LAND USE AND LAND COVER CHANGES IN THE CENTRAL HIGHLANDS OF ETHIOPIA: THE CASE OF YERER MOUNTAIN AND ITS SURROUNDINGS

A THESIS

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES,

ADDIS ABABA UNIVERSITY

IN PARTIAL FULFILMENT OF

THE REQUIREMENT FOR THE DEGREE OF

MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

BY

KAHSAY BERHE GEBREHIWET

JUNE 2004

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
ENVIROMENTAL SCIENCE PROGRAMME

LAND USE AND LAND COVER CHANGES IN THE CENTRAL HIGHLANDS OF ETHIOPIA: THE CASE OF YERER MOUNTAIN AND ITS SURROUNDINGS

BY
KAHSAY BERHE GEBREHIWET
ENVIRONMENTAL SCIENCE PROGRAMME

APPROVED BY EXAMINING BOARD:	Signature
Professor Zerihun Woldu Advisor	___________________________
Dr. Dagnachew Legesse Advisor	___________________________
Dr. Belay Semani External examiner	___________________________
Dr. Tesfaye Korme Internal examiner	___________________________

ACKNOWLEDGEMENTS

This work would have not been completed without the contribution of many institutions and individuals, among which I am indebted to the International Livestock Research Institute (ILRI) for allowing me to carry out this study and research towards this Thesis. In addition, the International Water Management Institute (IWMI), through its Comprehensive Assessment Project funded part of this work and deserves acknowledgement. I am greatly indebted to my advisors Professor Zerihun Woldu, Dr. Dagnachew Legesse and Dr. Don Peden for their advice and sharing their invaluable time and ideas and for critically reading the earlier versions of this manuscript. I am especially indebted to Dr. Peden of ILRI, my supervisor, for his enormous support and kindness because without his help my endeavours would have been fruitless. He facilitated my study with Addis Ababa University and supplied all necessary materials and resources required for my study. His deeds are so special that they will remain in my mind. Dr. Girma Taddesse's encouragement during the course of my study and facilitation towards finalising this research work was also special and deserves acknowledgment. Dr. Sonder's technical support and friendly thoughts during data collection and the write up of this manuscript deserves acknowledgement. Ato Abiye Astatke, Dr. Berhanu Gebremedhin and Ato Abate Tedla all from ILRI are also acknowledged for their encouragements and sharing their ideas. I would like to thank Dr. Fernandez-Rivera, ILRI, for assistance rendered in calculating daily dry matter livestock requirements.

The assistance from Ato Alemayehu Mamo, Woody Biomass, was so much that without his support the GIS related works could have not been completed on time. He devoted much of his valuable time in helping me finalise this work. He has a special place in my mind for his contributions were so much. Mr. Sutcliffe of Woody Biomass also made comments on the earlier version of this manuscript and shared his ideas and resources.

My special thanks also go to Adaa Liben, Gimbichu, Bereh Aleltu and Akaki wereda Bureaus of Agriculture for their collaboration and facilitation during the study are also cordially acknowledged. The Development Agents of all ten Peasant Associations, where the survey was conducted are also acknowledged. All the enumerators who worked with me during the survey also deserve acknowledgement, but particularly Degefa Birru, ILRI, contributed immensely towards the completion of the survey work and deserves acknowledgement. My other ILRI colleagues Ato Solomon Gebreselassie, Ato Aklilu Bogale and Ato Abebe Misgina, who helped during the analysis of the socio-economic data, deserve special acknowledgement. All colleagues of the then “Mountains Project” of ILRI are all acknowledged, but W/o Genet Delelgne is especially thanked for her keen interest in my carrier development. In addition, Ato Aklilu Alemu of ILRI, Debre Zeit walked with me during gully assessment and deserves acknowledgement. The ILRI library staffs W/o Azeb Abraham, Goshu Chernet and Hailu Birbo are all acknowledged for their assistance during search for literature.

My classmates are all acknowledged for their friendship and support during my enrolment at Addis Ababa University, but especially that of Elias Gugsa was so special he deserves special thanks.

It would be a mistake not to mention the role of the sample farmers in this study who kindly spared their time and effort and responded tirelessly to the lengthy process of the interview.

Finally, the unfailing encouragement, tolerance and support rendered from my wife Meaza Tsehay, our children and all my families deserves particular thanks. The prayers of my mother have contributed to the success of my work.

TABLE OF CONTENTS

CHAPTER FOUR

MATERIALS AND METHODS

CHAPTER FIVE

RESULTS AND DISCUSSION

CHAPTER SIX

CONCLUSSION AND RECOMMENDATIONS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

APPENDICES

LIST OF ACRONYMS

CSA = Central Statistics Authority
CSE = Conservation strategy of Ethiopia
DA = Development Agent
DAP = Di-ammonium phosphate
DM = Dry matter
DTM = Digital terrain Model
EARO = Ethiopian Agricultural Research Organisation
EFAP = Ethiopian Forestry Action Programme
EHRS = Ethiopian Highlands Reclamation Study
EMA = Ethiopian Mapping Authority
FAO = Food and Agriculture Organization of the United Nations
FFDME = Finfinne Forest Development and Marketing Enterprise
GDP = Gross Domestic Product
GIS = Geographic Information System
ILCA = International Livestock Centre for Africa
ILRI = International Livestock Research Institute
ITCZ = Inter-Tropical Convergence Zone
IUCN = International Union for Conservation of Nature
IWMI = International Water Management Institute
K = Potassium
Km^2 = Kilometre square
Landsat ETM+= Landsat Enhanced Thematic Mapper
LULC = Land Use and Land Cover
M asl = Metres above sea level
MEm = Metabolisable Energy for maintenance
MoA = Ministry of Agriculture
MOPED = Ministry of Planning and Economic Development
m/s minutes per second
N = Nitrogen
^{o}C = Degree Centigrade
OM = Organic Matter
P = Phosphorus
PA = Peasant Association
Qt = Quintal (100 kg)
SC = Service Cooperative
SPSS = Statistical Package for Social Sciences
SWC = Soil and Water Conservation
t/ha/yr^{-1} = ton per hectare per year
TLU = Tropical Livestock Unit
TSP = Triple Super phosphate
UNCED = United Nations Conference on Environment and Development
UNDP = United Nations Development Program
UNFCC = United Nations Framework Convention on Climate Change
UTM = Universal Transverse Mercator
WHO = World Health Organization of the United Nations
WWF = World Wildlife Fund

ABSTRACT

Land Use and Land Cover changes that occurred from 1971/72 to 2000 in Yarer Mountain and its surroundings were monitored using remote sensing and geographic information system (GIS) with field verifications. The study was conducted in about 287.41 km^2 area within the East Shewa Zone of Oromia region. The study area is a reflection of the Ethiopian highland degradation in many ways because land degradation, deforestation, land fragmentation, steep slope cultivation are also common features in the study area. These problems have been the driving forces to Land Use and Land Cover changes in many parts of Ethiopia.

The objective of this study is to understand the dynamics of Land Use and Land Cover in and around Yerer Mountain and analyse implications of Land Use and Land Cover changes in terms of soil erosion and nutrition of both human and livestock. Two sets of remotely sensed data, aerial photograph (1971/72) and Landsat ETM+ imagery (2000), with a time span of thirty years were used for the study. In addition to the biophysical data, socio-economic characteristics of households was also used to interpret the biophysical feature occurring in the study area.

Results from land cover change analysis show cultivated land increased from 25% in 1971/72 to 56.4% in 2000. The increase in cultivated land in three decades was 125%, which was mainly at the expense of the grasslands. At the same time, grasslands decreased from 65.35% in 1971/72 to 32.7% in 2000. The area, which was under mainly *Juniperus procera* in 1971/72 changed to dense shrubland where Juniper trees became remnants, while the overall size also decreased. Size of water body increased by about 65.2% mainly because of the man-made dam (Wedecha dam) but also because of the fact that the imagery was taken in February, when the seasonal water was not dry.

Based on the survey data and 2000 imagery, about 80% of the human minimum daily maintenance energy, 72% livestock minimum annual energy (+20% production) and 81% of the household fuelwood requirements are met. These shortfalls in food, feed and fuelwood are indications that the study area is not sustainable. Unless remedial actions are taken, the problems will be out of hand and will endanger the overall environment of the area. In

addition, more than 50% of children are not going to school, which implies high potential demand for primary education in the study area. Otherwise, number of children who become illiterate farmers will increase and hence land fragmentation will further aggravate encroachment on to the hills and mountains.

If current trends are allowed to continue food, feed and fuelwood will become far below the minimum requirements in the study area. On the other hand, damage to the natural resource base will continue and land lost due sheet and gully erosion will increase, especially affecting households in the low-lying areas due to increased flood, siltation and gullying. In addition, as a result of low vegetative cover, water is already a scarce resource and will further be aggravated because of high surface runoff and poor water retention capacity of soils affecting the existence of springs in the foothills of the study area. Therefore selecting appropriate land use systems that are suitable to the conditions of the study area will be important.

Giving land use rights to individuals (other than crop fields), for planting trees on hilly areas could contribute to this effect. This will contribute to the conservation of natural resources as well as the betterment of livelihoods. Experiences regarding this can easily be drawn from some parts within the country. Construction of physical structures to minimise concentration of water to avoid effects of gully erosion, early planting and re-instatement of grass boundaries on farmers' fields will be important activities in order to minimize effects of erosion in the study area.

Promoting tethering of livestock is another important issue for minimizing their impacts on the environment and also will have a positive social dimension in releasing children to go to school. The existing efforts of introducing appropriate forage and fodder plants in backyards should also be strengthened along with mixed cropping (cereals and forages) in the fields. This will improve availability and quality of livestock feed as well availability of fuelwood in the area. In addition, identification of alternative sources of energy, like biogas, could help foster tethering of livestock and at the same time help alleviate health problems that arise from using other bio-fuels.

Along with all these efforts however, education of households about the impacts of population increase is essential. Strong family planning and sex education should also go hand in hand with these efforts.

CHAPTER ONE

INTRODUCTION

1.1 Background

Ethiopia is the third largest country in Africa with an area of over one million km^2. The country is endowed with a variety of agro-ecological conditions ranging from desert to rainforest and from 200 m below sea level to highlands with altitudes of over 4500 metres above sea level (m asl). This diversity in climatic conditions has enabled Ethiopia to grow a large number of crops and its farmers to keep almost all types of livestock. It is estimated that there are about 6000 - 7000 species of higher plants, of which 10-12 percent are considered to be endemic to Ethiopia (Tewelde Berhan Gebre Egziabher, 1989)**.** Its complex topography and wide altitudinal variations also ensure a variety of temperature and rainfall patterns. As a result of this, it is common for some parts of the country to suffer from drought, while it is excess in other parts of the country.

Mohamed–Saleem (1995) has shown that the Ethiopian highlands, areas with altitudes above 1500 m, cover about 500,000 km^2 accounting for about 45% of the landmass. These areas are home for about 88% of the population; more than two thirds of the livestock population; 95% of the cropped lands and 90% of the economic activities in the country (Constable, 1984). Many of the highland farming systems appears to be well adjusted to environmental conditions since they have thus so far permitted permanent cultivation. The basis for early development of agricultural systems and high human population in this agro-ecological zone may have been the favourable climatic and ecological conditions, sufficient rainfall, moderate temperatures, and well-developed soils in these areas. It may be for this reason that the highlands have been settled for millennia and known for a similar long-standing agricultural history (McCann, 1995). This long history of settlement and high population pressure brought about unsustainability in agriculture. The unsustainable agricultural practices along with many other physical, socio-economic and political factors have been the driving forces to a series of land degradation problems. According to some studies, the highlands of Ethiopia are considered to be amongst the most degraded lands in Africa (El-Swaify and Hurni, 1996).

Increase in population density, type and the use of land and climatic conditions of an area are few of the major driving forces to cause change in Land Use and Land Cover (LULC). The fact that the study area lies within the central highlands, where population density is relatively high, and the fact that the terrain is undulating (for most parts), makes it more vulnerable to faster LULC changes. Knowledge of the distribution and types of LULC are believed to be important indicators for resource base analysis with regard to land degradation and productivity, hence problems or possibilities for sustainable development (Solomon Abate, 1994). Inference could be possible by examining the changes in distribution and types of LULC in the past, and also those future predictions will be possible.

In many parts of the highlands agriculture has gradually expanded from gently sloping land onto the steeper slopes of the neighbouring mountains on the one hand, and into the flat swampy plains of the plateau on the other. Hence, there is pressure on land, vegetation and water resources in the highlands. Some reports associate these effects to high population growth who also predict that population of Ethiopia will increase by about three folds by the year 2030 (Mohamed–Saleem, 1995). Despite this increase, the agricultural productivity is lagging behind the population growth rate. At the same time, the per capita land holding is also expected to decline from an average of 1.76 ha in 1985 to 1.1 and 0.66 ha in the year 2000 and 2015, respectively (IUCN, 1990). This will lead to severe land-use conflicts between crop, grazing and forestlands. That is why land degradation is widespread and has become a critical environmental problem. The overall problems of land degradation will continue to pose threat as far as high population increase coupled with low technological development; insecure land tenure, current agricultural practices and others are still in place. These are creating a near total dependence of employment in the agricultural sector.

The severity of soil erosion in the Ethiopian highlands is the result of the past and present agricultural activities, mountainous and hilly topography, torrential rainfall, and low degree of vegetative cover. Some of the farming practices within the highlands even now encourage erosion because cultivation of cereal crops such as tef (*Eragrotis tef* L.) and wheat (*Triticum sativum* L.) require the preparation of a fine-tilth seedbed, single cropping of fields, and down slope final ploughing to facilitate drainage (Feoli *et al*., 2002). Soil erosion is greatest on cultivated land where average annual loss was 42 t/ha/yr^{-1}, compared to 5 t/ha/yr^{-1} from pastures (Hurni, 1990). In some areas soil loss from newly cleared forest land for crop production purposes was reported to be 130 t/ha/yr^{-1} (Solomon Abate, 1994). Almost half of the soil loss comes from land under cultivation, even though the cultivated lands cover only 13 percent of the country. The highest average rates of soil loss are accounted from former cultivated lands, which are currently unproductive due to degradation and have very little vegetative cover to protect them from erosion. In the highlands, crops are harvested to ground level, even though the problem of soil loss could have been reduced and nutrient recycled, had crop residues been retained on the crop lands (Mando and Stroosnijder, 1999). However, the option of crop residue retention cannot be practical under the current conditions in the highlands because the demand and supply for livestock feed is not balanced. The other option of nutrient recycling could have been applying manure onto crop fields but again with the lack of alternative energy sources, this is also impossible as at now.

It is estimated that about 1.9 to 3.5 billion tons of topsoil is being removed from the Ethiopian highlands, every year (EFAP, 1993). Consequently, some areas of the country are totally out of production where land is irreversibly damaged and the highland farmer and livestock are commonly considered as the culprit for such spectacular depletion of the country's natural resources. The Ethiopian Highlands Reclamation Study (EHRS, 1984) indicated that about 10 million farmers in the highlands could lose their farmlands due to land degradation. However, there are some people who challenge this notion (Sutcliffe, personal communication). Furthermore, this study also indicated that the agricultural cost of land degradation in 25 years time is estimated at about 150 million US dollars. Other studies also assert the monetary loss due to land degradation (Sutcliffe, 1993). The immediate consequence of land degradation is reduced crop yield and livestock productivity followed by economic decline and social stress. Hence, due to excessive land degradation plant nutrient exhaustion, reduced soil moisture capacity and structure of the soil would lead to extremely low average crop yield per unit area.

In many areas, farming populations have experienced a decline in real income due to demographic, economic, social, and environmental changes associated with land degradation. The average yield ha^{-1} is estimated to be 1.2 tons for cereals, 0.6 ton for pulses and 0.5 tons for oil crops (FAO, 2000). Total produce of most farmers is not even enough to cover their annual consumption. In Sub-Saharan African countries, the per capita consumption of cereals is said to have stagnated since the 1970s, consequently, between 1975 and 1995 daily calories and protein supply averaged 2169 calories and 55 grams, respectively, which were 83 and 78% of the world average (FAO, 2000 as cited in Ehui and Pender, 2003). In Ethiopia, in 1962, daily per capita calorie available was reported to be 1,816, while three decades later the same study indicated that it was even much lower, at 1621 calories (McClelland, 1998).

Similarly, according to the study by the Ethiopian Ministry of Economic Development and Cooperation, 50 percent of the Ethiopian population are living below the food poverty line and cannot meet their daily minimum nutritional requirement of 2200 calories (MOPED, 1999).

Women in the reproductive age group and children are most vulnerable to malnutrition due to low dietary intakes, inequitable distribution of food within the household, improper food storage and preparation, dietary taboos, infectious diseases, and care. This is especially aggravated due to the recurrent droughts in Ethiopia. Moreover, decrease in the amount of cultivated area as a result of land lost due to complete removal of topsoil by erosion is another land degradation aspect, which has significant impact on crop production, and hence human nutrition. Because of these situations, the economic condition of the larger mass of the population has been gradually affected, leading to poverty and famine.

Currently, little of the natural vegetation remains in the highlands, existing in only small patches in the southern and south-western parts of the country. In Ethiopia, annual loss of natural forest cover, mainly for agriculture, has been estimated at 150,000 to 200,000 hectares per year. In 1989, forest cover was estimated at only 2.7% of the Ethiopian land mass (EFAP, 1993). This figure is expected to be much lower at present.

The conversion of woodlands and shrublands into croplands has resulted in loss of the natural vegetation cover and has caused severe soil erosion (McDougall *et al*., 1975; and Virgo and Munro, 1977) as cited in Feoli *et al*. (2002). Therefore, the state of the resource base of the Ethiopian rural system should be examined in relation to population pressure by integrating environmental protection strategies with development strategies and their implementation (Feoli, *et al.*, 2002).

Part of the failure to halt, or at least reduce, the rate of land degradation could be due to a poor understanding of the patterns and processes of degradation, even though fundamental data on some processes exist, like rates of soil erosion from farmlands (Hurni, 1990). Even with the availability of relevant data on the magnitude of the problem, what is missing is an integrated approach to the multifarious nature of degradation, where the patterns, processes and consequences of degradation are understood in the socio-economic context of the land user. For example, some concern is expressed to imply that insecurity of land and tree tenure in the past has discouraged farmers from investing in soil conservation practices (Badege Bishaw, 2001).

Therefore studies on land degradation should not focus only on biophysical aspects of the problem, but equally also on the socio-economic factors that affect farmers’ land management practices. This is because, despite the magnitude of soil erosion, and efforts to address the issue, which had started in the early 1970s, conservation technologies are still not widely adopted due to the absence of continued public support in many areas of the country (Fitsum Hagos *et al*, 2002; Betru Nedessa, 2002). As some people also argue, the loss of land due the soil conservation structures, in addition to increased number of rodents in these structures, could also be some of the reasons that farmers may not be willing to adopt the technology. Periodic reallocation of land, eviction from farms, which they have been tilling for many years, villagisation processes and tenure insecurity, could also be some of the major insecurity reasons. As a result of these, very little effort would be made by farmers to conserve their land holding or to plant perennial crops including trees, which may lead to a continued land degradation and deforestation in the country.

Hence, a broader perspective should be taken to define and consider possible solutions in order to address land degradation and its linkages to agricultural productivity and poverty in Ethiopia. This will lead to consideration of broader set of solutions than only the biophysical measures. It is therefore for this reason that socio-economic study is included as part of the Land Use and Land Cover change study. Policy intervention, such as land tenure policy may have much greater impact than conservation programmes only or determine the potential success of those programmes. Hence, the potential for such alternative policy and programme responses should be investigated

In any case, land needs to be better matched to its uses to increase production, while at the same time protecting the environment, biodiversity, and local climate systems. It is therefore essential to have detailed and in-depth knowledge of potentials and limitations of the present uses through the use of modern techniques. Currently, technological advances, such as the vast amount of remote sensing data is available from aerial photos and earth observation satellites, it is increasingly possible to map, evaluate and monitor Land Use and Land Cover changes over wide areas. This kind of information is required in many aspects of land use planning and policy development, as a prerequisite for monitoring, modelling and environmental change, and as a basis for land use statistics at all levels.

1.2 Statement of the problem

The study area can represent mountain degradation in most parts of the Ethiopian highlands for reasons below:

1. Rapid population growth has forced farming families to expand their fields onto the steeper slopes.
2. As a result, large areas, which were once under forest cover, are now exposed to heavy soil erosion resulting into a massive environmental degradation and serious threat to sustainable agriculture and human health.
3. The loss of the vegetative cover has resulted in flash floods which has resulted in formation of big gullies and hence loss of farms in both the bottom and the slope lands. This also causes seasonal flooding of farmlands in the bottomlands, which is affecting several farming families. The effect is not only limited to the farming families but also to the International Livestock Research Institute (ILRI), Debre Zeit Research Station, which has conducted research since 1976. The research station has been flooded almost every main rainy season and research activities affected as a result.
4. Crops are frequently waterlogged or washed away due to flood from the main rainy season, which has resulted into reduced yield or total crop failure, on the bottomlands. On the other hand, the standing water becomes a fertile ground for mosquitoes to breed and cause malaria, which is a common phenomenon after the main rains around Debre Zeit. In addition, many farmlands are not cropped or used for livestock production because of the standing waters, even though crops mainly, chick pea or rough pea, are planted late after the waters recede (personal observation). However, these crops are normally planted immediately after a cereal crop (double cropping), but here water logging is causing loss of a crop every season and hence affecting livelihoods in the area. Farmers in the bottomlands blame their mountain neighbours whose mismanagement has affected both their farm productivity and their health.

In order to understand the historical and contemporary linkages between LULC change and its resulting effects on ecosystem health, and other systems, it will be necessary to make significant advances in documenting the rates and causes of LULC changes. Our current understanding of historic LULC change in Ethiopia is not adequate. Future understanding of LULC changes will need to be greatly improved with systematic methods and designs addressing land use change research. In order to understand the forces of change, it will be necessary to conduct studies that explicitly reveal the variations in change characteristics. In the historical and contemporary data needed to develop models that project LULC for specific intervals into the future could be produced.

The study site is a reflection of Ethiopian highland degradation in many ways and studies made in this site may have wider application to other highland regions of the country. Some attempts are being made to consider the Yerer Mountain as a botanic garden, even though not much has been achieved in that line (Ensermu Kelbessa, personal communications).

Therefore, this research will address relevant issues on Land Use and Land Cover changes in relation to the socio-economic set up of the study area and try to provide recommendations which may contribute to the sustainability of highland environments and hence the betterment of the livelihoods of farming communities in the study area and beyond.

The socio-economic features of the area were studied along with the land cover and land use change study to obtain information on:

- The rational for the prevailing land cover and land use,
- Socio-economic factors that stimulate changes in land cover and land use,

- The management techniques applied and their influence on the state of land degradation and productivity,

1.3 Objectives of the study

The general objectives of the study are to:

Establish previous and current trends in Land Use and Land Cover changes in the study area

The Specific objectives are to:

1. Study the major causes of Land Use and Land Cover changes in the study area
2. Study the effect of Land Use and Land Cover changes on human and livestock nutrition in the study area
3. Quantify soil losses due to sheet erosion and area taken up by major gullies for the study area.
4. Recommend appropriate interventions for the study area

1.4 Approaches used in the study

Two sets of remotely sensed data were used to analyse LULC changes of the study area. The temporal changes in Land Use and Land Cover during three decades were evaluated from both aerial photographs and satellite image. Using Geographic Information System (GIS), the effect of Land Use and Land Cover changes over this period was captured. In addition, the extent of sheet and gully erosion was also elucidated to quantify the rate of soil loss due to sheet erosion and expansion of gullies in terms of length and area over the specified period.

In addition to biophysical situations, in order to understand the possible causes of LULC changes of the area and address issues that enhance LULC, socio-economic situation of the area was assessed. For the socio-economic survey, each Peasant Association (PA) was subdivided into three landscape categories known as flatlands, midlands and uplands. Flatlands are those farmlands that are found in the bottomlands of each PA. Uplands are also farmlands that are found in areas that are at higher altitudes relative to other farmlands in the rest of the PA. While midlands are those areas found in between the upland and flatlands.

Both sources of data (biophysical and socio-economic) are believed to complement each other because the socio-economic data may explain the biophysical changes coming from the remotely sensed data. This may also help show future possible LULC changes and set appropriate policy mechanisms in place.

1.5 Organisation of the Thesis

This document is organised into six main chapters and a reference which are explained below.

Chapter one: This chapter deals with the background to the problem.

Chapter two: Here the literature review is detailed with environmental impacts of cover change where national and international experiences of LULC are also explained.

Chapter three: This chapter describes the study site, where climate, soils topography and socio-economic characteristics of the study area are discussed.

Chapter four: This is the materials and methods section where the methodologies employed are detailed. Sampling techniques, socio-economic and remote sensing resources used, equipment and analytical procedures and software applied are also detailed here.

Chapter five: This chapter deals with the interpretation of the results from both the socio-economic and remotely sensed data and presents different tables and figures. In this chapter, the existing farming conditions, as obtained from the socio-economic survey and remotely sensed data, are presented. Using GIS, current and three decades old Land Use and Land Cover data are also presented.

Chapter six: Conclusions and recommendations are made in this chapter where an overview of the findings is elucidated and prediction on future trends based on the results from both the socio-economic and remotely sensed data are also presented.

1.6 Overall expectations from the study

Evolving public and private land management questions call for decision-making based on robust information and data analyses. They also require continuity in data collection, and the acquisition of data at higher resolution. Hence, research on the past and current Land Use and Land Cover will provide information to enable the production of regular updates on the distribution of land cover at scales relevant for watershed or regional analyses and resource management decisions. Remote sensing and GIS provide quick and comparatively less costly information about land cover changes. In addition the ground-based surveys can provide detailed information on site conditions, including species composition, soil type, habitat quality, tillage and crop rotation history, land use classification, in addition to socio-economic situation of the area. Integrating ground-based and remote sensing data collection systems can provide an opportunity to vastly improve the speed and overall quality of Land Use and Land Cover data acquisition necessary for research and decision-making.

This study is therefore expected to achieve the following:

- Contribute to the future national land cover database that includes attributes of land cover and vegetation canopy characteristics.
- Quantify the rates of Land Use and Land Cover change for the study area.
- Recommend appropriate intervention for rehabilitation of the study area and also develop appropriate methodologies that could be applied at a larger scale.
- Predict what will happen in the future if current land use systems and population trends continue for the study area.

- Provide the necessary information for scenario simulation based on the dynamism of the situation in the study area.

1.7 Limitations of the study

The study had some limitations of its own and attempts are made to figure out some of them. It was not possible to find aerial photographs of earlier dates covering the whole study area, even though the 1957 were supposedly the earliest aerial photograph that covered most of the country. Even the ones that were available for scanning were only paper copies and may have an impact on the quality of the output.

The other limitation was that the socio-economic survey could not include as many farmers as should have been mainly due to shortage of time. The sample size for the survey was 132 household heads, around 2.5% of the total number of households in the study area, which might make generalisations a bit difficult. On the other hand, the socio-economic data analysed is mainly based on primary data collected on a single visit through interviews of these sample farmers and hence it may somehow suffer from inaccuracies in some aspects of the measurements used.

In the study area, livestock feed mainly comes from crop residues and natural pasture. Of these resources, based on the survey data it was possible to quantify the amount of crop residue available to livestock, calculated indirectly through harvest indexes, obtained from different sources. Otherwise, direct measurement, using quadrants was not possible because the survey was conducted during the dry season. Direct measurement could have enabled to quantify the composition, grasses and legumes, and thereby have a better picture of the feed resources in the study area.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 Land-Use and Land-Cover dynamics and links

Land cover has gone under continuous change for millennia. This change has occurred through the use of fire for game hunting and clearance of patches of land for agriculture and livestock production, since the advent of plant and animal domestication. This is because human's production demands cannot be fulfilled without modification and/or conversion of land covers. In the past two centuries, the impact of human activities on land has grown enormously because of population increase, technological development and the requirements thereafter, altering entire landscapes, and ultimately impacting the biodiversity, nutrient and hydrological cycles as well as climate (de Sherbinin, 2002), especially in the developing world. These diverse roles have been recognised in a large number of research publications and international conferences, symposia, and workshops devoted to the subject over the past few years.

According to de Sherbinin (2002), land use is the term that is used to describe human uses of land, or immediate actions modifying or converting land cover. On the other hand, land cover refers to the natural vegetative cover types that characterise a particular area. Land-use change is the proximate cause of land-cover change. The driving forces to this activity could be economic, technological, demographic, scenic and or other factors. Hence, Land Use and Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions which may occur at various temporal and spatial scales (Reid *et al.*, 2000).

Among others, the three international conferences on Human and the Environment (Stockholm, 1972) and the United Nations Conference on Environment, Development (UNCED) (Rio, 1992) and the World Summit for Sustainable Development (Johannesburg, 2002), called for substantive studies of land-use and land-cover changes and since then has become a global issue. This is because the effects of land-use and land-cover are directly related to the livelihoods of people. According to Pimentel (1993), as cited in Bewket (2003a), for almost all food requirements, people of the world totally depend on land resources, except for only 3% of the food which is coming from aquatic resources. Therefore, this important resource needs careful management for the sake of sustained ability to feeding the world population.

