farm operations in time?
    1.Yes 2.No

    If NO, how do you manage your farm operations during peak periods?
    1. Hire labor__________________
    2. Exchange labor______________
    3. Share labor_________________
    4. Mobilize family members______
    5. Other (specify)______________

18. Have you hired labor for any of your farm operations during the last harvest (1992/93 E.C.[1] production year)?
    1. Yes 2. No

    If YES, for which type of farm operation?
    1. Sowing________ 3. Harvesting_____
    2. Weeding_______ 4. Other(specify)______

19. Have you or your family members been engaged in off-farm work at last harvest (last year), during the farming (production) time ?.
    1. Yes 2. No

    If YES, indicate the type of engagement ________

20. Have you or your family members been engaged in off-farm activities during slack period (outside the production period)?
    1. Yes 2. No

    If YES, indicate the type of non – farming activity
    1. small trading______ 4. brick-making________
    2. handicraft_________ 5. transport service_____
    3. sewing clothes______ 6. other (specify)_____

    If NO, what are the limitations not to do off-farm activities?
    1. Capital_____________ 3. location/place_______
    2. Knowledge__________ 4. Other (Specify)_____

21. For full time farm workers, how many hours do they work per day during peak periods?

    1. Maximum of 10-12 hours______
    2. Maximum of 8-10 hours_______
    3. Maximum of 6-8 hours________

[1] E.C. means Ethiopian Calendar

4. Maximum of 4-6 hours_______

22. For part-time farm workers, how many hours do they work per day during peak periods?

    1. Maximum 6-8 hours______
    2. Maximum 4-6 hours______
    3. Maximum 2-4 hours______
    4. Maximum 1-2 hours______

D. Use of land resources

23. Land owned by the farmer (by soil types)(in timad)

    1. Heavy black soil (merere) = _______
    2. Light white soil = _______
    3. Sandy soil = _______
    4. Red soil = _______
    5. Areda (garden land) = _______
    6. Other (specify) = _______

24. Land used in different tenure forms (in timad)

    1. Own land = ______ 4. Shared-in land = ______
    2. Land rented in = ______ 5. Shared-out land = ______
    3. Land rented out = _____ 6. Relatives land = ______

25. Land allocation to different uses (in timad)

    1. Cultivated land = _____
    2. Grazing land = _____
    3. Fallow land = _____
    4. Other form of use (specify)=______

26. Area of crops grown in this cropping season (1992/93 E.C.)

Crops	Area(timad)	Crops	Area(timad)
1. Tef		10.Field peas(Ater)	
2. Wheat		11. Lentils(Misir)	
3. Sorghum		12. Oats (Aja)	
4. Maize		13. Linseed(Telba)	
5. Barley		14. Fenugreek(Abish)	
6. Groundnuts(Lewuz)		15. Coffee	
7. Horse beans(Bakela)		16. Chat	
8.Haricot beans(Boleke)		17. Other (specify)	
9. Chickpea(Shibura)			

27. Do you grow legumes, in rotation with other crops, to maintain soil fertility? 1. Yes 2. No

If NO, what are the limitations to grow more legumes? Specify:

1.____________________
2.____________________
3.____________________

28. Can more organic manure, crop residues and stubble be returned to the soil? 1. Yes 2. No

If NO, what are the limitations? Specify
1. ________________________________
2. ________________________________
3. ________________________________

E. Use of production technology

E1. Use of new varieties of crops

29. Have you used new varieties of crops in this production year?
1. Yes 2. No

If YES, specify the varieties you are using in this cropping season (1992/93 E.C.)

Crop	Var 1	Var 2	Var 3	Crop	Var 1	Var 2	Var 3
Tef				Horse beans			
Wheat				Haricot beans			
Sorghum				Chickpea			
Maize				Field peas			
Barley				Lentils			
Groundnuts				Other (specify)			

30. Do you find the new varieties to be profitable compared to the local varieties? 1. Yes 2. No

If YES, what is the improvement in yield per timad (in Kg)?

	Improved		Local	
Crop	With fertilizer	Without fertilizer	With fertilizer	Without fertilizer
Tef				
Wheat				
Sorghum				
Maize				
Barley				
Groundnuts				
Horse beans				
Haricot beans				
Chickpea				
Field peas				
Lentils				
Oats				
Linseed				
Fenugreek				
Coffee				
Chat				
Other (specify)				

If NO, what are your main reasons for not planting new varieties in this season?
1. ____________________
2. ____________________
3. ____________________
4. ____________________