Even though, natural processes may also contribute to changes in land cover, the major driving force is human induced land uses (Allen and Barnes, 1985). In order to understand the various implications of land cover change, understanding of land-use change is essential. Different human driving forces mediated by the socio-economic setting and influenced by the existing environmental conditions, lead to an intended land use of an existing land cover through the manipulation of the biophysical conditions of the land (Turner *et al*., 1995 http://www.ihdp.uni-bonn.de/html/publications/reports/report07/luccsp.htm).

The fact that human beings are the major contributors to land cover changes and are the ones experiencing the consequences of these changes, it will be of paramount importance to understand the interaction between humans and the terrestrial environment. This need becomes more imperative as changes in land use become more rapid affecting the livelihoods of societies. In Ethiopia, inappropriate agricultural practices, deforestation and overgrazing are affecting crop and livestock productivity of the rural poor and hence their livelihoods. These alterations of ecosystem services, due to changes in LULC, negatively affect the ability of the biological systems to support the human needs. These changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations. Of course, other environmental and socio-political issues added up, Ethiopia is one of the top six food aid recipient countries in the world (McClelland, 1998). Therefore, understanding the driving forces behind land-use changes and developing appropriate measures to control or at least minimise the effects will then be very important.

2.2 Population increase and natural resources

Malthus had long hypothesised that populations growing exponentially would takeover food production growing linearly (Malthus, 1798 as cited in Boserup, 1965). On the other hand, Boserup (1965, 1981) hypothesized that increasing population pressure will lead to adjustments in production and hence the quality and productivity of the land improves. This has been true because agricultural production managed to outpace population growth due to green revolution, which allowed for a much increased productivity. Hence, growth in agricultural production exceeded population growth for almost three decades (Squire, 2000). At present, there is enough food produced around the world, the problem is that the food is unevenly distributed. However, others argue that there are ecological limits to food production which may provide little scope for future expansion (Ehrlich and Holdren, 1971).

In any case, population growth has an important influence on land use, even though other influences, such as increased per capita income (and hence consumption), governmental policies and instabilities, technological change, national and international markets for goods and agricultural products, are also likely to play key roles in land use changes. The direct impact of population growth is increased consumption of resources which would lead to increased demand for food and fibre and necessitate more intensive use of agricultural land. In the Ethiopian highlands for example, increased population has lead to more widespread use of marginal land in order to meet the increased demand of human needs. In this respect, different land uses compete with one another, and can degrade the future productivity of the land and the quality of the environment in general.

Contrary to this, case studies have highlighted situations where population growth and agricultural intensification have been accompanied by improved rather than deteriorating soil and water resources (Tiffen *et al.*, 1994). Experiences from this study in Machakos, Kenya proved opposite to what has been discussed in the preceding paragraphs. Similar trends may also be witnessed in the highlands of Ethiopia, even though what is commonly known about rural Ethiopia is environmental and social crisis due to population pressure and stasis in peasant farming technologies. However, despite of continuity of backward farming practices, farmers in some parts of Wello have innovated and responded well to physical and social environment (Crummey and Winter-Nelson, 2003). In addition, in the *enset* based farming systems, especially in Welyta, Kembata, Sidama and others, the number of trees and vegetative cover in general, has been increasing or at least has been maintained, despite these areas being few of the highly populated in the country. On the other hand, Konso, which is semi-arid and with relatively high population and marginal lands, the area is still productive and supportive of the population due to the indigenous knowledge of the people on soil conservation effects. On the other hand, some of the northern highlands are degraded almost beyond recovery, despite the long history of government efforts to arrest soil erosion. This is because these areas were settled early and support high population, in addition to the nature of their topography and geology, which make them prone to this phenomenon.

From the preceding information, it is not possible to make a blanket conclusion as to whether population is likely to enhance land degradation, as in the case of the northern highlands or land will be rehabilitated, as in the case of the *enset* based farming systems in Ethiopia and Machakos in Kenya. Hence, socio-economic and biophysical aspects of each area should be considered in order to make relevant conclusions, which may lead to appropriate recommendations.

2.3 Studies on long term changes in LULC in Ethiopia

The need to conduct research on historical Land Use and Land Cover change is that by understanding the past, it could be possible to make projections for the future. As mentioned previously, among the land use changes occurring, the most significant historical change in land cover has been the expansion of agricultural lands. Since the start of plant domestication the progression of cropland was relatively slow (Houghton 1994 as cited in de Sherbinin, 2002), however, the potential future expansions of croplands will continue to be great in land used for cultivation in the developing world.

Different studies, made using remotely sensed data of different years, for some parts of Ethiopia, indicate that croplands have expanded at the expense of natural vegetation, including forests and shrublands (Selamyihun Kidanu, 2004; Girmay Kassa, 2003; Belay Tegene, 2002; Gete Zeleke and Hurni 2001; and Solomon Abate, 1994). While Kebrom Tekle and Hedlund (2000) reported increases in the size of open areas and settlements at the expense of shrublands and forests. Open areas increased by about 333% while urban and rural settlements increased by about 192 and 57%, respectively in twenty eight years (between 1958 and 1986), in Kalu area of Wello. However, contrary to other studies, majority of the croplands remained unchanged over the study period. The reasons for this being that the areas left uncultivated were either not suitable or were protected by the government.

In other studies made in the central highlands, homesteads were reported to increase, during 1957 and 1986 (Wøien, 1995), which may indicate increasing population density. Girmay Kassa (2003) in his study, in southern Wello, reported the decline of natural forests and grazing lands due to conversion to croplands. Similarly, Feoli, *et al*. (2002) also reported the expansion of bush land and evergreen vegetation with population increases. However, such expansions of cultivation, commonly into steeper slopes and marginal areas, may have been done without appropriate soil and water conservation measures. As a result, these lands become unproductive in short period of time, leading to soil erosion.

Shibru Daba *et al.* (2003) also reported the effect of Land Use and Land Cover changes in causing major gullies and quantified the expansion rate of these gullies and their effects on the livelihoods of people in eastern Ethiopia. Similarly, Selamyihun Kidanu (2004) also reported that increases in surface area of gullies from 16.6 to 36.2 ha, (from 1957 to 1994), in the central highlands of Ethiopia.

2.3.1 Land cover changes and its impacts in Ethiopia

2.3.1.1 Crop production and land degradation

Cereals occupy two thirds of the cultivated land in the Ethiopian highlands. Some reports even indicate that grain crops to occupy about 90% of the area cultivated under all crops in Ethiopia (CSA, 2003).

Soil degradation in Ethiopia can be seen as a direct result of the past and present agricultural practices on the highlands. The dissected terrain, the extensive areas with slopes above 16 percent, and the high intensity of rainfall lead to accelerated soil erosion once removal of vegetation occurs. Also some of the farming practices within the highlands encourage erosion. These include cultivation of cereal crops such as tef (*Eragrotis tef*) and wheat (*Triticum* spp.) which require the preparation of a fine-tilth seedbed, single cropping of fields, and the down slope final ploughing to facilitate drainage. Furthermore, it is also assumed that insecurity of land and tree tenure has discouraged farmers from investing in soil conservation practices.

Research has shown that soil erosion is greatest on cultivated lands where almost half of the loss of soil comes from, even though they cover only 13 percent of the country (Hurni, 1990). The highest average rates of soil loss are from currently unproductive but formerly cultivated lands with less vegetative cover (Table 1). Excessive land degradation, along with other climatic factors such unreliability and high intensity of rainfall could lead to reduced average crop yields per unit area (FAO, 2000). As a result of continuous low crop yields, the total produce of most farming families is not sufficient to cover their annual consumptions. The following table shows amount of soil erosion lost from different land cover types in the Ethiopian highlands.

Table1. Estimated rates of soil loss on slopes in Ethiopia (including Eritrea)

Land cover	Area of country (%)	Estimated soil Loss tons/ha/yr	Total soil loss million tons/year	% of total
Annual crops	13.1	42	672	45
Perennial crops	1.7	8	17	1
Grazing and brows	51.0	5	312	21
Forests	3.6	1	4	-
Wood and bushland	8.1	5	49	3
Currently unproductive	3.8	70	325	22
Currently uncultivable	18.7	5	114	8
Total			1,493	100

Source: Hurni (1990).

Associated with the soil movement is the loss of organic matter (OM), nitrogen, phosphorus and potassium and other essential plant nutrients. According to Tamirie Hawando (1997), lose of OM associated with removal of surface soil ranged from 15-1000 kg/ha/year, which amounts to 1.17-78 million tons of OM per year from 78 million ha of cultivated and grazing lands. Similarly, the loss of soil nitrogen ranged from 0.39-5.07 million tons/year and that of phosphorus ranged from 1.17-11.7 million tons/ha/year. Taking an average loss of 30, 200 and 75 kg/ha/year of nitrogen, OM and phosphorus, respectively, the corresponding loss of the plant nutrient amounts to 15.6, 2.34 and 5.85 million tons/year of OM, nitrogen and phosphorus, respectively, from the same area of land (Tamirie Hawando, 1997) (Table 2). However, care should be taken in making inferences by only looking at these values, which are alarming, because natural mineralisations also occur. For example, Barber (1984) estimated an annual mineralisation of 40 to 80 kg/ha from N "store".

However if one attempts to calculate the nutrient losses, without considering the amount of nutrient mineralisations, the amount may be alarming. Based on the average annual losses of nitrogen and phosphorus in Table 2 and converting these losses further into the common fertilizer types, DAP (diammonium phosphate; 18-46-0), Urea (46-0-0) and TSP (0-46-0), this will be approximately 86,670, 17,000 and 40,217 tons, respectively. Considering the present prices, these fertilizers would have a value of about birr 255 million (based on 2001 prices at Akaki, for the common fertilisers and 100 birr per quintal for TSP). On the other hand, Ethiopia had imported 192,995 and 92,828 tons of DAP and Urea fertilizers during 1999, respectively (FAO/WFP, 2000), which was worth about birr 572 million. At the nationally recommended application rates of 100 and 50 kg/hectare of DAP and Urea, for cereals, the fertilizer lost due erosion could be sufficient to fertilize, approximately one million ha of the cereal crops grown nationally, assuming it was only applied on cereals.

Comparing to what has previously been reported by EHRS (1984), Sutcliffe (1993), and Bojö and Cassells (1994), the soil lost from the Ethiopian highlands ranged from 14.8 to 150 million US dollars, and with the present exchange rates are roughly equivalent to be between 150 and 1500 million birr. Even though these studies were meant for the highlands (about 500,000 km^2) and considering the area proportionally, what Tamirie Hawando (1997) had reported falls in between those earlier reports. However, similar to the forestry case, (which will be detailed soon), the issue of soil erosion is also reflecting inconsistencies in reports. It is evident however that, at any scale of measurement, soil erosion in Ethiopia is among the highest in Sub-Saharan Africa (El-Swaify and Hurni, 1996).

Table2. Annual loss of organic matter, nitrogen and phosphorus associated with the loss of top soil under various land use systems

			Nutrient documented range of annual loss, kg/ha					
		OM	15	50	100	200	500	1000
Land use type	Land area	N	5	10	15	30	50	65
	Million ha	P	15	30	50	75	100	150
			Amount of nutrient loss, million kg					
Cultivated land	18	OM	270	900	1800	3600	9000	18000
		N	90	1800	270	360	900	1170
		P	270	360	900	1350	1800	2700
Pasture & rangeland	60	OM	900	3000	6000	12000	30000	60000
		N	300	600	900	1800	3000	3900
	78	P	900	1800	3000	4500	6000	9000
Total		OM	1170	3900	7800	15600	39000	78000
		N	390	780	1170	2340	3900	5070
		P	1170	2160	3900	5850	7800	11700

Source: Tamirie Hawando (1997).

2.3.1.2 Livestock resources and land degradation

According to the Conservation Strategy of Ethiopia (CSE, 1997a), production from cattle has been estimated to be 620,000 tons of milk, 244,000 tons of meat, 24 million tons of manure, and 2.4 million hides annually. The nations protein intake is one of the lowest in the world, in which the estimated per capita milk and meat consumption is only 19 litres and 13.9 kg/year, respectively.

Increased attention to livestock-environment interactions is of critical importance in sustaining the resource base. Finding balance between increased food production and preservation of the natural resources remains a major challenge. Globally, demand for meat and milk is increasing and the livestock sector is growing at an unprecedented rate. For example, Delgado *et al.,* (2001) estimates the annual demand for meat in the developing world to grow from 111 million ton in 1997 to 213 million ton in 2020. Over the same period, milk consumption would grow from 194 million ton to 324 million ton per year in the developing world.

As in other parts of the world, livestock are essential for the livelihoods of rural poor in Ethiopia. The rural people depend on crop farming and livestock production. Currently, the livestock population in Ethiopia is estimated at about 32.8 million Tropical Livestock Units (TLU, which is equivalent to 250 kg live weight), where Ethiopia is considered to have the largest livestock population in Africa (FAO, 2002). The rural economy of Ethiopia manifests itself in the usual strong correlation between human and animal populations. As a result, the mixed crop-livestock farming system of the highlands is home for most of the livestock population in Ethiopia. Perhaps except in very limited areas of hoe culture, livestock are the essential input of the mixed farming agriculture where crop farming itself is entirely dependent upon livestock. Livestock provides the entire draught power requirement in Ethiopia. In the rural Ethiopia context, livestock population increase with human population increases so as to support the farming activity and overall rural life.

According to Befekadu Degefe and Berhanu Nega (2000), livestock contribute about 30–35% of agricultural gross domestic product (GDP), about 13–16% of total GDP and more than 85% of farm cash income. It has also been reported that between 1987–88 and 1995–96, the share of livestock in total exports averaged 16%, even though it had declined from 21% in 1987–88 to 12.9% in 1995–96 (Befekadu Degefe and Berhanu Nega, 2000).

Livestock population and hence the ability of highland farmers to produce crops, have been severely affected by recurrent droughts, because they play an important role in providing draught power and manure for crop production and energy. This is in addition to being the sources of meat, milk, fat and source of cash. Furthermore, they act as a store of wealth and determine social status within the community. Due to these important functions, livestock play an important role in improving food security and alleviating poverty (Ehui *et al*., 1998).

The deteriorating environmental conditions have also adversely affected availability of feed resources, leaving the country's herds poorly nourished and prone to diseases.

The fact that the Ethiopian highlands support a large livestock population (Table 3), the area experiences a severe deficit of animal feed. Hurni (1988) forecasted that all pastureland will be fully utilized by the year 2005; this is because the demand for cropland has come into increasing competition with that for grazing land. As yet, this has however not been proven to be totally true, even though reduction in size of the natural pasture land is inevitable.

Livestock feed in Ethiopia is derived mainly from grasses, forbs, shrubs and tree leaves. In addition, crop residues and processed by-products contribute significantly to livestock feed in the highlands. Except in some parts of Ethiopia, like the Hararghe highlands where some limited degree of cut-and-carry system is practiced, livestock are left to open grazing and browsing. According to Tamirie Hawando (1997), this figure is at about 60 million ha, with an over five million ha reduction in size due to land use change.

Shortage of livestock feed supply is highest during both the dry and wet seasons. This is because crops occupy the land and large areas of permanent pastures on the flatlands become waterlogged. An important factor contributing to the decline in fodder resources is the ever-increasing human population, which resulted in an increase in cropland at the expense of traditional grazing areas such as bush lands, natural pasture and forests (Hoekstra *et al*., 1990), which has been aggravated since recently. The simultaneous upward surge in both human and livestock populations would, therefore, bring about the depletion of the biological resources. This in turn would force livestock to move mainly to the upper slopes in search of feed or to concentrate on the small natural pasturelands or on to the roadsides. This has induced overgrazing and soil erosion, which eventually led to land degradation. Cow dung droppings from livestock, which could have been used to enrich soil fertility, are consistently collected to fulfil energy requirements of the household.

In Ethiopia, livestock were also reported to affect the physical properties of moisture content and infiltration rates (Girma Taddese *et al*., 2002a) and increased soil erosion rates on Vertisols (Mwendera and Mohamed Saleem, 1997; Mwendera *et al*., 1997). The actions of animal hooves, especially, the small cloven hooves of sheep and goats are believed to be destroying vegetative covers hence enhance land degradation.

Heavily grazed plots were reported to have lower species richness than those medium grazed ones, where the latter had consistently significant increases (Mwendera and Mohamed Saleem, 1997; Girma Taddese *et al*., 2002b). Similarly, Zerihun Woldu and Mohamed Saleem (2000) reported that heavily grazed and non grazed plots to have promoted growth of annual plant species, even though their production potential was low due to their small sized nature and short growing cycles. However, these reports indicate that moderate grazing increases species richness better than non-grazing but at the same time, as grazing intensity increases, species richness also decreases.

Table 3. Composition of livestock in highlands and lowlands of Ethiopia

Livestock	Total head (000)	Highlands		Lowlands	
		Head (000)	%	Head (000)	%
Cattle	35095	28076	80	7019	20
Sheep	22000	18260	83	3740	17
Goats	16950	12374	73	4576	27
Equines	8580	6521	76	2059	24
Camels	1050	0	0	1050	100
Poultry	55000	49500	90	5500	10

Source: FAO (1999) and Hoekstra *et al.* (1990).

2.3.1.3 Forest resources degradation

According to FAO (2001), there is roughly 39 million km^2 (29 percent) of the world's land surface is under forest cover. The World Resources Institute (WRI, 1997) estimates that only one-fifth of the world's original forest cover remains, largely in blocks of undisturbed frontier forests in the Brazilian Amazon and boreal areas of Canada and Russia.

Vegetation cover and dead plant biomass are known to reduce soil erosion by intercepting and dissipating raindrops and wind energy. Under this situation, lowest erosion rates have been recorded from undisturbed forests, with ranges from 0.004 to 0.5 t/ha per year (Pimentel *et al*., 1998 as cited in Bezuayehu *et al*., 2002). However, once forestland is converted to agriculture, erosion rates increase because of vegetation removal, over-grazing, and continuous cultivation. On the other hand, there is a better understanding that forests burnt in certain parts of the world are important contributors to greenhouse gases and contributing to climate change. Overall these changes affect the livelihoods of societies.

In Ethiopia, population pressure is inducing, the clearing of forests for agriculture and other purposes, and the attendant accelerated soil erosion, is gradually destroying the soil resource (Hurni, 1990). This is because natural forests are the main sources of wood for fuel, construction and industry, even though plantation forestry is also increasingly becoming important. In Ethiopia forests may have existed long before history was recorded, but the present day forest cover does not correlate with human population in recorded history, even though environmental problems such as droughts may have also contributed to this phenomenon.

The annual loss of natural forest cover has been estimated to be 150,000 to 200,000 ha/yr^{-1} and in 1989 forest cover was estimated at only 2.7% of the Ethiopian land mass (EFAP, 1993). Today, little of the natural vegetation of the highlands remains, except for the southern and southwestern parts of the country. For example, this is evident when one drives on the road to Awasa and Arba Minch, to the south, where most of the acacia trees were removed and as a result the lakes, which once were not seen, are now easily seen from the road. The removal of these trees may result into siltation of the rift valley lakes, due to water and/or wind erosion. Consequently, large forest areas of the country are now exposed to heavy soil erosion resulting in a massive environmental degradation and serious threat to sustainable agriculture and forestry. It has been projected that, if the present rate of deforestation continues, by 2010, the area covered by natural forests will be reduced to scattered minor stands of heavily disrupted forests in remote parts of the country (EFAP, 1993). However, some believe that this is simply conjectural and argue that 2010 is only 6 years from now and the situation does not seem to have changed much (Zerihun Woldu, personal communication). However, reliable and accurate information about forest condition of Ethiopia are usually inconsistent. For example, Forest Resources Assessment 2000 (FAO, 2001) estimated that the 1997 forest cover of Ethiopia was 4.2%. The same series of studies, a decade before (FAO 1993), presented a tabulated output that indicated the 1989 forest cover to be around 12.9%. It seems that there is an inconsistency in the definition of forests. On the other hand, there is again a huge disparity in the estimation of forest cover as well as the rate of deforestation between regional, national and international studies. The Ethiopian Forestry Action Programme (EFAP, 1993) estimates the annual rate of deforestation in the range of 150,000 and 200,000 hectares. However, Conservation Strategy of Ethiopia (CSE, 1997b) reported that it ranges from 80,000 to 200,000 hectares. Such an estimate may entertain a certain amount of exaggeration to alert the public or policy makers. On the other hand, the decadal forest resources assessment studies by Food and Agriculture Organization (FAO, 1993; 2001), even though an ad hoc statement warns not to compare it with national statistics, estimates the deforestation to be between 38,600 and 40,000 hectares of natural forest per year, respectively. In fact, information on forest area considered by FAO, reflects the area actually covered with forests, assessed through field survey or remote sensing as opposed to forestland that some opt to use.

Something that cannot be ruled out, though, is the inability to clearly estimate the change due to technical difficulties or organizational inconveniencies. Hence, calls for a nation wide assessment in order to stop these inconsistencies of the Ethiopian forestry reports, be it from regional, national or international point of view.

Generally, deforestation can result in the loss of biodiversity; which in turn results in declines in ecosystem integrity, and also genetic losses that may impede future scientific advances in agriculture and pharmaceutics. WHO *et al. (*1993) reported that as many as 80% of the world population depend on herbal medicine for primary health care needs which are mainly derived from forests. The consequences of deforestation will therefore be felt by the many poor because of lack of cash to buy modern medicine. In addition, deforestation can also impact hydrological processes, leading to localized declines in rainfall, and more rapid runoff of precipitation, causing flooding and soil erosion, a common phenomenon in the study area and areas close to it (Dagnachew Legesse *et al*., 2003).

2.3.1.4 Land Use and Land Cover change and biodiversity

In Ethiopia LULC changes have been reported to cause loss of biodiversity. Amongst others, the losses of biodiversity due to encroachment to national parks are common. Even those national parks that seem difficult to reach because of mountain picks and dissected terrain, are being affected due to human encroachment. This problem of biodiversity loss is not only limited to national parks per se, but to all areas, especially the vegetation and soils of the highlands which are being affected significantly. For example, the amount of soil lost due erosion is so huge (EFAP, 1993), that it will not be difficult to imagine how much of the gene pool, especially microbes, is being eroded along with the soil and nutrients.

2.3.1.5 Land Use and Land Cover changes and the hydrological cycle

It is obvious that land cover can affect both the degree of infiltration and runoff following rainfall events, while the degree of land cover can affect rates of evaporation.

Land cover has various properties that help to regulate water flows both above and below ground. For example, tree canopy and leaf litter can help reduce the impact of raindrops on the ground, hence reduce soil erosion, while roots hold the soil in place and also absorb water. In the absence of vegetative cover, soil erosion will result and the effects of this phenomenon have been detailed previously.

Ethiopia is the water tower of northeastern Africa. However, land cover change can affect the amount of runoff to the down stream countries of the Nile basin, where every main rainy season big floods are reported. The effects of land cover are not only contained within the country, but also on the low-lying countries of northeastern Africa as well. That is why agreements are being signed between Ethiopia and these countries so that Ethiopia takes care of its soil erosion. Land cover change does not only affect the neighbouring countries but also the Awash basin, within the country, where flooding is a common phenomenon. As a result of this, millions worth of resources are lost nearly every main rainy season. Low level vegetative cover could also affect infiltration and could lead to reduced groundwater levels and therefore the base flow of streams (Dagnachew *et al.*, 2003).

2.3.1.6 Land Use and Land Cover changes and climate change

Land cover change and other anthropogenic emissions are contributing towards this problem. The United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol has been a result of the recognition of man’s role in changing the climate. Changes in land use can result in the release of carbon into the atmosphere, or withdrawal of carbon from it. In the former, land-use change is a source, and in the latter it is a sink. For example, if forest is burned, this results in a direct emission of greenhouse gases into the atmosphere. Similarly, methane is also released from livestock among others and cause climate change.

CHAPTER THREE

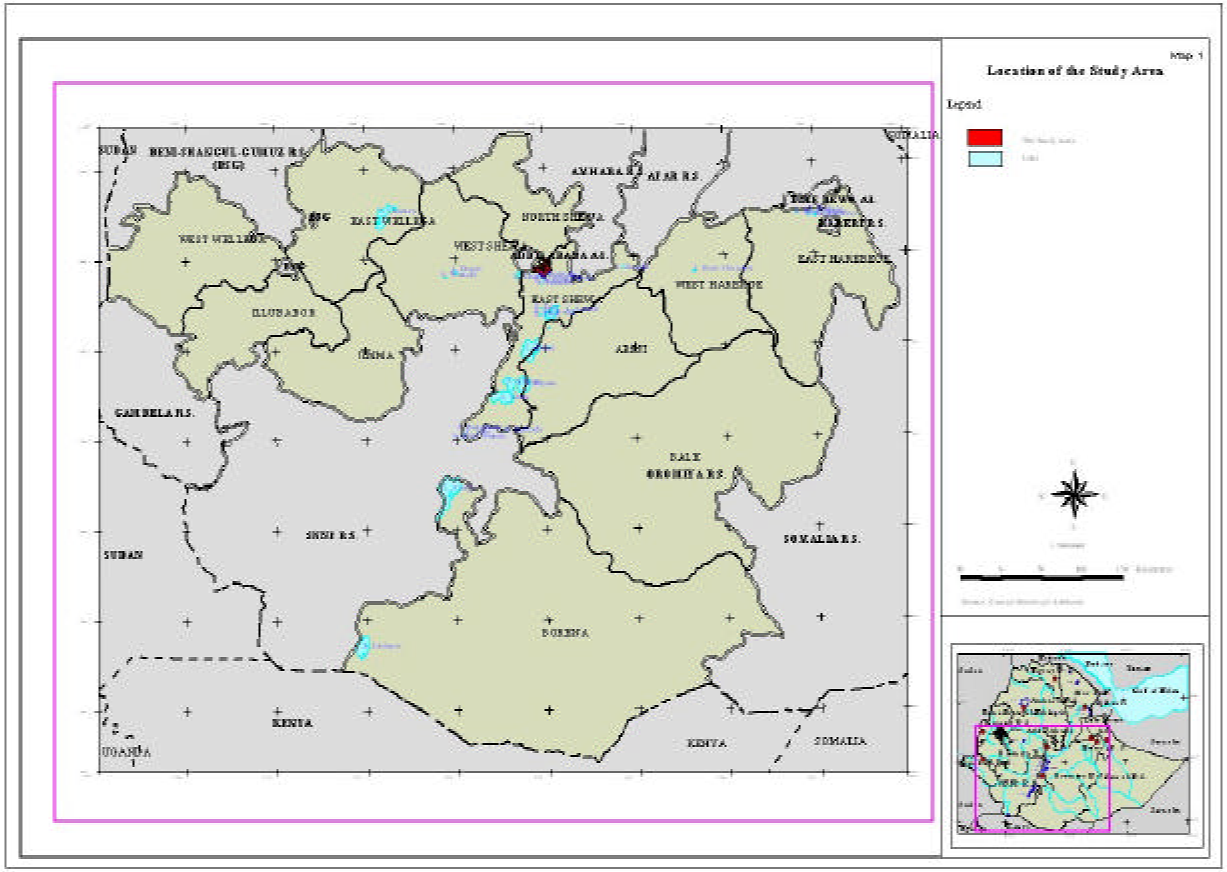
GENERAL DESCRIPTION OF THE STUDY AREA

3.1 Location

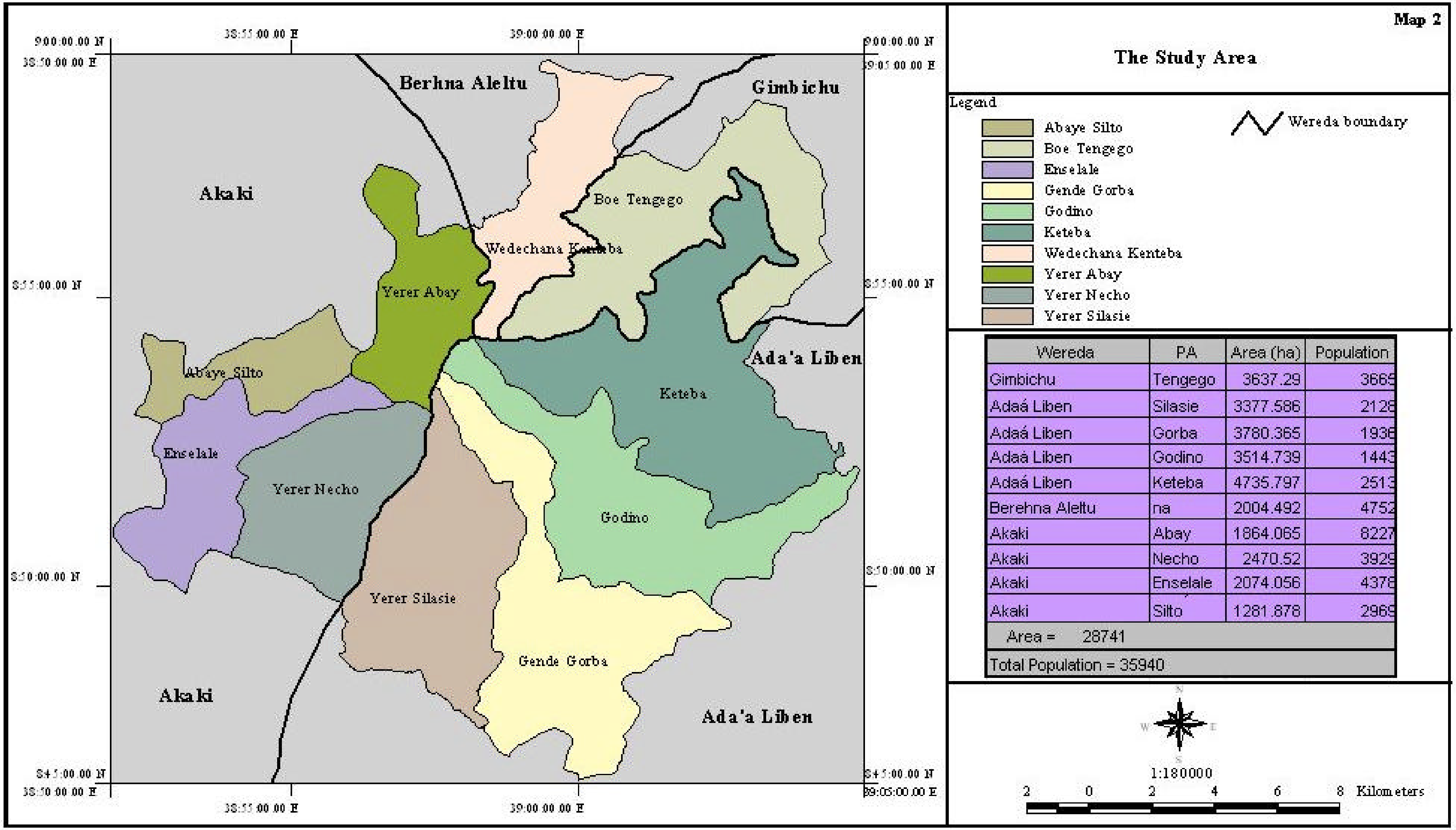
The study was conducted in Oromia Region around Yerer mountain, 40 km southeast of Addis Ababa on an area of 287.41 km^2 (after digitising CSA wereda maps with PA boundaries). The southern part of the mountain is located 14 km north of Debre Zeit town. The study site falls within 38^{0}51´ 43.63″ to 39^{0}04’ 58.59″ E and 8^{0}46´ 16.20″ to 8^{0}59´ 16.38″ N, located on the western margin of the great East African Rift Valley, close to the ILRI Debre Zeit Research Station (Map 1). Ten PAs surrounding Yerer mountain were selected for the study. The study area is located in four weredas, where the northern, southern and southeastern, western and northwestern parts are within Gimbichu, Ada Liben, Akaki and Bereh Aleltu weredas, respectively from Yerer mountain (Map 2). All PAs, except one, fall within the East Shewa Zone of Oromia.

3.2 Topography, geology and soils

Tertiary rocks (the trap series) chiefly basaltic materials of volcanic origin predominate in the Ethiopia highlands (Akundabweni, 1984). The escarpments are characterised by Precambrian crystalline rocks, while the deep river valleys have sandstone and limestone which are Mesozoic in origin. The mountain is partially eroded composite volcano mainly built up of acidic to intermediate pyroclastics and lava flows (Seifu Kebede, 1999). Yerer Mountain is the peak for the study area and the landmass of the study area slopes down from it in all directions. Majority of the study area is found in the low-lying areas which are relatively flat. The soils for these areas are predominantly Vertisols. The general slope range on which these soils occur is at 0 to 8%, but are more frequently found in 0-2% slope range (Berhanu Debele,



Map 1. Location of the study area



Wereda	PA	Area (ha)	Population
Gimbichu	Tengego	3637.29	3665
Adaá Liben	Silasie	3377.586	2128
Adaá Liben	Gorba	3780.365	1936
Adaá Liben	Godino	3514.739	1443
Adaá Liben	Keteba	4735.797	2513
Berehna Aleltu	na	2004.492	4752
Akaki	Abay	1864.065	8227
Akaki	Necho	2470.52	3929
Akaki	Enselale	2074.056	4378
Akaki	Silto	1281.878	2969
Area = 28741			
Total Population = 35940			

Map 2. The study area

1985). These areas are usually found in landscapes of impeded drainage, such as seasonally inundated depressions, deltas, alluvial/colluvial plains and others. These soils swell when wet, (have water holding capacity of up to 60-70%), and crack (as deep as 1 m) when dry, making farm operation difficult during the pick rainy and dry seasons. That is mainly why crops in the low-lying areas in and around the study area are planted late so that soils are naturally drained. This is a common practice in many Vertisol areas in the country.

Several technical constraints relating to hydro-physical properties of these soils are of particular significance to the smallholder subsistence farmer in the area where cash inputs and farm power sources are meagre. Firstly, accumulation of excess water in the soil profile and soil surface is creating serious problems for growth of most of the crop plants. Hence only part of the potential rainy season is utilised for growing crops. Secondly, time available for carrying out tillage operations are usually very small as the soil becomes hard when dry and too plastic when wet. However, a farm implement called the broadbed maker (BBM) was developed by a consortium of institutions so that early planting of crops is possible in these area (Jutzi *et al.*, 1986). Thirdly, cultivated Vertisols are generally susceptible to excessive soil erosion if they are not protected from rain and gully forming processes. These soils (0 to 50cm depth) are reported to have a pH of 7.10 (1:1, soil: water ratio), 1.82% OM, 0.07 % total nitrogen (N), 0.63 ppm available phosphorus (P) (Bray II extractable) and clay contents of about 50% (Kamara and Haque, 1988).

Based on information obtained from the PA administrations, wereda Bureau of Agriculture offices and development agents (DAs) in the field, landscape categories for the study area were classified into relatively flatland, midland and uplands, which occupy about 43, 39 and 18% of the total landmass of all PAs in the study area, respectively.

The southern frontier, which is bordering the ILRI Debre Zeit Research Station, is much flatter than other parts of the study area. Around these areas, evidences indicate that, as early as 1939 (during the Italian invasion), farm machineries were used for growing, mainly wheat and tef, by Italian farmers (McCann, 1995).

At ILRI, different studies have been carried out on the bottomlands (Vertisols) and uplands (alfisols), and detailed mineralogical studies have been made by Kamara and Haque (1987; 1988). These studies indicate however that the soils are of Rhyolite/Trachyte parent material. Most of the soils in low-lying (flatter) areas are Vertisols with pale to greyish brown in colour.

The topography of the study area is rugged and altitude ranges from about 1800 m in the southern bottomlands to about 3100 m asl on the tip of the mountain. As a result of the topography soil erosion, gully formation on the slopes and bottomlands and flooding on the bottomlands is a common phenomenon. The clearing of forest for expanding cultivated land and the attendant accelerated soil erosion is gradually destroying the soil resource in the study area, similar to other areas of the highlands (Hurni, 1990).

3.3 Water resources of the study area

There are more than ten seasonal rivers and streams that spring out from the Yerer mountain. Through these small streams and rivers, the study area drains to Awash river and its tributaries. Amongst these, Wedecha river, on which the Wedecha dam is built, with a capacity of 15Mm3 of water, is a major river where many farmers depend for irrigation water and hence for their livelihoods. Currently, about 80 hectares of land are being irrigated, even though the potential is believed to be more than this (Oromia Water, Mineral and Energy

Resources Development Bureau, 1999). In some areas however, water for both human and livestock is not easily available. In most instances the water sources are either unclean running water, where at times, both human and livestock share the same water together. In few cases, farmers use water from deep wells which were dug by Non-governmental Organizations (e.g. Kale Hiwet church), especially to the southern frontier of the mountain, where some farmers also use springs. Otherwise, for majority of the people, the source of water is not clean, because both livestock and humans use the same source of water.

On the northern frontier of the mountain there exists a dam, which was built on the Wedecha River. Four PAs from the study area and others use this water as their main source for both human and livestock. The water is highly turbid, due to fine soil particles, mainly eroded from around the mountains and low-lying Vertisols. This is a phenomenon happening through out the year. Otherwise, this river is an important source of irrigation water and many farmers depend on. Onion, sugarcane, chickpea and other vegetables are commonly grown using this source. Many farming families totally depend on this source for their livelihoods. In addition, a small town called Godino is totally dependent on this river both for drinking and irrigation purposes.

Chelekleka is a seasonal water lake and according to Getachew Tefera (1980), as cited in Seifu Kebede (1999). It was a permanent water body since 1968-69, with an area of about 1.7 km^2 and a maximum depth of 1.5 m. As part of the water body recedes (depending on the intensity of the small rains), some farmers grow chickpea and harvest the crop before the on set of the main rainy season. Additionally, there is another small seasonal lake, Chefe, which falls within the study area, which again drains to Wedecha river during the rainy season and dries in about February. Farmers use the land that was under the water body for growing chickpea. Chickpea is a crop that is mainly grown on residual moisture in the flatter parts (Vertisols) of the area, as is common in other areas with the same soil type.

3.4 Climate

3.4.1 Rainfall

Ethiopia's seasons result from three influences on air mass circulation. They are: Inter-Tropical Convergence Zone (ITCZ), the northeast trade winds, and the southwest monsoons. The inter-annual oscillation of the surface position of the ITCZ causes variations in the wind flow patterns in Ethiopia. In its oscillation to the north and south of equator, the ITCZ passes over Ethiopia twice a year and this migration alternatively causes the onset and withdrawals of winds from north and south (EMA, 1981). As it drifts towards the north, equatorial jet streams from the south and southwest invade most parts of Ethiopia while the Trade Winds retreat. Its southward drift marks the onset of Trade Winds from the north and causes the equatorial monsoons to retreat. This periodical anomaly of winds causes rainfall to be variable and seasonal in Ethiopia.

There are two rainy seasons in the Ethiopian highlands known as "Meher" (Kiremt), which denotes the big rains while "belg" denotes the small rains. The big rains occur between June and September when the ITCZ is to the north of Ethiopia, while the small rainy season is usually between March and May. Winds from the gulf of Eden and Indian Ocean highs are drawn towards this centre and blow across central and southern Ethiopia. These moist easterly and south-westerly winds produce the main rains for the south-eastern Ethiopia and the small rains of spring to the east central part of the north-western highlands.

Although rainfall is bimodal, it is the big rains that are mainly used for crop production. Rains during the months of July and August are very intensive. Cropping operations are not carried out during the small rains, but it helps to grow grasses for livestock and is also used for preparation for the main rains. However, a small portion of the highlands, about 10%, use the short rains for crop production.

The weather data reported here is based on information from EARO Debre Zeit Research Centre and ILRI Debre Zeit Research Station, which are the nearest stations around the study area. The long-term (1953-2003) annual rainfall of the area is 839 mm on an average (Figure 1). Rainfall shows large seasonal variability. The area has a bimodal rainfall pattern, with the small rains occurring from March to May and the main rains from June to September. Based on the long-term data, more than 75% of the annual rainfall is received during the main rains, which is when cropping normally takes place. The highest rainfall was recorded in the year 1966, where the annual rainfall was 1287.mm, much higher than the average (Annex 1). The small rains could sometimes be erratic but there is no cropping during this period, except it is important for softening the land which will facilitate land preparation in addition to growth of some fluffy grasses for livestock.

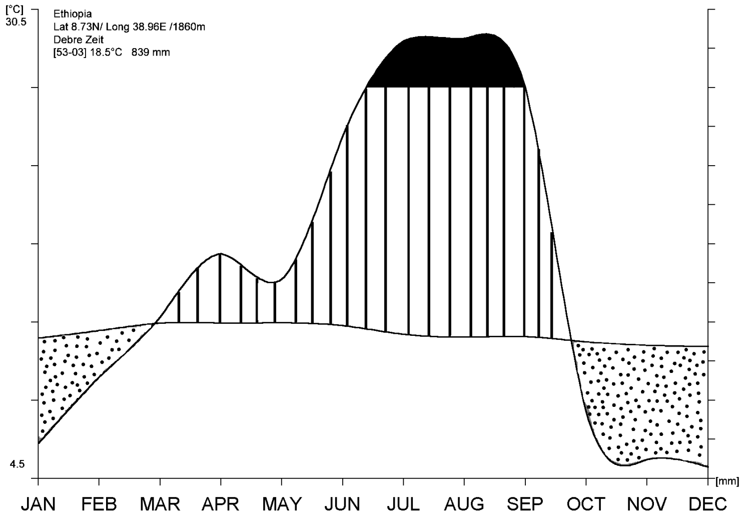


Figure 1. Climadiagram for Debre Zeit for 1953–2003 (rainfall) and 1977-2003 (temperature)

3.4.2 Temperature

Latitude, altitude, winds and humidity, with varying magnitude have significant impacts on temperature conditions in Ethiopia. The overall temperature in the Ethiopian highlands is lower than those in tropical lowlands. The average fall in temperature is 0.6 ^{o}C for every 100 m rise in elevation. The average temperatures are typically tropical and fluctuate by 5 ^{o}C between the coldest and warmest months (Sanchez, 1976). The annual variation is from 2 to 6 ^{o}C in the Ethiopian highlands (Griffiths, 1972 as cited in Akundabweni, 1984). The average minimum and maximum air temperature data at 1.5 m for twenty seven years (1977-2003) (Annex 2) ranged from 7.9 (1985) to 28.2 ^{o}C (1987), respectively. However, mean annual temperature for this period was 18.5 ^{o}C. Highest temperature was observed for the months of March, April, May and June. While the months October, November and December had the lowest temperatures (Annex 2).

Temperature and rainfall are considered to be the two most important factors in the agriculture of the highlands as further recognized by the traditional names used to describe their combined effects on the climate of the highlands (Amare Getahun, 1980).

3.5 Sheet erosion

Sheet erosion is a uniform removal of soil in thin layers from slopping lands. It is the soil movement from raindrop splash resulting in the breakdown of soil surface structure and surface runoff. This occurs rather uniformly over the slope and may go unnoticed until most of the productive topsoil has been lost. Raindrop erosion is important for sheet erosion because it has velocities of about 6 to 9 m/s, where as overland flow velocities are about 0.3 to 0.6 m/s (Schwab *et al.*, 1981). The effects of sheet erosion are severe where rainfall intensity, slope gradient and length are high and at the same time where vegetative cover is low. Raindrops cause soil particles to be detached and the increased sediment reduces the infiltration rate by sealing the soil pores. Areas where loose shallow topsoil overlies tight subsoil, like the soils of the uplands and midlands around the mountain, are most susceptible.

3.6 Gully erosion

Due to the topography and possibly poor vegetative cover around Yerer Mountain, flash flood is released forcefully down to the productive bottomlands. When the floods reach the bottomlands (Vertisols), the soft and easy to move soils are easily damaged. This is because the farmers' management practices, like fine seedbed preparation on croplands will facilitate easy movement of the soils and enhance erosion (Hudson, 1971). Majority of crops in the area are grown on flat and midland parts of the study area, which are also prone to gully erosion (Hussein and Adey, 2001). It is very common to see the highly productive lands affected by gullies. In addition to damaging the productive lands and affecting productivity, accessibility to many of the villages is affected during the rainy seasons and many farmers complain about this issue. During rainy seasons, large amount of water is carried down the slope resulting in flash floods. These are causing enormous damage on the existing trails through the change of courses, silt deposition, increasing in width, depth and number of these gullies. The following figure (Figure 2) taken in July 2003 demonstrates the magnitude of flooding around ILRI Debre Zeit Research Station and the neighbouring smallholder farmers' plots. As a result, many farmlands are being taken out of production.

Courtesy: Azage Tegegne

Figure 2. Flood photo at ILRI Debre Zeit Research Station (July 23, 2003)

This is mainly due to the topography and possibly poor vegetative cover around Yerer mountain where flash flood is released forcefully down to the productive bottomlands. When the floods reach the bottomlands, the soft and easy-to-move soils are then damaged. In addition, farmers' management practices, like fine seedbed preparation facilitates and enhances erosion (Hudson, 1971). Majority of crops in the study area are found on flat and midlands, which are mainly Vertisols and are also prone to gully erosion (Hussein and Adey, 2001). In nearly all places, it is common to see the highly productive lands affected by gullies. In addition to damaging the productive lands and hence productivity, accessibility to many of the villages is affected during the rainy seasons. A quick Participatory Rural Appraisal (PRA) was conducted to identify priority problems for two of the peasant associations within the study area, where lack of accessibility was considered as the number one problem for these communities. This is because the gullies become full of floodwater and hamper accessibility to their villages during rainy seasons. It is even feared that the newly expanding gullies in one of these peasant associations is close to destroying a spring which is the only source of water for many households (Figure 3). This in turn will have an impact on livelihoods of the farmers in the area. Therefore, if proper land management practices are not practised, land degradation could be enhanced.

Courtesy: Kai Sonder

Figure 3. A newly coming up gully approaching one of the springs in the study area

3.7 The mixed crop-livestock farming systems

The major composition of livestock is cattle, even though sheep, goats, donkey and horses are also important in the study area. Cow dung is burnt for fuel but not used as manure, crop residues are fed to livestock rather than returned to the soil, and even harvesting is made as low as to the ground level. Hence, croplands are left without much of ground cover in the study area. On the other hand, livestock also graze whatever is left on the ground immediately after harvest, giving it no time to decompose and contribute to soil fertility improvement. The area is intensively cultivated for crop production and feed resources are in short supply, except in some months of the year, when availability is better. Details about livestock production for the study area are presented in Chapter 5.

In general, wheat and tef are the dominant crops grown in the area, but there is a trend that farmers in the northern part of Yerer Mountain predominantly grow wheat, while those in southern part grow mainly tef. In addition, farmers on uplands grow mainly barley, faba bean and field peas. Of the tef varieties grown in the area, mainly white *tef* and some times mixed *tef* are grown to generate cash to the household, while red *tef* is purely produced for home consumption. However, as a result of the population increase, household land holdings have been diminishing from time to time, about which farmers have complained of low crop and livestock productivity.

According to the four wereda Bureau of Agriculture offices, all households depend on agricultural (mixed crop-livestock systems) production for their livelihoods. However, in very few cases, mainly widows, practice mini trade while some relatively better off male farmers, practice some kind of business like livestock marketing.

3.8 Socio-economic characteristics of the study area

3.8.1 Social organisations

Immediately after the downfall of the emperor Haileselassie in 1974, the then new government created what are known as Peasant Associations (PAs). These associations were the legal institutions formed as the lowest administrative units in the country. These are responsible to handle arbitration among fellow members, collection of taxes and credit repayments. Service Cooperatives (SC) established some years later by the Ministry of Agriculture (MoA), are also responsible for linking the farmer and industries and vice versa.

It avails fertilizer, improved seeds and hand tools and other consumables to members, while raw materials from farmers are sold to industries. They were also established to stabilize market and reduce exploitation of members of the SC.

Up until now, the modern organisations in rural Ethiopia, PAs, Service co-operatives and the new association called farmers' union, which is a coalition of many service co-operatives at a wereda level, are institutions linking the government with the rural population. The main aim of the latter organisation is similar to what SC has been doing, but at a higher level (wereda level). In addition, to these modern institutions, it is very common to find many traditional social organisations like *idir, ikub, debo, sembete, Mekenjo (*oxen sharing arrangement), oxen owners' *idir* and many others, in the study area. Oxen owners' *idir* is meant to help share expenses when a draught oxen dies, because draught oxen are one of the major assets of the rural population, which is similar to what has been reported by Kahsay Berhe *et al*. (2001). Equally important also is *debo,* which is applied during crop production, house construction, when a major labour force is required which a single household alone cannot accomplish. Mengistu Woube (1986), as cited in Solomon Abate (1994), has detailed the significance of these kinds of institutions.

Due to the recent reorganisation of administrations in the country, it is now very common to find formerly two to three PAs forming a single PA and equally so, service co-operatives have also been merged. It is for this reason that it is very common to find PAs with sizes of more than 800 ha. This was the size of one PA when the PAs were created by the Dergue regime. However, there was no limitation on the number of households a PA should be composed of.

As the PAs, where the study has been conducted, are distributed in four different weredas they fall into different service cooperatives as well. During the survey some service co-operatives were observed buying grain from farmers (when crop prices are very low) for sale at a different markets. This will enable farmers to obtain a reasonably better price.

3.8.2 Settlement patterns

When villagisation was very active, small countryside villages looked like small towns. However, once the Dergue regime was removed from power in 1991, the situation changed. Farmers were given the option to either stay or go back to their old premises, many farmers opted to go back. However, some of their villages were abandoned and as a result their trees, garden and fences were all dismantled. Those that decided to return had to be re-established from scratch. For example, during the change of government in 1991, demand for tree seedlings was very high around Ginchi, mainly for fencing purposes (personal observation). However, in some areas where farmers also opted to stay behind, which is evident in some villages within the study areas. This is especially so in areas where some infrastructure were set up. For example, due to the construction of Wedecha dam and development of irrigation facilities coming closer to these homes, most of the farmers in Godino and Goha Worko remained in these new settlement areas.

Behailu Abebe *et al*. (1996) also indicated that farmers from Sirba Godeti, around the study area, complained about the villagisation programme because of smaller backyards (1000 m^2). In addition, they also reported that their livestock were affected by communicable diseases. This has resulted into 50% of the households to demolish their houses and construct new ones in their old premises or in other new areas.

Even though settlements are scattered in general, the bottomlands, which are usually waterlogged, are normally left for cultivation because of inaccessibility and livestock production associated problems during rainy seasons. Instead, well drained areas within the bottomlands are always preferred.

3.8.3 Farm activities

The major farm activities in the area include land preparation, planting, weeding, harvesting and threshing. These operations are done differently depending on the crop type.

Land preparation: This operation starts long before planting is done and depends upon the crop type and its planting time in order to expose weeds and pulverise the crop fields. This is carried out using draught oxen, except under very few cases where hand hoe might be used. Hoe cultivated plots are usually under the hops plant (*Rhamnus prinoides)* and maize and the size of these plots are usually very small.

Planting time: This is the next operation after land preparation. This operation determines the erosion rate from crop fields. Traditionally, crops on Vertisols are planted late because of the waterlogging problems and hence a substantial amount of the rains are wasted. The commencements of the first showers determine this operation, but because many years of experience on the timing of the rains by farmers, planting time is almost defined. Planting is done by broadcasting seeds.

Weeding: This is a labour intensive operation. Crops like *tef* will require about three times of weeding and is the most labour intensive operation. This is especially so because plants are tiny and can not stand competition at the initial stage. Care is also needed so that the tiny plants are not mistakenly removed for weeds and the operation becomes time taking. Weeding for other crops is not as intensive as for *tef*.

Harvesting: This operation is usually carried out by family labour, but it is also very common for farmers to seek for casual labour, especially for tef. There are farmers who usually come from north Shewa zone seeking for employment opportunities.

The timing of these operations for the major crops grown in the study area is shown in Figure 4.

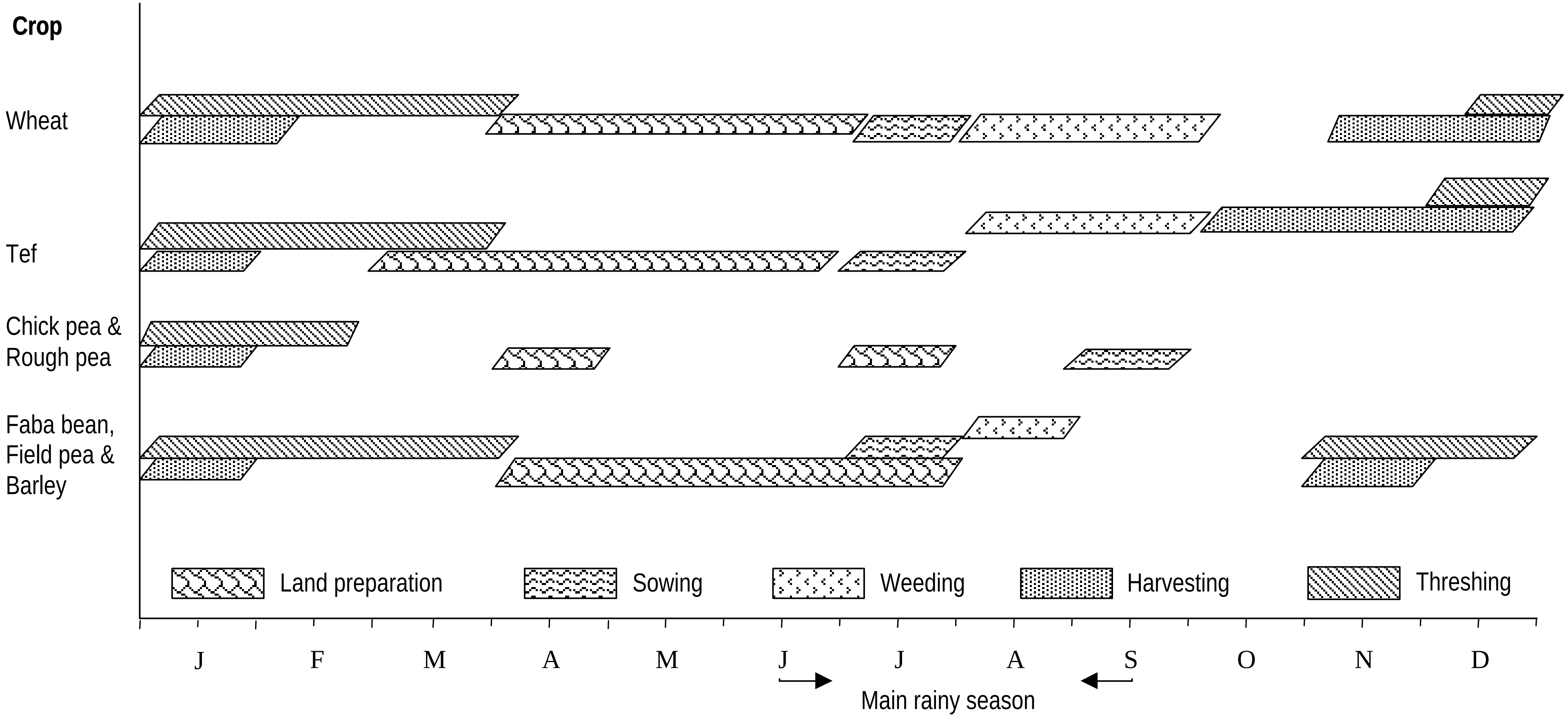


Figure 4. Farm activities for some crops in the study area

3.8.4 Labour requirements

Under normal situations farm families are labour self-sufficient. However, seeking for casual labour is also common, especially during harvest periods. Similarly, exchange of labour, mainly for harvesting and threshing and sometimes for weeding is also common. Of these exchange systems, the most common system is "*debo*" Under this system the host is expected to provide food and drinks at noon and evening. Reciprocation in this case is not obligatory. Another system followed is "*wenfel*" which differs from "*debo*" in that reciprocation is obligatory and in that it is practiced in small numbers of 3-4 persons. Yet another system is "*jigge*" which is mostly organised for rendering assistance to members of the community afflicted with natural calamities in rebuilding damaged houses etc. or community activities like road building. The beneficiaries are not expected to provide food and drinks as in the case of "*debo*" or reciprocity as in "*wenfel*". When oxen labour is in short supply, human labour is exchanged at the rate of two days of work for every one pair of oxen used per day. Seed is exchanged at sowing time. After harvest only the same amount of grain is to be paid back.

Farmers at times get work done, mainly harvesting, at piece rates. For harvesting one hectare of *tef* crop birr 240 to 260 is paid. Occasionally, casual hiring of male labours is also reported for ploughing who are paid at birr 65 per month, while a herder could be employed at birr 40 and 200 kg of grain per year. These are usually young illiterate males. If employing a farmer, who does all farm activities on behalf or with the household head, is needed 300 kg of grain and birr 60 is paid annually. All of these employments include food and clothing from the employer.

As far as the share of responsibility among family members is concerned, men are responsible for the bulk of the farm activities. Women and children are also the main labour forces for hand weeding, harvesting, transporting of grains and straw, winnowing. From the survey, it was found that children, as young as 13 years of age, were given the responsibility of farm operations in women (widow) household headed families, where older male household members were missing. Employed labour also contributes to some farm families during peak seasons of agricultural operations like, weeding and harvesting.

3.8.5 Demographic features of the study area

The total population of the study area is with an area of about 287.41 km^2, (obtained after digitising the ten PA boundaries included in the study), and a total population size of 35,940 people, as obtained from respective Bureaus of Agriculture Offices (BoA). According to these figures, the household size would be about 6.5 people. Considering the size of the study area, the average population density would stand at about 125 persons per km^2. This also takes into account the FFDME administered natural forest area, which is scattered (FFDME, 2001), which will mean that the population density will be higher than what is reported here, if only the land area under the PAs is only considered. According to the same reports from BoA offices, the proportion of women household heads in the study area was about 12% (Annex 4). Current population density for the weredas where the PAs are located is 137.1 persons/km^2 (Annex 3).