31. Out of total area, what is the area covered by improved varieties (in timad):

Crops	Total area sown	Area covered by improved variety	Crops	Total area sown	Area covered by improved variety
1. Tef			10. Field peas		
2. Wheat			11. Lentils		
3. Sorghum			12. Oats		
4. Maize			13. Linseed		
5. Barley			14. Fenugreek		
6. Ground nut			15. Coffee		
7. Horse beans			16. Chat		
8. Haricot beans			17. Other (specify)		
9. Chickpea					

32. Are improved seeds available at any time you want to buy?
1. Yes 2. No

If NO, what are the reasons, for it, not to be available when you want to buy?
1. ____________________
2. ____________________

E2. Use of fertilizer

33. Have you applied fertilizer in this cropping season?
1. Yes 2. No

If YES, what is the rate of DAP and Urea application per timad? (kg)

Crop	Improved Variety		Local Variety		Crop	Improved Variety		Local Variety	
	DAP	Urea	DAP	Urea		DAP	Urea	DAP	Urea
Tef					Field peas				
Wheat					Lentils				
Sorghum					Oats				
Maize					Linseed				
Barley					Fenugreek				
Ground nut					Coffee				
Horse beans					Chat				
Haricot beans					Other (specify)				
Chickpea									

If NO, what are the reasons for not using fertilizer

1. ____________________
2. ____________________
3. ____________________

34. Have you heard anything about the recommended fertilizer rate for the new varieties per timad?

1. Yes 2. No

If YES, what is the recommended rate per timad (in kilogram)?

Crop	Fertilizer		Crop	Fertilizer	
	DAP	Urea		DAP	Urea
1. Tef			10.Field peas		
2. Wheat			11. Lentils		
3. Sorghum			12. Oats		
4. Maize			13. Linseed		
5. Barley			14. Fenugreek		
6. Ground nut			15. Coffee		
7. Horse beans			16. Chat		
8.Haricot beans			17. Other (specify)		
9. Chickpea					

If NO, what are your reasons for not applying the recommended rate on the new variety?

1. Crop lodging__________
2. Lack of cash to purchase more________
3. Unavailability of fertilizer to buy more_____
4. Does not pay___________
5. Other (specify)__________

35. Is fertilizer available at any time you want to buy?

1. Yes 2. No

36. Out of the cultivated area, what is the area applied with fertilizer (timad)?

Crops	Total area sown	Area covered by fertilizer	Crops	Total area sown	Area covered by fertilizer
1. Tef			10.Field peas		
2. Wheat			11. Lentils		
3. Sorghum			12. Oats		
4. Maize			13. Linseed		
5. Barley			14. Fenugreek		
6. Ground nut			15. Coffee		
7. Horse beans			16. Chat		
8. Haricot beans			17. Other(specify)		
9. Chickpea					

F. Cropping practice

Practice		crops							
		Sorghum	Maize	Wheat	Barley				
Land preparation	Month								
	Implement								
Planting	Month								
	Implement								
weeding	Month								
	Implement								
Harvesting	Month								
	Implement								
threshing	Month								
	Implement								

G. Farm input and output data on main crops

37. Estimate of farm inputs use on **Sorghum** land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
7	Other(specify)				
	Total				

38. Estimate of farm inputs use on **Maize** land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
7	Other(specify)				
	Total				

39. Estimate of farm inputs use on **Wheat** land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
5	Other(specify)				
	Total				

40. Estimate of farm inputs use on **Barley** land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
5	Other(specify)				
	Total				

41. Estimate of farm inputs use on _____ land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
5	Other(specify)				
	Total				

42. Estimate of farm inputs use on _______ land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
5	Other(specify)				
	Total				

43. Estimate of farm inputs use on _______ land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
5	Other(specify)				
	Total				

44. Estimate of farm inputs use on _______ land (for one timad) in 1992/93 cropping season

No.	Items	Unit of Measurement	Quantity	Unit Price (Birr)	Total (Birr)
1	Seed used - local	Kg			
	- improved	Kg			
2	Fertilizer at Sowing				
	DAP	Kg			
	Urea	Kg			
3	Oxen days	Oxen-day			
4	Human labor for:				
	Ploughing	Man-days			
	Sowing	"			
	Manuring/fertilizing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
5	Pesticides	Liter(kg)			
6	Herbicides	Liter			
5	Other(specify)				
	Total				

45.Estimate of crop yield(in Kg) and farm income(in Birr)

No.	Crop	Area sown(in timad)	Yield/ timad	Total Yield produced	Total output sold	Price/ Kg	Total income
1	Tef						
2	Wheat						
3	Sorghum						
4	Maize						
5	Barley						
6	Ground nut						
7	Horse beans						
8	Haricot beans						
9	Chickpea						
10	Field pea						
11	Lentils						
12	Oats						
13	Linseed						
14	Fenugreek						
15	Coffee						
16	Chat						
17	Others(Specify)						

46. Do you know your family consumption of farm produce per year?

1. Yes 2. No

If YES, what quantity of your total yield is retained on the farm for family consumption purposes (Kilograms)

Crop	Yield retained for the family	Crop	Yield retained for the family
1. Tef		10.Field peas	
2. Wheat		11. Lentils	
3. Sorghum		12. Oats	
4. Maize		13. Linseed	
5. Barley		14. Fenugreek	
6. Ground nut		15. Coffee	
7. Horse beans		16. Chat	
8. Haricot beans		17. Other (specify)	
9. Chickpea			

If NO, please estimate your family consumption per month on the above table.