3.9 Vegetation

The natural vegetation is diverse and reveals successions of species based on altitude. This is despite the fact that much of natural vegetation has been destroyed or altered by prolonged cultivation and human settlements. However, information regarding the types of species in different altitude ranges with in the study area is not available, except for some studies made by ILRI and a field report from the Finfinne Forest Development and Marketing Enterprise (FFDME, 2001). Before the 1950s, the report by FFDME (2001) and the elders of the area indicate that, the mountain was covered with indigenous trees of mainly *Juniperus procera.* Other common bush and shrub species in the mountain include *Dodonea angustifolia, Carissa edulis, Otostegia integrifolia, Rhus retinorrhoea, Osyris compressa, Myrsine africana, Euclea shimperi, Erica arborea* and others. In addition to these species, the common tree species currently found in the Yerer mountain include, *Cupressus lustanica,* (in the woodlands), *Eucalyptus camaldulensis and Euphorbia* spp. *(*around homes*), Acacia albida, A. seyal, A. sieberiana* (on farm lands). *Eucalyptus camaldulensis,* which was introduced to the area in 1950s (FFDME, 2001) seems to increase in the landscape. The grasslands composition of the bottomlands includes *Andropogon* species, *Festuca* species, *Eleusine* species, *Sorghum arundinaceum, Brachiaria eruciformis, Setaria pallide, Commelina latifolia, Dinebra rectoflexa, Trifolium* species, *Indigofera arrecta, Medicago sativa, Plantago* spp. and others.

In addition to cow dung, the forest is the main source of energy and construction for villages surrounding the Yerer mountain, as a result of which the area is continually deforested due to indiscriminate cutting and fire. Early in 2003, the forest was set into fire and about 156 ha, mainly composed of old *Juniperus procera* trees, was burned down (Adaa Liben wereda Ministry of Agriculture, personal communication).

3.10 Wild life

According to the field report of FFDME (2001), the common wild animals of the mountain include Dikdik (*Madoqua phillipsi*), Baboon (*Papio hamadryas*), serval cat (*Leptailurus serval*), bush brick (*Tragelaphus scriptus*), warthog (*Phacochoerus ethiopicus*), spotted hyena (*Crocuta crocuta*).

CHAPTER FOUR

MATERIALS AND METHODS

This chapter gives an over view of the materials and equipment used, methods applied for data collection, analysis, aerial photograph and image classification procedures.

4.1.Socio-economic study

4.1.1 Data acquisition and sampling technique

Through structured questionnaires, socio-economic data were obtained from randomly selected 132 farmers, from ten PAs surrounding Yerer Mountain. Peasant Association level information was also collected from both DAs and Bureaus of Agriculture offices of respective weredas. Census data from CSA were also used, along with own-generated data through farmers' interviews. Field observations also helped to answer some questions. In addition, literature from different sources, both published and unpublished was used.

According to the current administrative arrangements, there are ten PAs surrounding the Yerer mountain and all were selected for the study. Each PA was stratified into three landscape categories, flatland, midland and upland, depending on where the farmlands of the households exist. The PA officers and DA in each PA estimated the area under these landscape categories. Then, proportional to the population of the PA, number of farmers was then identified at each landscape. Once the number was determined, farmers to be included for the survey were randomly selected from the lists of farmers in each PA, obtained from either the DA or PA administration offices. High school leavers were recruited and trained to conduct the survey. The facts that the farmers in the area are Oromifa speakers, bilingual enumerators from the study area were recruited. Prior to implementing the survey, household questionnaire was tested after which necessary amendments were incorporated.

Two types of questionnaires were designed to assess the socio-economic situation of the study area, which were administered to sample households and sample PAs (Annex 5; Annex 6). The total number of farmer households to be interviewed for the household questionnaire was pre-determined to be 150, but for technical reasons only 132 households were interviewed. These were 57, 51 and 24 household heads from flatlands, midlands and uplands, respectively. Number of households was assigned to each PA based on its population. In addition to the household questionnaire, other relevant data were also collected at PA level. The PA level questionnaire was obtained from a group of PA administrators, elders and from data existing in DA offices. The PA level and household questionnaires helped to collect data on farm size, cropping patterns, human and livestock population, household size, area under crop production,

In order to bridge information gap, secondary data that could not be available from the households or PAs were also obtained from governmental organisations, ILRI and other personal communication.

4.1.2 Data analysis

The socio-economic data obtained from the survey was entered and analysed using Statistical Package for the Social Sciences (SPSS, 2002). Data were checked for consistency and were cleaned when necessary and made ready for analysis. Multiple Duncan’s test and Pearson Correlation were used for interpretation of results.

4.2 Land Use and Land Cover study

4.2.1 Data acquisition and stratification of the study area

Present and past information on land cover and land use change for the study area was generated from remotely sensed data. Seventeen black and white aerial photos from 1971/72 (scale of about, 1: 43,000) were obtained from Ethiopian Mapping Authority (EMA). In addition to the aerial photos, satellite image from Landsat ETM+, number 168-54 (February 2000), was obtained. Both resources were used to analyse land cover and land use changes over the years for the study area. Detailed digital image processing and visual interpretation of satellite images and the aerial photos were made. It is believed that the time gap of about three decades between the aerial photos and the satellite imagery is wide enough to show changes and trends in Land Use and Land Cover in the study area. Topographic maps and maps of four weredas with PA boundaries, both at 1:50,000 scales, were obtained from Ethiopian Mapping Authority (EMA) and Central Statistics Authority (CSA), respectively.

Image classification is the extraction of differentiated classes of land cover and land use categories from remotely sensed data from both satellite and aerial photos. For the satellite image, pre-field image processing was done using colour composite of bands 3, 2, and 1 in RGB transformation. Geo-referencing of the image from February 2000 was used to establish relationship between row and column numbers with actual coordinates using the topographic maps. Supervised classification was undertaken by following three stages, training sites, classification and outputs. The classification legend was made based on spectral characteristics. Classification was done using maximum likelihood classifier (Lillesand and Kiefer, 1999). A 3x3 pixel moving windows majority filter was employed to smooth the classification. A map was produced at a scale of 1:25, 000 for sampling design and fieldwork.

4.2.2 Data analysis

4.2.2.1 Land cover and land use classes and definitions

From visual and digital interpretations of the aerial photos and imagery, different LULC categories were distinguished, so that it will be possible to investigate changes that occurred since 1971/72. Based on the 1971/72 aerial photograph (base year), the land cover classes analysed for changes were: cultivated land, grasslands, degraded grasslands, dense and open shrubland, wetland and water body. The description of these land cover categories is given in Table 4.

Table 4. Description of land cover categories for change detection between 1971/72 and 2000 for the study area

Land cover	**General description**
Cultivated land	Areas of land ploughed/prepared for growing rainfed or irrigated crops. This category includes, areas currently under crop, fallow and land under preparation. Unless mapping scale allows, physical boundaries are broadly defined to encompass the main areas of agricultural activity and are not defined on exact field boundaries. The class may include small inter-field cover types (e.g. hedges, grass strips, small windbreaks, etc.) as well as farm infrastructure.
Dense shrubland with scattered remnant juniper trees	Areas covered with shrubs forming closed canopies and trees inclue *Juniperus procera*, *Eucalyptus camaldulensis*, *Cupressus lustanica* and others, which are relatively tall and dense trees.
Open shrubland	Areas covered with small trees, bushes and shrubs, mainly *Dodonia viscose, Carissa edulis, Otostegia integrifolia, Rhus retinorrhoea, Osyris compressa, Myrsine africana, Euclea shimperi* and *Erica arborea* with less crown cover.
Degraded grassland	Areas under degraded grasslands and with some areas that are bare ground (rocks).
Grassland	All areas covered with mainly natural pasture, but also other small sized plant species.
Wetland	Natural areas where water level is shallow and when it recedes, some of the land could be used for crop production.
Water body	Areas covered by manmade small dams, known as Wedecha dam and seasonal water bodies.

The land cover categories from the aerial photo were scanned as polygon coverage in vector format using a scanner called Microtek Scanner Server MRS-3200 A3. In order to have uniformity in the analysis, the aerial photos were scanned at the same spatial resolution as that of panchromatic Landsat ETM+, i.e. 12.5 m, using Microtek ScanWizard Pro V6.10 for Windows, (2003). The image and the photos were orthorectified to the Universal Transverse Mercator (UTM) projection using. Contour lines from the 1:50,000 topographic maps at 20 m distance were digitised using Calcomp Drawingboard II digitising table and interpolated to create the digital terrain model (DTM). All image processing was carried out using software called Geomatica Version 9.1 software (2003).The satellite image was overlayed with the 90 m DTM and the aerial photos. The Land Use and Land Cover maps obtained from aerial photos and the image were then compared with altitude, slope, soil type and population. This will help to establish the degree of land degradation in relation to these parameters.

The following flow chart shows the procedures followed during the Land Use and Land Cover change analysis and the input resources used (Figure 5).

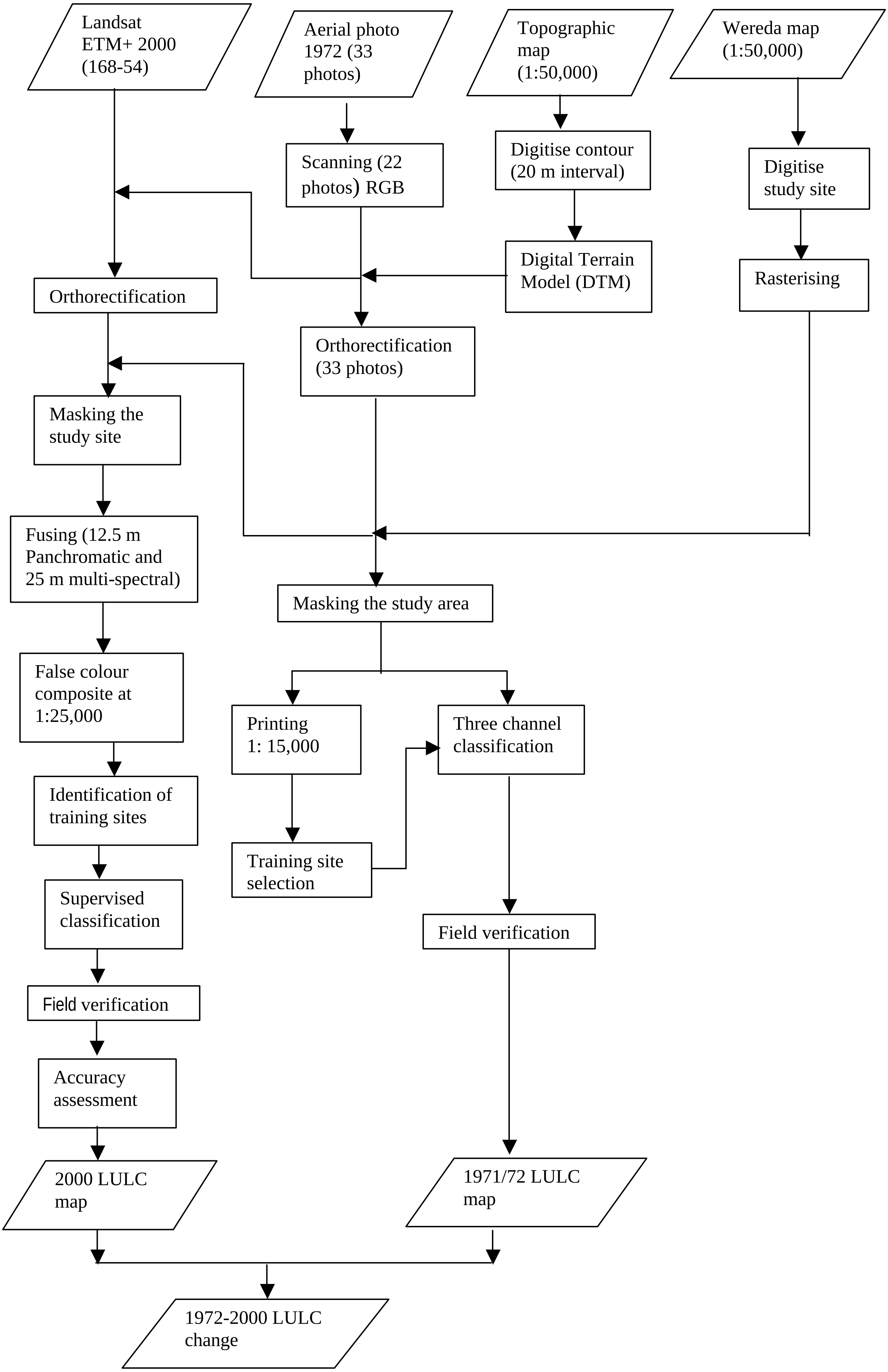


Figure 5. Flow chart showing the processes involved in Land Use and Land Cover change analysis

Five land use categories were identified for the study area. These are, agriculture, forestry, pasture, water reservoirs and wetlands. Their description is given as follows:

Agriculture: This includes both rainfed and irrigated area for cultivation.

Pasture: All grassland areas in the study area.

Forestry: This land use includes natural and plantation trees including *Juniperus procera, Eucalyptus camaldulensis,* including shrublands and other bigger tree species.

Water reservoirs: Man made dam and seasonal water bodies.

Wetlands: Lands that are seasonally under water.

Global Positioning System (GPS), Garmin eTrex (2003) was used during training site collection and ground verification of image interpretations.

4.2.2.2 Feed resources

Amount of feed from crop residues was calculated by using harvest index (grain: crop residue ratio) obtained from different sources (Annex 7) and are summarised in Table 5 below. Other feed resources that could be obtained from grasslands, shrublands and wet lands have also been estimated using systems adopted by Woody Biomass Inventory and Strategic Planning Project (WBISPP, 2000). This methodology consulted different earlier works of quantifying natural pasture productivity from within Ethiopia and elsewhere.

Table 5. Multipliers used to estimate crop residues from grain yields in the study site

Crop	Average straw to grain ratio
Wheat	2.06
Tef	2.47
Barley	1.86
Chickpea	1.31
Faba bean	1.42
Rough pea	1.54
Field pea	3.3
Maize	2.04
Lentil	1.56

Source: Calculated based on Annex 7

In addition, daily minimum DM requirements for working animals (Table 6) were also used when calculating feed resource needs for the study area.

Table 6. Daily DM requirement for MEm for animals by livestock type

Livestock type	Dry matter requirement (kg/head/day)
Cattle (local)	4.237
Sheep	0.617
Goats	0.651
Donkeys	3.125
Horses	5.000
Mules	4.375

Source Berhanu Gebremedhin, *et al*., (2004).

These two tables (Table 5 and 6) will be subsequently used as desired throughout the course of the paper.

4.2.2.3 Sheet erosion

Universal Soil Loss Equation (USLE), adapted for Ethiopia (Hurni, 1988a) was used to determine the areas currently suffering from soil erosion. The USLE uses six sets of factors to calculate soil loss in tons per hectare per year: erosivity of rainfall (R), erodibility of soil (K), slope (L), slope length (S), land cover (C) and land management (P).

The Soil loss equation is written as: A=R*K*L*S*C*P Where A= Total soil loss (t/ha/yr).

Values for these factors were obtained from data sets within the GIS. The rainfall erosivity factor of the USLE was applied to the 1:2 million map of mean annual rainfall and the soil erodibility factors were applied to FAO soil units identified on the FAO (1984) 1:1 million soil-geomorphology map of Ethiopia. Slope percentages were derived from a digital terrain model created from the 1:50,000 topographic maps of Ethiopian Mapping Agency. Slope length was assumed to be related to slope angle.

The land cover factors were based on the Woody Biomass's Land Use and Land Cover map for Oromia region. Soil erosion was grouped into five classes as follows:

0 - 3.125 t on/ ha/year	equivalent to 0 – 0.25mm of topsoil removed
3.125 - 6.250 tons/ha/year	equivalent to 0.25 – 0.50mm of topsoil removed
6.250 - 12.500 tons/ha/year	equivalent to 0.50 – 1.0mm of topsoil removed
12.50 - 25.000 tons/ha/year	equivalent to 1.0 – 2.0mm of topsoil removed
25.00 - 50.000 tons/ha/year	equivalent to 2.0 – 4.0mm of topsoil removed
> 50.00 tons/ha/year	> 4.0 – 8.0mm of topsoil removed

4.2.2.4 Gully erosion

Based on the knowledge of the area, two major gullies, which are currently active, were identified and areas damaged by these gullies were quantified. These two gullies are very important for ILRI and the neighbouring smallholder farmers because they are the sources of floodwater to their respective areas.

In order to know their current area, these gullies were measured by walking on the sides using two Garmin eTrex (2003) GPS, on track mode (real time). Both observers walking on the sides also estimated maximum depths of each gully visually at similar points and average values were recorded for each point. Following this, the maximum depth of each gully was summarised. After the data was downloaded and processing of the data made, the gully lines were created and were overlayed onto the 2000 Landsat ETM+ satellite imagery, which showed an exact overlap of these gullies on the image. Trail lines from GPS were then converted into polygons for area calculation. Following the completion of the work, area lost due to these two major gullies and their corresponding maximum width was quantified using ArcView GIS.

CHAPTER FIVE

RESULTS AND DISCUSSION

This chapter deals with results obtained from the socio-economic survey as well as the analysis of the remotely sensed data.

5.1 Socio-economic characteristics of the study area

5.1.1 Demographic features

According to the currently available figures on human population and land size, population density for the ten PAs in the study area was about 141 persons/km^2. While average family size for these PAs was about 6.1 persons (Source: Different reports from Ada Liben, Gimbichu, Bereh Aleltu and Akaki wereda Bureau of Agriculture offices). The population density reported for the study area is also in line with what has been reported (144 persons/km^2) for East Shewa zone (Oromia National Regional Government, 2000a). However, based on the sample farmers the households survey results show that the average family size is 7.7 persons, ranging from 2 to 15. This is higher than what has been obtained from the BoA offices of each wereda, previously. Looking at the recent CSA data (CSA, 2003a) for these weredas, the population density is similar to what has been reported before, which is 137.1 persons/km^2 ,(Annex 3).

Out of the 132 household heads who participated in the survey, 80 household heads (60.6%) were illiterate, 28 (21.2%) were able to read and write, while the rest (24 households (18.2%)) had some kind of formal education. Exactly half of the households involved in the survey, 66 (50%), were of less than 50 years of age while the rest 66 were 50 or more years of age. Fifty years was the mean age of the sample households. The number of sample female farmers was only nine (~7%) (Table 7).

Table 7. Literacy level of sample household heads by sex and age group

Education level	< 50 years		> 50 years		Total			
	Male	Female	Male	Female	Male	%	Female	%
Illiterate	26	5	46	3	72	54.5	8	6.1
Read and write	15	0	12	1	27	20.5	1	0.7
Primary (grades 1-6)	17	0	3	0	20	15.2	0	0
Secondary and above)	3	0	1	0	4	3.0	0	0
Total	61	5	62	4	123	93.2	9	6.8

Similarly, literacy level of all family members, including the household heads (n=1020), also indicated a similar trend as for the literacy level for households, in that the illiterate were also high (58.4%) (Table 8). Out of the 416 school age children (between 5-17 years of age), only 204 (49%) are going to school. However, according to Oromia National Regional Government Regional Conservation Strategy (2000a), primary school participation rate had reached 52 % in the year 1999/2000, which is slightly better than in the study area. According Oromia National Regional Government (2000b), even from this low enrolment, a significant proportion of the children who joined grade one leave schools early and only less than 10 % enrolled for first grade complete high school. Under this situation, the likelihood that these children may end up becoming farmers and contributing to the degradation of the natural resource is very high. The following table (Table 8) illustrates the literacy level of all household members in the study area.

Table 8. Literacy level by age group and sex, for all household members in the study area during 2003 (excluding children under 5 years)

Education level	5-13 years		14-17 years		18-60 years		>60 years		Total	% of total
	Male	Female	Male	Female	Male	Female	Male	Female		
Illiterate	66	84	36	26	137	146	21	9	525	58.40
Read and write	0	0	0	0	30	11	5	1	47	5.23
Primary	60	81	29	18	42	30	2	0	262	29.14
Secondary	1	2	6	7	32	16	1	0	65	7.23
Total	127	167	71	51	241	203	29	10	899	100

Given the present population, there is a high potential demand for primary education in the study area. This will require both the government and the society, for a robust action plan to help increase the number of school age children enrolment in schools. Otherwise, the number of children who become illiterate farmers will increase and hence land fragmentation, which will further aggravate encroachment on to the hills and mountains.

Relationships using Pearson's Correlation Coefficient (*r*) between literacy of household heads and some socio-economic characteristics were compared for the sample farmers. The correlation between literacy of household heads and age was negatively correlated ($r=-0.145$) but was not significantly different ($p>0.05$). This implies that the literate household heads are in the lower age ranges among the households. Similarly, correlation between literacy of household head with income from crop production/ha showed negative relationship ($r=-0.052$) even though difference was not significant ($p>0.05$). This shows that the more literate young in the study area earn less income from crop production on a hectare basis. The relationships between literacy level with number of trees planted; and literacy with livestock holding were not significantly different. However, livestock holding and number of trees planted showed positive correlation ($r=0.224$) and relationship was significantly different ($p<0.05$). This shows that farmers who have more livestock tend to have more trees in the study area than those with less livestock. Similarly, correlation between family size and livestock holding was positive and relationship was significantly different ($P<0.01$). The results also indicate that households with higher family size to have more livestock. At the same time, family size had positive relationship with income from crop production (*r=0.242)* and correlation was highly significant (p<0.01). Livestock holding was also positively correlated to income from crop production per hectare (*r=0.428*) and relationship was highly significant (P<0.01). This shows that farmers with higher number of livestock also earn higher income from crop production.

5.2 Cropping systems

5.2.1 Land holdings

As is the case for most highland areas, the farm size of households for the study area is also small. Based on the survey, the average land holding for a household was 2.1 ha which ranged from.0.5 to around 4 ha for all landscape categories. Mean land allocated to different crops by farmers in the three different landscapes did not differ significantly (P<0.05), except for chickpea and rough pea. Farmers in the flatlands allocated significantly more (P<0.05) to these crops than their counterparts in the other landscapes (Table 9). Total land holding varied among households in different landscape categories and ranged from 1.96 to 2.27 for uplands and flatlands, respectively. In the study area the unit of measure for land is "*kert*", in which four "*kert*" are equivalent to a hectare and conversion was made on this basis. Similarly, average yearly land allocation for different crops over the three years (2001-2003) did not change significantly (P<0.05) and results were not shown here.

Table 9. Three years (2001-2003) mean household land allocation (ha) for some crops by landscape

Crop type	Mean land allocation by land type			Mean
	Flat	Midland	Upland	
Wheat	0.72 ^{a}	0.76 ^{a}	0.65 ^{a}	0.71
Tef	0.51 ^{a}	0.41 ^{a}	0.45 ^{a}	0.46
Chickpea	0.40 ^{a}	0.24 ^{b}	0.27 ^{b}	0.30
Faba bean	0.15 ^{a}	0.20 ^{a}	0.22 ^{a}	0.19
Rough pea	0.20 ^{a}	0.09 ^{b}	0.06 ^{b}	0.12
Field pea	0.13 ^{a}	0.29 ^{a}	0.20 ^{a}	0.21
Others	0.16 ^{a}	0.16 ^{a}	0.10 ^{a}	0.14

Note: Means within rows followed by the same letter are not significantly different at $P<0.05$.

5.2.2 Crop production

Average crop productivity is low in the highlands in general, but particularly on the Vertisols (under traditional production systems), due to their physical characteristics (Berhanu Debele 1985). However, due to the use of commercial fertilizers, crops in the study area show an increase in yield, compared to what was reported previously. Productivity of all crops in the study area was not significantly different ($P<0.05$) in all landscapes (Table 10), even though there is difference in the landscape types. This could probably be due to similar management systems by farmers in all landscapes. The data shows that there is a slight increase in yield, even though it is still far below what could possibly be obtained from these crops. For example, at the start of the extension package activities in the mid 1990s, there were reports indicating that farmers were able to obtain more than sixty quintals of wheat. Hence, the potential of these crops is far below from what farmers could possibly obtain even under their relatively poor management systems in the study area. This will mean that with the current family size of 7.7 persons in a household, what is produced is very low and will not suffice to fulfil the daily calorific requirements of family members. The human nutrition aspects will be discussed on section 5.2.3 of this chapter.

In any economy, where agriculture is the main occupation and where locally grown food is the main basis of family nutrition, agricultural output per person is an important measure of welfare. It is frequently feared that, where population is growing rapidly, the value of output per person is expected to drop. Hence, out put per hectare is an important indicator of productivity, and also of sustainability, since falling outputs might indicate deterioration in the natural resource base.

Table 10. Average productivity (qt/ha) of six major crops as grown in different landscapes in the study area

Crop type	Average productivity (kg/ha)			Mean
	Flat	Midland	Upland	
Wheat	14.2 ^{a}	14.3 ^{a}	14.1 ^{a}	14.18
Tef	9.4 ^{a}	11.0 ^{a}	9.5 ^{a}	9.4
Chickpea	9.4 ^{a}	11.1 ^{a}	11.9 ^{a}	10.8
Faba bean	12.5 ^{a}	9.2 ^{a}	12.9 ^{a}	11.5
Rough pea	9.2 ^{a}	9.2 ^{a}	9.6 ^{a}	9.2
Field pea	6.5 ^{a}	6.0 ^{a}	11.1 ^{a}	7.9
Barley	9.1 ^{a}	9.4 ^{a}	14.7 ^{a}	10.9

Note: Means within rows followed by the same letter are not significantly different at $P<0.05$.

Major crops grown in the study area include, wheat, tef, barley, lentils, field pea and chickpea. Based on the interviews from the sample farmers, the proportion of land allocated to each crop and natural pasture, out of the total cultivated and natural pastureland is shown in Table 11. Among the major crops, the two most dominant crops are wheat and tef, covering more than two-thirds of the croplands in the study area.

Table 11. Land use pattern for crop production and grazing with corresponding area coverage for sample farmers

Crop type	**Scientific name**	**Area (ha)**	**% of total area**
Wheat	*Triticum durum*	94.0	34.3
Tef	*Eragrostis tef*	92.6	33.8
Chickpeas	*Cicer aritinum*	34.5	12.6
Faba bean	*Vicia faba*	11.2	4.1
Rough pea	*Lathyrus sativus*	6.7	2.4
Field pea	*Pisum sativum*	6.6	2.4
Barley	*Hordeum bicolour*	6.2	2.3
Onion	*Allium spp.*	1.9	0.7
Lentils	*Lens culunaris*	1.1	0.4
Maize	*Zia mays*	1.8	0.6
Potato	Solanum tuberosum	0.2	0.1
Hops	*Rhamnus prinoides*	1.7	0.6
Private grazing	-	15.4	5.6
Total		273.9	100

The household survey also quantified how much of the produce was consumed, sold or carried over by sample farmers. The results indicate that out of the total crop produced by the sample farmers (2001 to 2003), majority of the produce went for home consumption (55%), while crop sale and carryover had a share of 32.2% and 12.8%, respectively (Table 12). Carryover is mainly used as source of planting material for the next season. Farmers in the area produce three local varieties of *tef* (white, mixed and red). Among these varieties, white *tef* is nearly totally sold for fertiliser credit repayment, while mixed *tef* is used for both consumption and sale, but nearly all the red *tef* produced is consumed at home.

Table 12. Average household production and utility of major crops produced (qt) by land type as mean of three years (2001-2003) for sample farmers

Crop type	Production (qt)	Utility (qt)					
		Consumption	% of total production	Sale	% of total production	Carry over	% of total production
Wheat	10.2	5.52	54.0	3.29	32.2	1.40	13.7
Tef	5.0	2.55	51.0	1.95	39.0	0.50	10.0
Barley	1.9	1.42	73.0	0.26	13.0	0.24	12.5
Chickpea	3.6	1.75	48.3	1.42	39.2	0.45	12.4
Faba bean	2.1	1.04	49.2	0.80	37.9	0.27	12.9
Rough pea	1.7	0.77	46.1	0.70	41.9	0.21	12.5
Field pea	2.2	1.37	63.1	0.49	22.5	0.31	14.2
Total	**26.7**	**14.4**	**55.0**[1]	**8.9**	**32.2**[1]	**3.4**	**12.6**[1]

[1] Mean values

5.2.3 Human nutrition

The overall average consumption indicates that cereals are the major sources of energy contributing to 66% while the rest (34%) was from legumes. The total energy taken by household members in the study area is relatively higher than what was reported for households in Tigray (Feoli, *et al*., 2002), but similar to the enset-based households (Samson *et al*., 1999). However, this value, 1853 kcal/person/day (Table 13) is about 80% of the minimum daily maintenance requirement, which is 2300 kcal/person/day. However, the study did not quantify energy from animal sources, vegetables and fruits, even though the share of these foods is not expected to change the energy values as such. This is because consumption of these types of food is not high as has been reported previously (CSE, 1997a).

Table 13. Food grain production, consumption (kg grain) and Kcal/person/day from different crops for sample households, mean of 3 years (2001-2003)

Crop type	Annual consumption (kg grain) [1]	Daily family consumption (kg grain)	Food energy (Kcal/kg) [2]	Kcal/person/day [3]
Wheat	552	1.5	3623	712.6
Tef	255	0.7	3551	322.2
Barley	142	0.39	3720	188.0
Chickpea	175	0.48	3723	231.8
Faba bean	104	0.28	3514	130.0
Rough pea	77	0.21	3470	95.1
Field pea	137	0.38	3553	173.2
Total				1852.9

[1] Obtained from Table 12
[2] EHNRI (1997)
[3] Calculated on the basis of 7.7 members/family

5.2.4 Soil fertility management practices

Farmers in the study area acknowledge deterioration of soil fertility and account this problem to continuous cultivation of farmlands, fragmentation and erosion. All farmers except two perceive the decline of fertility of their farmlands. The study area is one of the longest settled areas in the country and it is expected that soil fertility declines would occur even though farmers may also develop means of combating the fertility decline. Application of commercial fertilizer is the most common practice in the study area. It was reported that majority of the farmers interviewed 118 (88%) used commercial fertiliser for soil fertility improvement, which is an indication that soil fertility is declining. Nationally, CSA (2003) reported that fertiliser was applied to over 3.8 million ha (38.6% of the total area) under cropland during the 2001/2002 agricultural sample enumeration, the majority of which was applied to cereals. In addition to use of commercial fertilizer, a traditional fertility restoration measure (crop rotation) known as "*Iker*" was also practised by 8 (6%) farmers. In this system a piece of land which was under cereal crops for at least two seasons will be rotated to be planted with one of the legumes, especially chickpea or rough pea on the flatlands (Vertisol areas), while faba bean or field peas on the midlands and uplands.