47. Do you keep livestock ?

1. Yes 2. No

If YES, what is your livestock number since last year and for what purpose do you keep them?

Livestock type	number	Purpose*
1. Oxen		
2. Cows		
3. Heifers		
4. Calves		
5. Bulls		
6. Sheep		
7.Goats		
8. Poultry		
9. Camel		
10. Donkeys		
11. Others (Specify)		

* 1. Consumption(egg, milk, meat)
  2. Cash income(eggs, milk, butter, live animals, etc)
  3. Draft power
  4. Transport
  5. Others(specify)

48. What is your estimated farm income (in Birr) since last year?
   1. Agricultural
      a) Sales of crops ____________________
      b) Sales of animals __________________
      c) Sales of animal products ___________
   2. Non agricultural
      a) income from trade: ______________

b) Off-farm income ________________
c) Income from rent ______________

3. Other income

a) Capital sales:

Land ____________

Old plough _________

Other farm implements___________

b) Sales of hand craft ______

49. Do you save some money income till the next harvest?

1. Yes 2. No

If YES, for what purpose do you save money?__________

50. Estimate of cash expenditure in this cropping season

No.	Expenditure item	Unit of Measurement	Quantity	Wage rate/day Or price/ Unit (Birr)	Total Cash (Birr)
1	Hired labor for:				
	Land preparation	Man-days			
	Sowing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
2	Fertilizer:				
	DAP	Kg			
	Urea	"			
3	Seed:				
	Improved	Kg			
	Local	"			
4	Herbicide	liter(Kg)			
5	Pesticide	Liter(Kg)			
6	Other cash expenses:				
	1. Oxen rent	Birr			
	2. Land rent	"			
	3. Interest on loan	"			
	4. Others (specify)	"			
	Total expenditure	Birr			

51. Do you have constraints in achieving your farm potential?

1. Yes 2. No

If YES, rank according to their importance (urgency)

1. Lack of land ___________
2. Lack of labor____________
3. lack of capital_____________
4. lack of technology (seed, fertilizer)__________

5. lack of knowledge____________
6. Water logging problem___________
7. Poor soil fertility____________
8. Lack of rainfall____________
9. Disease and insect problem___________
10. Others (specify)_____________

52. Rank the crops according to your need for research attention

1. Wheat_____
2. Tef_______
3. Maize______
4. Sorghum________
5. Pulses_________
6. Other (specify)______

53. Do you receive subsidies from government or any other organization for farm inputs or outputs ?

1. Yes 2. No

If YES, for which inputs do you receive subsidies ?

No.	Type of input	Unit of Measurement	Quantity you use per timad	Wage rate/day Or price/ Unit (Birr)	subsidy per unit (Birr)
1	Hired labor for:				
	Land preparation	Man-days			
	Sowing	"			
	Weeding	"			
	Harvesting	"			
	Threshing	"			
2	Fertilizer:				
	DAP	Kg			
	Urea	"			
3	Seed:				
	Improved	Kg			
	Local	"			
4	Herbicide	liter(Kg)			
5	Pesticide	Liter(Kg)			
6	Other cash expenses:				
	1. Oxen rent	Birr			
	2. Land rent	"			
	3. Interest on loan	"			
	4. Others (specify)	"			
	Total expenditure	Birr			

Thank you for your cooperation !

Note: 1 timad = 0.125 hectares

APPENDIX B: FRAMEWORK FOR SECONDARY DATA COLLECTION

A . Secodary data at zonal level

The data should be based on the 1992/93 E.C. production period

1. What is the number of Woredas in Eastern Hararghe Administrative zone ?

   ____

2. List down the Woredas in Eastern Hararghe Administrative zone together with their capital city and the distance of the capital city from Harar.