Use of fallow and manure is very low in the study area. This is an indication that farmers heavily depend on the use of commercial fertiliser than others. Those farmers who applied fallowing for soil fertility restoration reported a time span of 1-6 years before the land is used for crop production.

Other options that are taken by farmers include claiming additional new lands, which has been reported by some farmers on uplands, because these farmers had better access to use the sloppy lands and clear some bush lands. However, since recently, the BoA offices in the area have prohibited this practice. The writer of this thesis had observed that some farmers, who cleared shrubland for crop production on the upper slopes, were put in jail for their practices.

The reason for very few farmers to use manure for soil fertility restoration is that, fresh and dry dung droppings from the field and the barn are all collected and made into cow dung cake, which is the most commonly used energy source in the area. It is very common for households in the area to pile dry cow dung cakes which could last for more than a year (Figure 6). The size of the cow dung pile depends on the number of livestock in a household and/or number of children who would go and collect both dry and fresh cow dung especially from the field.

Figure 6. Piles of cow dung cakes

An animal produces around 1.2 tones of dung per year which if used as fertilizer gives an equivalent of 20 kg super phosphate, 12 kg potassium sulphate and 30 kg of ammonium sulphate (Reddy, 1982). Hence, the use of cow dung for fertility amelioration could have helped minimise the ever-increasing expenses on commercial fertilizer. This is in addition to avoidance of total dependence on commercial fertilisers. Had farmers applied the cow dung for soil fertility, it would have been the only good source of potassium (K) for the soils in the highlands. This is because farmers do not normally apply any form of commercial K to replenish the depletion of soils by crops, except for some who may apply ash, which is a good source of K. However, if cow dung is to be used for fertility amelioration purposes, alternative sources of energy are required.

5.3 Livestock Production systems

5.3.1 Livestock population and ownership

Where agriculture is a major source of livelihood for farm households, livestock play an important role and are the major assets. Survey results show that the average number of draught oxen per household to be 2.7, which is higher than cows or even other cattle. The higher number of draught oxen indicates that the study area is a major cereal growing area and heavily dependent on draught oxen for its farming operations. Sample households, on an average, own 4.85 TLU and the total TLU for all the sample farmers was 639.3 (Table 14).

Consumption of food from livestock is less pronounced as compared to that of crops, due to low productivity of these products, but livestock offer multiple services, and because of their capacity of self-renewal through reproduction, livestock are the most important and unique production asset for farmers. Even though, crop production is carried out totally by the use of draught oxen, hoeing is also practised on sloppy lands around Yerer mountain. However, the cultivated area under this system is very small.

Table 14. Livestock holding as average and total for sample farmers and total number for the study area

Livestock type	Average holding per sample farmer		Total livestock holding of sample farmers		Total Number of livestock in the study area	
	No	TLU[1]	No	TLU[1]	No	TLU[1]
Sheep	1.05	0.11	138	13.8	8153	815.3
Goat	0.86	0.09	113	11.3	9091	909.1
Horse	0.14	0.10	19	13.3	633	443.1
Mule	0.08	0.06	11	7.5	231	161.7
Donkey	1.44	0.72	190	95.0	8164	4082
Calves	0.36	0.25	48	33.6	4385	3069.5
Young bull	0.75	0.53	99	69.3	2411	1687.7
Heifer	0.65	0.46	86	60.2	3516	2461.2
Cow	0.93	0.65	123	86.1	8443	5910.1
Draught oxen	2.70	1.89	356	249.2	12707	8894.9
Total		4.86	712	639.3		28434.6

[1] Conversion factors used into TLU was: Sheep and goats, 0.1; Horses 0.8; Mules, 0.7; Donkey, 0.5; all cattle, 0.7 (Jahnke, 1982)

5.3.2 Feed resources

Analyses of feed resources availability from the survey indicated that October to January are months when feed resources are abundant or sufficient. However, May to September are months when feed resources are severely in short supply in which all the rainy months are included into this category, while the other months are intermediate. From this information, it is clear that feed is in short supply both during the dry and wet season. This has caused livestock productivity to be low because it is only during four months of the year that feed is sufficiently available, even though this available feed is also poor in quality.

Feed sources for livestock mainly come from crop residues and crop aftermath, bush lands, natural pasture, and some industrial by-products in the study area. The commonly used crop residues are those of wheat, tef, barley and some pulses. Many of the pulse residues are however not stored like the cereals because they are easily damaged by rain. As a result, what ever is produced from most of these pulses is left on the threshing fields for immediate consumption by livestock. However, pulse residues have better nutritive values, especially with regards to crude protein, compared to cereals (Kahsay Berhe *et al*. 1993).

Livestock suffer due to feed shortages during the cropping season, when most of the land is under crops and the remaining land is waterlogged, making most of the pasturelands inaccessible. As all of the PAs in the study have access to the mountain, livestock are sent to the neighbouring hills during the rainy season, even though there is hardly enough fodder. Better off households also supplement livestock with agro-industrial by-products. Similarly, few farmers were observed to grow some Napier grass (*Pennisetum purpureum*) plants and multipurpose trees like pigeon pea (*Cajanus cajan), tagasaste (Chamaecytisus palmensis),* leucaena *(Leucaena diversifolia and L. pallida),* and sesbania *(Sesbania sesban)* obtained from ILRI. However, the number of these plants is so small that fodder produced will not be enabling to supplement any type of livestock, even the small ruminants. Otherwise, improved pasture and forage management is not practiced in nearly parts of the study area.

Total amount of feed obtained from different crop residues for the sample farmers has been analysed. Using the conversion factors in Table 5, the total possible crop residues (air dried) available for livestock was calculated to be 431.21 tons from the crops grown on 255.7 ha by the sample farmers. This means at an average, 1.69 t/ha of crop residue (air dried) could be obtained from the cultivated land in the study area. From among the cultivated crops, *tef* and wheat are the major sources of crop residue, contributing to about 82% of the total residue for the livestock owned by the sample farmers (Table 15).

Table 15. Estimated yearly dry matter obtainable from different crop residues for the sample farmers

Crop type	Total area (ha) [1]	Grain yield (t/ha) [1]	Total crop production (t)	Conversion factor (Straw: Grain ratio) [2]	Crop residue (t DM)[3]
Wheat	94.00	1.42	133.29	2.06	192.49
Tef	92.60	1.00	92.32	2.47	160.11
Chickpeas	34.50	1.05	36.23	1.31	33.22
Faba bean	11.20	1.10	12.30	1.42	12.25
Rough pea	6.70	0.92	6.18	1.54	6.64
Field pea	6.60	0.79	5.23	3.30	12.04
Barley	6.20	1.09	6.75	1.86	8.80
Lentils	1.10	0.55	0.61	1.56	0.66
Maize	1.80	0.78	1.40	2.04	2.00
Total	255.70				431.21

[1] Based on three years' mean data (2001-2003) from household survey,

[2] Obtained from Table 5

[3] Assuming that 70% of the crop residue will be used as livestock feed

Considering the minimum daily maintenance and 20% production requirement for different livestock types (Table 6), annual feed requirement for all livestock types in the study area would be 63,491 t/year (Table 16).

Table 16. Daily and annual DM requirement for MEm plus 20% production requirement for different livestock types for the study area

Livestock type	Daily DM requirement (kg/head/day) [1]	Total number of livestock owned (heads)	Total annual feed requirement (t)[2]
Cattle (local)	4.237	31462	48,656.14
Sheep	0.617	8153	1,836.10
Goats	0.651	9091	2,160.16
Donkeys	3.125	8164	9,312.06
Horses	5.000	633	1,155.23
Mules	4.375	231	368.88
Total			63,490.57

[1] Source: Berhanu Gebremedhin, *et al.*, (2004)
[2] Based on Table 6

In order to determine the proportion of the feed resource is available for livestock in the study area, the feed resources available for the whole study area was estimated in Table 17. Crop residues from cultivated areas for the study area were calculated proportional to what was obtained from the information in Table 15. However as crop residues are only air dried and requirements are on the basis of DM, it is assumed that 90% by weight of the crop residue will be considered for further calculations. Hence, all available cultivated lands would be multiplied by 90% of the 1.69 t/ha reported previously. As depicted in Table 15, it is assumed that out of the total crop residue produced, 70% of it will be utilised as livestock feed (Bekele Shiferaw, 1991). The rest of the residue will be used as a source of energy, construction, sale and others.

Table 17. Estimated yearly feed dry matter obtainable from different land cover types for the whole study area based on 2000 imagery

Land cover type	Area (ha)	DM yield (t/ha/year)	Annual DM production (t)
Cultivated land	16204	1.52[1] + 0.52[2]	33,056.16
All other land cover categories except water body	12224	0.8256[3]	10,092.13
Total	28428		43,148.29

[1] DM from crop residue based on Table 15 (total crop residue/total area, multiplied by 90% to change to DM yield/ha)

[2] Crop aftermaths at 0.6 t/ha/yr (air dried), but data is multiplied by 90% to convert it to DM (Source: WBISPP, 2000)

[3] Source: WBISPP (2000).

According to the analyses, feed resources in the study area could only meet about 68 % of the minimum annual energy required plus additional 20% for production by livestock in the study area. In the central highlands of Ethiopia, other similar works also reported that farms produce only 60% of the feed needed by livestock (ILCA, 1994). Reports from Oromia Region also indicate that the total feed requirement is higher than the naturally available feed potential, hence, there is a significant deficit of feed supply in the Region (Oromia National Regional Government, Regional Conservation strategy, 2000a).

Analysis from the current study further showed that the overall annual available feed resources in the study area to be at 43,148 tonnes, of which 33,056 (76.61%) tons of the DM would come from crop residues (including crop aftermath). In earlier works, it was also reported that 71% of the feed supply for Ada district (part of the study area) to originate from crop residues, while only 12% coming from natural pasturelands (Bekele Shiferaw, 1991). Crop encroachment is blamed for the decreased contribution of natural pasture as sources of feed supply in the district. Even though crop residues (including aftermath) were known to be supplements to livestock, they are at present providing the highest share in terms of feed resources. Contrary to this however, CSA (2003) reported that grazing was the major source of feed supply accounting for 60%, while crop residues accounted for 26%, nationally.

In general, as in other parts of the highlands feed is in short supply. This is mainly because farmers' priorities are to grow food crops rather than forages or fodder for livestock. Under increasing population pressure with an increase in the area of cropland at the expense of grazing land (Figure 7), crop and livestock production systems are becoming integrated even more through a greater dependence of livestock on crop residues and on-farm production of fodder. In the past, the relatively larger area of land, supply of animal feed, distances among crop fields and smaller number of livestock were sufficient to maintain an adequate level of crop and livestock production.

Courtesy: Stirling Throne associates

Figure 7. Conversion of natural pasturelands into crop production in the highlands

5.4 Sources of energy

The most important sources of energy in Ethiopia are fuelwood, cow dung and crop residues. Among these sources fuelwood is the most widely preferred and used source of energy in the country. According to the current survey, the average annual energy consumed on a household basis was 2484, 869 and 744 kg of cow dung, fuelwood and crop residues, respectively for cooking, heating and lighting purposes (Table 18), On an average, one dry cow dung weighted about 0.5 kg in the study area.

Table 18. Mean annual household energy consumption for different domestic uses as reported by sample farmers

	Mean household annual energy consumption								
	Fuelwood[1]			Cow dung		Crop residue		Kerosene	
Energy utility	Kg	M^3	N[2]	Kg	N	Kg	N	Litre	N
Cooking	540	0.90	64 (49)	1932	132 (100)	432	110 (83.3)	6	3 (2.2)
Heating	280.8	0.47	54 (41)	552	127 (96.2)	312	9 (4.4)	0	0 (0)
Lighting	48	0.08	4 (3)	0	0 (0)	0	0 (0)	2.33	129 (97.7)
Total energy	868.8	1.45	-	2484	-	744	-	8.33	-

[1] One M^3 of fuelwood = 600 kg

[2] Number of respondents (Number in parenthesis are percent of respondents)

Table 18 above indicates that majority of the energy for cooking and heating comes from cow dung, which is almost twice as much for fuelwood in these households. While the use of kerosene for cooking is very low, three household heads have only reported using this source of energy for cooking. This could be because of the initial cost of the stove and the consequent price of kerosene. Contrary to this however, kerosene was widely used for lighting as was reported by 129 (~98%) of the households in the study area. Cow dung is the most dominant source of energy for cooking and heating, contributing to about 60.6% of the energy required by a household (Table 18). While fuelwood and crop residue contribute to about 30.5% and 16%, respectively. Cooking accounted for about 71% of the energy consumed in the study area. This has also been the case for the whole country as it was reported that 86% of the energy was required for cooking (EFAP, 1993). The overall picture shown here is that traditional bio-fuels are almost the only sources of energy in the study area, which is also true for the whole country. In 1990/91 petroleum products and electricity contributed for only 5% of the overall energy consumption. The extraordinary dependences on bio-fuels have persisted over many years.

Based on Table 18, annual per capita fuelwood requirement was calculated to be at 1.45 m^3, while the national average in the 1990s was at about 1.19 m^3 (EFAP, 1993). The same study had also anticipated rise in the use of fuelwood requirements over the years and what is reported here is in line with the projection. Moreover Woldeamlak Bewket (2003b) reported that the average fuelwood used per household in Chemoga watershed, NW Ethiopia, ranged from 1300-2450 kg per year for the three sites studied, and what is reported (869 kg) in this paper falls below the reported range. The major source of fuelwood comes from bush/lands in the study area, even though using wood as a source of energy is highly inefficient. From the discussions held with the farmers it was found that preparing injera alone takes a share of about 50% of the energy required for cooking. The study area being predominantly tef and wheat growing area, it is true that majority of the fuelwood would be used for making *injera*. Hence, calls for sustained supply of energy for the households.

Based on estimations by WBISPP (2000), the total annual woody biomass that could be potentially be produced from the land cover classes for 2000 was 3507.59 tonnes (Table 19). However, considering the annual requirements for sample farmers (Table 18), the total fuelwood requirement for the total households in the study area (total households 5518, Annex 4) would be 4794 tonnes/year tonnes (air dry) (Table 19), and multiplying this figure by 90% to get DM would be about 4315 tonnes. What is potentially available, according to the estimation of WBISPP (2000) and the fuelwood need of households (socio-economic survey), is only 81% of the requirement. This implies that the likelihood of what is available in the form of shrubs is not enough to the needs of the people.

This indicates that, if deforestation and degradation of forests, woodlands and shrublands, and further adverse effects on agricultural productivity are to be minimized or avoided, substitution of the traditional fuels with modern fuels will be a must. However, total dependence on imported petroleum products cannot also be sustained, hence it will be necessary to promote commercial energy production from domestic sources.

Table 19. Potential woody biomass for the study area (2000)

Land cover types	Area in 2000 (ha)	Woody biomass productivity (t/ha/yr)[1]	Potential woody biomass produced
Cultivated land	16204	0.11	1782.44
Grassland	8414	0.14	1177.96
Degraded grassland	983	0.03	29.49
Open shrubland	479	0.10	47.9
Dense shrubland with remnant Juniper trees	2217	0.20	443.4
Wetland	132	0.20	26.4
Total	28429		3507.59

[1] Source: WBISPP (2000)

5.5 Soils of the study area

The study area has been classified into six different soil units according to FAO/UNESCO (1973). The soil types, their corresponding area and percentage covered under these soils are presented in Table 20. The table also includes the area covered by rocks.

Chromic Luvisols constitute the largest taxonomic group in the study area occupying 10,637 ha (37%). These soils are found on the highest peaks of the mountain where the shrublands, remnant Juniper trees and scattered eucalyptus plantation are grown. Soils with Vertic characteristics are distributed on the low-lying slope ranges throughout the study area. These are the soils where crops are predominantly grown. While majority of the area in the north-western side of the study area is covered with Vertic Cambisols.

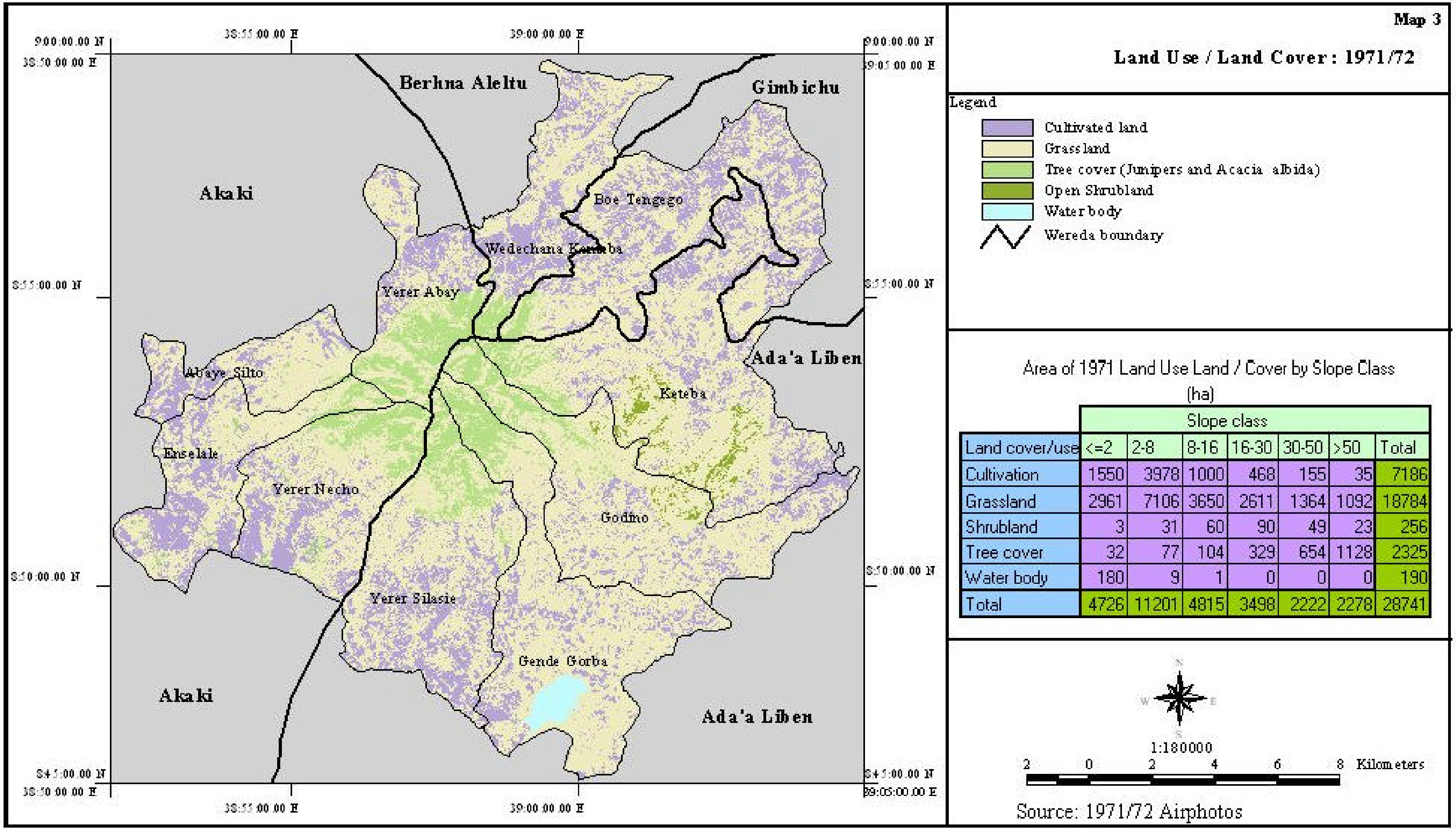
Table 20. Soil types in the study area

Soil type	Area covered (ha)	% of total area
Chromic Luvisols	10638.91	37.02
Pellic Vertisols	8232.36	28.64
Vertic Cambisols	6889.73	23.97
Chromic Cambisols	817.37	2.84
Chromic Vertisols	364.43	1.27
Eutric Nitosols	327.92	1.14
Rock surface	1470.28	5.12
Total	28741.00	100.00

5.6 Land Use and Land Cover

The study area has been defined to have six land cover categories, which were: cultivated land, forestland, grasslands, shrubland, wetland and water body. The description of these land cover categories was presented previously in Table 4.

The land cover analysis for 1971/72 from aerial photos (Map 3) showed that majority of the study area was under grasslands accounting for 18,784 ha (65.4%), while cultivated land and *Juniperus procera* and *Acacia albida* trees (including the open shrublands) amounted to about 7186 ha (25%) and 2581 ha (9%), respectively (Table 21). The share of open shrub from the



Area of 1971 Land Use Land / Cover by Slope Class (ha)

	Slope class						
Land cover/use	<=2	2-8	8-16	16-30	30-50	>50	Total
Cultivation	1550	3978	1000	468	155	35	7186
Grassland	2961	7106	3650	2611	1364	1092	18784
Shrubland	3	31	60	90	49	23	256
Tree cover	32	77	104	329	654	1128	2325
Water body	180	9	1	0	0	0	190
Total	4726	11201	4815	3498	2222	2278	28741

Source: 1971/72 Airphotos

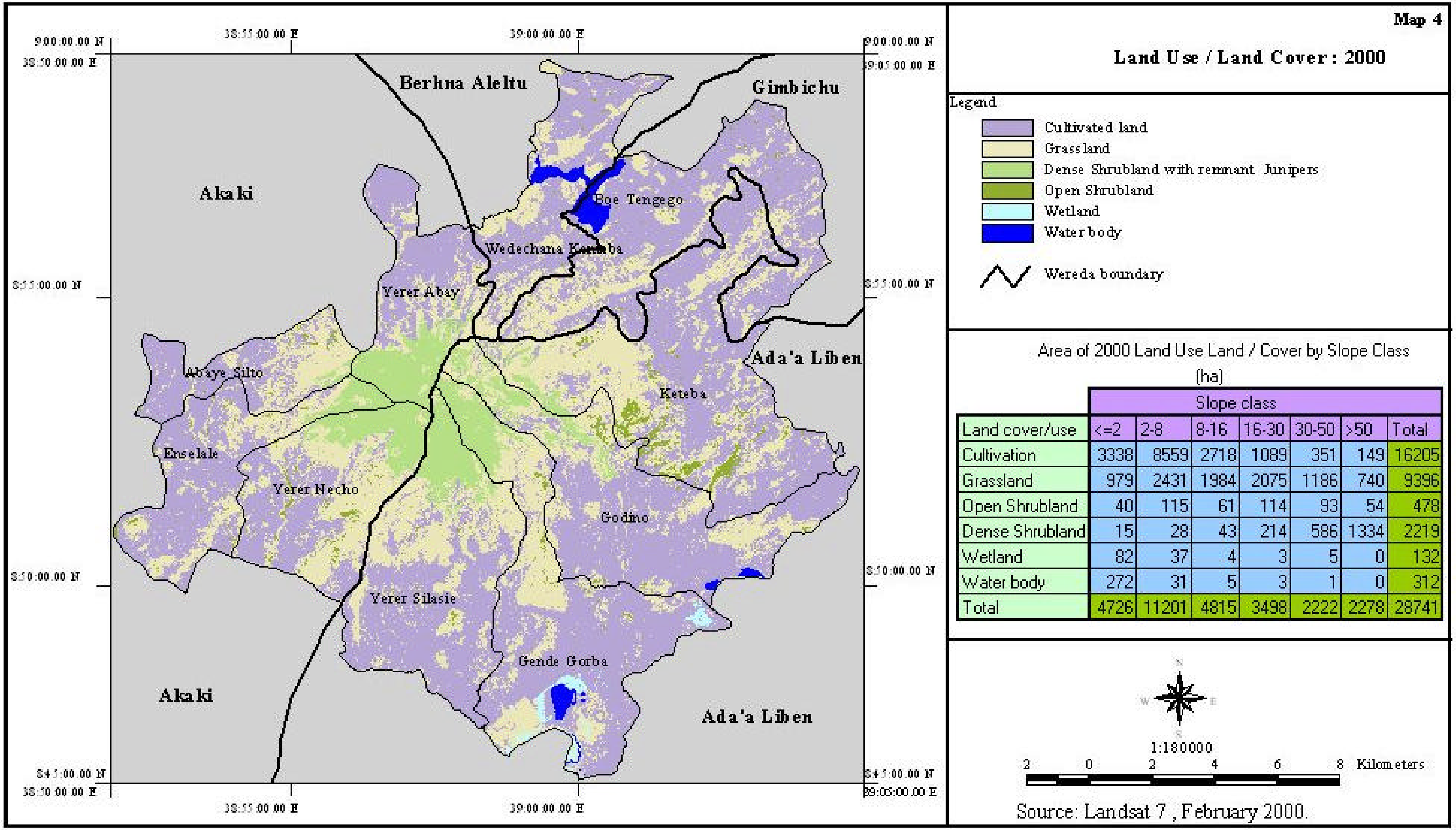
Map 3. Land Use and Land Cover: 1971/72 latter class was only about 256 (0.6%), showing that majority of this class was under *Juniperus procera* and *Acacia albida* trees. Overall, these land cover classes took almost 100% of the area, except for some land which was under wetlands and seasonal water body, accounting for less than one percent during 1971/72. The dense shrubland during this period was dominated by trees. A report by FFDME (2001) and the elders of the area indicate that, the mountain was covered with indigenous trees of mainly *Juniperus procera.*

On the other hand, the land cover analysis for February 2000 from Landsat ETM+ imagery (Map 4) showed that majority of the study area is under cultivated land accounting for about 16204 ha (56.4%), while grasslands (including degraded grasslands) and shrublands (dense and open) accounting for 9396 ha (32.7%) and 2697 ha (9.4%) of the landmass of the study area, respectively (Table 21). This shows that these cover categories are dominant while the remaining categories, water body and wetlands, only accounted for 1.09%. The area under natural forest (*Juniperus procera*) is very small and the shrubs are dense that it was difficult to distinguish between the two. This is because all the juniper and eucalyptus trees were scattered around the mountain peaks and are dominated by tall and dense evergreen crown cover shrubs. Hence, it was difficult to distinguish between the two vegetation types.

Table 21. Land cover classes, their corresponding areas and change, (1971/72 and 2000)

Land cover types	Area in 1971/72 (ha)	(%) Of land cover (1971/72)	Area in 2000 (ha)	% Of land cover	Change between 1971/72 and 2000		
					(ha)	(%)	Average rate (ha/ yr)
Cultivated land	7186	25.00	16204	56.38	+9018	125.5	+300.6
Grasslands	18784	65.35	9396	32.70	-9388	50.0	-312.9
Open shrubland	256	0.89	478	1.66	+222	86.7	+86.7
Juniperus procera *Acacia albida* trees[1]	2325	8.09	2219	7.71	-106	4.55	-0.2
Wetland	0	0	132	0.46	+132	**????**	+4.4
Water body	190	0.66	312	1.09	+122	64.2	+4.07
Total	28741	100	28741	100			

[1] For 2000 this cover category refers to “dense shrubland with remnant Juniper trees”



Area of 2000 Land Use Land / Cover by Slope Class (ha)

	Slope class						
Land cover/use	<=2	2-8	8-16	16-30	30-50	>50	Total
Cultivation	3338	8559	2718	1089	351	149	16205
Grassland	979	2431	1984	2075	1186	740	9396
Open Shrubland	40	115	61	114	93	54	478
Dense Shrubland	15	28	43	214	586	1334	2219
Wetland	82	37	4	3	5	0	132
Water body	272	31	5	3	1	0	312
Total	4726	11201	4815	3498	2222	2278	28741

Source: Landsat 7 , February 2000.