No.	Name of Woreda	Name of capital city	Distance of the capital city from Harar

3. How many peasant associations do you have in each Woreda in East Hararghe administrative zone ?

No.	Name of Woreda	Number of peasant associations

4. How many farmers do you have in each peasant association of each woreda?

No.	Name of peasant association	The woreda it belongs	Number of farmers

5. Which woredas in East Hararghe administrative zone are best producers of food crops ?

Production per Woreda (recent production year)

No.	Name of Woreda	Cereals production (qt)	pulses produc-tion (qt)	oil seed produc-tion (qt)	total produc-tion (qt)	Rank	No. of PA
1	Meta						
2	Haremaya						
3	Girawa						
4	Malkabelo						
5	Kersa						
6	G/Gutu						
7	Bedeno						
8	Jarso						
9	Deder						
10	Kurfachele						
11	Kombolcha						
12	Gursum						
13	Fedis						
14	Babile						
15	G/oda						

6. What is the total population of East Hararghe administrative zone?

No.	Woreda	Male population	Female population	Total population

7. Indicate the demographic composition of the population in East Hararghe administrative zone

No.	Woreda	People under 15 years old	People between 15 and 64 years old	People over 64 years old	Total population

8. Please supply the following information :

8.1. The climatic conditions of East Hararghe administrative zone such as
- climatic zones
- rainfall
- temperature
- humidity
- etc.

NB. Please supply this information on a separate paper.

8.2. The livestock number and composition in the zone

No.	Woreda	livestock type	livestock number

8.3. The current land use pattern of the zone, in terms of the total land under cultivation, grazing land, land occupied by houses and towns, land occupied by forest and bushes, waste land, etc.

No.	Woreda	land under cultivation	grazing land	towns land	forest and bush land	waste land	total land

B. Secodary data at woreda level

Name of woreda : ____________________

Name of capital city : ____________________

Total population of the woreda : Male : ____________________

Female : ____________________

Total : ____________________

Number of peasant associations in the woreda :____________________

No.	Name of peasant association	Number of farm households in each peasant association			Total population in each peasant association
		Male	Female	Total	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					

Land use in __________ woreda for the last five years in Ethiopian calendar (in hectares)

No.	Land use for	1988	1989	1990	1991	1992
1	Annuals					
2	Perennials					
3	Pasture					
4	Forest and Bush land					
5	Towns land					
6	Waste land					
7	Maize land					
8	Sorghum land					
9	Teff land					
10	Wheat land					
11	Barely land					
12	Field peas land					
13	Horse beans land					
14	Cheek pea land					
15	Oats land					
16	Haricot beans land					
17	Fenugreek land					
18	Lentils land					
19	Linseed land					
20	Ground nut land					
21	Coffee land					
22	Chat land					
23	Other land use					

APPENDIX C: SAMPLE MATRIX OF EASTHAR MODEL

	Farm type 1								Farm type 2							
	Production activities	Buying activities						Selling activities	Production activities	Buying activities						Selling activities
	Yield of products	Variable inputs use	Hired oxen from		Labour use own	Hired labour from		Sold products	Yield of products	Variable Inputs use	hired oxen from		Labour use own	Hired labour from		Sold products
			FT2	FT3		FT2	FT3				FT1	FT3		FT1	FT3	
Economic surplus (Birr)		IP	OP	OP		LP	LP	PP		IP	OP	OP		LP	LP	PP
Yield of products FT1	-1							1								
Variable input use FT1	1	-1														
Oxen per month FT1	1		-1	-1							1					
Labour use per month FT1	1				-1	-1	-1									
Household labour FT1					1									1		
Land use FT1	1															
Yield of products FT2									-1							1
Variable input use FT2									1	-1						
Oxen per month FT2			1						1		-1	-1				
Labour use per month FT2									1				-1	-1	-1	
Household labour FT2						1							1			
Land use FT2									1							
Yield of products FT3																
Variable input use FT3																
Oxen per month FT3				1								1				
Labour use per month FT3																
Household labour FT3							1								1	
Land use FT3																

Abbreviations

MCR = Minimum consumption requirement per farm type
OAM = Oxen availability per month per farm type
HHLAM = Household labour availability per month per farm type
LA = Land availability per farm type per year

IP = Input price
PP = Product price
OP = Oxen rent
LP = hired labour wage
RHS = Right Hand Side

Farm type 3									
Production activities	Buying activities						Selling activities		RHS
Yield of products	Variable Inputs use	hired oxen from FT1	hired oxen from FT2	Labour use own	Hired labour from FT1	Hired labour from FT2	Sold products		
	IP	OP	OP		LP	LP	PP		Maximize
								<=	MCR
								<=	0
		1						<=	OAM
								<=	0
					1			<=	HHLAM
								<=	LA
								<=	MCR
								<=	0
			1					<=	OAM
								<=	0
						1		<=	HHLAM
								<=	LA
-1							1	<=	MCR
1	-1							<=	0
1		-1	-1					<=	OAM
1				-1	-1	-1		<=	0
				1				<=	HHLAM
1								<=	LA