Map 4. Land Use and Land Cover: 2000

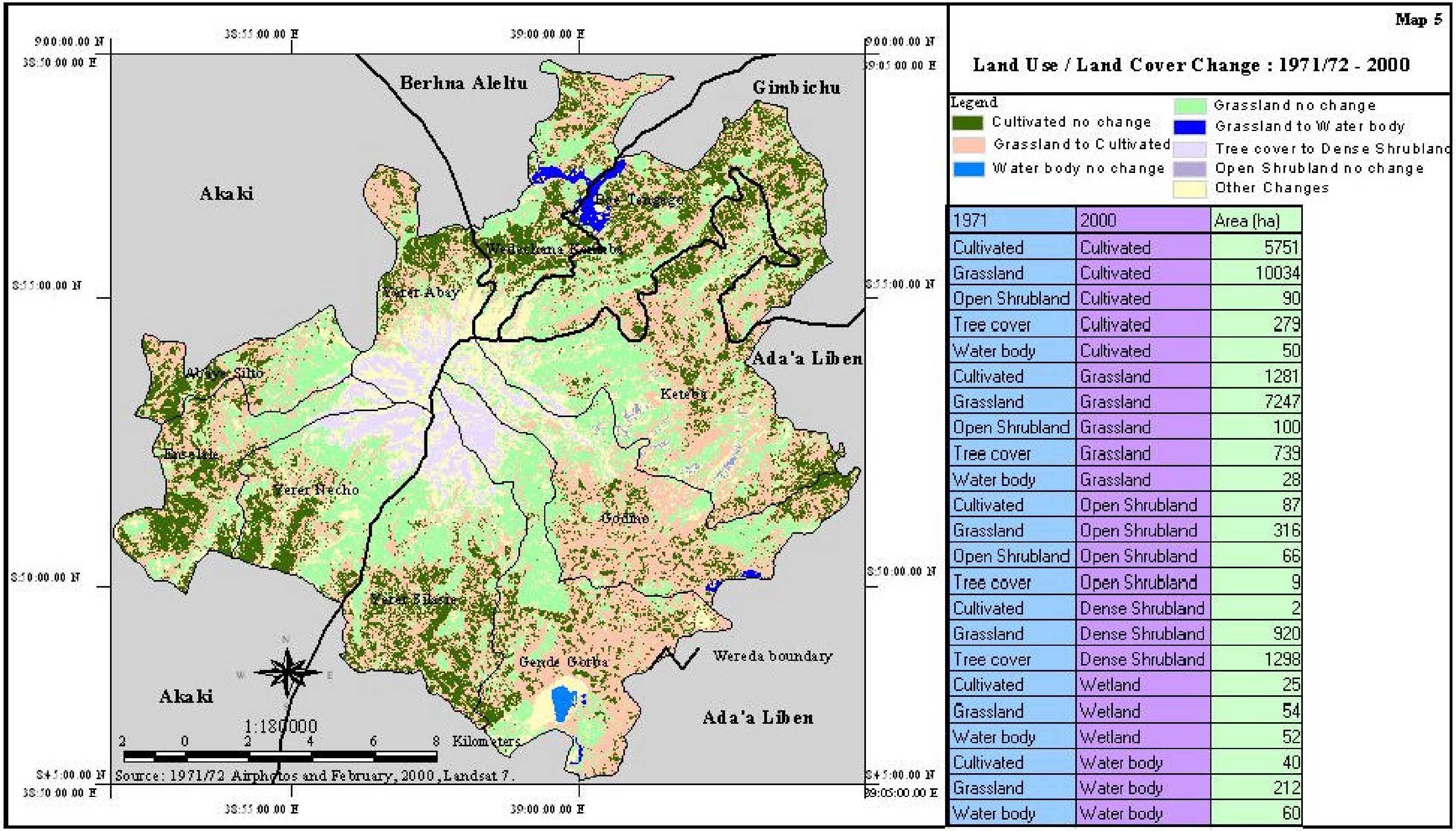
Much of the change from the base year (1971/72) occurred on cultivated land, where it changed from 7186 ha in 1971/72 to 16204 ha in 2000 (Map 5). The increase in cultivated land was 125%, which was mainly at the expense of the grasslands. Out of the total cultivated land in 1971/72, 80% remained under the same land cover while 1281 ha (17.8%) was converted to grasslands in 2000. The remaining 2% changed into shrublands and water (Wedecha dam). The reason that land was converted to grassland and shrubland in 2000 could indicate that the land is no more suitable for agriculture. Other wise, under the current population pressure, the need for added land is high. The increase of cultivated land from 7186 in 1971/72 to 16204 in 2000 is purely population induced.

Grasslands decreased from 18784 ha in 1971/72 to 9397 ha three decades later due to agricultural expansion (Table 21). Fifty-three percent of the grassland in 1971/72 was changed into cultivated land (Table 22). Similarly, size of water body increased by about 65.2% mainly because of the man-made dams ("Wedecha dam") but also because of the fact that the imagery was taken in February, when the seasonal water is not dry. Usually, the seasonal water body, (Chefe) recedes in late February and March (personal observation).

Table 22. Distribution of the land cover categories by slope (%), in the study area (1971/72)

Land cover type	% Slope						Total
	<2	2-8	8-16	16-30	16-30	>50	
Cultivated land	1550	3977.5	999.9	468.45	155.48	35.06	7186.39
Grassland	2961	7106.3	3650.16	2610.8.	1363.92	1091.8	18783.98
Open shrubland	3.4	31.06	60.04	89.55	48.79	22.86	255.7
Juniperus procera Acacia albida trees	32.5	77.20	103.9	329.30	653.5	1128.33	2324.73
Water body	179.6	9.13	1.41	0	0	0	190.14
Total	4726.5	11201.19	4815.41	3498.1	2221.69	2278.05	28740.94
% of total area	16.44	38.97	16.75	12.17	7.73	7.93	100

Classification of the study area into different slopes in 2000 also showed that around 21,000 ha (>72%) is found between relatively flat and 16% slopes, of which the majority, 11,191 ha



Source: 1971/72 Airphotos and February, 2000, Landsat 7.

1971	2000	Area (ha)
Cultivated	Cultivated	5751
Grassland	Cultivated	10034
Open Shrubland	Cultivated	90
Tree cover	Cultivated	279
Water body	Cultivated	50
Cultivated	Grassland	1281
Grassland	Grassland	7247
Open Shrubland	Grassland	100
Tree cover	Grassland	739
Water body	Grassland	28
Cultivated	Open Shrubland	87
Grassland	Open Shrubland	316
Open Shrubland	Open Shrubland	66
Tree cover	Open Shrubland	9
Cultivated	Dense Shrubland	2
Grassland	Dense Shrubland	920
Tree cover	Dense Shrubland	1298
Cultivated	Wetland	25
Grassland	Wetland	54
Water body	Wetland	52
Cultivated	Water body	40
Grassland	Water body	212
Water body	Water body	60

Map 5. Land Use and Land Cover change: 1971/72 to 2000

(38.94%) is found between 2-8% (Table 23). More than 3500 ha (12.2%) is also found on slopes ranging from 16-30%, while, 4494 ha (>15%) of the landmass of the study area is found on slopes of more than 30%. This indicates that the topography of the study area is substantially mountainous.

In the base year, of the 7186 ha cultivated land 3978 ha (55.3%) was found between 2-8% slope range. More than 90% of the cultivated land was found in slope ranges from between less than 2 to 30%. Indicating that what was then cultivated land was in the agriculturally suitable area with regards to slope.

Similarly, in 2000, majority of the land, 8550 ha (52.8%), was found on slopes between 2-8%, while 3344 ha (20.64%) of this category was found on less than 2% slope. Moreover, 2718 ha (16.8%) of the cultivated land were also found between 8-16% slope. While, 1592 ha (~10%) of this cover category was found at slopes of ≥16% slopes. It is very easy to imagine the consequences of cultivating the upper slopes in terms of causing de-vegetation, hence causing intensified soil erosion, and flooding on the mid and flat lands in the study area. The following table (Table 23) shows the distribution of land cover categories to different slope ranges in 2000.

Considering agriculturally suitable areas (<30%), based on slope only, 15704 ha (**64.8**%) is already under cultivation. If all other suitability factors are considered, the agriculturally suitable areas might have already been exhausted.

Table 23. Distribution of the land cover categories in to different slopes (%), in the study area (2000)

Land cover type	% Slope						Total
	<2	2-8	8-16	16-30	30-50	>50	
Cultivated land	3344	8550	2718	1092	351	149	16204
Grassland	854	2043	1692	1935	1155	735	8414
Degraded grassland	128	386	293	141	30	5	983
Open shrubland	40	116	62	114	93	54	479
Dense shrubland with remnant Juniper trees	15	28	43	214	586	1331	2217
Wetland	82	37	4	4	5	0	132
Water body	273	31	5	3	0	0	312
Total	4736	11191	4817	3503	2220	2274	28741
% of total area	16.48	38.94	16.76	12.19	7.72	7.91	100

The change in the size of cultivated land with regards to slope, from 1971/72 to 2000, was crosscutting because the increase affected all slope ranges, even those lands that are at higher slopes. For example, above 30% slope, cultivated land increased from about 90 ha in 1971/72 to about 500 ha in 2000, an increase of over 455%. The implication of cultivating these lands, in the absence of proper soil and water conservation is detrimental to the environment. These changes imply that land on the slopes is severely eroded because of inappropriate agricultural practices and as a result of which flooding occurs on the flat lands. The development of permanent water bodies like Chelekleka in the late 1960s, as has been reported previously, could be associated to the takeover of the shrublands by cultivated lands. Had the land remained under its previous vegetative cover it would have enhanced development of springs on the low-lying areas as opposed to the present conditions where water is a scarce resource.

As mentioned previously, the five land use classes were also identified as, agriculture, forestry, water reservoirs, wet lands and others, which were also discussed in the preceding chapter. All land use classes increased in area. However, the increase is very low compared to others. Moreover, one has to be cautious with regards to the increase. It is true that in absolute terms that forestry increased but it is the bushes that have increased but the natural forest did diminish. The area covered by each class of land use is given below (Table 24).

Table 24. Area under different land use categories in 1971/72 and 2000

Land cover types	Area in 1971/72 (ha)	(%)	Area in 2000 (ha)	(%)	Change between 1971/72 and 2000 (ha	
					(ha)	(%)
Agriculture	7186	25	16204	56.38	+9018	+125.5
Forestry	2581	8.99	2696	9.37	+115	+4.4
Water reservoirs	190	0.66	312	1.09	+122	+64.2
Wetlands	0	0	132	0.46	+132	na[1]
Pasture	18784	65.35	9397	32.7	-9388	-50.0
Total	28741	100	28741	100		

[1] Not applicable

5.7. Sheet erosion

As depicted in Table 25, more than 21,000 ha (73%) and 15,200 ha (53%) show low sheet erosion hazard with expected soil losses of < 6.25 t/ha, in 1971/72 and 2000, respectively. The same table clearly shows that the increase of human population, which led to increased agricultural activities in three decades, has affected sheet erosion rates. The estimates indicate that over 19,000 ha (67.4%) of the study area had less than 3.125 tonnes/ha/year of soil loss in 1971/72, while slightly higher than 12,000 ha (42.52%) of land had less soil erosion rate in 2000. This shows that land exposed to higher sheet erosion levels have increased over the years, comparing it with base year. This could be attributed to the increase in cultivated land in those three decades. In 2000, over 7% of the total land was exposed to more than 25 tonnes/ha/year of soil erosion, while only less than 2% was exposed to this magnitude of soil erosion in 1971/72. The higher erosion rates would be expected from less vegetated areas with higher slopes, due to agricultural activities. This is because there is high elevation difference between the peak of the mountain, which is 3100 m asl, while the low-lying areas are around 1860 m asl. Researches conducted elsewhere reported that sheet erosion contribute to about 87% of the total sediment, while the rest was due to gully erosion (Stocking, 1996).

Table 25. Sheet erosion hazards by slope in 1971/72 and 2000 in the study area

Level of sheet erosion (t/ha/yr)	1971/72		2000	
	Total area affected	%	Total area affected	%
≤ 3.125	19357.89	67.36	12220.07	42.52
3.125-6.25	1682.62	5.86	3032.52	10.55
6.25-12.5	5380.21	18.72	7116.93	24.76
12.5-25.0	1802.23	6.27	4310.39	15.00
25.0-50.0	342.88	1.19	782.42	2.72
≥ 50	175.07	0.61	1278.67	4.45
Total	28741	100.00	28741	100

5.8 Gully erosion

The planimetric area taken up by only two big gullies amounted to 83.2 ha (Table 26). The total length of these two gullies was 20 km in 2004. The increase in length of these two gullies was due to initiation of new gullies and linear expansion of the existing ones. Initiation of new gullies continues more noticeably in the cultivated land than in the other land cover categories. Considering the average land holding of 2.1 ha, the area under these two gullies could have supported about 40 families every year, for their livelihoods. Unless other wise proper protective/control measures are taken, considerable croplands will be taken out of production in a short period of time. As can be seen from the amount of flood during 2003 (Figure 2), there could even be other gullying activities (initiation and expansion), in almost every heavy rain.

There were some efforts to controlling or at least minimising effects of one of the gullies close to ILRI Debre Zeit research Station, but efforts do not seem to be fruitful because the amount of the water that is carried down by this gully is so huge that the structure is not in a position to contribute much in either minimising the extent of gullying or flooding of the research fields. Other than this, there has not been any apparent conservation practice in the area. Therefore, if proper land management practices are not practised, land degradation could be enhanced.

Many farming communities are affected due to the expansion of these two gullies as there were points at which the gullies were more than hundred metres wide and about twenty metres deep covering for long distances, from the mountain foots to areas with lower slope ranges in the flatlands (Table 26).

Table 26. Total area, length, maximum width and depth of two big gullies in the study area

Name of gully	Length (km)	Max. width (m)	Estimated depth (m)	Total area lost due to gully erosion (ha)
Kefele	13	85	18.	45.8
Eyitu	7	126	20	37.4
Total				83.2

The driving forces to the initiation of gullies are associated with accelerated erosion and landscape instability. The deprivation of the slopes and the farmlands from vegetation during the heavy rains induces higher detachment of soil and lower infiltration of rainwater leading to more runoff and soil erosion. This is due to either removal of the shrubs for fuelwood and/or agriculture, overgrazing or movement of people and livestock, which create trails on the slopes. These trails are used as a means of conveyance of the excess runoff from the mountain creating new channel other than the old and established waterways. On the other hand, lack of vegetative cover on farmlands during the heavy rains is also contributing to the initiation of gullies as they are weak areas and erode easily.

5.9 Land Use and Land Cover change analysis

5.9.1 LULC change and human population in the study area

Land Use and Land Cover dynamics is a result of complex interactions between several biophysical and socio-economic conditions. The effects of human activities are immediate and often radical, while the natural effects take a relatively longer period of time.

Counting of houses from the 1973 topographic map (1: 50,000) which was based on 1971/1972 aerial survey (on which this is based) showed that there were 2064 houses. The average family size from the second round of the national sample survey conducted from

December 1968 to June 1971 for the then Shewa province, where the study site is located, was 4.5 persons per household (CSA, 1974).

Based on this information, the population density for the study area in 1971 was estimated to be 32.32 persons/km^2, while it was 137.1 persons/km^2 for 2003 (Annex 3). This implies that population increased from 9,288 in 1971 to 35,940 in 2003, which increased by about 286% in just over three decades. The annual increase was at a rate of about 833 persons/year. At the same time, the cultivated area increased from 7186 in 1971/72 to 16,204 ha in 2000, which increased by over 125%. The total number of houses (households) in 1971 was 2064, while currently is 5518, which increased by 167%. The difference in increase by both households and land indicates the pressure on land. Even though cultivated land affected all slope classes, on slopes of >30% was much higher. At this slope range, cultivated land was about 190 ha in 1971 was about 190 ha but increased to about 500 ha in 2000. The rate of increase was about 309%.

This implies that population pressure is believed to be one of the major driving forces for the changes in the study area. The effect of increased population on LULC changes was also reported by many writers and was presented in Chapter two of this Thesis. However, some also argue that population increase to bring about technological changes in order to ease the increased pressure on the natural resource base. These two different viewpoints indicate on how each and every situation should be handled. In order to make relevant conclusions and recommendations of an area, one has to therefore properly consult situations of the past and present, i.e. socio-economic and biophysical aspects of the area. Hence, in the case of this analysis, the major driving force to changes in LULC is increased population change.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

6.1.1 Socio-economic study

Despite the fact that the contribution of educated manpower is indispensable, and particularly for countries like Ethiopia, higher proportions of the household heads (>60%) and school age children (>50%) are illiterate. Higher number of children not going to school will imply high potential demand for primary education in the study area. Currently, there are only one junior high school and six primary schools in the whole study area. This is showing that the number of schools is not keeping pace with the increasing population. The analysis for relationship between literacy of household heads with other socio-economic features was made, but there were no significant differences for most relationships. Correlations between family size and income from crop production were positive and relationship was highly significant ($p<0.01$). Similarly, positive correlations were observed between livestock holding and income from crop production on a hectare basis, which was also highly significant ($p<0.01$).

Comparing the current family size (7.7 persons/household) in the study area and that of Shewa province (where the study area is located), which was 4.5 persons/household about three decades ago (CSA, 1974), there is a high population increase in and around the study area. As a result, it is very easy for one to see the effects of this high population increase on the natural resource base.

Landholding of households is relatively better than most highlands but the output per unit of land is still low. This is because of the nature of the dominant soils (soils with vertic properties) in the area, which are planted late, and hence a good proportion of the rainfall is wasted. This and other technical reasons have made productivity per unit area to be low in the study area, even though it is slightly better than what has been reported previously for these soils. As a result the daily minimum calorific requirement is not met at this productivity level. The energy produced from these crops only meets 80% of the daily minimum energy requirement in the study area.

Framers in the area acknowledge soil fertility decline and hence is maintained mainly through application of commercial fertilizers because the traditional means of fertility restoration are no more able to sustain productivity due to higher population. Fallowing has been reported by only four farmers and hence is generally absent because land cannot rest for longer periods of time and is instead cultivated without rest in order to meet the food needs of households. Manure, which was traditionally used to restore fertility, is now totally used for meeting the needs of energy. Hence, there is total dependence on commercial fertilizer.

Livestock are integral parts of the communities in the study area and number of draught oxen is relatively higher which was 2.7 heads of draught oxen/household. This is an indication that the study area an extensive agricultural area without which farmers are not able carryout their farm activities. At the same time, the number of donkeys is also high mainly because watering points are far away that they are used for transporting water for both human and livestock, in addition to transporting other commodities.

Despite the fact that number of livestock is relatively high, available feed resources are limited and as a result livestock are suffering during both the dry and wet seasons. Feed resources are only abundant/sufficient for only four months (October to January) of the year, which means livestock are in short of feed for most parts of the year in the study area. The quality of feed even during the months of abundance is even very poor. Among the feed resources available, crop residues have a reasonably good share in the study area because of conversion of grazing lands into croplands. Hence, crop and livestock production systems are becoming more integrated because crop residue is becoming the major source of feed for livestock in the highlands and particularly in the study area. Based on the metabolizable energy (MEm) for maintenance and 20% production requirements, crop residues contributed to about 52.1% (DM basis) of the total feed required for the number of livestock in the study area.

The overall contribution of crop residues as feed resources, from what is available, for the whole area was 77%, while the rest comes from natural pastures. Feed requirement for the whole study area is only 68% of what is needed by the livestock in the study area. This will imply that productivity of livestock to remain very low in the area. This is because the number of livestock is not proportional to the available feed in the study area. Other than crop residue, the only source of feed is the mountain, where livestock may be able to graze for some months. The movement of livestock onto the mountain has also another effect of land degradation, which again will impact the livelihoods of many people down the slope.

The socio-economic survey also looked at energy resources for the study area. The results indicated that cow dung is the major source, accounting for 60.6% of the energy required by households, followed by fuelwood (21.2%) and crop residue (18.2%). Use of petroleum products as a source of energy is very limited in the study area. The major household use for which the major source energy is used for cooking. Cooking accounted for about 70% of the energy consumed in the study area. *Injera* making is believed to consume most of the energy resources because the major crops grown in the area are dominantly *tef* and wheat.

6.1.2 Land Use and Land Cover

The Land Use and Land Cover changes, soil erosion and population pressure analysis for the period between 1971/72 and 2000 for Yerer Mountain and surroundings indicate that soil erosion is much more severe on croplands and hence shows strong relationship to population pressure.

The analyses also showed that grasslands declined from 18784 ha (65.35%) to 9396 ha (32.7%), while cultivated land increased from 7186 ha (25%) to 16,204 ha (56.4%) in 1971/72 and 2000, respectively. The water body, Wedecha dam did not exist in 1971/72 but the Chefe increased from 190 ha (0.66%) to 312 ha (1.09%) in 1971/72 and 2000, respectively. This is probably because these wetlands started accumulating water just before the aerial photos were taken in 1971. The formation of these water bodies could be associated to human activities on the higher slopes. This could therefore be associated to deforestation, steep slope cultivation and increased human and livestock movements on the slopes, which could have increased the overflow of water into the low-lying areas. This indicates population playing a major role in these aspects.

From the viewpoint of environment, these changes are important because the water collected in these water bodies is causing malaria incidences around Debre Zeit, especially in these areas which are not close to standing waters of the crater lakes. The fact that it is extensive, especially after the rains, may cause more mosquitoes to breed and cause more malaria sicknesses in the area. Other than this, these water bodies are also indications of change in the ecology of the area as a result of human activity.

6.1.3 Soil and water conservation

Society in the study area is experiencing the degradation of water, plant and animal resources directly. Degradation of the soil resource, by contrast, is mostly felt indirectly through its detrimental impact on the other resources. Therefore, soil degradation is often not perceived as a problem until the damage is considerable and corrections are costly. Hence, SWC practices are likely to be adopted where this activity has the potential to increase yields crops.

Therefore before embarking into SWC practices in the study area, policies for SWC should therefore be designed to provide tangible benefits to the individual household or community. The emphasis should be on SWC in the context of raising agricultural productivity, food security and income, against the background of wider livelihood strategies, rather than on controlling land degradation per se. That could have been one of the main reasons why the efforts of many years of SWC in Ethiopia were not successful.

This present study tried to link the systemic nature of the use-cover relationship, which includes the biophysical and the human activities. Thus, the study on land-use and land-cover change around Yerer mountain has linked research on the natural resources with the human dimensions, and the understanding gained from these linkages is expected to contribute to decision makers on how the natural resource around the study area and elsewhere in the country should be managed.

6.2 Recommendations

The following recommendations emanate from the fact that the present land use systems and trends of population growth will remain for the study area at least for the foreseeable future.

Access to primary school education: Level of illiteracy is high in the study area, despite the fact that the area is close to big towns including the capital city, which could have made households more aware of the benefits of education. Increased access of to primary education will encourage households to send their children to school and hence improve the literacy level and thereby the takeoff of family members from the area. This indirectly could contribute to at least contain further fragmentation of farmlands and denudation of the remaining vegetation. In addition as the present level of productivity in the area will not sustain the ever-increasing population in the area, intensification of agriculture will be a must. Under this condition, literate farmers will be able contribute to this end. This will require both the government and the society, for a robust action plan to help increase the number of school age children enrolment in schools.

Population policy: Increased population is causing LULC changes in the study area and the country in general. The current family size of the households in the study area will not be sustained by the existing farming practices. Therefore, informal education of households about the impacts of population increase is of paramount advantage. Strong family planning and sex education is therefore a timely activity. There are currently efforts in the country to make people aware of consequences of population pressure but should be carried aggressively in schools and other social gatherings, with appropriate tools made available freely or at a price affordable by farmers.

Giving land use rights to individuals (other than the crop lands): Attempts are being made in some parts of the Amhara and Tigray Regions where some hills were given to individuals for rehabilitation through SWC and tree planting practices, where benefits from selling trees or other exercises are obtained. This will encourage individuals to participate in the conservation of natural resources. Most youth in the area are landless and blamed to be the main sources of denudation of shrub/bushlands. Informal discussions held with some elders, other than those sample farmers, had revealed that some community members, especially the youth, are dependent on sale of fuelwood from shrublands around Yerer Mountain. Giving land use rights could be started in the study area so that natural resources are conserved when at the same time contributing positively to livelihoods of people. This initiative should however be upon the consent of the willingness and understanding of the community.

Landscape management: The following are biophysical recommendations to the different landscape categories in the study area.

Midlands and Uplands: In most areas where vegetation cover is low, conservation measures are a requirement. In areas where sheet erosion hazards are moderate, measures like contour bands, hillside drains, development of grassed waterways afforestation programmes would be required, even though some crops could as well be grown in these areas. Livestock grazing may be allowed but will require controlling to avoid overgrazing. Actually, cut and carry is much preferred in these areas than allowing livestock but would mean changing the by-laws used by communities in managing crops and grazing areas.

However, in areas where sheet erosion is severe due to higher slopes and shallow soils, cropping should not be practised and livestock should not be allowed to such areas. Tree planting would be important for availing fuelwood requirements of communities in the area. Under conditions of poorly managed crop and livestock production systems, soil erosion will be enhanced and hence should not be allowed to these areas.

Flatlands*:* These landscapes are usually with nearly no vegetative cover, except some scattered *Acacia albida* trees and some trees in the backyards. These areas are continuously cultivated and area also affected by activities on the upper slopes. These areas have generally gentler slopes as they are the foot of the Yerer Mountain. The dominant soils in this landscape are Vertisols, which are easily waterlogged during the rainy season and at the same time gullies are also easily developed which affect productivity. In these areas physical structures to avoid concentration of running waters would be required before these gullies take most of the land out of production. The traditional grass boundaries between crop field are inexistent and plots seem to be continuous even though farmers know the boundaries of their plots. It would be strongly recommended that grass boundaries be reinstated so that erosion is reduced and what ever is removed (eroded) from the fields will remain within.

Improvement of non-timber products: Making the existing vegetation, especially around the southern and western parts, more productive through introduction of apiculture could help communities benefit from the vegetation and hence the existence of the vegetation will be of more interest to the community than any body else and could be taken care of without the government spending resources for protection.

Early planting: Late planting of crops is one of the common practices in the study area. This practice is known to enhance more erosion on farmlands and hence lower productivity. Early planting on the other hand will help minimise the effects of sheet erosion and also gully initiations through early vegetative cover of croplands. Early planted crops benefit from accumulation of more photosynthates during the extra growing period thereby producing higher yields compared to yields obtained from late-planted crops.

Diversification of crops: Diversification of food crops is also essential in the area because nearly all diets for the people in the area is nearly cereal based only. Especially those that have access to irrigation may be encouraged to grow and consume vegetables.

Forage improvement: Solution towards this should include identifying and introducing forage/fodder species that could easily grow under wet conditions and at the same time that can stand and produce sufficient biomass during the dry season. Protein rich feed sources should be encouraged especially in backyards and appropriate indigenous fodder species should be identified from within the area or country along with imported but already known potentials. Efforts underway in two PAs in the study area by ILRI is a good start provided introduction of these feed resources is more strengthened with increased number of plants per farmer. These forage/fodder plants would be important feed resources for both dairy development and fattening programmes which is exercised by some farmers in the area. In addition to the above, the following are also believed to increase feed availability.

Undersowing: Undersowing cereals with forage legumes has important advantage of producing fodder crops without taking any cropland out of production. Using the dominant crop in the study area, wheat, experiments at ILRI have shown that clovers could be sown together with this crop in order for both the quality and quantity of forages to improve. Even though there is a little of grain loss, the increase in both quality and quantity of the fodder will off set the decline. This will also contribute to reduction in fertiliser use, especially N, for the following cropping season.

Livestock management systems: The study area has a severe shortage of grazing lands relative to the needs of the livestock population, if livestock exclusion is going to be carried out on highly erosion susceptible areas as recommended. There should be alternative livestock management systems like tethering, instead of letting livestock to move freely. This will reduce overgrazing and increase biomass productivity, which may also increase the productivity of livestock. On the other hand this will minimize effects of livestock in causing land degradation. This has another positive social dimension because it releases the children, who mainly look after the livestock to going to school, even though it may incur additional labour force to collect feed for livestock.

Alternative energy resources: There is total dependence of households on bio-fuels and this has impact on the existing natural resources. To this effect, farmers should be encouraged to plant fast growing trees on their farm boundaries, homesteads or on unproductive (degraded sloppy lands), while private entrepreneurs should be able to produce alternative non traditional sources of energy, so that multiple benefits could be attained. On the one hand it will avail the source of energy needed by the household/community and feed for livestock, on a cut and carry basis, and on the other hand it will contribute to soil and water conservation purposes.

Introduction of other energy saving stoves from within the country, like the one used in northern Ethiopia, will increase energy efficiency for the study area. Extension should therefore be more strengthened along with non-governmental organisations and promote this stove for better use of the existing energy resources.

The other possibility is use of biogas if livestock are tethered because: 1. In most cases, the number of humans and livestock in a household are sufficient to generate daily energy requirement for the household. 2. The slurry coming out as a by-product from the biogas could be used for crop production or homestead garden. 3. Using biogas would also improve the health of the people who may be suffering from respiratory related diseases because of smoke from the use of bio-fuels.

However, this will require a cultural change on the side of the farmers to construct and use latrines for humans and proper barn and tethering of livestock so that the wastes could be mixed. On the other hand, the initial cost of the biogas plant might be a bit expensive that farmers may be discouraged to use. There are however, smaller locally available biogas chambers, which are also relatively cheaper. In some places water could as well be a limiting factor, even though there is a culture of using donkeys for transporting water for both livestock and humans, from long distances.

Application of remote sensing and GIS was found helpful in quantifying past and present resources so that appropriate planning could be made for the future. It is therefore hopped that future development activities will exploit these resources more than the present study for better use of natural resources in the study area and elsewhere.

REFERENCES

Abate Tedla, Tekalign Mamo and Getnet Gebeyehu (1992). Integration of forage legumes into cereal cropping system in Vertisols of the Ethiopian highlands. *Tropical Agriculture (Trinidad).* **69**(1): 68-72.

Abiye Astatke, Jabbar, M. and Tanner, D. (2003). Participatory conservation tillage research: An experience with minimum tillage on an Ethiopian highland Vertisol. *Agriculture, Ecosystems and Environment*, **95**: 401-415.

Abiye Astatke, Tekalign Mamo, Peden, D. and Diedhiou, M. (2004). Participatory on-farm conservation tillage trial in the Ethiopian highand Vertisols: The impact of potassium application on crop yields. *Experimental Agriculture*, **40**: 1-11.

Adamu Molla (1991). Effect of preceding crops and N, P fertilisers on barley yield in North eastern Ethiopia. *Rachis: Barley and wheat Newsletter*, 10(2) ICARDA, Aleppo, Syria.

Akundabweni, L. (1984). Forage potential of some annual native Trifolium species in the Ethiopian highlands. *PhD Thesis*, South Dakota State Univiversity, Brookings (USA). 208 pp.

Allen, J.C. and Barnes, D.F. 1985. The Causes of Deforestation in Developing Countries. *Annals of the Association of American Geographers* **75**: 163-84.

Amare Getahun (1980). Agroclimates and agricultural systems in Ethiopia. *Agricultural Systems* **5**:39-50.

Badege Bishaw (2001). Deforestation and land degradation on the Ethiopian highlands: A strategy for physical recovery. Paper presented at an international conference on contemporary development issues in Ethiopia, Kalamazoo, Michigan, U.S.A. August 16-18, 2001 http://www.etff.org/badeg_def.htm. Accessed, October 2003.

Barber, R. (1984). An assessment of the dominant soil degradation processes in the Ethiopian highlands: Their impacts and hazards. Ethiopian Highlands Reclamation Study. Working paper 23, FAO/Ministry of Agriculture, Addis Ababa. 82 pp.

Befekadu Degefe and Berhanu Nega. (2000). *Annual report on the Ethiopian economy: Volume I, 1999/2000.* The Ethiopian Economic Association, Addis Ababa, Ethiopia. 429 pp.

Behailu Abebe, Solomon Tegegne, Zelalem Bekele and Abu Girma (1996). Sirba and Godeti: Ada'aa. Ethiopian Village Studies. Department of Sociology, Addis Ababa University, (Ethiopia) and the Centre for the Study of African Economies, Oxford, UK. 57 pp.

Bekele Shiferaw (1991). Crop-livestock interactions in the Ethiopian highlands and effects on sustainability of mixed farming: A case study from Ada District. PhD Thesis. Agricultural University of Norway. 163 pp.

Belay Tegene. (2002). Land cover/ use changes in the Derekolli catchment of the South Welo Zone of Amhara Region, Ethiopia. *Eastern Africa Social Science Research Review* **18** (1): 1-20.

Berhanu Debele (1985). The Vertisols of Ethiopia: Their properties, classification and management. **In**: World Soil Resources Report No. 56. 31-54. FAO, Rome, Italy.

Berhanu Gebremedhin, Fernandez-Rivera, S., Peden, D. and Solomon Gebresselassie (2004). Crop residue as feed in the Ethiopian highlands: Result from maize-based crop-livestock mixed system. Unpublished. 26 pp. (Paper prepared for a workshop).

Betru Nedessa (2002). Soil and water conservation programme in the Amhara National Regional State. Paper presented at a conference on natural resources degradation and environmental protection in the Amhara National Regional State held from July 24-26, 2002, Bahir Dar, Ethiopia. 17 pp.

Bezuayehu Tefera, Gezahegne Ayele, Yigezu Atnafe, Jabbar M.A. and Paulos Dubale. 2002. *Nature and causes of land degradation in the Oromia Region: A review*. Socio-economics and Policy Research Working Paper 36. ILRI (International Livestock Research Institute), Nairobi, Kenya. 82 pp.

Bojö and Cassells (1994). Land degradation and rehabilitation in Ethiopia: A re-assessment. AFTES Working paper No. 17. The World Bank, Washington DC, USA. 48 pp.

Boserup, E. (1965). The Conditions of Agricultural Growth: The Economics of Agrarian Change Under Population Pressure. Chicago: Aldine Press. 108 pp.

Boserup, E. (1981). Population and Technological Change: A Study of Long-Term Trends. University of Chicago Press, Chicago, USA.

Constable, M. (1984). Resources of rural development in Ethiopia. Ethiopian Highlands Reclamation Study. Working paper 17, FAO/Ministry of Agriculture, Addis Ababa. Ethiopia

Crummey, D. and Winter-Nelson, A. (2003). Farmer Tree-Planting in Wällo, Ethiopia. In: *African Savannas: Global narratives & local knowledge of environmental change,* p. 91-120 (Bassett, T.J. and Crummey, D. eds.). Woolnough, Irthlingborough, UK.

CSA (1974). Results of the national sample survey: Second round. The demography of Ethiopia. Volume I. Central Statistical Office, Statistical Bulletin 10. 132 pp.

CSA (2003). Statistical report on farm management practices, livestock and implements. Part II. Ethiopian Agricultural sample enumeration, 2001/02. Central Statistical Authority, Addis Ababa, 345 pp.

CSA (2003a). Statistical Abstracts 2002. Central Statistical Authority. 411 pp.

CSE (Conservation Strategy of Ethiopia) (1997a): The resources base, its utilisation and planning for sustainability. Volume I. Federal Democratic Republic of Ethiopia, Environmental Protection Authority. 138 p.

CSE (Conservation Strategy of Ethiopia) (1997b): Federal Policy on the Environment. Volume II. Federal Democratic Republic of Ethiopia, Environmental Protection Authority. 114 p.

Dagnachew Legesse, Vallet-Coulomb, C. and Gasse, F. (2003). Hydrological response of a catchment and land use change in tropical Africa: Case study south central Ethiopia. *Journal of Hydrology* 275: 67-85.

Daniel Keftasa (1987). Role of crop residues as livestock feed in the Ethiopian highlands. **In**: *African forage plant genetic resources, evaluation of forage germplasm and extensive livestock production systems,* p. 430-439. (Dzowela, ed.). ILCA, Addis Ababa, Ethiopia.

de Sherbinin, A. (2002). Land-Use and Land-Cover Change, A CIESIN Thematic Guide. Center for International Earth Science Information Network (CIESIN) of Columbia University, Palisades, NY, USA. http://sedac.ciesin.columbia.edu/tg/guide_main.jsp. Accessed, April 15, 2004.

Delgado, C; Rosegrant, M. and Meyer, S. (2001). *Livestock to 2020. The Revolution Continues* Paper presented at the International Trade Research Consortium January 2001. Auckland, New Zealand.

EFAP (Ethiopia Forestry Action Programme). (1993). Draft Final Report, Volume II. The challenge for Development. Draft Final Report. Addis Ababa, Ethiopia. 78pp.

EHNRI (Ethiopian Health and Nutrition Research Institute) (1997). Food compositiin Table for use in Ethiopia. Part III, 34 pp.

Ehrlich, P. R. and. Holdren, J. P. (1971). Impact of population growth. *Science* **171**:1212-1217

EHRS (Ethiopian Highland Reclamation Study) (1984). An assessment of the cause, severity, extent and probable consequences of degradation in the Ethiopian highlands. Land use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia.

Ehui S., Li Pun H., Mares V. and Shapiro B. (1998). *The role of livestock in food security and environmental protection*. *Outlook on Agriculture* **27**(2):81–87.

Ehui, S and Pender, J. (2003). Resource Degradation, Low Agricultural Productivity and Poverty in Sub-Saharan Africa: Pathways out of the Spiral. Paper prepared for the plenary session on Environmental Stewardship of the 25th International Conference of Agricultural Economists, 16-23 August 2003, Durban, South Africa. 58 pp.

El-Swaify, S.A and Hurni, H. (1996). Trans-boundary effects of soil erosion and conservation in the Nile basin. *Land Husbandry* **1**: 6-21.

EMA (Ethiopian Mapping Agency) (1981). National Atlas of Ethiopia.

FAO/UNESCO (1973). Soil map of the world, Vol. VI, Africa. FAO/UNESCO Paris.

FAO (1984). Assistance to Land-use Planning Ethiopia: Geomorphology and of soils. 246 pp

FAO (1993). Forest Resources Assessment 1990: Tropical Countries. FAO Forestry Papers 112. FAO, Rome. 104 pp.

FAO (1999). FAO Production Year Book 1999. Vol. 53.

FAO (2000). Biophysical, socio-economic and environmental impacts of degradation. http://www.fao.org/landandwater/agll/madssea/topic3.htm. Accessed, May 16, 2004.

FAO (2001). Global Forest Resources Assessment 2000: Main Report. FAO Forestry Paper 140. FAO, Rome.

FAO (2002). FAO Production Year Book 2002. Vol. 56.

FAO (Food and Agriculture Organization) (1986). Ethiopian Highlands Reclamation Study. Final Report. Volume 1. pp. 334.FAO, Rome.

FAO/WFP (2000). FAO/WFP crop and food supply assessment mission to Ethiopia: Special report. FAO global information and early warning system on food and agriculture, World Food Programme.

Feoli, E., Gallizia, L.V. and Zerihun Woldu (2002). Evaluation of environmental degradation in northern Ethiopia using GIS to integrate vegetation, geomorphological, erosion and socio-economic factors. *Agriculture, Ecosystem and Environment*. **91**:313-325.

FFDME (Finfinne Forest Development and Marketing Enterprise) (2001). Yerer Mountain Plantation Forest Inventory and Preliminary Resource Survey. 25 pp.

Fitsum Hagos, Pender, J. and Nega Gebreselassie (2002). Land degradation and strategies for sustainable management in the Ethiopian highlands: Tigray region (second edition). Socio-economics and Policy Research Working Paper 25. ILRI (International Livestock Research Institute), Nairobi, Kenya. 80 pp.

Garmin eTrex (2003). Garmin eTrex Ltd. Personal navigator. Garmin International Inc.

Geomatica Version 9.1 (2003). PCI Geomatics, Richmond Hill, Ontario, Canada.

Getachew Asamnew, Jutzi, S., Abate Tedla and McIntire, J. (1988). Economic evaluation of improved Vertisol drainage for food crop production in the Ethiopian highlands. **In**: *Management of Vertisols in Sub-Saharan Africa*, p. 263-283, (Jutzi, S., Haque, I., McIntire, J. and Stares, J.E.S. eds.). Proceedings of a conference held at LCA, Addis Ababa, Ethiopia, 31 August - 4 September 1987.

Gete Zeleke and H. Hurni. (2001). Implications of Land Use and Land Cover dynamics for mountain resource degradation in the northwestern Ethiopian highlands. *Mountain Research and Development* **21**: 184-191.

Girma Taddese, Mohamed Saleem, M.A. and Wagnew Ayaneh (2002a). Effect of livestock garzing on physical properties of a cracking and self-mulching Vertisol. *Australian Journal of Experimental Agriculture,* **42**(2):129-133.

Girma Taddese, Mohamed Saleem, M.A., Abiye Astatke and Wagnew Ayalneh (2002b). Impact of grazing on plant species richness, plant biomass, plant attribute and soil physical and hydrological properties of Vertisol in the East African highlands. *Environmental Management*, **29**(2): 279-289.

Girmay Kassa (2003). GIS based analysis of landuse/land cover, land degradation and population changes: A study of Boru Metero area of south Wello, Amhara Region, *MA Thesis*, Department of Geography, Addis Ababa University. 110 pp.

Hoekstra, D.A., Torquebiau, E. and Badege Bishaw (1990). Agroforestry: potentials and Research Needs for the Ethiopian Highlands. Agroforestry Research Network, No. 21, ICRAF. Nairobi, Kenya. 115 p.

Hudson, N. (1971). *Soil conservation*. Batsford Academic and Educational Ltd. London, UK. 324 pp.

Hurni, H. (1988a). Degradation and conservation of the resources in the Ethiopian highlands. *Mountain Research and Development*, **8** (2/3): 123-130.

Hurni, H. (1988). Ecological issues in the creation of famine in Ethiopia. Paper presented to the National Conference on a Disaster Prevention and Preparedness Strategy for Ethiopia, December 5-8, 1988, Addis Ababa, Ethiopia.

Hurni, H. (1990). Degradation and conservation of the soil resources in the Ethiopian highlands. **In**: *African Mountains and Highlands: Problems and Perspectives* pp. 51-64, (Messerli, B. and Hurni, H. eds.). Marceline, Missouri (USA)

Hussein, J. and Adey, M. (2001). Soil and water conservation stratgies for Vertisols: Past experiences and challenges ahead for Africa. **In**: *The sustainable management of Vertisols* pp. 21-41, (Syers, J.K., Penning De Vries, F.W.T. and Nyamudeza, P. eds.). IBSRAM Proceedings No. 20. CAB International and IWMI. Biddles Ltd, UK.

IAR (Institute of Agricultural Research) (1983). Animal Science, Pasture, Forage and Range Management Report for the period April 1982-March 1983.

IAR (Institute of Agricultural Research) (1986). Department of Animal Science, Pasture and Forage Team Progress report for the period April 1983-March 1984.

ILCA (International Livestock Centre for Africa) (1994). Improving livestock production in Africa: Evolution of ILCA's Programme 1974-1994. ILCA, Addis Ababa, Ethiopia. 233 pp.

IUCN (International Union for the Conservation of Nature) (1990). Ethiopian National Conservation Strategy. Phase I Report. International Union for the Conservation of Nature, Addis Ababa, Ethiopia.

Jahnke, H. (1982). Livestock production systems and livestock development in tropical Africa. Kieler Wissenschaftsverlag Vauk. 253 pp.

Jutzi, S.C., Anderson, F.M. and Astatke, A. (1986). Low cost modifications of the traditional Ethiopian type plough for land shaping and surface drainage of heavy clay soils: Preliminary results from on-farm verifications. In: *Animal power in farming system,* pp. 127-132, *(*Starkey, P. and Ndian*e*, F. eds.), Eschborn, Germany: German Technical Agency.

Kahsay Berhe, Abate Tedla and Mohamed Saleem, M.A. (1993). Establishment and evaluation of multipurpose trees for sustainable farming systems in the Ethiopian highlands. Paper presented on the 5th Annual Conference of the Crop Science Society of Ethiopia, held in Addis Ababa, Ethiopia from Feb. 2-3, 1993.

Kahsay Berhe, Berhanu Gebremedhin and Abiye Astatke (2001). Farm power and farm household livelihoods in the Ethiopian Highlands: Case study of two peasant associations. A joint ILRI/FAO study. Submitted to FAO. 46 pp.

Kamara, C.S. and Haque, I. (1987). Characteristics of Vertisols at ILCA research and outreach sites in Ethiopia. Working Paper No B5. Plant Science Division, ILCA, Addis Ababa. 69 pp.

Kamara, C.S. and Haque, I. (1988). Characteristics of upland soils at ILCA research sites in Ethiopia. Working Paper No. B6. Plant Science Division, ILCA, Addis Ababa. 83 pp.

Kebrom Tekle and Hedlund, L. (2000). Land cover changes between 1958 and 1986 in Kalu District, southern Wello, Ethiopia. *Mountain Research and Development* 20: 42-51.

Lillesand, M. and Kiefer, R.W. (1999). Remote sensing and image interpretation. Fourth edition. John Willy & Sons Inc. Newark, Chichester, Wenheim, Brisbane, Singapore, Toronto. 595 pp.

Mando, A. and Stroosnijder, L. (1999). The biological and physical role of mulching the rehabilitation of crushed soils in the Sahel. *Soil Use and Management* 15:123-130.

McCann, J. (1995). *People of the plow: An agricultural history of Ethiopia*, 1800-1900. University of Wisconsin Press, Madison, USA. 298 pp.

McClelland, D.G. (1998). U.S. Food Aid and Sustainable Development: Forty Years of Experience. U.S. Agency for International Development, USAID Program and Operations Assessment Report No. 22. 90 pp.

Mohamed-Saleem, M.A. (1995). Fragile East African highlands: A development vision for smallholder farmers in the Ethiopian highlands. *Outlook on Agriculture*. **24**(2): 111-116.

MOPED (Ministry of Planning and Economic Development) (1999). *Poverty situation in Ethiopia*. Welfare Monitoring Unit, Addis Ababa, Ethiopia.

Mwendera, E. J., Mohamed Saleem, M.A. and Asgelil Dibabe (1997). The effect of livestock grazing on surface runoff and soil erosion from sloping pasture lands in the Ethiopian highlands. *Australian Journal of Experimental Agriculture*, **37**:420-430.

Mwendera, E.J. and Mohamed Saleem, M.A. (1997). Infiltration rates, surface runoff and soil loss as influenced by grazing pressure in the Ethiopian highlands. *Soil use and Management*, **13**:29-35.

Oromia National Regional Government Regional Conservation Strategy (2000a). Regional conservation strategy. The Resource base, its utilization and planning for sustainability, volume I. Finfinne,. 171 pp.

Oromia National Regional Government Regional Conservation Strategy (2000b). Regional conservation strategy. identification and analysis of constraints and issues, volume II. Finfinne,. 81 pp.

Oromia Water, Mineral and Energy Resources Development Bureau (1999). East Shewa Zone, Adama.

Raven, P.H. (1991) Winners and losers in the twentieth-century struggle to survive, , **In**: *Resources, Environment, and Population: Present Knowledge and Future Options,* A supplement to Vol. 16, 1990, pp. 259–266, (K. Davis and M.S. Bernstam, eds). *Population and Development Review*. New York: The Population Council and Oxford University Press.

Reddy, C.V. (1982) Role of draught animals as alternative energy sources in agriculture, Draught animal system in India. Indian Institute of Management. Seminar papers.

Reid, R.S., Kruska, R.L., Muthui, N., Taye, A., Wotton, S., Wilson, C.J. and Woudyalew Mulatu (2000). Land-use and land-cover dynamics in response to changes in climatic, biological and socio-political forces: the case of southwestern Ethiopia. *Landscape Ecology* **15**: 339-355.

Samson, Taffesse, Garzia, M. and Woldemariam Girma (1999). Maternal energy and macronutrient inecurity in an enset-corn staple village of southern Ethiopia. *The Ethiopian Journal of Health Development,* **13** (3): 285-291.

Sanchez, P. (1976). *Properties and management of soils in the tropics*. John Willy and Sons, London. 618 pp.

ScanWizard Pro V6.10 for Windows, (2003). Microtek, Redondo Beach, California, USA.

Schwab, G.O., Frevert, R.K., Edminister, T.W. and Barnes, K. K. (1981). *Soil and water conservation engineering*. John Wiley and sons. Third edition. 525 pp

Seifu Kebede (1999). Hydrology and hydrochemistry of Bishofu crater lakes (Ethiopia): Hydrological, hydrochemical and oxygen isotope modelling. *M.Sc. Thesis*, Addis Ababa University, Addis Ababa, Ethiopia. 128p.

Selamyihun Kidanu (2004). Using Eucalyptus for soil and water conservation on the highland Vertisols of Ethiopia. *Ph.D. Thesis*. Wageningen University, The Netherlands. 195 pp.

Shibru Daba, Rieger, W. and Strauss, P. (2003). Assessment of gully erosion in eastern Ethiopia using photogrammetric techniques. *Catena* **50**: 273– 291.

Solomon Abate (1994). Land use dynamics, soil degradation and potential for sustainable use in Metu area, Illubabor Region, Ethiopia. African Studies Series No. A 13. *Ph.D. Thesis*, University of Berne, Switzerland. 135 pp.

SPSS (Statistical Package for Social Sciences) (2002). *SPSS for Windows Release11.5.1*. Standard Version SPSS Inc., 1989-2002.

Squire, E. (2000). Hunger, agriculture, and the end of cheap oil. (http://www.geocities.com/Ericsquire/globenag.htm). Accessed, May 29, 2004.

Stocking, M. (1996). Soil erosion: Breaking new ground. **In**: *The lie of the land: Challenging received wisdom on the African environment*, (Leach, M. and Mears, R. eds). African issues. Villiers Publications. UK. 240 pp.

Sutcliffe, J.P. (1993). Economic Assessment of land degradation in the Ethiopian highlands: A case study. National Conservation Secretariat, Ministry of Planning and Economic Development, Addis Ababa, Ethiopia.

Tamirie Hawando (1997). Desertification in Ethiopian highlands. Rala report no. 200. pp. 75-86.

Tewelde Berhan Gebre Egziabher, (1989).The rates of ecological crises in Ethiopia. **In**: Pages 103–110, Proceedings of the First Natural Resources Conservation Conference. Addis Ababa, Ethiopia (mimeographed).

Tiffen, M., Mortimore, M. and Gichuki, F. (1994). *More people less erosion: Environmental recovery in Kenya*. London, John Willy and Sons Ltd. 311 pp.

Turner, B.L., Skole, D., Sanderson, S. Fischer, G., Fresco, L. and Leemans, R. (1995). Land-Use and Land-Cover Change Science/Research Plan. HDP Report Series No. 7. http://www.ihdp.uni-bonn.de/html/publications/reports/report07/luccsp.htm. Accessed, May 10, 2004.

WBISPP (Woody Biomass Inventory and Strategic Planning Project), (2000). The Oromiya Regional State. A strategic plan for the sustainable development, conservation, and management of the woody biomass resources. Volume II. 158 pp.

WHO, IUCN, and WWF (1993). Guidelines on the Conservation of Medicinal Plants. IUCN, Gland, Switzerland.

Wøien, H. (1995). Woody plant cover and farming compound distribution on the Mafud escarpment, Ethiopia: An aerial photo interpretation of changes 1957-1986. Working paper on Ethiopian development No. 9. Trondheim: Centre for Environment and Development Unit, SMU, University of Trondheim.

Woldeamlak Bewket (2003a). Land degradation and farmers' acceptance and adoption of conservation technologies in the Digil watershed, northwestern highlands of Ethiopia. Social Science Research Report Series no. 29, OSSREA, Addis Ababa, Ethiopia. pp.

Woldeamlak Bewket (2003b). Household level tree planting and its implications for environmental management in the northwestern highlands of Ethiopia: A case study in the Chemoga watershed, Blue Nile basin. *Land Degradation and Development* **14**: 377-388.

WRI (World Resources Institute) (1997). The last frontier Forests: Ecosystems and Economies on the edge. Washington D.C., USA.

Zerihun Woldu and Mohamed Saleem, M.A. (2000). Grazing induced biodiversity in the highland eco-zone of East Africa. *Agriculture, Ecosystems and Environment*, **79**: 43-53.

Annex 1. Mean monthly rainfall (mm) Debre Zeit EARO and ILRI Research Stations

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov	Dec.	mm/yr.
1953	0	24.4	11	88	18	77.8	97	165	53.2	0	2	24.7	561.1
1954	0	0	57	30.5	6.6	70.5	160	161	174.2	29	0	0	688.8
1955	0	0	23	36.4	0	80.1	354	208	142.9	0	0	0	844.4
1956	1.5	1.4	8.9	48	7.1	84.3	135	78	0	51	8.5	0.4	424.1
1957	0	25.6	65	91.5	48.1	123	210	305	24.8	5	1	1	900
1958	65.5	52.3	23.8	49.7	7	176	244	245	172.2	16	0.8	0	1052.3
1959	18	34	33.4	43.9	42.1	108	244	197	154.2	15	0	16	905.6
1960	0.8	5	48.1	16.6	99.5	56.3	168	270	161	0	5.2	0	830.5
1961	0	3.2	111	41.9	28.2	107	154	227	89.9	39	16.7	0	817.9
1962	0	1	62	24.7	2.7	0	203	237	181.8	47	0.9	21	781.1
1963	3	1.6	0	61.9	104	76	281	457	105.2	0	2.7	27.5	1119.9
1964	0	0	0	184	46.9	5.6	435	365	187.1	23	0	11	1257.6
1965	37.8	0	58.5	29.5	0	38.2	409	249	125.6	77	6.7	0	1031.3
1966	0	161	15.1	150	9.9	120	265	381	147.6	37	0	0	1286.6
1967	0	0	100	76.9	164	62.1	314	260	136	16	79.1	0	1208.1
1968	0	190	12.6	102	5	60.1	272	140	203	0	17.8	0	1002.5
1969	11	0	56.7	104	24.9	137	125	279	64.6	7.5	3.2	0	812.9
1970	44.1	31.1	7.5	21.4	45.3	56	251	290	112	5.9	0	0	864.3
1971	0.7	0	16.5	63	108	121	216	281	123.1	2.9	3	14.4	949.6
1972	0	95.2	53.7	136	47	102	214	225	66	2.6	0	0	941.5
1973	0	0	0	2.7	28	100	139	252	133.7	42	0	2	699.4
1974	0	12.5	104	7.6	98.1	114	307	199	140	3	0	0	985.2
1975	0	20	19.5	72.1	54.5	150	375	223	154	7	0	0	1075.1
1976	0	0	71.1	75	81.7	103	240	232	42.2	3.8	35.2	0.8	884.8
1977	43.1	1	87.7	90.2	57.6	101	273	203	82.2	15	3.4	0	957.2
1978	1.4	69	34.5	47.7	28.5	134	132	191	122.3	25	0	0.1	785.5
1979	77.7	0	54.7	13.4	76	111	225	188	83.8	13	0	0.1	842.7
1980	20	10.1	32.3	24.2	69.4	76.1	242	216	58.1	41	0	0	789.2
1981	0	20.5	164	62.1	7.1	35.8	295	152	162.8	4.2	0	1.2	904.7
1982	20.8	75.4	34.5	47.3	57.7	91	124	234	46.1	26	9.4	0	766.2
1983	0	10.2	46.8	105	209	149	129	345	88.6	23	0	0	1105.6
1984	0	0	19.3	0	109	80.7	221	290	85	0	0	3.6	808.6
1985	3.5	0	14.5	51.9	112	74	307	273	1.1	1.1	0	0.6	838.7
1986	0	23.6	51.7	142	72.4	167	179	163	90.2	3.2	0	0	892.1
1987	0	61.4	138	90.1	164	65.5	83	156	80.9	4.6	0	0	843.5
1988	8	14.9	6	44.6	36.8	101	146	237	121.4	17	0	0	732.7
1989	0.9	12.2	35.1	47	0.4	59	139	172	135.2	21	0	0	621.8
1990	11.2	25.7	73.6	65.6	61.2	102.4	209.1	203	97.5	23.7	0.8	1.7	875.5
1991	0.3	37.6	53.7	7.9	1.9	48.2	170	191	50.1	4.6	0	0	565.3
1992	6.8	51.2	2	8.3	3.9	42.2	150	156	101.4	29	1.3	1	553.1
1993	0	53.7	0	76.5	42.9	52.3	113	143	93.9	12	0	1.7	589
1994	0	0	9.5	23.1	19	36.2	169	124	98.9	0	11.3	1	492
1995	0	17	3.6	33.9	6.2	19.3	140	143	56.3	0	0	0	419.3
1996	10.4	0	79	20.6	80.9	148	130	189	65.3	0.2	0.9	0	724.3
1997	13.4	0	16.7	38.7	6.1	150	147	148	46.5	74	7.5	0	647.9
1998	15.4	56	16.2	54.5	60.7	77.1	198	322	100.9				900.8

1999	0	0	19.4	6.1	15.4	126.8	224.5	318	42.3	71.7	0	0	824.2
2000	0	0	27.2	54.8	75.7	63.6	192.6	135.5	131.8	18.4	38	1.1	738.7
2001	0	25.6	128.3	36.8	0	101	19	130.9	38.9	1.5	0	0	482
2002	6	0	53.5	25.5	21.5	171.5	203.2	218.5	73.3	0	0	24.7	797.7
2003	44	39.4	64.6	65.2	14	125.6	303.8	271.5	36.5	0	0	29.5	994.1
Ave.	**8.98**	**26**	**41.3**	**57.5**	**51**	**87.7**	**212**	**226**	**103.7**	**17**	**4.92**	**2.91**	**839.01**

Annex 2. Mean monthly average minimum and maximum air temperature (^{0}C) for ILRI Debre Zeit Research Station from 1977-2003

Year	Temperature[1]	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Mean
1977	Av. Max	26.7	28	28.5	26.9	28.3	27.4	24.9	26	26	26.5	25	25	26.6
	Av. Min	10.4	10.5	10	10.7	11	10.8	12.3	7.2	11	10	6.5	4.8	9.6
1978	Av. Max	23.8	24.2	24.6	23.3	21.8	26.5	20.3	17.3	18	19.4	19.5	19	21.5
	Av. Min	5	10.3	10	10.7	8.4	9.9	11.9	7	6.8	5.5	9.7	5.4	8.4
1979	Av. Max	24.1	26.9	26.9	28.9	27.9	25.3	24	24.8	25	25	25.7	25	25.8
	Av. Min	11.1	9.8	11.3	11.5	11.5	12.5	13.8	12.7	12	9.4	8.1	9.2	11.1
1980	Av. Max	23.5	24.9	25.9	25.9	25.5	21.4	20.8	20.6	21	21.6	22.7	21	22.9
	Av. Min	9.4	12.2	13.2	13.9	12.1	12.8	13.5	13.3	13	11.1	8	6.8	11.6
1981	Av. Max	22	22.8	23.2	22.3	23.5	23.2	17.4	18.4	18	NA	NA	NA	21.2
	Av. Min	9.1	11.1	11.1	10.6	9.5	10.1	10.3	9.8	10	NA	NA	NA	10.2
1982	Av. Max	18.8	19.5	20.8	20.1	21.1	28.1	25.2	23.2	25	24.8	25.3	25	23.1
	Av. Min	10.7	10.7	10.7	12	10.2	10.7	12.2	11.9	13	12.2	12.2	12	11.5
1983	Av. Max	25	25.6	25.4	25.3	25.4	25.6	25.7	23.6	25	24.7	25.8	25	25.2
	Av. Min	12	11.7	12.5	12.6	12.4	12.2	11.7	10.9	10	7.9	6.8	6.5	10.6
1984	Av. Max	25.9	26.9	28.3	24.5	27.4	26.2	24.3	24.6	25	25.6	26.4	25	25.8
	Av. Min	5.4	5.4	9.5	8.5	10.2	9.1	9.8	9.9	8.8	6.3	5.6	5.5	7.8
1985	Av. Max	26.4	26.8	27.6	26.3	26.4	27.3	23.4	23.4	24	25.1	25.5	26	25.7
	Av. Min	5.8	7.6	10.2	9.2	8.5	7.6	8	9.2	9	7	6.7	6.1	7.9
1986	Av. Max	25.7	26.7	26.4	25.9	27.3	25.5	24.2	25.5	25	26.4	26.8	27	26.0
	Av. Min	5.3	9.9	9	10.9	9.8	9.6	9.6	9.4	8.3	6.2	5.9	7	8.4
1987	Av. Max	26.6	29.3	29.7	29.3	29.7	30.3	29.5	25.9	27	27.4	27	27	28.2
	Av. Min	7.5	8.2	11	9.5	10.2	9.1	10.3	14.9	15	15.3	14	14	11.6
1988	Av. Max	26.6	27.4	29.2	28.4	28.2	27.2	23.4	24.2	25	24.5	24.6	26	26.2
	Av. Min	14.1	15.3	15.9	17.3	15.2	15.1	15.2	14.9	15	13.1	9.4	13	14.4
1989	Av. Max	25.3	26.1	27.8	25.5	27.6	27.2	24	24.6	25	25.3	25.9	26	25.9
	Av. Min	12.1	14.8	15.2	15.2	14.8	14.9	14.8	14.6	15	12.5	10.9	14	14.1
1990	Av. Max	25.9	26.8	26.5	26.3	28.9	27.5	24.8	25.2	26	26.2	28.2	28	26.7
	Av. Min	14	15.2	14.6	14.8	14.5	14.3	14.5	14.7	15	11.1	12.4	11	13.8
1991	Av. Max	29.6	29.3	29.4	29.2	29.7	30.4	25.4	23.5	25	24.6	24.5	25	27.1
	Av. Min	14.1	15	15.1	15.7	14.6	14.7	14.7	14.8	14	11.3	8.8	9.4	13.5
1992	Av. Max	24.8	25.6	28	28.6	29.2	27.7	24.3	23.5	23	23.8	24.3	25	25.6
	Av. Min	12.9	13.9	14.5	15.1	13.6	13.6	14.3	14.9	14	11.6	11.2	12	13.5
1993	Av. Max	25	24.8	27.9	26.7	26.3	25.7	24.3	23.7	24	24.2	24.6	25	25.2
	Av. Min	14.3	13.3	11.9	15	14.4	14.4	14.5	14.4	15	12.5	10.3	9.6	13.3
1994	Av. Max	25.6	27.3	28.4	27.8	28.7	26.3	23.4	22.9	24	24.3	24.3	25	25.6
	Av. Min	10.6	13.2	14.5	15.6	14.7	14.7	14.9	14.9	13	9.6	10.5	8.6	12.9
1995	Av. Max	25.8	28.2	27.7	27.3	29	28	24.2	23.6	24	24.9	25.4	27	26.3
	Av. Min	9.5	13.1	14.9	15.5	14.5	15.5	14.8	15	14	12	10.8	12	13.5
1996	Av. Max	28.3	28.7	28.4	29.1	28.8	25	24	23.7	22	26.4	25.7	26	26.4
	Av. Min	12.4	11.9	13.9	13.3	12.7	13.8	13.4	13.9	12	9.1	8.7	7.8	11.9
1997	Av. Max	26.7	25.8	29.3	27.9	29.9	28.7	25	24.8	26	25.3	25.1	26	26.7
	Av. Min	11.7	9.7	13.3	12.2	12.6	13.3	13.6	13.4	12	11.2	11.2	7.6	11.8
1998	Av. Max	26.9	28.4	28.4	30.2	29.8	29	25.1	23.4	25	25	25	25	26.8
	Av. Min	10.9	13.5	12.9	13.3	13	12.1	13.3	13.7	13	11	5.7	4.5	11.4

1999	Av. Max	26.7	28.6	27.7	29.6	30.1	28.3	23.4	23.9	25	24.7	24.7	25	26.5
	Av. Min	7.9	8.2	11.9	12.1	12	11.6	13	12.9	12	10	5.3	5.8	10.2
2000	Av. Max	26.9	27.9	29.3	29	28.8	28	25.1	23.7	25	25.6	25.9	26	26.8
	Av. Min	6.7	7.9	11.1	12.4	11.5	10.2	13.1	12.9	12	8.4	7.1	4.8	9.8
2001	Av. Max	26.9	28.8	27.3	28.8	28.2	26.5	24.5	23.7	26	26.8	26.1	26	26.6
	Av. Min	7.4	7.9	11.3	11.1	12	11.6	13	13.4	11	8.9	7.3	8.9	10.3
2002	Av. Max	26.4	28.5	28.6	29.5	30.4	28.2	26	24.2	26	26.8	26.6	26	27.2
	Av. Min	9.9	9.6	12.3	12.1	11.9	12.3	13	12.7	11	8.2	7.8	11	11.0
2003	Av. Max	26.6	28.3	28.7	27.7	30.5	27.8	23.8	23.5	25	26.2	26.1	25	26.6
	Av. Min	9	10.3	10.9	12.4	10.4	11.2	12.9	13.1	12	7.5	9	6.6	10.5
1977-2003	Mean	17.81	18.93	19.86	19.88	19.9	19.56	18.46	18.07	18.18	15.03	14.64	14.71	18.5

[1] 1.5m above ground level

Annex 3. Population size by sex, area and density at wereda level

Wereda	Population		Total	Total area (km^2)	Density (Persons/km^2)
	Male	Female			
Adaa Liben	162324	158570	320894	1635.16	196.2
Akaki	35288	33287	68575	571.41	120.0
Gimbichu	41057	39472	80529	707.49	113.8
Bereh Aleltu	78280	78539	156819	1325.79	118.3
Total	316949	309868	626817	4239.85	137.08[1]

Source : CSA (2003a)

Annex 4. General information about the ten PAs where the study was conducted

Zone	Wereda	PA	No of HH		Total HH	Population		Total population	Total area (ha) [1]	Area (ha) after digitisation [2]
			M	F		M	F			
East Shewa	Gimbichu	Bui Tengego	557	87	644	1827	1838	3665	2400	3622.70
	Akaki	Yerer Necho	338	56	394	1101	1027	2128	2309	2465.04
		Abeye Silto	250	64	314	878	1058	1936	800	1275.03
		Yerer Abeye	210	50	260	750	693	1443	1454	1855.92
		Enslale Finchawa	380	44	424	1301	1212	2513	2264	2067.25
	Ada Liben	Yere Selase	525	67	592	1960	2792	4752	3372	3369.25
		Gende Gorba	1008	78	1086	3450	4777	8227	3820	3862.40
		Godino	534	82	616	1876	2053	3929	3515	3505.87
		Keteba (Lugo)	622	62	684	1674	2704	4378	4780	4719.30
North Shewa	Bereh Aleltu	Wodecha Konteba	459	45	504	1492	1477	2969	1600	1477
		Total	**4883**	**635**	**5518**	**16294**	**19646**	**35940**	**26314**	**28741**

[1] Area known by respective weredas BoA offices

[2] Total area of PAs after digitising the PA boundaries obtained from CSA according to the new administrative structure

Annex 5. Household level questionnaire

Land cover and land use change under conditions of high population pressure in peasant associations around Yerer mountain

Household level Questionnaire

Questionnaire Number:____

Date of interview: Day: ___________ Month: ________________ Year: _______________

Interviewed by ____
Date entered: Day: __________ Month: ________________ Year: _______________
Entered by: ____
Region: _________________________ Code:___________
Zone: _________________________ Code:___________
Woreda: ______________________________ Code: ___________
PA: ______________________________ Code: ___________
Household : ______________________________ Code: ___________
GPS coordinates of residence:
North: _______________ East: ________________ Altitude (m.a.s.l.): ________________

Part 1. Household Composition

1.1 Household composition, education and occupation. (Please fill in the codes given after the table)

No	Name	Sex	Age (Year**)**	Marital Status	Relation to HH-head	Years of schooling	**Occupation**	
							Primary	**Secondary**

1.2 Participation in agricultural training programs for soil and water conservation, forestry and general agriculture

Name of household member	Type/Areas of training	Code	Provided by	Code	Duration of training (Days)	Remark

2 Household access to infrastructure and services

2.1. Household access to infrastructure and services Indicate time taken one way (in minutes) from residence to nearest infrastructure and services, in each year since 2003

Access to nearest:	Code	2003	
		Walking	Vehicle (if applicable.)
Input supply shop (ex. Fertilizer, tree seedlings, hand tools, etc)			
Crop market			
Livestock market			
Health Centre			
Others (specify)			

2.2 Expenditure on agricultural inputs (birr/year)

Input	**Code**	**2001**	**2002**	**2003**
Fertilizer				
Purchase of improved seeds				
Veterinary expenses				
Purchase of oxen				
Purchase of other animals				
Purchase of pesticides				
Purchase of animal feeds				
Hired labor in crop production				
Hired labor in livestock				
Purchase of Herbicide				
Other expenses for improved inputs (specify)				

Note: 2001 is 1993/94 Ethiopian calendar; 2002 is 1994/95 Ethiopian calendar; 2003 is 1995/96 Ethiopian calendar

2.3 Did your water point for household use change in the past ten years? _______________ 0= No 1= Yes

2.4. If the answer for **question 2.3** is No, what is the distance from your house to the water point?
Distance_________________(km)
Walking time ____________(minutes)

2.5. If the answer for **question 2.3** is yes, what is the distance from your house to the water point?
Distance________________ (km)
Walking time ____________(minutes)

2.6 How about the previous water point?
Distance________________ (km)
Walking time ____________(minutes)

2.7 Did your water point for livestock change in the past ten years? ______________ 0= No 1= Yes

2.8 If the answer for **question 2.7** is yes, what is the distance from your house to the water point?
Distance_________________(km)
Walking time ____________(minutes)

2.9. If the answer for **question 2.7** is yes, what is the distance from your house to the water point?
Distance_________________(km)
Walking time ____________(minutes)

2.91 How about the previous water point?

Distance_______________ (km)
Walking time ___________(minutes)

Part 3 Crop production and use

3.1 List major crops, in order of importance, those easily grow in your area (Rank)

1. _______________
2. _______________
3. _______________
4. _______________

3.2. Did the total area you cultivate from year to year

Increase__________________
Decrease_________________
Show no change ___________

3.3 If it increased or decreased, state reason(s):

1. ____
2. ____
3. ____
4. ____

3.4 What measures do you take when the productivity of your land (farm) declines?

Look for additional land _______
Improve the fertility __________
Fallow ______________________
Other (specify) _______________

3.5 If you look for additional land, what kind of land do you opt for:

1. ____
2. ____
3. ____

3.6 Is fallowing practised in your area? ______0=No 1=Yes

3.7 If the answer for **question 3.6** is yes, how long should it rest before being used again?
____ (year)

3.8 If your answer for **question 3.4** is "**improve the fertility,**" how do you do it?

Use manure___________
Add commercial fertilizer ____________
Rotate crops_________
Other (specify) ___________________________________

3.9 Please provide the following information on your crop production on all operated land (i.e. owned, sharecropped in, rented in, borrowed) (2001-2003).

Crop type	Code	Area (Kert/ Timad)	2001				2002			
			Production (qt)	Consumption (qt)[1]	Sale (qt)	Carry over (qt)	Production (qt)	Consumption (qt)[1]	Sale (qt)	Carry over(qt)
White tef										
Wheat										
Barley										
Field peas										
Others										

1 ha =___________________________ local units

1 qt = 100 kg

[1] Consumption= crop consumed in house in the form of injera, kita, tella, kolo, nifro or else.

Continued from 3.9 on previous page…………

Crop type	Code	Area (Kert/ Timad)	2003			
			Production (qt)[1]	Consumption (qt)[1]	Sale (qt)[1]	Carry over (qt)[1]
White tef						
Wheat						
Barley						
Field peas						
Others						

1 ha =___________________________ local units

1 qt = 100 kg

[1] Consumption= crop consumed in house in the form of injera, kita, tella, kolo, nifro or else.

3.10 Prices of crops and residue (2003)

Crops	Unit price (birr/qt)
White tef	
Wheat	
Barley	
Field peas	
Others	
Crop Residues	
Tef straw	
Wheat straw	
Barley straw	
Maize stover	

3.11 Cropping pattern and private grazing area in 2003

Crops	**Number of plots**	**Total Area (kert/Timad)**
White tef		
Wheat		
Barley		
Field peas		
Others		
Private grazing land		

3.12 Do you use fertilizer for crop production? ________________0= No 1= Yes

3.13 If the answer for **question 3.12** is no, why?

1.____

2.____

3.____

3.14 If the answer for **question 3.12** is yes, please fill your fertilizer use (kg) for 2003

Crops	**Number of plots**	**Area (kert/Timad)**	**DAP**	**Urea**
Tef				
Wheat				
Barley				
Field peas				
Others				

3.15 If the answer for **question 3.12** is Yes, how much did you use from 2001 to 2003? (kg)

	2001	2002	2003	Remark
DAP				
Urea				

3.16 Do you perceive that soil fertility is declining? ______________0= No 1= Yes

3.17 If the answer for **question 3.16** is No, how did you know that there is no decline in fertility?

1.____

2.____

3.____

3.18 If the answer for **question 3.16** is Yes, how did you know that there is a decline in fertility?

1.____

2.____

3.____

3.19 Do you have any knowledge of the following soil conservation methods?

Tree planting ________________

Terracing ________________

Check dam ________________

Contour hedges________________
Ploughing across the slope_______
________0= No 1= Yes

3.20 If the answer for **question 3.16** is Yes, did you take any conservation measure to correct it? ________0= No 1= Yes

3.21 If the answer for **question 3.20** is Yes, what measures did you take to correct the problem?
1.____
2.____
3.____

3.22 Do you think the conservation measures you took were enough? ________0= No 1= Yes

3.23 If the answer for **question 3.22** is No, what other measures could be taken?
1.____
2.____
3.____

3.24 If your answer for **question 3.19** is yes, but you did not use any of them, why?
1.____
2.____
3.____

3.25 Is any part of your farmland affected by gully? ______0= No 1= Yes

3.26 If answer for **question 3.25** is yes, did it expand? ______0= No 1= Yes

3.27 If answer for **question 3.26** is yes, since how many years did it expand? ______

3.28 If answer for **question 3.26** is yes, what measures did you take?
Check dam________________________________
Not ploughing to the edge of the gully___________
Grass planting on waterways___________________
Diverting into permanent waterways_____________
Others (specify)______________________________

3.29 Even if none of your farmlands are affected by gullying, do you observe it as a problem in other farms in your area? ________0= No 1= Yes

3.30 What do you think the major causes for gully formation in your area? (Rank in order of importance, 1 as very important)
Deforestation________________
Steep slope cultivation_________
Continuous cultivation_________
Human/livestock tracks_________
Others (specify)_______________

3.31 Off-farm income (Birr/year)

Type ____________________
(Birr) ____________________

3.32 Number of cultivations (passes with the maresha) up to seeding for selected crops

Tef__________________________
Wheat_________________________
Barley _______________________
Field peas_____________________
Maize________________________
____

Faba bean_____________________________
Chick pea______________________________
Rough peas_____________________________
Lentils_________________________________
____
____

3.33 Which of the following are problems of crop production (rank according to their importance, 1 as very important)

Problem	**Rank**
Shortage of cultivable land	
Lack of draught oxen	
Deterioration of soil fertility	
Drought	
Weeds	
Lack of cash/credit	
Others (specify)	

Part 4 Livestock production

Livestock owned: number owned in the beginning of the year for 2003 and changes in inventory during the same year

Type of Animal	**Code**	2003 beginning stock A		Died/lost in the year (2003) B		Bought in/gift in the year (2003) C		Gift out/sold /slaughtered the year (2003) D		Born in 2003 E		End stock F= A-B+C-D+E	
		No	Value (birr)	No	Value (birr)	No	Value (birr)	No	Value (birr)	No	Value (birr)	No	Value (birr)
Calf													
Young bull										▨	▨		
Heifer										▨	▨		
Cow										▨	▨		
Draft										▨	▨		
Sheep													
Goat													
Horse													
Donke													
Mule													
Poultr													

Calf = < 1 yr, young bull and heifer = 1-3 yrs, cow and oxen = > 3 yrs,

4.2 Livestock products: indicate livestock products in 2003 (excluding live animals)

Livestock type	Code	Product	Code	Production			
				Qty	Unit	Code	Value
Cattle		Milk[1]					
		Butter					
		Cheese					
		Hide					
		Dung cake					
Goats		Milk[1]					
		Skin (goat & sheep)					
Other (specify)							

[1] Total milk output

4.3 Which of the following are problems of livestock production (rank according to their importance, 1 as very important)

Problem	**Rank**
Shortage of feed	
Parasites and diseases	
Drought	
Lack of cash/credit	
Poor productivity of local breeds	
Shortage of labour	
Others (specify)	

Part 5 Feed fluctuations

5.1 Mark the following months in terms of **availability of feed** or **severity of feed shortage.**

Availability	code	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Abundant													
Sufficient													
Moderate shortage													
Sever shortage													

5.2 What are the major **sources of feed** on your farm?

Season	Code	Sources of feed
Wet		
Harvest		
Dry		

1 =Crop residue
2 =Communal grazing land
3 =Private grazing land
4 =Stubble grazing
5 =Hay
6 =Thinning (maize& sorghum)
7= Grasses and weeds
8 = Tree leaf
9=Others (specify)

5.3 What is the dominant grazing system used in your commu

____

1= Free and uncontrolled
2= Regulated by number of animal grazed
3= ,, ,, ,, ,, days grazed
4= ,, ,, season
5= ,, by number and days grazed
6= ,, by number and season
7 = ,, by number, days and season
99 = NA

5.4 What are the main **products** and **utilities** of livestock? (Prioritize/ rank products according to their importance)

Type of Livestock	Code	Products / Utilities							
		Draft Power	Milk	Meat	Cash	Manure	Asset	Prestige	Reproductive purpose
Cows									
Oxen									
Sheep									
Goat									
Equines									

5.5 How much is the daily average milk yield at your farm (excluding the amount suckled by the calf)?

1 = Local breeds ____________________

2 = Improved breeds__________________

5.6 Rank the following crops in terms of **quality of crop residue** as feed

Crop	Code	**Rank**
Tef		
Wheat		
Barley		
Field peas		
faba bean		

Chick pea		
Rough pea		
Lentils		
Maize		

5.7 Rank the following animals in terms of your priority for feed during feed shortage by season?

Season	Code	Type of Livestock					
		Draught Oxen	**Milking Cows**	**Calves**	**Other cattle**	**Small ruminants**	Equines
Wet							
Harvest							
Dry							

5.8 What were the consequences of insufficient feeding? (list in order of importance or rank).

Consequence	Code	Draught oxen	Milking cow	Other cattle	Small ruminants	Equines	Others (specify)
Weight loss							
Lower milk		▨				▨	
Increased mortality							
Weakness							
Extended calving, Lambing, kidding etc		▨					
Others (specify) List first and rank							

5.9 What measures do you take to alleviate feed shortage? (list or rank in order of importance)

Measure	**Code**	**Rank**
De-stocking		
Planting productive forages		
Conserving hay and straw		
Purchasing feed		
Renting grazing land		
Transferring stock to other farmers		
Owner moving stock to other places		
Others (specify) (list first and rank)		
None		

6.0 Energy use and construction

6.1 What is your present source of energy for your household use? Rank

a. **Cooking** Cow dung_________

Fuel wood_________

Crop residue_______
Others______________
b. **Heating** Cow dung_________
Fuel wood_________
Crop residue_______
Others_____________
c. **Lighting** Kerosene __________
Fuel wood_________
Candle____________
Others______________

6.2 Was there any change on the type of your energy source for the last ten years?
_______0=No 1= Yes

6.3 If yes, what were the sources of your energy in the last ten years?
a. **Cooking** Cow dung_________
Fuel wood_________
Crop residue_______
Others_____________
b. **Heating** Cow dung_________
Fuel wood_________
Crop residue_______
Others_____________
c. **Lighting** Kerosene _________
Fuel wood_________
Candle____________
Others_____________

6.4 If the answer for **Question 6.2** is yes, what were the reasons?
1.____
2.____
3.____

6.5 Is there any seasonal difference in the use of sources of energy?_______0=No 1=Yes

6.6 If yes, what is your major source of energy for cooking and heating during the following seasons?
a. **Wet** Cow dung_________
Fuel wood_________
Crop residue_______
Others_____________
b. **Harvest** Cow dung_________
Fuel wood_________
Crop residue_______
Others_____________
c. **Dry** Cow dung_________
Fuel wood_________
Crop residue_______
Others_____________

6.7 What is your average monthly energy requirement for
a. **Cooking** Cow dung_________(kg)
Fuel wood_________(kg)
Crop residue_______(kg)
Others_____________(unit)

b. **Heating** Cow dung_________(kg)
Fuel wood_________(kg)
Crop residue_______(kg)
Others____________(unit)
c. **Lighting** Kerosene __________(l)
Fuel wood_________(kg)
Candle____________(No.)

6.8 Do you have own-planted trees in your farmland/backyard? ______ 0= No 1= Yes

6.9 If answer for **question 6.8** yes, state types of species and number of trees.

	Local name	Scientific name	No. of trees
1.	____________	______________________	________________
2.	____________	______________________	________________
3.	____________	______________________	________________
4..	____________	______________________	________________

6.10 Where do you get wood for construction?
1.Own-planted trees_______________________
2. Buy from Debre Zeit/Godino/Dukem towns_____________
3.Buy from the surroundings_____________________
4. Other places (specify)

6.11 What are the major wood species used for construction (houses, fences, barns and maintenance)? List species of trees used.
1.____
2.____
3.____

6.12 If you bought wood for construction, did the prices
Increase____________
Decrease____________

6.13 If answer for **question 6.12** is increased, what could be the reasons?
1.____
2. ____
3. ____

6.14 If answer for **question 6.12** is own trees, do you also earn income from selling trees?
______ 0= No 1= Yes

6.15 If answer for **question 6.14 yes,** how much did you earn in
2001_______________________
2002_______________________
2003_______________________

Annex 6. PA level Questionnaire

Land cover and land use change under conditions of high population pressure in peasant associations around Yerer mountain

Questionnaire Number:____
Date of interview: Day: ____________ Month: ____________ Year: _______________
Interviewed by ____
Entered by:____
Region ______________________________ Code: __________
Zone: ______________________________ Code: __________
Woreda: ______________________________ Code: ___________
PA: ______________________________ Code: ___________

1.1 Reference point in the PA (For example church, school, clinic, etc.- include name):
Reference point: _____________________________________
GPS coordinates of PA:
North: _______________ East: ______________ Altitude (m.a.s.l.): ________________

1.2 Distance and travel time from PA to the woreda town:

	Walking	**Pack animals (if applicable)**	**Vehicle**
Distance (Km):	______________	____________________	__________________
Travel time (minutes)	____________	_____________________	____________________

1.3 Distance and travel time from PA to the nearest all weather road.

	Walking	**Pack animals (if applicable)**	**Vehicle**
Distance (Km):	______________	______________	__________________
Travel time (minutes)	_______________	______________	__________________

1.4 Population in the PA:

Year	**Total population**	**No. of household heads**		**Average household size**
		Tax payers	**Non tax payers**	
2001				
2002				
2003				

1.5 Livestock population in PA

Livestock types	Year		
	2001	**2002**	**2003**
Cow			
Heifer			
Calves			
Oxen			
Bulls			
Sheep			
Goats			
Camels			
Donkeys			
Horses			
Mules			
Others (specific)			

1.6 Major Soil types: using the local classification, indicate the major soil types in PA based on abundance**.**

Soil Type rank	**Soil Type**
1st	
2nd	
3rd	

1.7 Land use: Rank based on abundance or area coverage and give estimated size in ha

Land use	**Estimated size**		
	2001	**2002**	**2003**
Cultivated rainfed			
Cultivated irrigated			
Homestead			
Grazing area			
Forest/woodlot			
Area enclosure			
Settlements			
Waste land			
Other (specify)			

1.8 Land use by crop cultivated (ha):

Crop Type	Estimated size		
	2001	**2002**	**2003**

1.9 What major natural calamities occurred in your PA in the last three years?

2001 ____

2002 ____

2003 ____

2.0 Input price assessment

Year	**Input**			
	DAP	**Urea**	**Pesticide**	**Herbicide**
2001				
2002				
2003				

2.1 Feed price assessment (birr/kg)

Year	**Input**				
	Teff straw	**Wheat straw**	**Barley straw**	**Oil seed cakes**	**Other (specify)**
2001					
2002					
2003					

2.2 What are the major holidays when farmers in your area do not carry out farm activities by month? Indicate in days.

Month	No. of holidays
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	

2.3 How many hours do livestock normally graze on communal grazing lands in your PA?

Season	**Code**	**Grazing hrs**

2.4 Indicate the Cropping calendar in your PA

Crop type	Land preparation (months)	Sowing (months)	Weeding (months)	Harvesting (months)	Threshing (months)

2.5 Indicate the months in each of the following seasons

1. Wet season ____
2. Harvest season ______________________________________
3. Dry season ____

Annex 7. Grain and straw yields of some cereals grown in the study area used as multipliers

Crop	**Grain yield kg/ha**	**Straw yield (kg/ha)**	**Straw to grain ratio**[1]	**Researched in**	**Source of information**
Tef	700	1500	2.14	Different sources	Jahnke, H. (1982)
	1050	2250	2.14	Different sources	Jahnke, H. (1982)
	2100	7100	3.38	Arsi	Daniel Keftasa, (1987)
	1050	2330	2.22	Adaa Liben	Bekele Shiferaw (1991)
Mean			**2.47**		
Barley	1400	1500	1.07	Sheno, Ethiopia	Adamu Molla, (1991)
	1533	1900	1.24	Kotu, Dalota & Cheki	IAR, (1991)
	1433	2067	1.44	Sheno	IAR, (1991)
	1417	2050	1.45	Sheno	IAR, (1991)
	3100	10800	3.48	Holetta	IAR, (1983, 1986)
	2737	7004	2.56	Arsi	Daniel Keftasa, (1987)
	2918	5972	2.05	Arsi	Daniel Keftasa, (1987)
	2581	5283	2.05	Arsi	Daniel Keftasa, 1987
	1100	1530	1.39	Adaa Liben	Bekele Shiferaw, (1991)
Mean			**1.86**		
Wheat	1500	1600	1.07	Sheno, Ethiopia	Adamu Molla, (1991)
	608	1604	2.64	Bichena, Inewari and Were Ilu	Abate Tedla *et al.*, (1992)
	2603	5401	2.07	Chefe Donsa	Abiye Astatke *et al.*, (2004)
	2314	4634	2.00	Chefe Donsa	Abiye Astatke *et al.*, (2003)
	3906	9057	2.32	Arsi	Daniel Keftasa, (1987)
	454	1291	2.84	Inewari, Were Ilu and Fogera plains	Getachew Asamnew, *et al.*, (1988)
	1200	1780	1.48	Adaa Liben	Bekele Shiferaw, (1991)
Mean			**2.06**		
Faba bean	1800	2600	1.44	Sheno, Ethiopia	Adamu Molla, (1991)
	2200	3900	1.77	Arsi	Daniel Keftasa, (1987)
	648	852	1.31	Inewari, Were Ilu and Fogera plains	Getachew Asamnew, *et al.*, (1988)
	800	920	1.15	Adaa Liben	Bekele Shiferaw, (1991)
Mean			**1.42**		
Field pea	2340	12000	5.13	Arsi	Daniel Keftasa, (1987)
	700	1020	1.46	Adaa Liben	Bekele Shiferaw, (1991)
Mean			**3.3**		
Chickpea	850	900	1.06	Adaa Liben	Bekele Shiferaw, (1991)
	950	1460	1.54	Ada Liben	Bekele Shiferaw, (1991)
Mean			**1.31**		
Lentil	500	780	**1.56**	Adaa Liben	Bekele Shiferaw, (1991)
Rough pea			**1.54**[2]	Adaa Liben	Bekele Shiferaw, (1991)
Maize	3194	6516	**2.04**	Awasa, Bako, and Debre Zeit	

[1] Multipliers to grain yield shown in bold

[2] Grain and straw yield not indicated

DECLARATION

I the undersigned declare that this Thesis is my original work and has not been presented for any degree in any university and all the sources of materials used for the Thesis have been duly acknowledged.

Name: Kahsay Berhe Gebrehiwet

Signature: _______________________

This Thesis has been submitted for examination with our approval as university advisors

Name	Signature
Professor Zerihun Woldu	______________
Dr. Dagnachew Legesse	______________
Dr. Don Peden (ILRI)	______________

Date and place of submission: Environmental Science Programme
Addis Ababa University
June 2004